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Preface

The European Conference on Technology-Enhanced Learning (EC-TEL 2008) was the third event of a series that started in 2006. The two first editions were organized by ProLearn (http://www.prolearn-project.org/), a European Network of Excellence. In 2008, several members of Kaleidoscope, the other European Network of Excellence (http://www.noe-kaleidoscope.org/pub/), joined as co-chair, committee members, reviewers and authors. These two networks are no longer funded, but our aim was to turn EC-TEL into a sustainable series of high-quality events and thereby to contribute to the scientific landscape of technology-enhanced learning. A new network, named STELLAR, will be launched in 2009, with members from both existing networks as well as new members and will support the future editions of this conference.

The scope of EC-TEL 2008 covered the different fields of learning technologies: education, psychology, computer science. The contributions in this volume address the design of innovative environments, computational models and architectures, results of empirical studies on socio-cognitive processes, field studies regarding the use of technologies in context, collaborative processes, pedagogical scenarios, reusable learning objects and emerging objects, groups and communities, learning networks, interaction analysis, metadata, personalization, collaboration scripts, learning adaptation, collaborative environments, resources, tangible tools, as well as learning management systems.

The contributions in these proceedings cover a variety of learning contexts. They are used in formal (primary, secondary, and higher) education, corporate training, and lifelong learning. Studies have been conducted in general curricula as well as in vocational training. The spread of mobile devices, social learning techniques, and personalization technologies is closing the gap between formal and informal learning. The authors integrate individual learning, small group collaboration, as well as class-wide or community activities within a coherent pedagogical scenario. These scenarios combine activities that intensively rely on computers with activities that marginally use technologies. Such activities occur in the classrooms and in the training centers but also across multiple other spaces and contexts: offices, homes, cars, field trips, ski lifts, etc. In other words, we are in an era of convergence among our multiple research communities. Most modern learning environments no longer fit within one pedagogical stream: they integrate heterogeneous software components such as a simulation tool, a hypertext, an argumentation tool, and a tutorial. Old barriers between different visions of learning technologies are fading out.

Thereby, we hope that these contributions will pave two roads: the road for a development of technology-enhanced learning practices towards improving the quality of education and training, and the road for high-quality research on the different scientific fields concerned with learning technologies.

July 2008

Pierre Dillenbourg
Marcus Specht

Organization

EC-TEL 2008 was organized by the Professional Learning Cluster (PRO-LC) and the European Association of Technology Enhanced Learning (EA-TEL).

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Using Interaction Analysis to Reveal Self-Regulated Learning in Virtual Communities

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Abstract. Aim of this paper is to analyse whether Interaction Analysis can help investigate the practice and development of Self-Regulated Learning (SRL) in Virtual Learning Communities (VLC). Interaction analysis is increasingly used to study learning dynamics within online activities. It proceeds by searching expressions that reveal the aspects under study in the written messages exchanged by the learners. To this end, we devised and classified a number of indicators suggesting the existence of self-regulated events, and tested this approach on the online component of a blended course for trainee teachers. We analysed the messages exchanged by a group of learners in two modules of the course and compared the results with those of a previous study carried out with more traditional methods. The similarity of the results obtained by the two approaches suggests that Interaction Analysis is an effective, though rather labour-intensive, way to study SRL in VLCs.

Keywords: Self-Regulated Learning, Virtual Learning Communities, Teacher Training, Computer Supported Collaborative Learning, quantitative content analysis of interactions.

1 Introduction

Virtual Learning Communities (VLC) and Computer Supported Collaborative Learning (CSCL) allow the implementation of collaborative learning in online environments. Both use computer-mediated communication, mostly textual and asynchronous, to support group interactions at a distance among trainees, with the guidance of facilitators and tutors. Research into this socio-constructivist approach to learning has been increasingly using Interaction Analysis (IA) to investigate and understand the learning dynamics that take place CSCL environments. IA is based on the detection of phrases and expressions that reveal the aspects under study in the written messages exchanged by the learners. It therefore combines qualitative analysis of individual messages with quantitative elaboration of results. This method takes advantage of the non-intrusive capability of technology to track events (such as students messages) during the learning process, therefore potentially replacing or at least complementing more intrusive ways for gathering data. For this reason, IA is considered a powerful source of data, although it often requires human intervention, both in the analysis phase and in the interpretation of data.

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Studies in IA may look at different types of content [11]. Manifest content is easily observable in that it concerns visible and objective communication features. An example of manifest content is the number of times students address each other by name. In general, manifest content can be spotted by looking for some particular expressions and hence the coding process is relatively easy to automate. In some cases, however, the aspects under study cannot not be directly connected with specific expressions, but rather they need to be inferred on the basis of the analysed texts. IA in these cases relies on the detection of "latent variables" [10]. Detection of latent content is much more complex, in that it requires interpretation and application of some heuristics in the analysis of the messages. Manifest content can obviously be investigated with more objectivity and can be automated more easily. Nevertheless, latent content is worth attention in that it is often related to interesting research questions. In this paper, we claim that Self-Regulated Learning (SRL) is one of those fields of study where it is necessary to handle latent content.

Self-Regulated Learning (SRL) is one of the fields of study where it is useful to handle latent content. The term SRL identifies a set of cross-curricular competences allowing the learners improve their learning efficacy, as well as to apply and adapt the acquired knowledge across different subjects. The research in this field investigates the pedagogical, behavioural, emotional, motivational, cognitive and meta-cognitive aspects involved when students learn to control their own learning processes [14, 15].

The relationship between SRL and CSCL is quite complex because effective use of CSCL environments appears both to require and to improve the ability of learners to self-regulate their own activity [6]. In CSCL, SRL competence and, in particular, meta-cognitive skills are often among the explicit or implicit objectives of the learning process. This is primarily due to the fact that learners who are new to this training method usually lack some of the meta-cognitive and self-direction skills that are needed to take full advantage of this learning approach, and therefore well designed courses try to stimulate learners in this respect. Moreover, learning in such context is mostly based on textual interaction, and this supports reflection not only on content knowledge but also on the learning process itself. As a consequence, such learning environments appear to foster SRL by putting into play several SRL-related skills, so that CSCL environments may be regarded as promising for its development [1, 9, 11] At the same time, SRL appears necessary to make good use of learning experiences within VLCs not only because students need to organize time and pace of their learning process, but also because collaborative activities entail negotiating objectives, strategies and concepts with peers.

Research into SRL is currently carried out by analysing students' actions, that is, by trying to understand to what extent they set their goals, plan their learning and evaluate their progress, practice meta-cognition and self-reflection. It is not surprising, therefore, that Interaction Analysis is rarely applied to the study of SRL in VLCs, in that it requires the detection of latent content. Currently, investigation of SRL mostly relies on interviews where learners are requested to describe, ex-post, the strategies and methods they used during the learning process, or on questionnaires aimed at eliciting information from the learners' about their strategic planning and the other choices made during the leaning process. It should be noted that even these traditional methods of analysis are not able to directly measure the practice of SRL, but they try to deduce its presence from students actions, their opinions and their verbalisations concerning the learning process. This confirms the intrinsic complexity of this field of analysis.

This paper proposes to use IA to investigate the practice of SRL in VLCs, as a possible way to rely on data of different nature, hence offering the possibility to complement studies based on traditional methods. It is true that the outcomes of IA are affected by coders' discretion, since SRL can be detected only by means of latent variables, but they depend less on students' discretion, since they are directly based on the students' actions, i.e. the messages they sent, rather than their interpretations of the learning events.

In the following, we propose a set of indicators of SRL and report on their application in an exploratory study carried out on the online component of a blended teacher training course in Educational Technology. The outcomes of the study are discussed and compared with those of a previous study carried out with more traditional means. Aim of this paper is to evaluate the feasibility, reliability and cost-effectiveness of the approach proposed, in view of a possible application on a larger scale.

2 Detecting SRL Indicators

We can define Self Regulated Learning as a learning process where students master and deliberately control their own learning, by setting their goals, by choosing their learning strategies, by reflecting on their own learning and by evaluating their progress and consequently adapting their strategies, with a cyclic process. Self- regulated learners are often intrinsically motivated and see learning as a proactive activity; in other words, they actively control rather than passively endure the learning process. They usually have a good degree of self-efficacy and are able to apply and adapt the acquired knowledge across different subjects.

The study of SRL in online environments by means of AI is complicated by the fact that, despite the variety of approaches that have been applied to investigate the nature and extent of SRL [16], this competence has always been characterised in terms of general, rather than specific, skills and actions. It is therefore necessary to start by defining SRL indicators that can guide the search for latent content items. We base our analysis on the characterization of SRL proposed by Zimmermann [14-16], taking into consideration also some subsequent elaborations of his studies [2, 4, 12] on the potential support to SRL granted by Technology Enhanced Learning Environments. Based on the work of all these authors, we can identify two orthogonal sets of aspects that characterize SRL, that we will call "process" model and "component" model of SRL. The process model views SRL as consisting of three phases that are cyclically repeated during learning activities of self-regulated learners: planning, monitoring and evaluation. The component model, on the other hand, distinguishes among the cognitive (behavioural), meta-cognitive, and motivational/emotional aspects of SRL, both at the individual and at the social level.

Based on these models, and taking into consideration the fact that in VLCs individual activity and social construction of knowledge are strictly intertwined and both very important, we think that SRL indicators to carry out IA in VLCs should concern the following aspects:

- The learners' abilities to plan, monitor and evaluate their own learning process; these can be investigated by spotting the learners' active contribution to: choosing learning objectives and contents, working out or adapting learning strategies; suitably configuring the learning environment; evaluating learning results by comparing one's outcomes with the outcomes of peers and with models possibly provided;
- The learners' abilities to cope with cognitive, meta-cognitive, emotional and motivational challenges imposed by the learning process, throughout the above mentioned phases; these can be captured by identifying clues that show deliberate application of strategies to solve complex problems, to cope with stress and anxiety, to keep up motivation, to relate with peers in a smooth and profitable way;
- The learners' abilities to practice all the above actions both in individual study and in a collaborative learning context, be it face-to-face or at a distance.

The indicators of SRL abilities proposed in this paper derive from this theoretical framework and are shown in Table 1. This table specifies what should be observed into students' messages in order to support the claim that their learning activity is self-regulated. Following Garrison et al. [8], we grouped cognitive with meta-cognitive aspects since it is often difficult to clearly mark the separation between them, especially in a context, like VLCs, that usually fosters meta-cognitive activities along with cognitive ones. Similarly, we grouped motivational and emotional aspects since the border between the two is quite blurred.

The underlying assumption of this study is that, when a message contains reference to the fact that the sender has carried out a self-regulated action, then we can think that he/she has taken that action, and therefore he/she has practised self-regulation to some extent. For example, let us suppose that a student sends a message commenting on the success of a group activity and another answers by proposing a deadline for the following task. In our approach, we assume that the first student has carried out some kind of self-evaluation and the second has engaged in a form of planning. The opposite, however, can not be claimed, because if a student does not express in his/her messages something that allows us to infer a self-regulation activity, this doesn't mean that self-regulation did not take place, it simply means that the student did not feel the need to express it.

3 A Case Study

We used the selected SRL-indicators to analyse the learning dynamics that took place in part of the online component of a blended teacher training course in educational technology. This course was run in 2005 by ITD-CNR for the Specialization School for Secondary Education of the Liguria region [5]. The course lasted 12 weeks (see course structure in Fig. 1) and involved 95 students and 8 tutors who exchanged, in total, 7605 messages. Among these, the students messages were around 77% of the total. We selected for this study the activities of Modules 3 and 4, to which we will refer in the following as Activity 1 and Activity 2. We focused in particular on one sub-group of eight students with one tutor. The selected activities lasted 3 weeks each and included a total of 249 messages exchanged, 218 of which by the students.

<table>
<tr><td>Week 1</td><td>Week 2</td><td>Week 3</td><td>Week 4</td><td>Week 5</td><td>Week 6</td><td>Week 7</td><td>Week 8</td><td>Week 9</td><td>Week 10</td><td>Week 11</td><td>Week 12</td></tr>
<tr><td colspan="12">FACE-TO-FACE</td></tr>
<tr><td>F2F 1</td><td>F2F 2</td><td></td><td></td><td></td><td>F2F 3</td><td></td><td></td><td>F2F 4</td><td></td><td></td><td>F2F 5</td></tr>
<tr><td colspan="12">ONLINE</td></tr>
<tr><td colspan="3" rowspan="2">Mod. 1
Familiarisation</td><td colspan="2">Mod.2
Online educational resources</td><td colspan="3">Mod.3
Web Quests and other educational uses of the web</td><td colspan="3">Mod.4
Collaborative learning and virtual learning communities</td><td>Mod.5
Final activity</td></tr>
<tr><td colspan="9">Transversal Mod.2 – Meta-cognitive reflection</td></tr>
<tr><td colspan="12">Transversal Mod.1
Socialisation</td></tr>
</table>

Fig. 1. Structure of the considered course. Interactions were analysed for Modules 3 and 4.

The sample chosen is a good representative of the whole cohort of course participants, in that it has similar characteristics: same ratio between males and females, same mixture of backgrounds, average grade in final assessment very close to the average grade of all the students (see Table 2 for data about the sample). Both the considered activities were based on collaborative learning strategies but involved different ways to organize the group activity. The first was a role play, where students were required to take the role of strongly characterized teachers (e.g. the technology enthusiast, the technology detractor, the bureaucrat, the pragmatist, etc) and to discuss from these different points of view strengths and weaknesses of a WebQuest. The second was a case study on school-based learning communities. Trainees were supposed to discuss pros and cons of a school project recently carried out by a few teachers with their classes. The features of this project were illustrated to the student teachers by its designers and the related documentation (instructional design, students products and assessment results) was made available to them.

Two coders examined all the messages of the sample. One coder had been involved in designing and running the course, while the other was an external rater. After coding, the inter-rater reliability was calculated, in terms of percent agreement, and resulted above 80% globally. After the computation of the inter-rater reliability, the coders discussed the controversial cases until they reached 100% agreement. The reported data refer to the agreed coding.

Table 3 reports the inter-rater reliability (Holsti's method). The fact that these values are quite acceptable is a point in favour of the replicability of this investigation approach. The same table shows that the percentage of significant messages was not very high, which might mean that SRL did not take place or it was not detected because students did not always feel the need to express the self-regulated actions they carried out.

Table 1. A taxonomy of indicators of self-regulation

		Planning	Execution and Monitoring	Evaluation
cognitive and meta-cognitive	**individual**	**Code: PCI** - Making plans on how to proceed in the learning process: breaking up tasks in sub-tasks, establishing deadlines, detecting priorities, etc. - Detecting plan changes necessary to overcome failures.	**Code: MCI** - Enact plans. - Work consistently on the assigned task. - Monitoring plan fulfilment. - Making syntheses of the work done and objectives reached.	**Code: ECI** - Assessing own learning. - Analysing results, spotting difficulties and causes of failures. - Reflecting on individual learning achieved. - Comparing one's work with that of peers
	social	**Code: PCS** - Making proposals on how to proceed in the learning process. - Discussing and negotiating on planning aspects. - Working out together plan changes necessary to overcome failures.	**Code: MCS** - Quoting peers contributions, asking questions, reacting to and mediating among peers. - Checking understanding - Summarising the ideas suggested by all group members. - Encouraging peers to act.	**Code: ECS** - Assessing group learning. - Commenting group achievements. - Reflecting on group learning. - Encouraging peers to express opinions
motivational and emotional	**individual**	**Code: PMI** - Exploring one's expectations about the current learning activity. - Anticipating possible emotional aspects.	**Code: MMI** - Expressing one's emotions and motivations - Looking for appropriate support when needed	**Code: EMI** - Comparing one's current motivation and emotions with the original ones. - Understanding the reasons of possible changes to plans. - Commenting on emotional aspects developed during the learning process
	social	**Code: PMS** - Discussing expectations and motivations about the current learning activity and learning in general. - Sharing motivations for own commitment. - Encouraging/requesting peers to make suggestions.	**Code: MMS** - Encouraging peers to express their emotions and motivations. - Disclosing oneself to peers, - Encouraging peers and providing them emotional support.	**Code: EMS** - Expressing appreciation for peers' efforts, contributions and results. - Spotting group's malfunctioning and analysing its causes.

Table 2. Features of the sample of messages analysed

	Stud. msgs.		Tutor msgs.		Total msgs.
	mean	SD	N	%	N
Activity1	11,3	5,4	14	13,5	104
Activity2	11,1	17,1	17	11,7	145

Table 3. Sample features in terms of coding results

	Meaningful messages		Inter-rater reliability
	number	%	
Activity1	32	35	88,6
Activity2	49	38	80,0

Fig.2 shows a comparison of the SRL-related expressions detected by the two coders. Coder 1 ratings are always slightly higher than those produced by Coder 2, which suggests a more open attitude of Coder 1 rather than a real disagreement on the way to interpret students' messages. This was confirmed by the comparison and discussion of the selected expressions and explains why it was easy to reach a complete agreement after comparing the differences.

The high agreement also suggests it was not difficult to classify the considered messages against the classification grid given in Table 1. This fact is important from the methodological point of view, in relation with the feasibility of the suggested method, since it suggests that the identified SRL-related indicators can be used to carry out a meaningful interaction analysis, even though they refer to latent content.

More accurate measures of the inter-rater reliability were not deemed necessary, given the exploratory nature of this study, which allowed us to compare all selected items and discuss the motivation for their selection. When the study will be extended to a bigger sample of messages, it will be necessary to adopt more advanced measures of reliability, which take into consideration chance agreement [7], along with accurate statistical analysis.

The chosen unit of analysis was the message. This choice appeared advantageous in that messages are objectively identifiable, their extent is determined by the message authors and they consist of a possibly large but still manageable set of cases. The analysed messages turned out to exhaustively contain all the indicators proposed in Table 1. On the other hand, several messages contained more than one occurrence of the same indicator or of different ones. This made the analysis of the data slightly more difficult to interpret, since, for instance, the percentage of messages containing SRL-related expressions does not give an exact idea of the concentration of indicators detected.

Some quantitative data about the two activities were also considered, such as the number of messages exchanged per day and the contribution of individual students to the discussion. These data helped us gain a global picture of the learning dynamics in the considered activities, but did not provide much information on the development of self-regulation, and therefore will not be reported in this study.

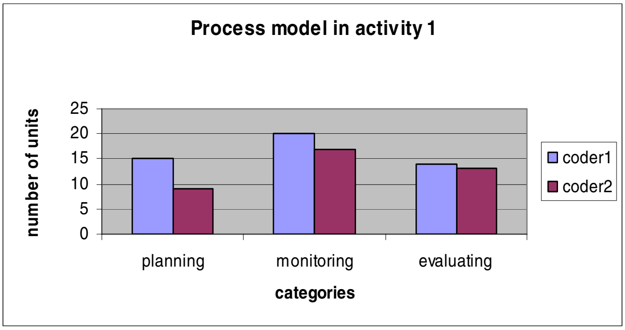

Fig. 2. A comparison of the SRL-indicators detected by the coders for Activity 1

4 Outcomes of the Study

The main results of the content analysis are reported in Table 4 and Figures 3 to 6. These figures show the raw data, without statistical elaborations on them, since the limited size of the sample analysed makes them more easy to read than complex elaborations. A wider study with more data, on the other hand, would certainly benefit of some statistical elaboration, like inferential statistics. In most cases we will refer to actual number of indicators found rather than percentages, because, as pointed out above, several messages contained more than one indicator, so the concentration of SRL related instances is better represented by the number of instances found rather than the percentage of SRL-related messages. It is useful to remind that the two activities had the same duration, which allowed us to compare the raw data in a meaningful way.

The data in Fig. 3 show that trainees participated more in Activity 2 (the case study) than in Activity 1 (the role play). This is true not only in terms of number of messages, but also as concerns “SRL density”. This clearly appears from Table 4, showing that the percentage of SRL-related messages and the average number of indicators per SRL-related message were higher in Activity 2 Also the number of messages exchanged in the second activity was higher (over 42% more) than in the first one. Activity 1, being a role play, had an inherent plan: once taken a role, the participants were required to adapt their behaviour to the activity constraints and this partially limited their freedom of planning. These data, however, can also support the hypothesis that the students, over the course, were learning to self-regulate themselves. Most likely, both explanations contributed to determine this distribution of SRL occurrences.

The limited amount of planning carried out in Activity 1 is confirmed by the data in Fig. 4, where indicators of planning events in this activity are significantly less than those of Activity 2, especially since the difference between the two activities is much more dramatic as concerns planning than the other two phases of SRL. However, Activity 2 shows a higher concentration of SRL-related events also as concerns monitoring and evaluation tasks, which again supports the idea that students generally self-regulated their learning more in this module.

Table 4. SRL indicators detected in the two considered activities

	Activity 1	Activity 2
total number of students' messages	90	128
number of messages containing SRL indicators	32	49
percentage of SRL related messages	35,56%	38,28%
total number of SRL indicators	39	70
average number of indicators per SRL-related message	1,21875	1,428571

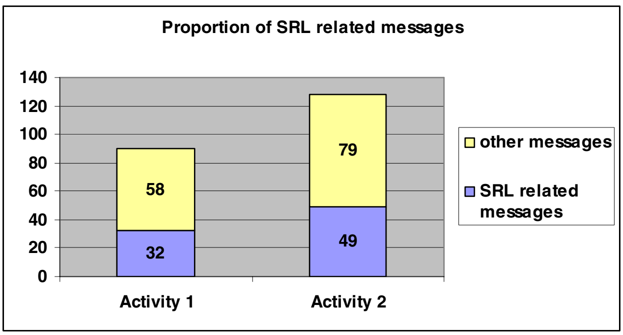

Fig. 3. Number of total messages posted by the students in the two activities and number of messages containing SRL indicators. The number of SRL indicators detected (which does not appear in this figure) is bigger than that of SRL-related messages, since several messages contained more than one indicator.

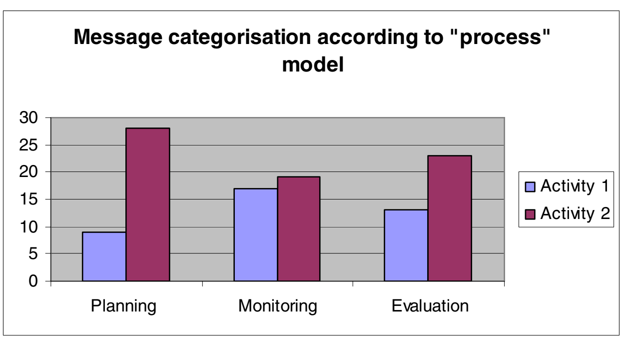

Fig. 4. Coding results according to the categories of the process model

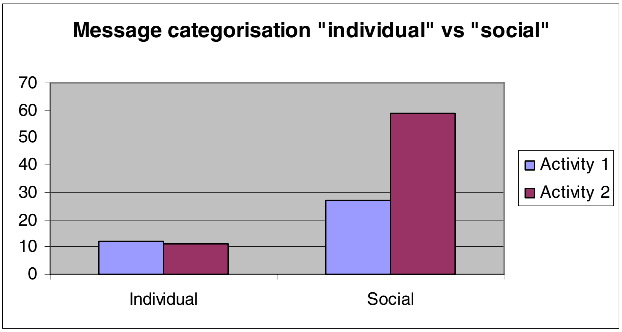

Fig. 5. Coding results along the individual vs. social categories

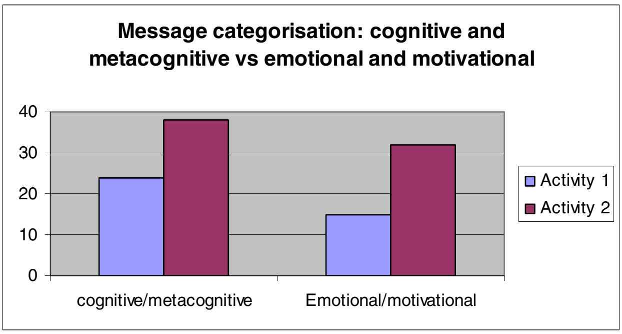

Fig. 6. Coding results along the categories cognitive and meta-cognitive vs. emotional and motivational

Fig. 5 shows that indicators related to SRL at a social level were definitely more frequent than indicators showing SRL at individual level. Once again, there are two possible reasons behind these data and it is likely that both are partially true. One reason is that VLCs tend to favour the social aspects of SRL more than its individual aspects (for example, students feel encouraged to plan, monitor and evaluate the group work, more than they do with their own individual work). The second explanation is that in online collaborative environments students feel the need to express, when writing messages, the social aspects of their learning activity more than they do with the individual aspects. In other words, they might be planning, monitoring and evaluating their own individual work as well, but they do not feel so much the need to write it in their messages.

The considerations raising from this analysis are very much in line with the outcomes of a previous study where a different method was used to investigate SRL development in the same course [6]. That study presented the results of a survey carried out with two questionnaires, one filled in by SRL experts and another by 72 of the 95 trainees taking part in this course. Both concerned the interviewees' opinions about the support received in practicing SRL during the course. The survey showed that the potential of the environment used was deemed valuable especially as concerns the social aspects of SRL: students, as a matter of fact, claimed that they felt a strong social support to their own SRL development from tutors and, even more, from peers.

Fig. 6 shows the message categorization according to the component model. From these data, the cognitive/meta-cognitive level appears to have been supported more than the emotional/motivational one.

In the study by Dettori, Giannetti and Persico [6] mentioned above, the comparison of these two categories was the only point of disagreement between the data related to experts' and students' opinions. As shown in Fig. 7, according to SRL experts, the emotional and motivational components of such support were stronger than the cognitive/meta-cognitive ones. According to the trainees, the former was weaker than the latter. This study, and in particular the data shown in Fig. 5, seems to confirm the results based on the students questionnaires.

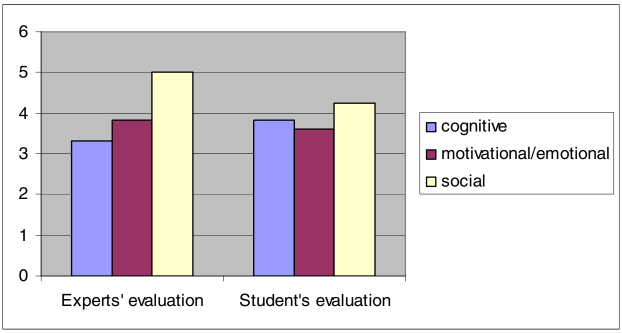

Fig. 7. Comparison between the average values obtained from the experts' evaluation and students' evaluation of the same course (from [6])

5 Concluding Remarks

The mere presence of SRL-indicators obviously does not prove the *development* of SRL, but only supports the claim that some particular aspects of SRL were *practiced*. However, Zimmerman's (1998) studies argue that SRL competence develops through social support and practice, which suggests that repeated practice likely corresponds to improved competence. Increased frequency of the indicators during the learning process can also be regarded as a clue of SRL development. The opposite, however, is not necessarily true: a lack of SRL indicators in students' messages doesn't necessarily mean that the students did not control their learning but simply that they might have not felt the need to make the process explicit in their messages.

This study mostly aims to understand if interaction analysis can provide significant information that could be regarded as complementary to data obtained with other methods. In general, information about SRL competence is searched by means of interviews with the subjects involved into the learning process, questionnaires and observation. Questionnaires and interviews collect *opinions* and information reported by the learners or their teachers. On the other hand, observation and content analysis of exchanged messages allow us to analyse directly what students actually did.

Messages do not give us access to all that has been taking place in a learning activity, but they allow us to work on data that have not been consciously filtered by the learners while expressing their opinions. Moreover, messages are distributed along the whole duration of a course. This means that we can analyse the evolution of self-regulation over time, which is not possible if such study is made by means of end-of-course questionnaires since these elicit students' opinion when the questionnaire is administered. For all these reasons, we believe that IA is a worthwhile approach, even though labour intensive, in that it appears as a possible valid tool to study SRL in VLCs, useful to complement other methods of analysis.

The features of this study, like the choice to work on a small sample, with a manual method and with limited statistical tools, were determined by its exploratory nature. Its aims were:

- To find out whether content analysis with the selected set of indicators would provide data consistent with previous research;
- To understand whether the method is cost effective and if the indicators are sufficiently well-defined to grant an acceptable reliability;
- To refine the indicators and verify whether there are ways to partially automate the textual analysis process.

As for the first point, according to the collected data, the cost-effectiveness of the approach is encouraging enough to plan an extension of the study to a wider sample and for a longer period, as well as to carry out similar studies in different contexts.

While the answers to the first point are quite satisfactory, the second point appears a bit controversial. The inter-rater reliability, on one side, turned out to be pretty good (at least, percent agreement is acceptable, but for bigger samples it would be worthwhile to use more sophisticated measures of reliability such as Kohen K (Capozzoli et al, 1999)). SRL-related messages, on the other side, are not a high percentage of the examined ones, and this makes the rating work not very cost effective.

On the third point we can make positive and negative considerations. A positive point is that the indicators' list (Table 1) appeared to be quite complete and apt to classify all the SRL-related situations encountered. Some refinements were made to the indicators list while rating the messages, since readings students' messages allowed us to spot the presence of learning actions which were clearly self-regulated but were missing from our table. Globally the structure and most of the original indicators were fit to the purpose.

As for negative elements, we realized that there is no easy way to automate the analysis process. As a matter of fact, while in many studies focused on manifest content the analysis can be carried out using software tools that look for typical expressions related to the searched clues, in the case of SRL there doesn't seem to be any typical expression that introduce the kind of sentences we are looking for. For instance, planning actions can be introduced by many different expressions, such as "I propose…", "Why don't we…", "We could make/do…" and many others (or their equivalent in other languages). The same holds for monitoring and evaluating sentence patterns: there are so many ways to introduce a sentence where monitoring or evaluation considerations are brought forward, that it appears hardly possible to employ typical text analysis software tools.

To conclude, SRL development can be revealed by a set of "latent variables", and the proposed set of indicators, derived from widely accepted models in the SRL literature, seems to work properly to this purpose. However, there are some important *caveat*. Firstly, we acknowledge that the use of this kind of variables makes content analysis an inherently subjective and interpretative process. Secondly, researchers who intend to use this method should be aware that what can be found in messages is likely to be true, but it may not provide a complete picture of the phenomenon.

Last but not least, it is widely acknowledged that content analysis is quite a labour-intensive research method. As a consequence, a very interesting applied research direction would be to develop Computer Mediated Communication tools that expressly support content analysis, for example by allowing to associate rater's annotations to each message and to compute statistics about them. These tools would be very useful for content analysts regardless of the aims of the research study they are carrying out.

References

1. Arbaugh, J.B.: Learning to learn online: A study of perceptual changes between multiple online course experiences. Internet and Higher Education 7, 169–182 (2004)
2. Banyard, P., Underwood, J., Twiner, A.: Do Enhanced Communication Technologies Inhibit or Facilitate Self-regulated Learning? European Journal of Education 41(3/4) (2006)
3. Capozzoli, M., McSweeney, L., Sinha, D.: Beyond kappa: a review of inter-rater agreement measures. The Canadian Journal of Statistics 27(1), 3–23 (1999)
4. Carneiro, R., Steffens, K., Underwood, J. (eds.): Self-regulated Learning in Technology Enhanced Learning Environments, Proceedings of the TACONET Conference. Shaker Verlag, Aachen (2005)
5. Delfino, M., Manca, S., Persico, D.: Harmonizing the online and face-to-face components in a blended course on educational technology (in print)
6. Dettori, G., Giannetti, T., Persico, D.: SRL in online cooperative learning: implications for pre-service teacher training. European Journal of Education 41(3/4), 397–414 (2006)
7. De Wever, B., Schellens, T., Valke, M., Van Keer, H.: Content Analysis schemes to analyze transcripts of online asynchronous discussion groups: a review. Computers & Education 46, 6–28 (2005)
8. Garrison, D.R., Anderson, T., Archer, W.: Critical inquiry in a text-based environment: computer conferencing in higher education. The Internet and Higher Education 2(2-3), 87–105 (1999)
9. Lynch, R., Dembo, M.: The relationship between self-regulation and on-line learning in a blended learning context. International review of Research in Open and distance learning 5(2) (retrieved, 2006), http://www.irrodl.org/content/v5.2/lynch-dembo.html
10. Potter, W., Levine-Donnersteirn.: Rethinking validity and reliability in content analysis. Journal of Applied Communication Research 27, 258–284 (1999)
11. Rourke, L., Anderson, T., Garrison, D.R., Archer, W.: Methodological Issues in the Content Analysis of Computer Conference Transcripts. International Journal of Artificial Intelligence in Education 12, 8–22 (2001)
12. Steffens, K.: Self-Regulated Learning in technology-Enhanced Learning Environments: lessons of a European peer review. European Journal of Education 41(3/4), 353–380 (2006)

13. Van den Boom, G., Paas, F., Van Merrienboer, J.J.G., Van Gog, T.: Reflection prompts and tutor feedback in a web-based learning environments: effects on students' self-regulated learning competence. Computer in Human Behaviour 20, 551–567 (2004)
14. Zimmerman, B.J.: Developing Self-fulfilling cycles of academic regulation: an analysis of exemplary instructional models. In: Shunk, Zimmermann (eds.) Self-regulated learning. From teaching to Self-reflective practice, pp. 1–19. The Guildford Press, New York (1998)
15. Zimmerman, B.J.: Attaining self-regulation: a social cognitive perspective. In: Boekaerts, M., Pintrich, P., Zeidner, M. (eds.) Handbook of self-regulation, pp. 13–39. Academic Press, London (2000)
16. Zimmerman, B.J.: Theories of self-regulated learning and academic achievement: an overview and analysis. In: Zimmerman, B.J., Schunk, D.H. (eds.) Self-regulated learning and academic achievement, pp. 1–37. Lawrence Erlbaum Associates, Mahwah (2001)

Evaluating Spatial Knowledge through Problem-Solving in Virtual Learning Environments

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Abstract. Modeling the cognitive processes of learners is fundamental to build educational software that are autonomous and that can provide highly tailored assistance during learning [3]. For this purpose, many student models have been developed. However to the best of the authors' knowledge there is no model for the evaluation and teaching of spatial reasoning. This paper describes how a knowledge representation model for modeling cognitive processes of learners is applied to represent the knowledge handled in a complex and demanding task, the manipulation of the robotic arm CanadarmII, and more specifically, how a training software for CanadarmII manipulations can benefit from the model to evaluate spatial mental representations and provide customized assistance.

1 Introduction

Many complex tasks involve relying on complex spatial representations. One such task is the manipulation of the CanadarmII arm on the international space station (ISS). The CanadarmII arm is a robotic arm with seven degrees of freedom (represented in figure 1). Handling it is a demanding duty since astronauts who control it have a limited view of the environment, being rendered by only three monitors. Each one show the view usually obtained from a single camera at a time among about ten cameras mounted at different locations on the ISS and on the arm. Guiding a robot via cameras requires several skills such as selecting cameras and setting views for a situation, visualizing in 3D a dynamic environment perceived in 2D and selecting efficient sequences of manipulations. Moreover, astronauts follow an extensive protocol that comprises many steps, because a single mistake (for example, neglecting to lock the arm into position) can engender catastrophic consequences. To accomplish the task, astronauts need a good ability to build spatial representations (spatial awareness) and to visualize them in a dynamic setting (situational awareness).

Our research team is working on a software program named CanadarmTutor [11] for training astronauts to the manipulation of CanadarmII in a manner similar as in the coached sessions on a lifelike simulator that astronauts attend. CanadarmTutor's interface (cf. fig. 2) reproduces part of CanadarmII's control panel. The interface's buttons and scrollwheels allow the user to associate a camera to each monitor and adjust the zoom, pan and tilt of the selected cameras. The arm is controlled via keyboard keys in

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inverse kinematics or joint-by-joint mode. The text field at the lower part of the window list all the actions done so far by a learner and display the current state of the simulator. The menus allow setting preferences, selecting a learning program and requesting tutoring feed-back or demonstrations.

The task of interest in this paper is moving the arm from one configuration to another, according to the security protocol. The aim of the work presented here is to describe the relevant cognitive processes of learners that interact with CanadarmTutor so that the integrated virtual tutor can precisely follow their reasoning and grant a tailored assistance. The remainder of the article is organized as follows. First, a literature review on spatial cognition is given. Then, the next sections describe a cognitive model and its extension. We then present the first results obtained from its application in CanadarmTutor. Finally, the last section announces further work and present conclusion.

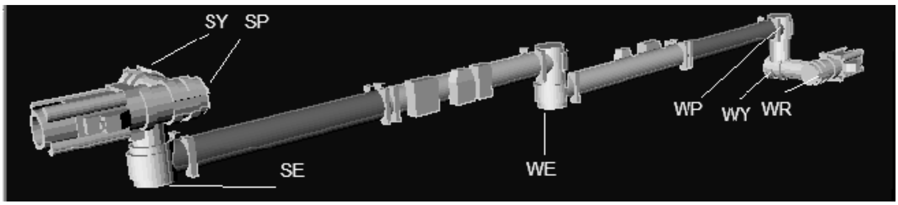

Fig. 1. A 3D model of the CanadarmII arm illustrating the 7 joints

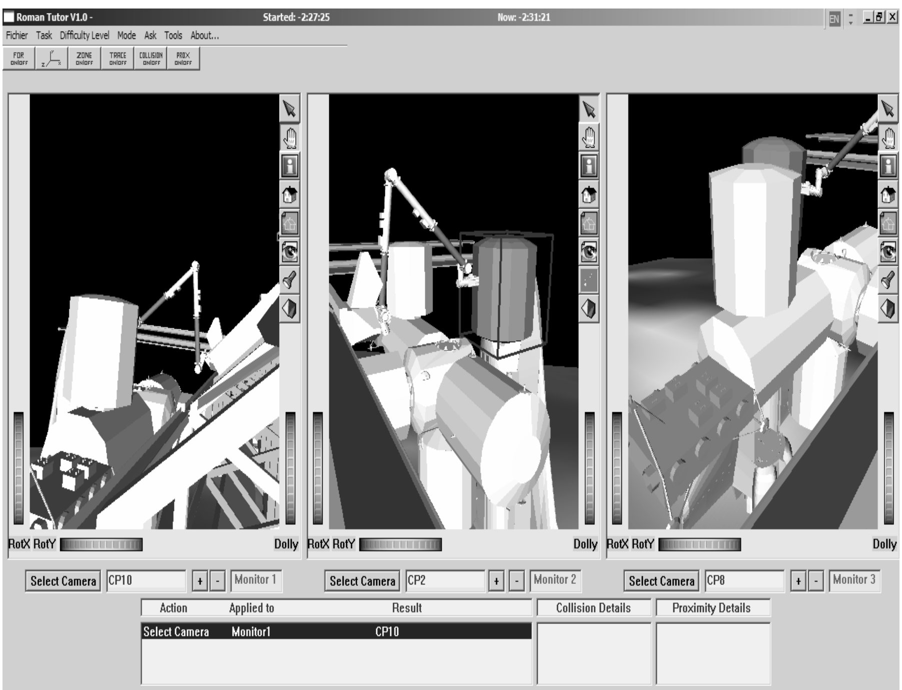

Fig. 2. The CanadarmTutor interface

2 Spatial Cognition

Since more than fifty years, many researchers have been interested in the mental representations involved in spatial reasoning. The concept of cognitive maps was initially proposed by Tollman [18], following the observation of rats behavior in mazes. He postulated that rats build and use mental maps of the environment to take spatial decisions. O' Keefe & Nadel [16] gathered neurological evidences for cognitive maps. They observed that some nerve cells of rats (called place cells) are activated similarly when a rat is in a same spatial location; this is observed regardless of what the rat is doing. These results and the results of other studies allowed O' Keefe & Nadel to formulate the assumption that humans not only use egocentric space representations (which encode the space from the person's perspective), but also resort to allocentric cognitive maps (independent of any point of view). According to O'Keefe & Nadel [16], an egocentric representation describes a route to follow to go from one place to another, and it is composed of an ordered set of stimuli/response associations. Usually, this knowledge is gained through experience, but it can also be acquired directly from descriptions (for instance, from textual route instructions). Route navigation is very inflexible and leaves little room for deviation. Indeed, choosing correct directions with landmarks strongly depends on the relative position of a person to landmarks. Consequently, a path deviation can easily disturb the achievement of the whole navigation task. An incorrect encoding or recall can also compromise seriously the attainment of the goal. According to Tversky [20], egocentric representations may be sufficient to travel through an environment, but they are inadequate to perform complex reasoning. For reasoning that requires inference, humans build cognitive maps that do not preserve measurements but keep the main relationships between elements. These representations do not encode any perspective but makes it possible to adopt several perspectives. Cognitive maps are also prone to encoding or recall errors. But it is generally easier to recover from an error, when relying on cognitive maps than on an egocentric representation. Recently, place cells have also been discovered in the human hippocampus [6]. In the light of this result and other researches carried out during the last decades in neuroscience, experimental psychology and other disciplines, there is no doubt that humans use allocentric and egocentric space representations [14].

Cognitive models of spatial cognition have been proposed. However, they are usually specialized in some particular phenomena of spatial cognition such as visual perception and motion recognition [5], navigation in 3D environments [10, 13] and mental imagery and inference from spatial descriptions [4]. Models that attempt to give a more general explanation of spatial cognition have no computational implementation (for example, [7]). Moreover, to the best of the authors' knowledge there is no model for the evaluation and teaching of spatial reasoning and spatial representations.

Cognitive models of spatial cognition can generally be viewed as proposing structures for modelling cognitive processes at either a symbolic level or at a neural level (for example [13]). Symbolic models that rely on allocentric representations [4, 5, 8] usually represent –with some particularities– spatial relationships as relations of type "a r b" where "r" is a spatial relationship such as "is at the left of" or "is on top of" and where "a" and "b" are mental representations of objects. Unlike allocentric representations, egocentric representations are typically represented as sets of relationships between the self and objects. This representation is in accordance with researchers in psychology such as Tversky [20] that suggest that cognitive maps are encoded as sets of spatial relationships in semantic memory. Since cognitive maps are key to complex spatial reasoning, tutoring software that diagnose and teach complex spatial reasoning requires the capacity to evaluate semantic knowledge.

3 The Theoretical Model

Our model for describing cognitive processes in tutoring systems [7] is inspired by the ACT-R [1] and Miace [12] cognitive theories, which attempt to model the human process of knowledge acquisition. It is a symbolic model that organizes knowledge as (1) semantic knowledge [15], (2) procedural knowledge [1] and (3) episodic knowledge [19]. This paper does not explain the episodic memory part of our model since it is not central to the discussion, here.

The semantic memory contains descriptive knowledge. Our model regards semantic knowledge as concepts taken in the broad sense. According to recent researches [9], humans consider up to four concept instances simultaneously (four dimensions) in the achievement of a task. However, the human cognitive architecture is able to group several of them to handle them as one, in the form of a vector of concepts [9]. We call described concepts these syntactically decomposable concepts, in contrast with primitive concepts that are syntactically indecomposable. For example, whereas the expression "PMA03 isConnectedToTheBottomOf Lab02" is a decomposable representation, the symbol "PMA03", "isConnectedToTheBottomOf" and "Lab02" are undividable representations. The concept "PMA03 isConnectedToTheBottomOf Lab02" represents the knowledge that the "PMA03" ISS module is connected at the bottom of the "Lab02" ISS module on the ISS (assuming the ISSACS coordinate system). In this way, the semantic of a described concept is given by the semantics of its components. While concepts are stored in the semantic memory, concept instances occur in working memory, and are characterized by their mental and temporal context [12]. Thus, each occurrence of a symbol such as "Lab02" is treated as a distinct instance of the same concept.

The procedural memory encodes the knowledge of how to attain goals automatically by manipulating semantic knowledge. It is composed of procedures which fires one at a time according to the current state of the cognitive architecture [1]. Contrary to semantic knowledge, the activation of a procedure does not require attention. For example, when someone evaluate automatically "PMA03 isConnectedToTheBottomOf Lab02" to obtain the value "true", the person does not recall the knowledge explicitly. It is a procedure acquired following the repeated recall of the "PMA03 isConnectedToTheBottomOf Lab02" semantic knowledge from memory. As Mayers et al., [12], we differentiate primitive procedures and complex procedures. Whereas primitive procedures are seen as atomic actions, the activation of a complex procedure instantiates a set of goals, to be achieved either by a complex procedure or a primitive procedure. We consider goals as a special type of semantic knowledge. Goals are intentions that humans have, such as the goal to solve a mathematical equation, to draw a triangle or to add two numbers [12]. At every moment, the cognitive architecture has one goal, a semantic knowledge that represents an intention. Our model is based on the proposal of many researchers that goals obey the same constraints as semantic knowledge. i.e. they are competing to become the activated goal, they can be forgotten and their activation vary according to the context [2]. In our model, this assumption means that cognitive steps may not always need to be achieved in a sequential order. Goals are realized by means of procedural knowledge execution. There can be many correct and incorrect ways (procedures) to achieve a goal. Our model represents goals as a special type of described concepts. A goal has zero or more components, which are concept instances. These instances are the object of the goal. For example, the concept instance “Cupola01” could be component of an instance of the goal “GoalSelectCamerasForViewingModule”, which represents the intention to select the best camera for viewing the “Cupola01” ISS module. The components of a goal are determined by the complex procedure that instantiated the goal.

4 The Computational Model

Our model describes knowledge entities (concepts, procedures and goals) according to sets of slots. A slot associates values to knowledge entities. Each value can be a pointer to another knowledge entity, or arbitrary data such as character strings or integers.

Concepts are encoded according to seven slots. The “Identifier” slot is a character string used as a unique reference to the concept. The “Metadata” slot provides general metadata about the concept (for example, authors’ names and a textual description). The “DLReference” slot describes the concept with a logical formalism. This logical description allow inferring logical relationships between concepts such as “is-a” relationships. These relationships between concepts should be seen as a feature to facilitate the task of knowledge authors, by allowing them to define goals, procedures and described concepts that can be applied to concepts that satisfy a concept’s logical description. This originality of our model is described in details in [7]. The “Goals” slot contains a goals prototypes list; it provides information about goals that students could have and which use the concept. “Constructors” specifies the identifier of procedures that can create an instance of this concept. “Components” is only significant for described concepts. It indicates, for each concept component, its concept type. Finally, “Teaching” points to some didactic resources that generic teaching strategies of a tutoring system can employ to teach the concept.

Goals have six slots. "Skill" specifies as a string the necessary skill to accomplish the goal, “Identifier” is a unique name for the goal, “Metadata” describes the goal metadata, "Parameters" indicates the types of the goal parameters, "Procedures" contains a set of procedures that can be used to achieve the goal, and “Didactic-Strategies" suggests strategies to teach how to achieve that goal.

Ten slots describe procedures. The “Metadata” and “Identifier” slots are the same as for concepts/goals. “Goal” indicates the goal for which the procedure was defined. “Parameters” specifies the concepts type of the arguments. For primitive procedures, “Method” points to a Java method that executes an atomic action. For complex procedures, “Script” indicates a set of goals to be achieved. “Validity” is a pair of Boolean values. Whereas the first indicates if the procedure is valid and so it always gives the expected result, the second indicates if it always terminate. "Diagnosis-Solution" contains a list of pairs "[diagnosis, strategy]" that indicate for each diagnosis, the suitable teaching strategy to be adopted. Finally, "Didactic-Resources" points to additional resources (examples, exercises, etc.) to teach the procedure.

A graphical tool has been built to ease knowledge authoring.

The model was used to represent the cognitive processes of learners that utilize a Boolean reduction rules tutoring system [7]. Although the model was successfully employed to offer tailored assistance, the model lays the emphasis on procedural knowledge learning and offers less support for semantic knowledge learning. The reason is that there is no structure for modeling the retrieval of knowledge from semantic memory, a key feature of many cognitive theories. As a consequence, it is impossible to specify, for instance, that to achieve a goal, one must be able to recall correctly the described concept "CameraCP5 AttachedTo S1" (the camera CP5 is attached to the ISS module named S1) to use it in a procedure thereafter. Evaluating semantic general knowledge is essential for diagnosing and teaching spatial reasoning, if we take the view that cognitive maps are encoded as semantic knowledge.

5 The Extended Model

To address this issue we extended our model. The extension adds a - pedagogical – distinction between "general" and "contextual" semantic knowledge. We define general knowledge as the semantic knowledge (memorized or acquired through experience) that is true in all situations of a curriculum. For instance, such knowledge is that the approximate length of the end effector of CanadarmII is one meter. To be used properly, general knowledge must (1) be properly acquired beforehand, (2) be recalled correctly and (3) be handled by valid procedures. A general knowledge is a described concept, because to be useful it must represent a relation.

Table 1. Partial definition of the concept "MPLM_Below_MPLM2" concept

SLOT	VALUE
Identifier	MPLM_Below_Node2
Metadata	Author: Philippe Fournier-Viger, Date : 2007
DLReference	…
Type	GoalRecallCameraForGlobalView
Components	Module, Module
RetrievalComponents	MPLM, Node2
General	True
Valid	False

Contextual knowledge is the opposite of general knowledge. It is the knowledge obtained from the interpretation of a situation. It is composed of concepts instances. For example, the information that the rotation value of the joint “WY” of CanadarmII arm is currently 42° is a contextual knowledge obtained by reading the display. Authors do not need to define contextual knowledge, since it is dynamically instantiated by the execution of procedures that represent each learner’s cognitive activity. We added three slots to described concepts. The “General” slot indicates whether the concept is general or not. The “Valid” slot specifies the validity of the concept (true or false), and optionally the identifier of an equivalent valid concept. In addition, the “RetrievalComponents” slot specifies a set of concepts to be instantiated to create the concept components when the concept is instantiated. Table 1 presents a concept encoding the knowledge that the spatial module “MPLM” is connected below the module “NODE2” on the ISS (according to the ISSACS coordinate system). The “Valid” slot indicates that it is an erroneous knowledge and that the valid equivalent knowledge is the concept “MPLM_TopOf_Node2” (cf. table 2). The “DLReference” slot content that is not presented in these tables allow the system to infer that these two concepts are subconcepts of the “SpatialRelationshipBetweenModules" concept that is the concept of spatial relationship between two ISS modules.

Table 2. Partial definition of the concept “MPLM_TopOf_NODE2 “ concept

SLOT	VALUE
Identifier	MPLM_TopOf_Node2
Metadata	Author: Philippe Fournier-Viger, Date : 2007
DLReference	…
Components	Module, Module
RetrievalComponents	MPLM, Node2
General	True
Valid	True

Table 3. Partial definition of the procedure “RecallCameraForGlobalView“

SLOT	VALUE
Identifier	RGlobalView
Metadata	Author: Philippe Fournier-Viger, Date : 2007
Goal	GoalRecallCameraForGlobalView
Parameters	(ConceptPlace: p)
Retrieval-request	ID: ConceptRelationshipCameraGlobalView A1: ConceptPlace: p A2: ConceptCamera

We added a retrieval mechanism to connect procedures to the general knowledge in order to model the recall process. It works as the retrieval mechanism of ACT-R, one of the most acknowledged unified theory of cognition. We choosed ACT-R, because our model is already based on that theory. A slot named "Retrieval-request" is added to procedures, to express a retrieval request for a concept in semantic memory, by means of patterns. A pattern specifies the identifier of a concept to be retrieved and zero or more restrictions on the value of its components. Table 3 shows the procedure "ProcedureRecallCameraForGlobalView". The execution of this procedure will request the knowledge of the camera on the ISS that give the best global view of a location taken as parameter by the procedure. The "Retrieval-request" slot states that a concept of type "ConceptRelationshipCameraGlobalView" (a relation that state that a camera gives a global view of a place) or one of its subconcepts is needed, and that its first component should be a place whose concept type match the type of the procedure parameter, and the second component need to be of type "ConceptCamera" (a camera). A correct recall following the execution of this procedure will result in the creation of an instance of "ConceptRelationshipCameraGlobalView" that will be deposited in a temporary buffer with a capacity of one concept instance and made available to the next procedures to be executed.

We have modelled the knowledge for the task of moving a load from one position to another with CanadarmII. To achieve this, we discretized the 3D space into 3D sub spaces named elementary spaces (ES). The spatial knowledge is encoded as described concepts that stand for relations as (1) a camera can see an ES or an ISS module, (2) an ES comprise an ISS module, (3) an ES is next to another ES, (4) an ISS module is at the side of another ISS module or (5) a camera is attached to an ISS module. Moving the arm from one position to another is modelled as a loop where the learner must recall a set of cameras for viewing the ESs containing the arm, select the cameras, adjust their parameters (zoom, pan, tilt), retrieves a sequence of ESs to go from the current ES to the goal, and then move to the next ES. CanadarmTutor detects all the actions like camera changes and entering/leaving an ES. Each of these actions is then considered as a primitive procedure execution. The model does not go into finer details like how to choose the right joint to move to go from an ES to another. This will be part of future improvements.

6 Evaluating the Knowledge

The model provides mechanisms for evaluating semantic and procedural knowledge. Evaluating procedural knowledge is achieved by comparing a learner's actions to the task description. We consider two types of procedural errors: (1) the learner makes a mistake or (2) doesn't react within a time limit. In the first case, we consider an error as the result of the learner applying an incorrect procedure for its current goal. For instance, a learner could forget to adjust a camera zoom/pan/tilt before moving the arm. In the second case, we consider that the learner either doesn't know any correct procedure for the present goal or doesn't recognize their preconditions. Because our model links goals to procedures that can accomplish them, the tutor has knowledge of all the correct ways to achieve the current goal in both of these situations. For complex procedures that specify sub-goals, the tutor can easily conceive an ordered sequence of valid procedures that allows accomplishing correctly any goal.

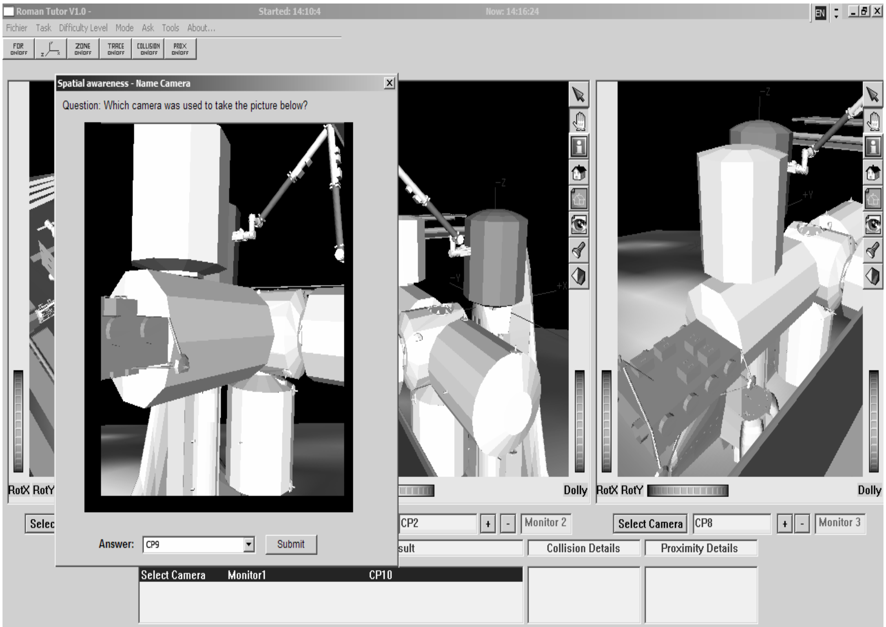

Fig. 3. A camera identification exercise

In addition to this procedural knowledge evaluation mechanism, the extension of this model provides two ways for evaluating general semantic knowledge. Whereas primitive procedures are detectable, it is only possible to detect the recall of knowledge from semantic memory indirectly. First, the tutoring system can test general knowledge directly with questions. For example, CanadarmTutor may verify the mastery of the described concept "CameraCP9 GivesGlobalViewOf JEM" by showing the learner a view of the JEM module and asking him to identify which camera was used (cf. fig. 3). Other types of questions are also implemented such as to ask to name the closest modules to a given module, or to ask to select the best cameras for viewing one or more modules. Second, general knowledge can be evaluated through problem-solving exercises. Initially, the system assumes that recalls are done correctly. Then, as the training progresses, a better evaluation is achieved. The result of each procedure makes it possible to infer through backward reasoning if a general knowledge was recalled (the result of the procedure allow deducing the retrieval buffer content). If the learner uses procedures to retrieve a valid knowledge several times, the system increases its confidence that the learner can recall that knowledge. In the case of the likely recall of an erroneous knowledge, the system heightens the probability of a recall error with that knowledge and will decrease its confidence that the learner masters the valid concept(s).

After many exercises and/or questions, the system acquires a detailed knowledge of the strengths and weaknesses of a learner regarding the procedural and semantic knowledge. It uses this information to generate exercises, questions and demonstrations tailored to the learner that will involve the knowledge to be trained for. For instance, if the system infers that a learner possesses the erroneous knowledge that camera “CP10” is a good camera to view the JEM module, it will likely generate direct questions about the corresponding valid knowledge or exercises that involve its recall.

The integrated pedagogical module currently takes pedagogical decisions based on some very simple rules. To teach general knowledge or procedures, the tutor extracts the didactic knowledge –consisting mostly of text hints or explanations –encoded in concepts’ or procedures’ didactic slots. The tutor also utilizes the spatial relations encoded in the general described concepts to generate dynamic questions. Figure 4 shows such a question that was presented to a learner to test his knowledge of the location of the S1P1TrussRight module. The virtual tutor randomly picked three erroneous question choices based on the spatial relationships. It selected one module that look similar to S1P1TrussRight (S1P1TrussLeft) and two modules that are close to S1P1TrussRight (PVARight01 and S34P34TrussRight01) based on the spatial relationships “lookSimilarTo” and “isConnectedTo”.

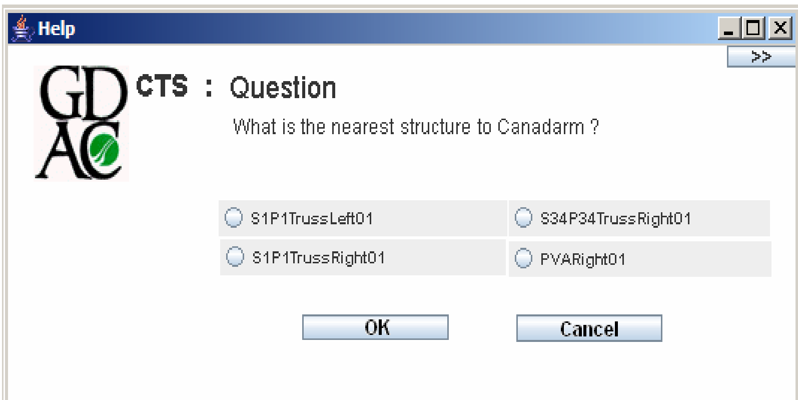

Fig. 4. A contextual question generated by the virtual tutor

Evaluating semantic knowledge through problem-solving exercise is an interesting alternative to the automatic techniques that require doing it separately from the evaluation of procedural knowledge. For instance, Taricani & Clariana [17] offer an automatic algorithm for the scoring of concepts maps drawn by learners. A concept maps is basically a graph where each node is a concept or concept instance and each link represents a relationship. The main information contained in a concept map can be encoded as general knowledge within our framework and be evaluated according to the process described above.

7 Conclusion and Further Work

We have presented an original extension of our model for describing domain knowledge in virtual learning environments. The extension offers a solution for evaluating and teaching general semantic knowledge that learners should possesses. Because the model connects semantic knowledge retrieval to procedural knowledge, evaluation of the general semantic knowledge can be achieved directly through questions or indirectly through observation of problem-solving tasks.

Moreover, virtual tutors based on our model should be able to generate better feedback, because they can know how the semantic knowledge recalled is connected to procedures. Furthermore, this paper has showed how this extension can be used to support spatial reasoning. A first work on modeling the knowledge handled in CanadarmTutor has been presented. Conceiving a more elaborate version of the tutor and verifying its effectiveness is part of our ongoing research.

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References

1. Anderson, J.R.: Rules of the mind. Lawrence Erlbaum, Hillsdale (1993)
2. Anderson, J.R., Douglass, S., et al.: Tower of hanoi: Evidence for the cost of goal retrieval. Journal of Experimental Psychology: Learning, Memory and Cognition 27(6), 1331–1346 (2001)
3. Anderson, J.R., Corbett, A.T., Koedinger, K.R., Pelletier, R.: Cognitive Tutors: Lessons learned. Learning Sciences 4(2), 167–207 (1995)
4. Byrne, R.M.J., Johnson-Laird, P.N., et al.: Spatial reasoning. Journal of Memory and Language 28, 564–575 (1989)
5. Carruth, D., Robbins, B., Thomas, M., Morais, A., Letherwood, M., Nebel, K.: Symbolic Model of Perception in Dynamic 3D Environments. In: Proceedings of the 25th Army Science Conference, Orlando, FL (2006)
6. Ekstrom, A.D., Kahana, M.J., Caplan, J.B., Fields, T.A., Isham, E.A., Newman, E.L., Fried, I.: Cellular networks underlying human spatial navigation. Nature 425, 184–187 (2003)
7. Fournier-Viger, P., Najjar, M., Mayers, A., Nkambou, R.: A Cognitive and Logic based Model for Building Glass-box Learning Objects. Interdisciplinary Journal of Knowledge and Learning Objects 2, 77–94 (2006)
8. Gunzelmann, G., Lyon, D.R.: Mechanisms of human spatial competence. In: Proceedings of Spatial Cognition V. LNCS. Springer, Berlin (2006)
9. Halford, G.S., Baker, R., McCredden, J.E., Bain, J.D.: How many variables can humans process? Psychological Science 16(1), 70–76 (2005)
10. Harrison, A.M., Schunn, C.D., et al.: ACT-R/S: Look Ma, no cognitive map! In: Proceedings of the Fifth International Conference on Cognitive Modeling, pp. 129–134. Universitats-Verlag Bamberg, Bamberg (2003)
11. Kabanza, F., Nkambou, R., Belghith, K.: Path-Planning for Autonomous Training on Robot Manipulators in Space. In: Proceedings of IJCAI 2005 (2005)
12. Mayers, A., Lefebvre, B., Frasson, C.: Miace: A Human Cognitive Architecture. Sigcue outlook 27(2), 61–77 (2001)

13. McNaughton, B.L., Battaglia, F.P., Jensen, O., Moser, E.I., Moser, M.-B.: Path integration and the neural basis of the. cognitive map'". Nature Reviews Neuroscience 7, 663–678 (2006)
14. Nadel, L., Hardt, O.: The Spatial Brain. Neuropsychology 18(3), 473–476 (2004)
15. Neely, J.H.: Experimental dissociation and the episodic/semantic memory distinction. Experimental Psychology: Human Learning and Memory 6, 441–466 (1989)
16. O'Keefe, J., Nadel, L.: The hippocampus as a cognitive map. Clarendon, Oxford (1978)
17. Taricani, E.M., Clariana, R.B.: A technique for automatically scoring open-ended concept maps. Educational Technology Research & Development 54(1), 61–78 (2006)
18. Tollman, E.: Cognitive Maps in Rats and Men. Psychological Review 5(4), 189–208 (1948)
19. Tulving, E.: Elements of Episodic Memory. Oxford University Press, New York (1983)
20. Tversky, B.: Cognitive Maps, Cognitive Collages, and Spatial Mental Models. In: Campari, I., Frank, A.U. (eds.) COSIT 1993. LNCS, vol. 716, pp. 14–24. Springer, Heidelberg (1993)

Role-Play Virtual Environments: Recreational Learning of Software Design

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Abstract. CRC cards and role-play sessions are two techniques widely used in responsibility-driven design and employed as active learning methods to teach object-oriented software design. Based on our experience using them, we propose a game-based approach to take the classroom experience into a virtual environment. We show how the proposed virtual environment must integrate a number of mechanics and we describe one possible interaction metaphor that combines features from first person shooters and sport games, along with its implementation.

Keywords: Game-based learning, object-oriented design, role-play.

1 Introduction

Designing object-oriented software requires common sense, experience and the capability to look at a problem from different points of view. According to our experience, lectures do not allow an easy transfer of these capabilities. Taking ideas from the way software is designed in industry, according to agile methodologies, we have tried a more active teaching approach using role-play and refactoring episodes. An empirical evaluation of our teaching approach has demostrated its good results [5]. It also has shown that the participation in the role-play in the classroom is more effective, from a pedagogical point of view, than just looking at the play. This is the main motivation for the work presented here: to transfer our teaching methodology to virtual environments.

ViRPlay3D2 is an instantiation of the generic architecture of role-play virtual environments (RPVEs) that we have defined. Taking ingredients from the interface and gameplay of first-person shooters and sport games, we have designed this virtual environment that intends to maintain, and even reinforce, the benefits of role-play in the classroom. ViRPlay3D2 is built on our previous experience developing game-based learning environments [3,4].

Next section describes the approach used for teaching software design in the classroom, as the starting point for the virtual environment. Section 3 describes the abstract elements that a role-play virtual environment requires, while Section 4 details our choices in ViRPlay3D2. Finally, Section 5 presents related work and concludes the paper.

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2 An Experience-Based Teaching Approach Used in the Classroom

In our object-oriented design courses, we successfully apply an experience-based teaching approach. This approach actively involves the students, who collaborate in, both, the comprehension and development of designs. CRC cards and role-play sessions are the active learning techniques that support our teaching approach. CRC cards [6] are widely used in responsibility-driven design. A CRC card represents a **C**lass and it contains information about its **R**esponsibilities and its **C**ollaborators. A responsibility is what a class knows and what it can do. A collaborator is a class that helps to carry out a responsibility. CRC Cards are employed in role-play activities in order to simulate the execution of a use case. Role play is a kind of active learning where participants learn complex concepts while they simulate a scenario [1].

The practical sessions in our courses include three stages:

1. Pre-simulation stage: Selection of the design scenario and role assignment. The instructor selects an appropriate scenario among these ones used in the course. A design scenario consists of a case study (the design problem), an initial (maybe incomplete) solution, and a set of use cases that will be used during the simulation in order to understand the proposed solution.
2. Cycle simulation-modification. The instructor starts the simulation by sending the first message to the appropriate object (student). The rest of the simulation is "student-directed": students are responsible for modifying CRC cards, when necessary, and they decide when the simulation finishes. During the simulation, the instructor can help the students when a deadlock happens and she registers the simulation by constructing a Role-Play Diagram (RPD). A RPD is a semi-formal representation of a scenario execution in an object-oriented application that capture objects' state [1].
3. Evaluation stage. After finishing the simulations of all the use cases in a scenario, the instructor evaluates the resulting design. If it is appropriate, the practical session finishes. Otherwise, the instructor discusses with the students the pitfalls found in the resulting design and analyses possible improvements. In this case, the practical session goes back to stage 2.

3 Requirements for Transfering the Learning Sessions to a Virtual Environment

Our good results using the approach described above have promoted the transfer of this kind of sessions to RPVEs where students participate in a role-play session in a similar way that they act in the classroom.

The following elements and mechanics need a representation in a RPVE:

Objects and classes. Each student controls an object, performing its role in the role-play session. The student moves the object representation in the virtual environment in order to look for information about the role-play session and the other entities in the world.

To create new objects, the students must invoke a constructor method in a class. So, the virtual environment also needs entities that represent classes.

CRC cards and scenario description. Every CRC card is bound to a class or an object. A class CRC card contains information about its constructors. An object CRC card describes the responsibilities and collaborators.

During the simulation, it could be necessary to refresh the students the scenario description that they are performing. So this information should be available for the students in the RPVE.

Role-play diagrams. The final result of a role-play session is a RPD that stores the interactions among the objects. In the classroom sessions, the RPD is always visible in order to guide the students during the role-play. In a RPVE, the current RPD should also be available.

Inventory and Information retrieval. Every entity in the virtual environment has an inventory that contains information about it. According to the type of the entity, the information contained in its inventory is different. The RPVE should define one or more actions to retrieve this information contained in the inventories.

Active object and Message passing. The object that is currently at the top of the execution context stack is the only one that can pass a message and it is called the active object. A RPVE should differ this object from the others in order to know which student is responsible for executing the next simulation step.

The mechanic that changes the active object is the message passing, transfering the execution control from one object to another. The message passing is divided into two stages: Message creation, that fixes the receiver, the requested responsibility and the actual parameters; and the message passing execution, that actually transfers the control from the sender to the receiver.

Communication, Undo and Finish. The RPVE is a collaborative tool that must provide a way to establish a conversation between the students, so they can discuss the design and the progress of the role-play simulation. It also needs actions to undo simulation steps (i.e., when resolving a mistake). Moreover, the students should also have a way to decide when the simulation has finished.

4 The ViRPlay3D2 Metaphor

In this section we present the metaphor that serves as the specification of ViRPlay3D2 (Figure 1), an extension of ViRPlay3D [4]. ViRPlay3D2 is a multiplayer environment, where students mimic the classroom role-play sessions. The students are immersed in the environment using a first-person view that simulates the point of view of the objets that participate in the role-play. We have employed the control system and the aspect of a first-person shooter, with an aiming point in the center of the screen to interact with other entities in the virtual world and to throw a ball to represent the message passing.

The RPVE elements described in Section 3 are represented in ViRPlay3D2 using the following metaphorical entities:

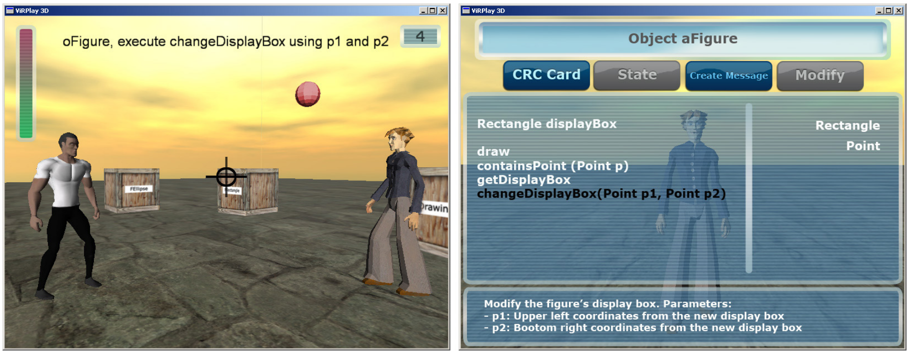

Fig. 1. Two screenshots from ViRPlay3D2. On the left, a student's point of view; on the right, the appearance of the object inventory.

Objects and classes. Each object is represented by an anthropomorphical avatar. In contrast, a wooden box represents a class. Each box carries a label showing the class name.

CRC cards and inventory. Every class and object in the virtual world has an inventory. An object inventory (see Figure 1) contains a CRC card with the object responsibilities and collaborators, and the current object state. A class inventory only displays information about the class constructors.

Scenario description. The virtual environment contains a desktop. This entity contains the general description of the played scenario: a textual description and a class diagram that shows the relations between the participants.

Role-play diagrams. In the upper right corner in Figure 1 (left) the interface shows a score. It shows the number of role-play steps executed during the current simulation. The student can use the "Show Score" tool in order to enlarge this score and see the RPD created with the executed role-play steps.

Active object and Message passing. In our environment, the active object is characterized by holding a ball. The ball contains information about the last passed message or the message that the active object is going to pass. The execution control is transferred from one object to another by throwing the ball. This throwing represents the message passing and it is divided into three stages:

– Creating the message. When the active object is looking up the inventory of one of its collaborators (or her own inventory), the student can create a message by selecting a responsibility, filling in the actual parameters and clicking on the "Create message" button (see Figure 1 (right)).

  If an object can send a return message to another object, the inventory of the first one contains a special responsibility called "Return". The student can create a return message selecting this responsibility and providing the returned value.

  Finally, a construction message allows the students to create new objects. Any object can create this kind of messages through the class inventory of one of its collaborator classes. There, the student can select the cons-tructor employed to create the new object, the descriptor of this object and the constructor parameters.

– Throwing the ball. A student throws the ball by clicking the left mouse button. While the student holds the button clicked, the power level bar in its interface increases. When the student releases the button, the avatar launches the ball in the direction that it is aiming. While the avatar throws the ball the environment displays a message with information about the message.
– Catching the ball. An avatar can catch the thrown ball by aiming at it and clicking on the left mouse button. This action is available only when the avatar that is aiming at the ball is close to it and the object that represents is the receiver of the message created before throwing the ball. When an avatar catch the ball containing a valid message, it becomes the active object and the RPD and the score are updated with the message details.

Information retrieval. The "Look at" action allows the student to see the information related to the entity that her avatar is aiming. The action is executed aiming at an object and clicking with the right mouse button. "Look at" displays the avatar inventory and it contains information about the CRC card. The student can also look at the desktop and display the information about the current simulated scenario. Moreover, if she looks at the ball, detailed information about the current invoked method is displayed. Furthermore, the student looks up her own inventory using the "My Inventory" tool. It displays the inventory of the object represented by the avatar. In this inventory, the student can see the CRC card and the object state. This inventory is also employed to create self-invoked messages.

Communication, CRC modifications, undo and finish. The students discuss during the simulation using the Commu-nication tool. This is a chat communication tool with an edit line, where the students write the message, and a memo box, where the messages are displayed.

The environment also provides a CRC card Modifier tool. This one is available through the object inventory (see the "Modify" button in Figure 1). This tool allows the student to modify the CRC card of the object that she is controlling in the simulation. Using this tool, a student can add, remove or modify the class responsibilities and collaborators.

When the students consider that they have made a mistake when sending a message, they can undo this simulation step. Only the active object can execute the "Undo" tool, but the execution requires the approval of the rest of the students. When the undo action is performed, the environment updates the state of the objects and the RPD according to the previous simulation step. The ball also returns to the right active object.

The students inform the environment when they consider that the simulation has finished by using the"End session" tool. The log file is completed with the final RPD and the modified CRC cards. The execution of this tool implies the confirmation of the students.

5 Related Work and Conclusions

In this paper we have described the transfer of a successful active learning methodology to teach object-oriented design into a virtual environment. Teaching object-oriented design using CRC cards and role-play techniques is not new and it is commonly employed in computer science courses [1]. Our own teaching experiences have revealed that this kind of techniques increases the student motivation [5] and the students better assimilate concepts in object-oriented design after attending and participating in role-play sessions.

For this reason, we have decided to develop a RPVE where the students collaborate to create and evaluate an object oriented design as in the classroom sessions. Although the use of this kind of environments is known to teach object-oriented programming [2], we have not found this kind of environments for object-oriented design in the literature.

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References

1. Börstler, J.: Improving CRC-card role-play with role-play diagrams. In: Companion to the 20th annual ACM SIGPLAN conference on Object-Oriented Programming, Systems, Languages, and Applications, pp. 356–364. ACM Press, New York (2005)
2. Egert, C., Bierre, K., Phelps, A., Ventura, P.: Hello, M.U.P.P.E.T.S.: using a 3D collaborative virtual environment to motivate fundamental object-oriented learning. In: Companion to the 21st annual ACM SIGPLAN conference on Object-Oriented Programming, Systems, Languages, and Applications, pp. 881–886. ACM Press, New York (2006)
3. Gómez-Martín, M.A., Gómez-Martín, P.P., González-Calero, P.A.: Dynamic binding is the name of the game. In: Harper, R., Rauterberg, M., Combetto, M. (eds.) ICEC 2006. LNCS, vol. 4161, pp. 229–232. Springer, Heidelberg (2006)
4. Jiménez-Díaz, G., Gómez-Albarrán, M., Gómez-Martín, M.A., González-Calero, P.A.: Software behaviour understanding supported by dynamic visualization and role-play. SIGCSE Bulletin 37(3), 54–58 (2005)
5. Jiménez-Díaz, G., Gómez-Albarrán, M., González-Calero, P.A.: Before and after: An active and collaborative approach to teach design patterns. In: 8th International Symposium on Computers in Education, vol. 1, pp. 272–279. Servicio de Imprenta de la Universidad de León (2006)
6. Wirfs-Brock, R.J., McKean, A.: Object Design: Roles, Responsibilities, and Collaborations. Addison Wesley Professional, Boston (2002)

A Socio-technical Approach towards Supporting Intra-organizational Collaboration

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Abstract. Knowledge work in companies is increasingly carried out by teams of knowledge workers. They interact within and between teams with the common goal to acquire, apply, create and share knowledge. In this paper we propose a socio-technical model to support intra-organizational collaboration which specifically takes into account the social and collaborative nature of knowledge work. Our aim is to support in particular the efficiency of collaborative knowledge work processes through an automated recommendation of collaboration partners and collaboration media. We report on the theoretical as well as practical aspects of such a socio-technical model.

Keywords: collaboration, media selection, knowledge work, recommender system.

1 Introduction

In times of information overload, acceleration of all life areas and world-wide globalization today's companies need highly qualified and motivated employees who are able to handle information efficiently and transfer them continuously into innovation. These knowledge workers are specialists. They have the relevant knowledge about facts, concepts, relations and methods of their working domain or discipline. With their ability to continuously acquire and apply theoretical as well as analytical knowledge, knowledge workers are the most valuable capital of innovation centered companies. In their self-conscious social role as specialists they are even willing to voluntarily share their knowledge out of moral obligation and community interest [1].

In parallel today's companies are looking for new strategies to gain access to and utilize highly qualified and motivated knowledge workers in order to increase the efficiency of knowledge work and to manage the continuously growing complexity of information, processes and resources. Their major challenge is to turn this hidden capital of knowledge workers into innovation as efficiently as possible.

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With this paper, we want to present a socio-technical approach for supporting knowledge workers as contributors to collaborative communities in work-integrated learning. This approach is being developed as part of the APOSDLE project[1].

2 Supporting Collaborative Communities

Collaborative communities are built up and growing through social interactions between knowledge workers with the common purpose to acquire, apply, create or share knowledge. These social interactions can be divided into interactions related to other knowledge workers and interactions related to knowledge, e.g. they *create*, *use*, *comment*, *rate*, *discuss*, *tag* knowledge or they *communicate*, *collaborate*, *rate*, *comment* or *tag* on each other. All interactions create new knowledge by externalization (tacit to explicit), internalization (explicit to tacit) and combination (explicit to explicit) of knowledge [2]. With our approach we want to increase the efficiency of knowledge creation in collaborative communities and support their social interactions. Thus we propose two ways of socio-technical support: *recommendation of collaboration partners* and *recommendation of adequate collaboration channels and tools*. Both ways are described in following sub sections.

2.1 Recommendation of Collaboration Partners

Before collaborations actually take place knowledge workers may ask themselves a question like "Who of my colleagues could help me with the work I'm currently doing?" To support knowledge workers in answering questions like this, recommendation of collaboration partners is the first step of our socio-technical support. In APOSDLE recommendations are based on the *work context learning model* [3]. The aim is to recommend for a knowledge worker (i.e. knowledge seeker) a set of knowledgeable persons (i.e. possible collaboration peers) adopting the expert role. To find them, APOSDLE maintains user profiles [4] based on a multi-layered overlay user model. From the user model perspective its structure shows similarities to the *ELM-ART* system described in [5]. APOSDLE's recommender system can also be classified according to [6] as knowledge based recommendation system because it heavily depends on knowledge about the users modeled beforehand.

The *work layer* of the user model is the basis for calculating recommendations of collaboration partners. It describes all tasks and work processes a knowledge worker has done while using the APOSDLE system. The work layer of the user profile is continuously updated with usage data as the knowledge worker interacts with the system.

The recommender system uses a learning need analysis as described in [3] as the foundation to calculate a knowledge seeker's learning need as well as knowledgeable persons. All found persons are then ranked based on how often they have gained competencies covering the learning need. At the end of this process a ranked list of knowledgeable persons has been generated which then will be presented to the knowledge seeker.

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[1] The goal of APOSDLE (http://www.aposdle.org) is to enhance the productivity of knowledge workers by supporting informal learning activities in the context of knowledge workers' everyday work processes and within their work environments.

2.2 Recommendation of Collaboration Media

In real-world - especially in computer-mediated - collaboration scenarios the selection of a collaboration tool[2] is mostly not reflected. Knowledge workers use the tool they like best or the tool everybody use or the tool provided by the organization or company. Very often the tool finally selected for computer-supported collaboration is not at all appropriate with regard to the task to be performed, the collaboration context and the collaboration partners. If we try to improve the performance of knowledge workers, we have to review this part of collaboration.

The research field of media selection provides a variety of different theories: t*rait theories* (social presence theory [7], task-oriented media selection [8], media richness theory [9] and task closure theory [10]), s*ocial interaction theories* (symbolic interactionist perspective [11], social influence model [12] and critical mass theory [13]), e*xperience-based media appropriateness* (technology acceptance model [14], channel expansion theory [15] and effects media appropriateness [16]) as well as *theories considering group dynamics* (media synchronicity theory [17]).

All these theories try to describe the user behavior regarding media selection. If we analyze the different media selection approaches considering experienced knowledge workers with individual preferences, we come to following key conclusions:

- Most approaches consider media selection from the perspective of a collaboration initiator only. The perspective of the cooperation partner is completely left out.
- Some approaches are focused on external conditions influencing media selection while personal conditions are left out (e.g. critical mass theory [11]).

Based on the critical observations [18][19] we design a media selection model that combines the strengths of different media selection theories like technology acceptance model, channel expansion theory, critical mass theory, social influence theory or social interaction perspective. Our *media selection model for intra-organizational collaboration* (see Fig. 1) provides an approach towards recommending and preselecting collaboration tools for a certain work or learning context. Therefore our model takes into account three elementary influence factors: knowledge seeker, knowledgeable person and collaborative community.

On the knowledge seeker's side we differentiate the factors *working task* (complexity and information spreading), *collaboration context* (time pressure, time to answer and location) and *collaboration experiences (*personal perspective and experiences of the knowledge seeker from earlier collaborations with a knowledgeable person). The knowledgeable person also has an own *collaboration context*. In addition, both knowledge seeker and knowledgeable persons are influenced by their *individual media experience*. This factor reflects the personal experiences with collaboration media and tools of each collaboration partner. We also need to consider further environmental influences which affect media selection at both ends: s*ocial environment media experiences* (media experiences of a team, department or other communities) and

[2] We use the term *tool* when describing a software application that provides the functionality to interact via a certain *medium*. Medium refers here to a certain communication transfer channel which stores and delivers information or data between sender and receivers.

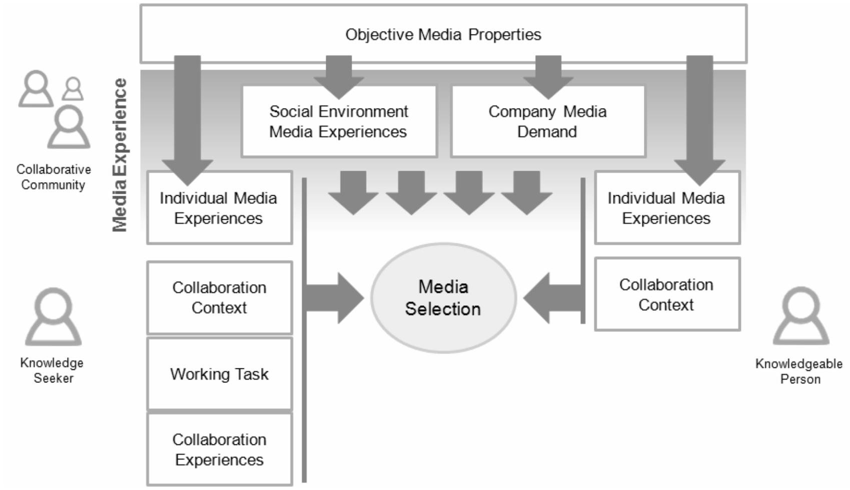

Fig. 1. Influence factors of media selection model for intra-organizational collaboration

the *companies media demand* (media experiences of the company or organization). The *objective media properties* (richness, feedback time, synchronicity, re-use etc.) go only indirectly into the model. They influence the individual media experience.

Beside other factors our approach focuses in particular on the medium experiences and preferences of the individual and their social context – for example their collaborative community. Thus it requires in depth knowledge about these experiences and preferences to allow a technical meaningful implementation.

The media experience of knowledge workers can be derived from their collaboration history. But without having initial history information our approach would not be able to produce meaningful recommendations. Therefore we combined this method with a straightforward *collaboration profile based media recommendation* taking the *collaboration profiles* of knowledge seeker as well as knowledgeable persons into account.

With this combination of collaboration profile and experience based recommendation of collaboration media, we support the technical aspect of social interactions within a collaborative community as well as increase the efficiency in working with knowledge.

3 Conclusions and Future Work

With this paper we proposed a socio-technical approach towards supporting collaborative communities of knowledge workers and motivating them to actively participate in organizational knowledge comunities. We aim to support them technically through recommending adequate collaboration partners and recommending suitable collaboration media and tools. We described a media selection model that is based on media experiences and the knowledge workers context. An important feature of our model is that we not only considered the knowledge seeker but also the other collaboration partners (knowledgeable persons) and their social context. The model combines experience-based factors and objective media properties influenced factors. Another advantage of the proposed model is its robustness and the simplicity. Thus if one factor in the model is missing the algorithm still calculates meaningful values.

The next step towards a verification of our proposed model will be a larger evaluation within the APOSDLE context. This evaluation comprises a comparison of model less media selection with our proposed model. In parallel we will analyze reasonable indicators for the efficiency of knowledge work in collaborative communities.

For the recommendation system of APOSDLE we plan to extend and refine the user model by integrating knowledge indication events. This new type of events will be collected in the learning space of the 3spaces model.

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References

1. Fahey, R., Vasconcelos, A.C., Ellis, D.: The Impact of Rewards Within Communities of Practice: A Study of The SAP Online Global Community. Knowledge Management Research and Practice 5, 186–198 (2007)
2. Nonaka, I.: Dynamic Theory of Organizational Knowledge Creation. Organization Science 5(1), 14–37 (1994)
3. Ley, T., Kump, B., Ulbrich, A., Scheir, P., Lindstaedt, S.N.: A Competence-Based Approach for Formalizing Learning Goals in Work-Integrated Learning. In: Proceedings of the ED-MEDIA 2008–World Conference on Educational Multimedia, Hypermedia & Telecommunications, Vienna (2008)
4. Montaner, M., López, B., De la Rosa, J.L.: A Taxonomy of Recommender Agents on the Internet. Artificial Intelligence Review 19(4), 285–330 (2003)
5. Weber, G., Brusilovsky, P.: ELM-ART: An Adaptive Versatile System for Web-based Instruction. International Journal of Artificial Intelligence in Education (JAIED) 12(4), 351–384 (2001)
6. Burke, R.: Hybrid Recommender Systems: Survey and Experiments. User Modeling and User-Adapted Interaction 12(4), 331–370 (2002)
7. Short, J., Williams, E., Christie, B.: The Social Psychology of Telecommunications. John Wiley & Sons, London (1976)
8. Reichwald, R., Möslein, K., Sachenbacher, H.: Telekooperation: verteilte Arbeits- und Organisationsformen. Springer, Berlin (2000)
9. Treviño, L.K., Lengel, R.H., Daft, R.L.: Media Symbolism, Media Richness, and Media Choice in Organizations: A Symbolic Interactionist Perspective. Communication Research 14(5), 553–574 (1987)
10. Straub, D., Karahanna, E.: Knowledge Worker Communications and Recipient Availability: Towards a Task Closure Explanation of Media Choice. Organization Science 9(2) (1998)

11. Treviño, L.K., Lengel, R.H.: The Richness Imperative and Cognitive Style: The Role of Individual Differences in Media Choice and Behavior. Management Communication Quarterly 4(2), 176–197 (1990)
12. Fulk, J., Steinfield, C.W. (eds.): Organizations and Communication Technology. Sage Publications, Newbury (1990)
13. Markus, M.L.: Electronic Mail as the Medium of Managerial Choice. Organization Science 5(4), 502–527 (1994)
14. Davis, F.D.: A Technology Acceptance Model for Empirically Testing New End-User Information Systems: Theory and Results. Doctoral Dissertation. Sloan Management School, Massachusetts Institute of Technology (1986)
15. Carlson, J.R., Zmud, R.W.: Channel Expansion Theory: A Dynamic View of Media and Information Richness Perceptions. In: Academy of Management Conference Proceedings, Dallas, Texas, pp. 91–105 (1994)
16. Carlson, J.R., Zmud, R.W.: Channel Expansion Theory and the Experimental Nature of Media Richness Perceptions. Academy of Management Journal 42(2), 153–170 (1999)
17. King, R., Xia, W.: Media Appropriateness: Effects of Experience on Communication Media Choice. Decision Sciences 28(4), 877–910 (1997)
18. Dennis, A., Valacich, J.: Rethinking Media Richness: Towards a Theory of Media Synchronicity. In: Sprague, R.H. (ed.) Proceedings of the 32th Hawaii International Conference on Systems Sciences. IEEE, Los Alamitos (1999)
19. Weber, A.: Medienwahl - Eine Auswertung von Ergebnissen der empirischen Forschung. Universität Zürich, Zürich (2003)

Reflect: An Interactive Table for Regulating Face-to-Face Collaborative Learning

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Abstract. In face-to-face collaborative learning, unbalanced participation often leads to the undersirable result of some participants experiencing lower learning outcomes than others. Providing feedback to the participants on the level of their participation could have a positive effect on their ability to self-regulate, leading to a more balanced collaboration. We propose a new approach for providing this feedback that takes the shape of a meeting table with a reactive visualization displayed on its surface. The meeting table monitors the collaborative interaction taking place around it using embedded microphones and displays a real-time feedback to the participants on an array of LEDs, inviting them to balance their collaboration. We report on an ongoing study that currently shows a positive effect our table has on group regulation.

Keywords: Collaborative Learning, Roomware, Ubiquitous Computing, Interactive Furniture.

1 Introduction

In situations of face-to-face collaboration, unbalanced participation often leads to undesirable results. In the context of learning, these results take the form of lower learning outcomes for members of a group that did not participate enough [1, 2, 3]. One way to overcome this effect is by encouraging members of a group to participate equally. This could be achieved by indicating to individual members their level of participation in a shared display.

There have been several recent attempts to enhance conversation with visualizations of member participation. Bergstrom and Karahalios [4] present an approach that transforms the conversation history into a interesting graphical representation that they refer to as a *Conversation Clock*. This "clock" shows individual user contributions in color-coded bars that run along the perimeter a large circle. As time goes by, the older bars move towards the center of the circle and new bars continue to appear on the outer circle. The result is an interesting snapshot of the conversation that captures the history of the conversation in terms of member participation. This snapshot contains a significant amount of information about the conversation; however, it does not focus the attention of the speakers on one or more specific aspects of that converstion, namely dominance or turn-taking patterns. In a more recent work [5], the authors present another system in which each speaker turn is displayed as a colored bar on a shared display. During

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each speaker turn, other members of the group may anonymously vote for the value of the contribution being made. The resulting display provides a global view of who is speaking more and how the others perceive the value of each person's contributions.

DiMicco [6, 7] uses a display that is projected on some shared surface such as the tabletop or a wall in order to show relevant information on the conversation taking place. The information displayed varies and can show dominance and turn-taking patterns among other things. DiMicco also explores different settings for the use of such a visualization by varying the detail presented in the visualization as well the the time it is presented (during or after the meeting).

In this paper we present our ongoing work on an interactive table, *Reflect*, that is similar to the works presented above in that it monitors the conversation taking place around it and displays a visualizaiton of that conversation on its surface. Among these works, *Reflect* is most similar to DiMicco's approach as we are also interested in highlighting overparticipation and underparticipation. We attempt to offer a visualization pattern that is more focused on participation levels and provides a stronger comparative view of these levels.

In the next section, we motivate the need for balancing participation in group learning situations. We then present the details of our own approach in Sect. 3 and our ongoing experimental study in Sect. 4. Some partial results from our study are presented in Sect. 5. We describe the possible and planned extensions to the table in Sect. 6.

2 Role of Participation

Most participation in face-to-face meetings takes the form of verbal communication in that members who are silent are seen as not participating or not contributing to the meeting. In the context of learning, this verbalization plays an important role in the formation of concepts and in the students' reassessment of their own understanding of a situation [8].

In this section we discuss how unbalanced participation in group meetings has a tendancy to reduce the effectiveness of the meeting, either in terms of the quality of the decision made, or in terms of the learning outcomes of the participants.

2.1 Effects on Group Learning

Whether or not they are required to do so, students often find themselves working together in groups. Empircal research has shown that collaborative learning can be more effective than individual learning [9]. However, this is not always the case.

Cohen [1] describes some criteria for group productivity, without which group learners might benefit less than individual learners. Among these, lack of equity in participation is presented as an obstacle to effective learning in a group. Cohen argues that participation is a predictor of learning gains such that the more individual members participate within a group, the more they learn.

Cohen also suggests that the difference in participation is not necessarily related to participants' abilities or their expertise, but rather it is related to their perceived status which can come from any number of stimuli including age, gender, or race of the participant. In some cases, perceived popularity or attractiveness of individuals can lead to more active participation on their part, which in turn leads to lower learning gains for their partners [1, 3].

Unbalanced participation in group learning can thus be seen as a deterrant for effective learning. Baker [10] even suggests that without symmetry in participation real collaboration cannot take place. There is thus a need to neutralize the effects of the perceived status on the levels of participation of group members by encouraging all members to participate equally.

2.2 Information Sharing

There is often a substantial risk that one or more participants who hold critical information are unable to effectively share this information [2]. Proper information sharing is thus a crucial aspect of effective collaborative work. In reality, however, the variety and number of participants who do in fact contribute in the discussion is often less than is deemed appropriate by post-hoc analysis [11]. As a result, discussions take place with some relevant and potentially critical information missing, leading to suboptimal results. This effect could be mitigated if participants were encouraged to participate in a more balanced manner, permitting all members to contribute.

3 *Reflect*: An Interactive Table for Balancing Participation

In its current form *Reflect* is a luminous board embedded in a table. It monitors conversations via an array of embedded microphones and shows a visualization of the current state of conversation using a board of color LEDs. Its main objective is two-fold: to support users in balancing their participation while remaining unintrusive to the natural flow of conversations.

Fig. 1. The current prototype of *Reflect*

At the center of the table, a three-microphone beam-forming array developed by Illusonic [12] permits the system to selectively filter out sounds coming from specific directions. This allows the table to listen to each speaker individually without encumbering the users with head-mounted or tie-clipped microphones.

Beneath the frosted-glass surface of the table, an electronic circuit board with 128 individually-addressable multi-color LEDs provides a low-resolution visual display. This LED board can be programmed to show any desired display. For our initial version of the table, we opted for a column display that clearly shows participation levels of individual speakers.

3.1 Quantity of Participation vs. Quality of Contribution

Regulating user participation is achieved by displaying on the surface of the table the different levels of participation of each group member. This takes the form of a column of LEDs that light up as the user speaks. The more each user speaks, the more LEDs in that user's column light up. At first glance, this may not seem a very convincing way of regulating participation, since participation is not solely dependant on speech levels. The member who contributed the most is not necesserily the one who spoke the most. However, at this point, no intelligent system has been conceived for automatically evaluating the quality of a person's contribution. We therefore rely on the users' own intelligence in determining whether their low speech level is due to low contribution or due to valuable but brief participation. In any case, we maintain that in the absence of more sophisticated technology, speech levels remain a good, though imperfect, indicator of a user's level of participation. This also allows the table to remain a low-cost and thus more accessible system.

3.2 *Reflect* as a Group Mirror

We see *Reflect* as a mirror for a group. A regular betroom mirror does not tell its users if their clothes match or if they need to redo their hair. In the same way, the visualization on the table does not suggest changes in participant behaviour. It simply shows the participants the state of their conversation, and it is up to the participants to decided if a change is needed. That said, we note that *Reflect* is not meant as a tool for *enforcing* balanced participation, but rather as a tool for *increasing the awareness* of participants. Thus, participants who feel that balancing their participation is desirable, would use the table as a means for doing so. However, participants who are not interested in regulating their participation are not expected to be influenced by our table.

4 Current Study

We are currently conducting a study on *Reflect* in which groups of students are asked to collaboratively solve a task. We present here the details of the study and then report some interesting episodes that show how students responded to the visualisation on the table.

4.1 Experimental Settings

Groups of four students are being randomly selected from a pool of bachelor level students that have volunteered for the experiments. Subjects were paid 50 Swiss Francs for their 2-hour involvement in the experiment. Each group is asked to solve a murder mystery task offered to us by Stasser and Stewart [13] and then translated into French to make it more accessible to students in our university community. Each student is given a copy of investigation logs that includes certain important pieces of information that are not available to others. This ensures that all students would be required to participate in the discussion in order to gather all the necessary information.

4.2 Experimental Conditions

There are two experimental conditions that are identical except for the information that is being displayed on the surface of the table. In the first condition, the students are shown their levels of participation i.e. how much time each student talked, and in the second, they are shown the focus of the discussion, i.e. how much time was spent discussing the case of each suspect. The visualizations had the same format for both conditions: a column of LEDs for each student (first condition) or suspect (second condition) would light up in response to the student talking or the suspect being talked about. By simply comparing the length of the columns of lit LEDs, one can easily determine who has spoken most or which suspect was discussed more than the others. Participation levels were detected automatically by the table, and the subject of discussion was determined by a human listening to the conversation as it took place.

A third neutral condition, in which no information is displayed on the table, was not included in the design of the study as it would be quite costly and the benefits of having such a condition are not compelling enough.

4.3 Experimental Procedure

The students are first asked to read the investigation logs individually for 30 minutes, during which the table is used as a simple timer that keeps the students informed of the time remaining. The students are allowed to annotate their copies of the logs and are told that they will keep the copies with them during the discussion. At this point, the students are not informed that their copies of the investigation logs contain information that is not available to others.

The students are then given 60 minutes to reach consensus on a given suspect. In order to jumptstart the discussion, the students are asked to come up, for each suspect, with possible means, motive and opportunity for committing the crime. They are informed that to accuse a suspect, they must prove that he has all of these three elements and that the other two suspects are missing one of the elements. The students are now made aware that they may possess unique information that is not available to others. They are then informed that they are not permitted to give their copy of the logs to another participants and that each participant is only allowed to read from his or her own copy. Finally the visualizations are explained to the students, but no mention is made of the theoretical benefit of a balanced discussion either in terms of participation or subject discussion.

4.4 Data Collection

During their discussion, the students were filmed and their voices were recorded using the table's built-in microphones. Logs of participation levels and of the time spent discussing each suspect were generated and saved. At the end of each experiment, the subjects were asked to fill in a post-experiment questionnaire that contained 19 questions mostly about the experience of the subjects during the experiment and included 4 open questions.

5 Partial Results

The study is still underway, and out of a total of 20 experiments planned (80 participants), 8 have already been completed (32 participants). As it is early at this point to attempt to make detailed statistical analysis, we content with some brief quantitative results and focus on some qualitative analysis of some interesting episodes that occured in some of our experiments. Our objective was to measure the effect of the table in terms of promoting self-regulation among group members. We wanted to answer the following questoin:

– Can a real-time visualization change the way participants behave by promoting self-regulation?

5.1 Case Study

At the end of the study we will attempt to answer this question by statistically analyzing the participants' levels of participation and their ability to estimate these levels. At this point, we focus our discussion to the qualitative aspect of the results. For that we look at the answers to two of the open questions that were given in the questionnaire. In particular, the questions:

1. Can you indicate one or more occasions where the visual display influenced your behaviour?
2. Can you indicate one or more occations where the visual display had a negative impact on the collaboration?

We discuss here a case study of a group who solved the murder mystery task in the first experimental condition. We chose this example because it illustrates both a clear regulatory effect the table had on some members, as well as a clear lack of effect it had on others. Figure 2 shows the *rate of participation* of each member in this group over time. Some interesting observations can be made about this group discussion.

1. Participant C responded to the second question by saying that when she noticed that her LEDs weren't lit, she got "frustrated." We can clearly see in Fig. 2 that the *rate of participation* for this student began much lower than that of participants B and D, but eventually, and for the remainder of the discussion, Participant C began speaking almost as much as participants B and D.

   Although frustration is not a desirable emotion we wish our table to invoke in its users, the end result of self-regulation is beneficial.

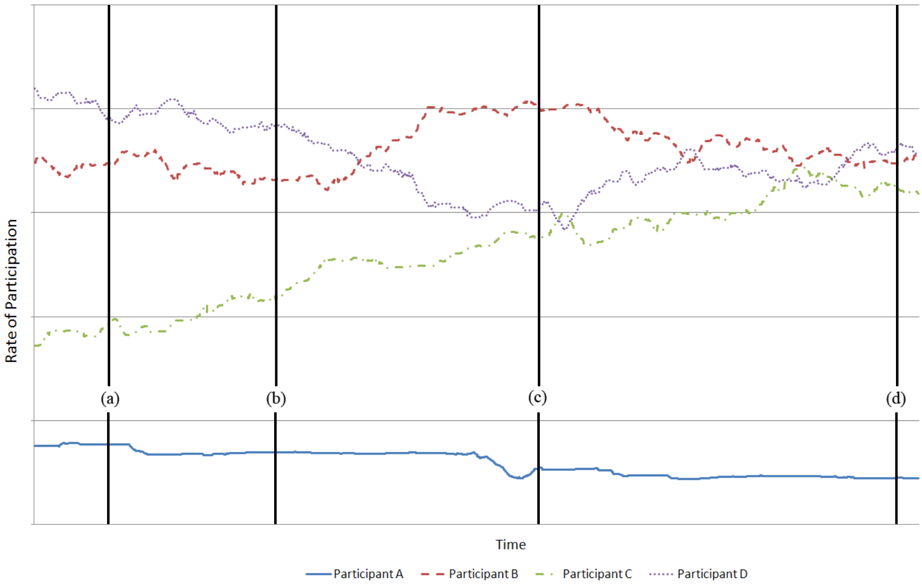

Fig. 2. *Rate of participation* of members of one group is the amount of speech produced by each member over a certain amount of time. Four points of interests are labeled. The state of the table on these points of interest can be seen in Fig. 3.

2. A clearer example of deliberate self-regulation was observed in Participant D who explicitly noted in her response to the open questions that she "tried not to surpass the speaking time of [Participant B]" and that sometimes she "refrained from talking to avoid having a lot more lights than the others." This is also visible in the graph where we see that Participant D started off participating slightly more than the others. At one point, she reduced her participation level and eventually maintained it at the same rate as Participant B.
3. In contrast, we clearly see the utter lack of effect the table had on participant A who kept his participation at an absolute minimum. This participant said, in response to questions in the questionnaire, that he *rarely* looked at the table and that he did not feel it is important for members of the group to participate equally.

   Note that the three other participants reported that they looked at the table either *sometimes* or *often*, and all three felt that it was important for members of the group to participate equally.

This case study, while far from sufficient, provides insight into the potential regulatory effect this table can have on group discussion. It also highlights some limitations of the table, namely: if a user is not interested in participating in a balanced manner, the table will have little or no effect on their behaviour. In any case, more detailed analysis needs to be made between behaviour of students who use participation level visualizations against those who use a topic-based visualizaiton.

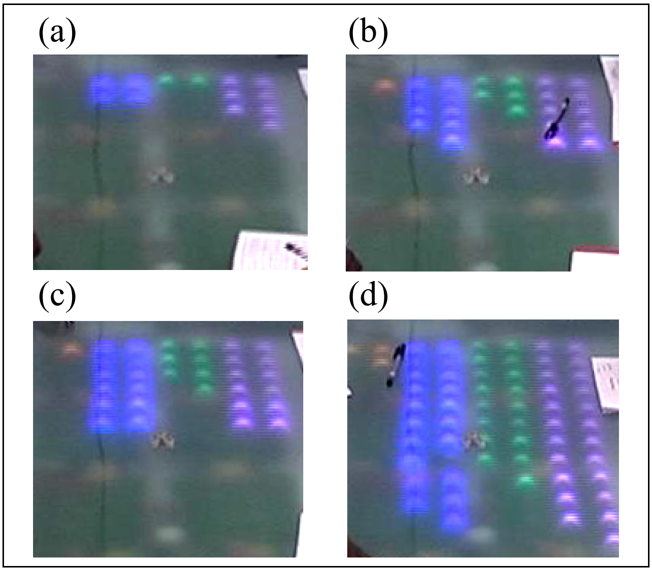

Fig. 3. The state of the table at the four points indicated in Fig. 2. 10 minutes into the discussion in (a) the participation is clearly unbalanced. Participant A begins reducing her level of participation. In (b), Participants B and D begin to approach each other while Participant C still lags behind with less than half the total speaking time. In (c), the point in Fig. 2 where we see Participant D begin to increase her participation again, the table shows Participants B and D with equal participation. Participant C is still increasing her rate of participation at this point. Near the end of the experiment, in (d), Participants B and D have almost equal participation levels, while C remains slightly behind. Participant A never shows concern for his low participation level.

5.2 Statistical Effect

We note here an initial test made on the data we currently have. In order to measure the regulatory effect of the table on members' participation levels, we measured the pair-wise difference between percentage of participation for members within each group.

We excluded from our results subjects in both conditions who answered "No" in the questionnaire to the question: "Do you think it's important that each participant speak more or less the same amount as others during the discussion?" The reason that these subjects were excluded is that their answer to that question indicates that they were not interested in regulating their participation, and thus their ability to regulate, with or without the help of our visualization, cannot be accuruately measured in this experiment. As we mentioned earlier, *Reflect* is not designed as a tool for enforcing regulation, but rather for supporting it by improving participant awareness. The intention to self-regulate must thus come from the users themselves, and when this intention is missing, any self-regulation the user exhibits would likely be coincidental. This may have been avoided by informing the participants before-hand that it is important that they participate equally. We have chosen not to do so because we wanted to keep the collaboration as natural as possible and because informing participants of the benefit of balanced participation could potentially lead to a strong bias in the results.

On the remaining pairs of students (26 pairs, 16 in condition with topic-based visualization and 10 in condition with participant-based visualization), we applied a robust test of equality of means, due to a highly significant difference between the variances in each condition . The robust test showed that there is a significant positive correlation between display of participation levels and the ability of the group members to regulate their behaviour ($t(18.720) = -3.067$, $p = 0.006$). This supports the claim we made in our case study indicating that, among members who are interested in regulating their participation, the table seems to have a positive regulatory effect.

6 Future Work

The current version of *Reflect* simply shows levels of participation for each member of the group. We are now considering implementing different patterns to represent some other aspects of conversations, namely turn-taking. We believe it might be interesting to indicate on the table any observable patterns in turn-taking such as when some participant consistently follows another in speech, or a participant consistently interrupting another's speech. Such additional visualizations might further increase the shared awareness of the participants, helping them further self-regulate in ways other than changing their level of participation.

Additionally, we are interested in extending our table to distinguish different kinds of contributions such as asking questions or giving explanations. We aim to do so by applying machine learning techniques on prosodic features of the speaker's voice in order to not only detect *who* is contributing, but also *how* they are contributing.

When asked if they looked at the display on the table, our 32 subjects responded as follows: 15 said "Often", 14 said "Sometimes", 3 said "Rarely" and none said "Never". This is encouraging as it indicates that users are capable of paying attention to the visualization while at the same time conducting their discussion. Knowing this, we can assume that what will be displayed on the table could be of great value to the users. It is for that reason that the focus our future work will also be producing meaningful and easy-to-interpret visualizations to display on the surface of *Reflect*.

References

[1] Cohen, E.G.: Restructuring the classroom: conditions for productive small groups. Review of Educational Research 64(1), 1–35 (1994)

[2] DiMicco, J.M., Pandolfo, A., Bender, W.: Influencing group participation with a shared display. In: CSCW 2004: Proceedings of the 2004 ACM conference on Computer supported cooperative work, pp. 614–623. ACM Press, New York (2004)

[3] Webster Jr., M., Driskel Jr., J.E.: Beauty as status. The American Journal of Sociology 89(1), 140–165 (1983)

[4] Bergstrom, T., Karahalios, K.: Conversation clock: Visualizing audio patterns in co-located groups. In: HICSS, p. 78 (2007)

[5] Bergstrom, T., Karahalios, K.: Visualizing co-located conversation feedback. In: IEEE TableTop (2007)

[6] DiMicco, J.M.: Changing Small Group Interaction through Visual Reflections of Social Behavior. PhD thesis, Massachusetts Institute of Technology (2005)

[7] DiMicco, J.M., Bender, W.: Group reactions to visual feedback tools. In: PERSUASIVE, pp. 132–143 (2007)
[8] Hoyles, C.: What is the point of group discussion in mathematics? Educational studies in mathematics 16, 205–214 (1985)
[9] Slavin, R.E.: Cooperative Learning. Longman, New York (1983)
[10] Baker, M.: Forms of cooperation in dyadic problem-solving. Revue d'intelligence artificielle 16(4-5), 587–620 (2002)
[11] Huber, G.P.: A theory of the effects of advanced information technologies on organizational design, intelligence, and decision making. The academy of management review 15(1), 47–71 (1990)
[12] http://www.illusonic.com
[13] Stasser, G., Stewart, D.: Discovery of hidden profiles by decision-making groups: Solving a problem versus making a judgment. Journal of Personality and Social Psychology 63(3), 426–434 (1992)

Face to Face Cooperation with CoFFEE

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Abstract. Co-located collaboration in classroom is the topic we tackle in this paper. In particular we will describe how CoFFEE implements this kind of collaboration. CoFFEE is an extensible platform on which to implement different collaborative tools. Every tool renders a different kind cooperation between users. In this paper we will also provide further details in about the newly implemented tools for collaboration, the Repository, the Positionometer and the Co-Writer.

1 Introduction

Cooperative learning refers to those situations where students work together in a group on a collective task. Cooperative learning has traditionally been studied in classroom settings where students meet face-to-face (for an overview, see e.g. [16,13]). The introduction of the use of personal computers in the classroom has led to a variety of technology-enhanced cooperative learning activities, inside as well as outside the traditional classroom context. Technology-enhanced learning in the classroom mainly concerns:

- 'Single display groupware' [15] where students collaborate through a single, shared computer screen,
- Tutor-student dialogue,
- The manipulations of visual objects or models in a shared workspace,
- The use of new technologies like handheld computers or table-top interactive displays.

In this paper we present a collaborative technology that is designed to support face-to-face group discussions in the classroom. A group discussion consists of one or more meetings between a group of students who communicate with each other, often face-to-face, in order to achieve some interdependent goal, such as increased understanding or the solution to a shared problem [2,8].

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The CoFFEE system [3], the collaborative technology that is discussed in this paper, is specifically designed to mediate (part of) the interaction of face-to-face group discussions in the classroom. The computer-mediated part of the communication occurs in a shared digital workspace of the CoFFEE system that can be accessed by all the students simultaneously. When the students work with the collaborative tool, their interactions will be distributed between the two modes of communication, i.e. an oral, face-to-face and an electronic, computer mediated part. We assume that a carefully tools may offer additional structural features that will change the nature of the communication and learning within a student group. The aim of the CoFFEE system is to support the task-related interactions that are associated with learning. Task-related interactions refer to knowledge and information that is shared and used by the students and that relates directly to task performance [12]. These interactions lead to cognitive activities often referred to as knowledge elaborations, which, in turn, are responsible for knowledge acquisition [5]. The task-related interactions are used as the main reference for the design.

2 Tools for Cooperation

CoFFEE [11,4,1] is an extensible platform on which to implement different collaborative tools. In Figure 1 we represented the currently implemented tools classifying them in three categories: *service tools*, *collaboration tools* and *private tools*. Every tool implements a different way of cooperation (see Figure 2).

Side by side with collaborative tools the CoFFEE system, some *service tools* are offered in order to better support the cooperative activities: the Presence tool that reports the members of the group the learner belongs to and a Quick Communication tool that lets the learner to share private channel for a quick chat. Following there is a short description of the tools Threaded Discussion, Graphical Discussion which are described in [11] and that implement some basic ways of collaboration.

Threaded Discussion. The Threaded Discussion tool allows synchronous messaging between the users, structuring the contribution in threads. As reported in literature (see, e.g. [14] for a detailed description) the standard chats have limitations at managing the discussion flow and organizing turn taking, making sometimes the whole discussion comprehension difficult. The usage of a threaded discussion aims to address the lack of control over discussion structure in the standard chat. It must be said, that the threaded discussion shows also some limitations due mainly to the lack of awareness about the location of new contribution. We addressed this issue by providing a simple (and configurable) awareness mechanism that highlights the most recently added nodes (or branches) in the threaded view.

Graphical Discussion. The Graphical Discussion tool allows synchronous messaging between users, representing the contributions as boxes in a graphical space, eventually linked by arrows. This tool is designed to support brainstorming processes and conceptual maps creation, but it is enough generic

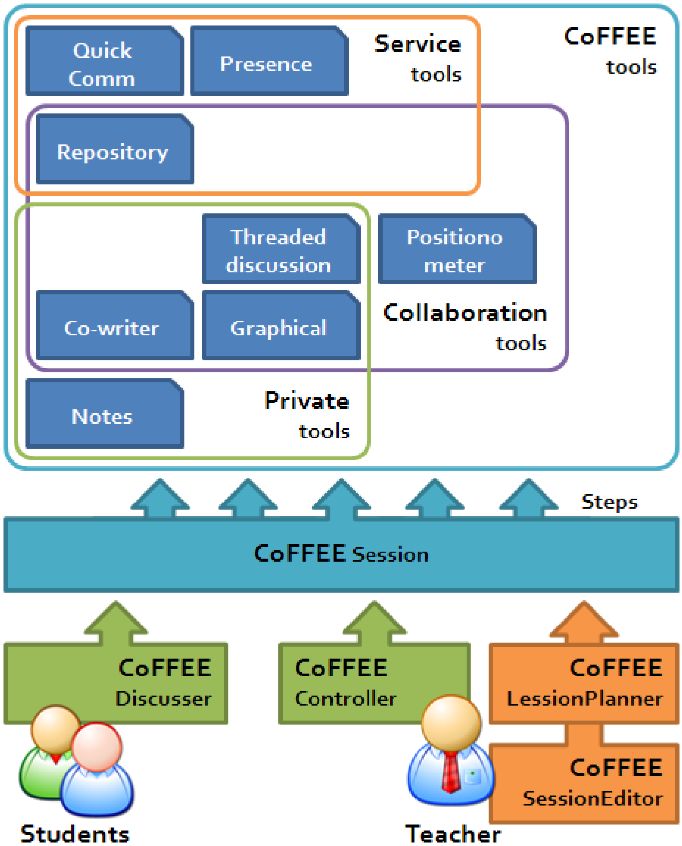

Fig. 1. A diagram showing the tools currently implemented in CoFFEE

and malleable [10] to satisfy other usage scenarios. The boxes can contain maximum 100 characters, and they have all the same size, so that any box can not "dominate" graphically the others on the screen. They can be configured to represent the contribution type through a label and a color.

Both the Threaded Discussion and the Graphical Discussion tool can be configured so that each contribution is tagged by the user according to a notation system, e.g., contributions are tagged as [Q] for Question, [A] for Answer and [C] for Comment. The notation system for each tool is fully configurable: for each tag we can define name, label, color. Moreover, for the Graphical Discussion tool also the shape and connections can be configured (color, linestyle, arrowheads, text label, number of allowed bendpoints, etc.), being part of the notation system.

2.1 Co-writer

This tool offers to the learners a shared text editor with turn-taking, so that only one learner is allowed to write into the editor and the others can only see

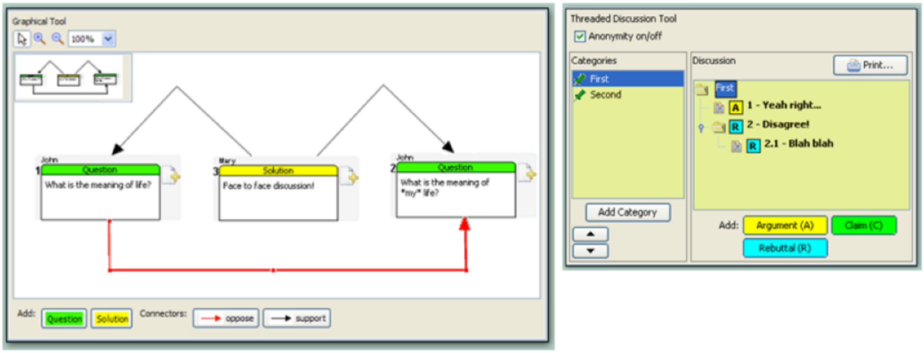

Fig. 2. Two basic cooperation tools Graphical Discussion (left) Threaded Discussion (right)

what he/she writes. The writer is selected by the teacher and each learner is informed about who is currently able to write into the text editor. The teacher is also offered the possibility to load a new document from the file system (that replaces anything that was written at that time) and to save the document written into a text file by using the two buttons above the droplist. The list shows who is the writer, i.e. who owns the "token" and is allowed to write.

2.2 Repository

The Repository tool provides file sharing functionalities among teacher and learners. The teacher manages a shared folder where each learner can get files (by saving them on his/her computer). Each learner, also, has a private folder where documents that he/she thinks can be useful to the activities are placed. The teacher can access all the private folders of the learners and can select a file to be placed in the shared folder to be accessible by the other learners. Each file can be associated with a note containing a description. The tool, then, shows to the teacher a "Shared Files" section and a section of the private files of each learner in the classroom.

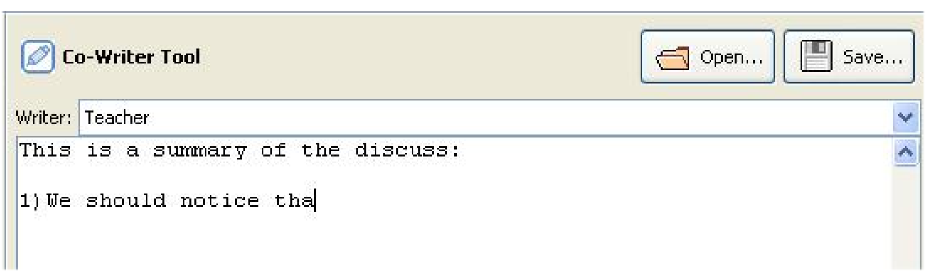

Fig. 3. A screenshot of the Co-writer tool

2.3 Positionometer

This tool provides voting functionalities. A student can express his/her position about an argument proposed by the teacher. It is possible to perform multiple voting operations within the same step, and it is possible to configure voting operations at run-time. In Figure 4 is shown the Positionometer view for the teacher. The slider allows the student to express his/her position in a discrete scale.

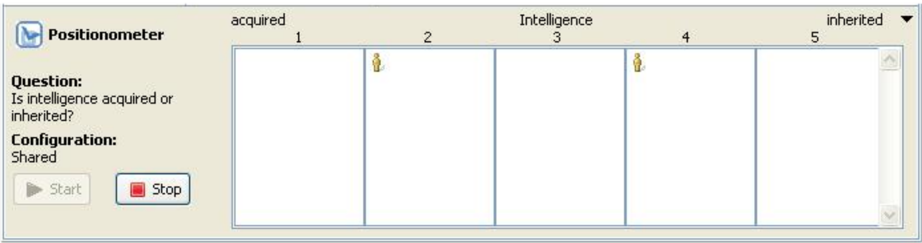

Fig. 4. A screenshot of the Positionometer tool running on the CoFFEE controller: a button is available to stop the votation

Vote visibility. The position expressed by the student can be "Shared by all" (the vote is seen by everyone) or "Personal" (the vote is seen only by himself and the teacher, during the votation, and at the end shown to everybody). In both cases, the teacher, on the CoFFEE Controller, can see everybody's vote. By clicking the Stop button, the teacher stops the voting operation. The clients' sliders are disabled, and the vote is saved (it will be shown when printing the session). If the vote was Personal the results (i.e. everybody's position) is shown to all the learners. For each voting operation, the teacher can specify the number of columns for the scale, as well as the information shown to the students: Question, Argument, Labels for bottom and top value of the scale.

Anonimity. If the vote is not set as "Anonymous", the avatar's name can be seen in a tooltip in every moment. The identities are hidden to the other students when the vote is set as "Anonymous". In this case the background colour is set to yellow. This setting has been shown to be important in classroom setting [9].

2.4 Tools Configuration

Every tool can be used in two different modes, *group* mode and *private* mode. In group mode tools can be used for dyads, small groups and class discussions. In private mode tools provide their functionalities within a private space where any single learner is able to collect ideas, organize a contribution before posting it to the cooperative space, take notes.

This vast amount of possible configurations for every single tool is summarized in Figure 1 using a diagram. Every tool belongs to different categories: for example the Repository tool is a service tool because it lets the teacher to distribute material for a particular lesson, but is also a collaborative tool when learners suggest documents relevant to a particular topic.

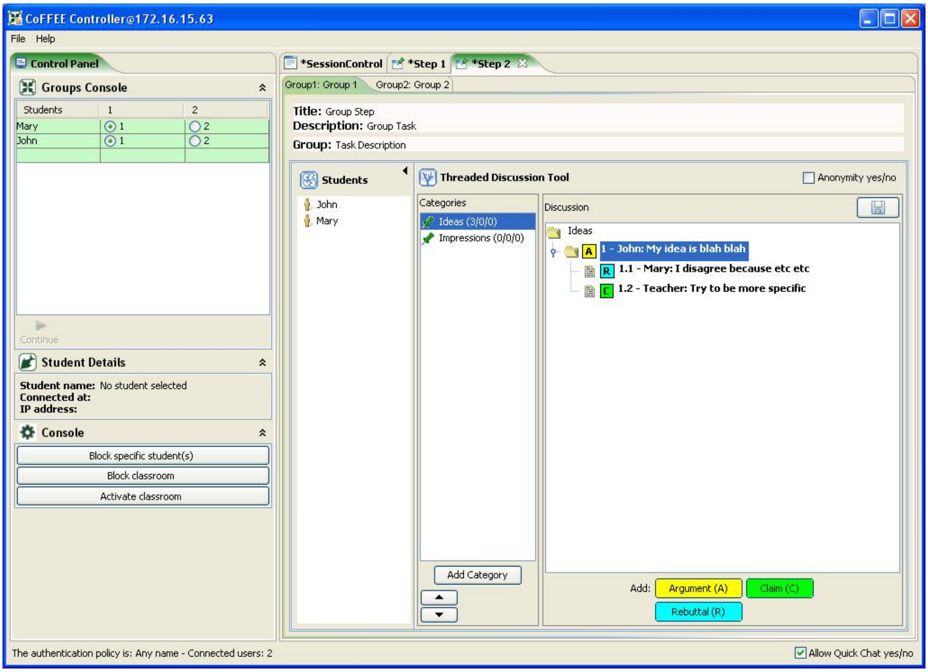

Fig. 5. A screenshot of the CoFFEE Controller. The notation system can be see in the Threaded Discussion tool: each contribution is tagged by the owner and, if configured properly, it can be later changed by the owner/anybody.

2.5 Sessions and Steps

The activities with CoFFEE are organized in *Sessions* [1]. A session can be a part of a whole lesson in the class or span several lessons over a period of several weeks. Every session is composed by *Steps*. A step is the unit of activity and is composed by a combination of tools. The tools in a single step are active and can be used simultaneously by the learners. Passing from a step to the successive oneis decided by the teacher and the tools present in every previous step are frozen. During the lesson, both the teacher and learners can navigates from through previous steps in order to read artifacts.

3 CoFFEE System Details

3.1 CoFFEE Functional Components

CoFFEE is implemented in four separate components (see Figure 1): Discusser, Controller, Session Editor and Lesson Planner. Discusser and Controller match the roles of the users they are designed for, respectively, learners and teacher. The Controller is in charge to host a session and to provide the necessary network infrastructure for the activities. The Discusser is designed to be run one per computer and is the interface that will be used to interact within the system. The Controller allows the teacher to load a session, run it step by step, manage groups, block and unblock learners and of course access each group's tools (except private tools) in order to monitor, facilitate or participate in the discussions. The third component is the Session Editor, it enables the teacher to design the session's steps and assigning for every step the tools[1]. Planning a session can begin from editing a pre-configured template to creating everything from scratch. The last component is the Lesson Planner and is designed to enable the teacher to customize the session without changing its structure. It is useful when a teacher intends to re-use the same session template.

3.2 Latecomer Users Management

CoFFEE provides native support for managing latecomers. A latecomer is a user that connect to the system after the cooperative session has started and some work has been carried out by users. This is an important issue that needs efficient solutions because it strongly influences the interactivity and the usability of the whole system. In fact, managing latecomers in a synchronous session, while difficult, it is an important requirements in a real setting, where latecomers or accidental disconnections and reconnections are possible.

The efficiency of the solution is compared with the settings of the problem, since a latecomer needs a snapshot of the whole system state to start collaboration with other users, and the state size is influenced by several factors like the number of connected users, the frequency of contribution and the average memory occupation of the contributions. Of course, the "later" is the latecomer, the larger is the state.

3.3 Software Technology

CoFFEE architecture is based on a foundational component-based framework Eclipse Rich Client Platform [7]. The network communication between the distributed components is based on the Eclipse Communication Framework [6]; it is a subproject of Eclipse community and provides framework for supporting the development of distributed Eclipse-based tools and applications by using asynchronous point-to-point or publish-and-subscribe messaging functionalities.

4 Conclusion

In this paper we describe the different ways of cooperation provided by CoFFEE for co-located collaboration in classroom. CoFFEE is an extensible platform on which to implement different collaborative tools. Every tool renders a different kind cooperation between users. The CoFFEE version currently available can be downloaded at the Lead project web site `http://www.lead2learning.org` and is available for different operating systems and in 4 different languages.

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References

1. Belgiorno, F., De Chiara, R., Manno, I., Scarano, V.: A flexible and tailorable architecture for scripts in f2f collaboration. In: ECTEL 2008 (Third European Conference on Technology Enhanced Learning) (to appear, 2008)
2. Bormann, E.G.: Discussion and Group Methods: Theory and Practice. New York (1975)
3. De Chiara, R., Di Matteo, A., Manno, I., Scarano, V.: CoFFEE: Cooperative face2face educational environment. In: De Chiara, R., Di Matteo, A. (eds.) Proceedings of the 3rd International Conference on Collaborative Computing: Networking, Applications and Worksharing (CollaborateCom 2007), New York, USA, November 12-15 (2007)
4. De Chiara, R., Manno, I., Scarano, V.: Design issues for a co-located collaborative learning system. In: EARLI 2007 Book of Abstracts, in the "Computer support for face-to-face collaborative problem solving" Symposia (2007)
5. Draskovic, I., Holdrinet, R., Bulte, J., Bolhuis, S., Leeuwe, J.V.: Modelling small group learning. Instructional Science 32(6), 447–473 (2004)
6. Eclipse Communication Framework (ECF), http://www.eclipse.org/ecf/
7. Eclipse, http://www.eclipse.org
8. Harnack, R.V.: Group Discussion: Theory and Technique. Allyn & Bacon (1977)
9. Hornsby, G.G., Ainsworth, S., Buda, M., Crook, C., O'Malley, C.: Making your views known: The importance of anonymity before and after classroom debates. In: International Conference of the Learning Sciences, Utrecht, The Netherlands, International Society of the Learning Sciences (2008)
10. Lonchamp, J.: Supporting synchronous collaborative learning: a generic, multi-dimensional model. International Journal of Computer-Supported Collaborative Learning 1(2), 247–276 (2006)
11. Manno, I., Belgiorno, F., De Chiara, R., Di Matteo, A., Erra, U., Malandrino, D., Palmieri, G., Pirozzi, D., Scarano, V.: Collaborative face2face educational environment (CoFFEE). In: Proc. of First International Conference on Eclipse Tecnhologies (Eclipse-IT), Naples (Italy), October 4-5 (2007)
12. Propp, K.: Collective information processing in groups. In: Frey, L.R., Gouran, D.S., Poole, M.S. (eds.) The Handbook of Group Communication Theory & Research, pp. 225–250 (1999)
13. Slavin, R., Hurley, E., Chamberlain, A.: Cooperative learning and achievement: Theory and research. In: Handbook of Psychology, pp. 177–198 (2003)

14. Smith, M., Cadiz, J.J., Burkhalter, B.: Conversation trees and threaded chats. In: CSCW 2000: Proceedings of the 2000 ACM conference on Computer supported cooperative work, pp. 97–105. ACM Press, New York (2000)
15. Stewart, J., Bederson, B.B., Druin, A.: Single display groupware: a model for co-present collaboration. In: CHI 1999: Proceedings of the SIGCHI conference on Human factors in computing systems, pp. 286–293. ACM Press, New York (1999)
16. Webb, N.M., Palincsar, A.S.: Group processes in the classroom. Macmillan, New York (1996)

The Influence of the Faculty Attitude on the Adoption of ICTs' Innovations for Learning Purposes: Analysis of a Shared Web

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Abstract. This work proposes that faculty attitude explains the satisfaction and using of the students of a shared web. Using a sample of 253 students, the work shows that the emotional support of faculty's member to the platform is influencing the satisfaction and usage of this platform. Meanwhile, students' background and technical support are not relevant for our sample.

Keywords: Innovation, web-based learning, networks, lecturer's role.

1 Introduction

ICTs are not only static tools but rather lead to the creation of specific contexts of teaching-learning and, to a considerable extent, they shape the nature of faculty members' and students' educational performances. Previous literature has repeatedly showed how users' acceptance of technology innovations is a key for a successful implementation of information technology [1]. The importance of different factors has been highlighted in order to understand the users' acceptance of technological innovations and authors have paid special attention to some of them such us: the technological background of users (e.g. [2]) and the own technical features and design of the innovation (e.g. [3]. Different models have tried to integrate all these variables and the Technology Acceptance Model (TAM) suggests that the easy use of the innovation and the potential benefits perceived by users are both influencing users' attitude to the innovation [4]. However, minor attention has been paid to the role of external agents related to the innovation in the process of implementation and acceptance of the technological innovation. Specifically, we analyze how students' perceptions of faculty attitude regarding the innovation influence the students' satisfaction and usage of the technological innovation.

This work show that the students' perceptions of faculty attitude to the ICT may be even more relevant to understand the satisfaction and students' use of the innovative system than the students' technological background or the students' expectative regarding the course.

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2 Hypotheses

In the last decades, communication networks have experienced a spectacular growth. These allow countless services and facilitate objectives such as the remote sharing of resources, the scalability and costs saving [5]. Research in psychology and marketing have suggested that perceptions of individuals become more specific after experience. When students are familiar with ICTs, they often find that ICTs are a splendid opportunity to ease their work. Therefore, literature assumes that technological background of users can explain their frequency of using and satisfaction with the technological innovation.

Nevertheless, this new culture also brings about certain disadvantages [6]. Firstly, networks need operative interdependence; that is to say that, to be able to connect to distant resources, it is required that both, lines and intermediate nodes, work correctly. Secondly, networks demand privileges' assignment. Thirdly, the use of networks has greatly increased the exposure risk to any type of attack. When offering services open to everybody, one runs a risk on the intentions final users have. Moreover, the increasing relationships and complexity of current ICT-related systems make global information and communication infrastructures highly vulnerable. It is assumed that these disadvantages may be more easily faced by students with a relevant technological background. Following previous literature, we propose:

- H1: Previous technological background of students will be positively related with their satisfaction using new technologies for learning support.
- H2: Previous technological background of students will be positively related with their frequency of using new technologies for learning support.

The use of ICTs helps the information transfer of contents as well as the direct intervention by the faculty member. They have still an important role, thus enhancing their tasks of coordinators of the learning process and to solve at least some of the difficulties with the systems (e.g. any project on networks should consider if the used system introduces security elements that palliate, where possible, the different types of attacks that networks can suffer [7][8]). Therefore, their work requires to keep on the learning process that students develop in a continuous way and to offer them the support they need at any moment. Following this argument, we propose:

- H3: Positive attitude of faculty members to support new technologies will be positively related with satisfaction of students who are using those technologies.
- H4: Positive attitude of faculty members to support new technologies will be positively related with frequency of using those technologies by students.

3 Methodology

The population for this study consisted of all the students attending a specific course of "Business Economics" at University of Granada. We offered the possibility of answering the questionnaire to students of 7 groups randomly selected (386 students). All of them were already advanced users after six months in the course. The questionnaire was answered before final exam for the course and, hence, before the students may get information of theirs final grades. 310 students completed the questionnaire (80.3% of the selected sample). Because missing data, we finally use 253 questionnaires (65.5%).

In order to prepare the questionnaire, we initially interviewed six students and three academics interested in the topic of innovation for educational purposes. Based on the interviews and extant literature, we developed a questionnaire to measure our constructs. We used 4 items to measure the students' perceptions of the faculty members' attitude towards the online platform. Responses were on a Likert seven-point scale ranging from "completely agree" to "completely disagree". We used two different dimensions here to measure the faculty attitude: emotional support(Cronbach's alpha=.809), and technical support(Cronbach's alpha=.719). Technological background was measured by asking how expert was the student using new technologies and internet. Responses were on a Likert four-point scale ranging from "high" to "none". Innovation literature has usually used subjective perceptions of users to evaluate users' satisfaction. Therefore, each respondent rated his or her satisfaction and use of the platform using two items. Responses were on a Likert seven-point scale. Because some previous literature have considered the potential association between gender and technology , we are controlling this variable for our study. Maybe more relevant was the potential influence of the student's perception regarding his/her academic performance (grades) in the course. We asked the expectation of grade using a scale of 0 to 10.

4 Results and Discussion

We used two different regression analyses introducing the satisfaction and use of the shared web as dependent variables for each model. Table 1 offers the results of each regression analysis (the dependent variables for each regression are student's satisfaction with the online platform and frequency of using). In the model 1, the control variables were entered. In the model 2, we introduced the three independent variables for our model: students`s background, technical support, and emotional support. The significant differences between the R^2 of models 2 and 1 reflect the strength of the predictive variables.

Table 1. Results of regression analyses (*p<0.1 ** p < 0.05 ; *** p < 0.01)

	Satisfaction		Frecuency	
	Model 1	Model 2	Model 1	Model 2
Constant	4,2***	3.141***	3.606***	3.056***
Grade's expectative	-.045	-.101	-.023	-.067
Gender	.396**	.307	.273	.185
Background		.153		.020
Technical support		-.054		-.004
Emotional support		.313***		.205***
R^2	.023	.115	.010	.055
Adjusted R^2	.015	.097	.002	.036
F	2.904**	6.442***	1.266	2.864**
Increase of R^2		.093		.045
Sig. F for increased R^2		.000***		.009***

Results do not support hypotheses 1 and 2 but partially support hypotheses 3 and 4. Our empirical results show that when the students perceive that faculties show an enthusiastic attitude regarding the potential of the web and encourage the use, the students use more the online platform and they are also more satisfied with the shared web. Interestingly, while that the emotional attitude significantly matters, the faculty's demos are not statistically relevant in order to understand the satisfaction and frequency of using for our sample. We believe that this result is linked to the easy use of the platform which was designed for all kind of users.

Additionally, students' technological background was not related with use and satisfaction of students with the platform for our sample. Again these results might be related to the relationships between innovation adaptation of ICTs and the ease of use of the platform [9] and the previous experience with the teaching web [3]. Students who are familiar with ICT and those who do not feel so comfortable with ICTs do not show differences using and enjoying the benefits of this platform because it was very easy to use for all of them or because they have had change to experience using it.

Therefore we believe that our results offer appealing guidelines for introduction of technological tools in the learning process. While the technological framework maintains simple, the faculty attitude is a key to improve the students' satisfaction with and their frequency of using an innovation. If more technological complexity was necessary, we believe that the faculty attitude would be also important, however technical background and demos might increase their importance in that context. Future work should explore those possibilities.

References

1. Yousafzai, S.Y., Foxall, G.R., Pallister, J.G.: Technology acceptance: a meta-analysis of the TAM: Part 1. Journal of Modelling in Management 2(3), 251–280 (2007)
2. Karjalouto, H., Mattila, M., Pento, T.: Factors underlying attitude formation toward online banking in Finland. International Journal of Bank Marketing 20(6), 261–272 (2002)
3. McKnight, D.H., Choudhury, V., Kacmer, C.: The impact of initial consumer trust on intentions to transact with a web site. Journal of Strategic Information System 11(3), 297–323 (2002)
4. Davis, F.D., Bagozzi, R.P., Warshaw, P.R.: User acceptance of computer technology: A comparison of two theoretical models. Management Science 35(8), 982–1003 (1989)
5. García Teodoro, P., Díaz Verdejo, J.E., López Soler, J.M.: Transmisión de datos y redes de computadores. Pearson Education, London (2003)
6. Stallings, W.: Cryptography and Network Security: Principles and Practice. Prentice-Hall, Englewood Cliffs (2006)
7. Fraser, B.E.: Site security handbook. RFC 2196 (1997)
8. Landwehr, C.: Computer security. International Journal on Information Security 1(1), 3–13 (2001)
9. Teo, H.H., Chan, H.C., Wei, K.K., Zhang, Z.J.: Evaluating information accessibility and community adaptively features for sustaining virtual learning communities. International Journal of Human-Computer Studies 59(5), 671–697 (2003)

Flexible Analysis of User Actions in Heterogeneous Distributed Learning Environments

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Abstract. In this paper, we describe an architectural framework for the engineering of distributed learning environments with different devices and multi-language agent support. The framework consists of a central Tuple Space server and clients that differ in hardware (PDAs, PCs with projection) and in programming languages (C#, Prolog, Java). The analysis components use state patterns and action patterns to be defined in and interpreted by Prolog. This framework has been used for supporting the design rationale method QOC in a collaborative visual modelling environment.

Keywords: Collaboration analysis, mobile devices, tuple spaces, design rationale, discussion support.

1 Introduction

This paper will explore technical issues relevant for the orchestration of classroom settings with interactive devices. With new mobile and wireless technologies, there is growing variety of options in terms of different types of devices that can be used for this. Both the cost and form factors support the feasibility of a one-to-one relation between learners and orchestration and interactive devices (cf. [1]). However, it is questionable if classroom orchestration can (or should) essentially rely on one type of computational device. Liu and Kao [2] have studied classroom interaction patterns with different combinations of devices, including tablet PCs and big interactive screens. These studies corroborate the hypothesis that the use of personalised devices combined with a single public interactive display is clearly superior to using only personalised devices (though with shared content). One of the reasons for the superiority mixed setting is the *lack of shared visual focus* with small personal devices only. This lack of shared visual focus is seen as a cause of fragmented communication observed in a classroom study. The Liu and Kao study provides details about communication patterns and micro activities, such as eye contact and hand/finger pointing, leading to the conclusion that "shared displays enable group members to participate closely in shared activities and establish ideal communication patterns".

In accordance with these plausible findings of Liu and Kao, we have designed dedicated classroom scenarios with heterogeneous device orchestration and "functional differentiation" exploiting the advantages of different device types. One of the

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results was the “Mobile Notes” system to support classroom discussions in which PDAs are used essentially as input devices in combination with a large interactive screen providing a graph structured visual representation [3]. The original version of “Mobile Notes” used a simple architecture with a relational database for buffering the contributions (text or simple sketches) prepared on the PDAs “waiting” to be inserted into the discussion graph. The discussion moderator could view the buffered messages and decide if and possibly when they should be inserted. In our recent work, we have further developed this scenario by adding the following features: (1) support for a specific kind of structured representation used in collaborative design scenarios, and (2) improved awareness for the moderator based on machine analysis of contributions. The solution is based on a more sophisticated distributed and heterogeneous architecture using different implementation languages and agent plug-ins for the analysis. The principles of analysis are based on a previously developed framework described in Gassner et al. [4].

In the sequel, we will describe the implementation platform, the specific scenario and the underlying architecture including aspects of knowledge engineering for intelligent support and a first study to evaluate the usefulness and ease-of-use of this environment.

2 The Use of Tuple Spaces as a Distributed Computing Platform

The Tuple Space approach is based on a blackboard architecture and was introduced together with the coordination language “Linda” [5]. It can serve different coordination and communication functions using a central server which acts as the blackboard and holds all messages or “entries”. The clients solely exchange messages with the server, there is no direct client-to-client connection. Entries are in “tuple” format, i.e. they consist of ordered lists of fields containing primitive data. So the server can be seen as a kind of tuple exchange place used as a shared working memory by the clients. A more recent implementation of Tuple Spaces is part of the Java Jini framework originally developed by Sun Microsystems in 1998 under the name of “JavaSpaces”. In addition to the standard read/write operations, JavaSpaces has also introduced a *notification mechanism*. Another extension of the original idea is the concept of *leases* to assign a limited life time to entries. Almost simultaneously, another Java based Tuple Space implementation called TSpaces has been developed and published by IBM’s Almaden Research Center [6].

The Tuple Space idea has recently gained attention for the purpose of designing and implementing cooperative environments: *Group Scribbles* [7] developed at SRI is a collaborative environment for sharing graphical and textual notes (“scribbles”). Group Scribbles uses TSpaces to support synchronous co-construction with shared and private workspaces and is available for different hardware platforms. A second relevant application of Tuple Spaces for groupware was developed in the *Amenities* project [8]. It uses JavaSpaces to synchronise appointment books of academic researchers. A main focus of this approach is on the provision of rich awareness functions using a Tuple Space architecture with synchronised views, user lists and remote references.

We will particularly draw on the work of Giemza et al. [9], in which Tuple Spaces are used as a general platform for engineering distributed cooperative systems with agent support. By providing standardised clients for different programming languages (such as Java, C#, Ruby or Prolog), the Tuple Space can also serve as a "language switchboard". This makes the provision of specific one-to-one interfaces between different language environments obsolete. For example, a C# client will connect any PDA environment to the shared memory, whereas an intelligent query agent may be formulated in Prolog and the connection to a learning platform will be provided through a PHP client.

The following features of this architecture and approach have turned to be of specific relevance and benefit:

- Once a TS-client interface is provided for a certain language, no more syntactic interfacing is needed for a specific application.
- The blackboard communication pattern provides a persistent data store and "data exchange service" for distributed applications and allows for a high degree of independence (loose coupling) in the development of the different system components.
- Language heterogeneity supports an effective way of specialization in a programming team.

There are multiple reasons for using the one or the other implementation language in nowadays application systems. An essential point to consider is certainly the adequacy of the language for the problem at hand. E.g., Prolog may be considered as particularly well suited for the analysis of complex objects with a symbolic representation, whereas Java may be seen as the language of choice for distributed applications with visual interfaces. But also the availability and support of a language on a specific class of devices may be an issue. In the case of PDAs, we have recently moved from using Java (J2ME) to C# for various (mainly practical) reasons. From a knowledge engineering point of view, this approach allows for defining collaboration patterns without having to deal with low level interfacing problems. In the rest of the paper these advantages will be explained in more detail based on the existing implementation.

3 The Application Scenario

3.1 Motivation

Recently, we have described an approach to support face-to-face discussions in classrooms or meeting rooms in which PDAs would not be used to share information but to provide individual input in the form of small notes or sketches [2]. In this *Mobile Notes* scenario, the information to be shared by the discussion group is provided on a big interactive screen or whiteboard. Now, we have specialised the quite general *Mobile Notes* scenario to a more specific structured representation of the discussion content. This representation (QOC) has its origin in the area of "design rationale" methods [10] (see also section 3.2). In our case it supports the externalization of a decision process.

The fact that we have a more specialized application and a more structured representation than in the *Mobile Notes* scenario allows us to analyse the discussion content and process based information on certain temporal and structural patterns. In this context, the blackboard communication model is used to plug in the corresponding analytic agents. Fig. 1 depicts a typical setup of this learning environment.

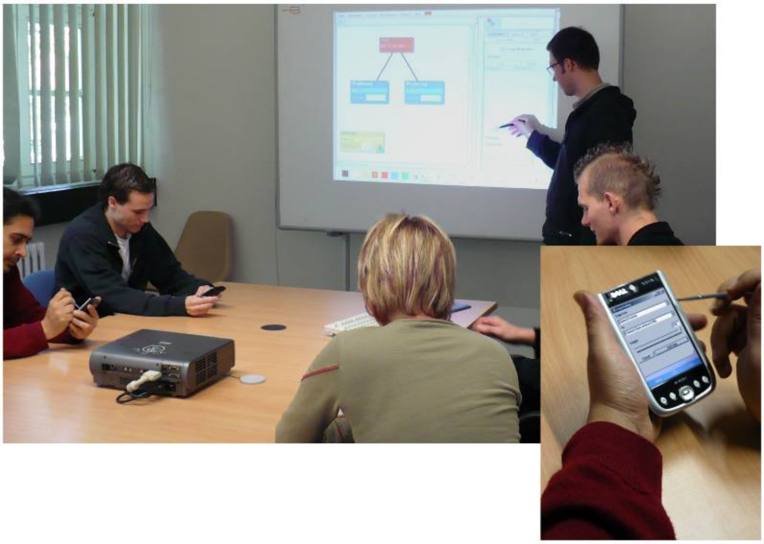

Fig. 1. The application scenario

3.2 QOC Based Design Decision

The concept of "design rationale" comprises a variety of methods to support structured decision making and externalization in the design of (technical) artefacts (cf. [10]). Design rationale techniques have been particularly applied and developed in the field of GUI and interaction design. Support technologies for design rationale approaches include the provision of machine readable representations (to be shared by humans) as well as interactive/cooperative media arrangements to facilitate communication and flow in the design process.

"Questions - Options - Criteria" or QOC [11] is in first place a structured representation to be used in a design rationale process, starting with a specific question or design issue to be resolved, than stating alternative options and introducing criteria for a comparative, weighted evaluation of the options. The final product is a QOC graph which would document and explain the specific decision (see Fig. 5).

The QOC representation is supported by a specific "palette" in our collaborative visual modelling environment *FreeStyler* [12]. It has been used quite successfully in classrooms as well in software development projects by students.

The specific application scenario to be supported here is the use of QOC in a face-to-face setting in which the shared visual representation is displayed on an interactive board under the control of a teacher or moderator. PDAs are used by the participants to make input to this shared model. The results of the analytic agents are fed back to the public display as a kind of content oriented awareness information.

3.3 Discussion Moderation

Additionally, the architecture described in the following chapter allows for the moderation of incoming students' contributions.

In the paper at hand, the term *moderation* describes the possibility of a moderator or teacher to preview and approve or reject students' actions. Single actions in our case are

- Adding a question, option or criterion
- Deleting or changing the content of one of the above
- Adding or removing an edge
- Changing the weight of an edge.

If one of these actions is conducted by a student, it will appear in the moderation interface in the *FreeStyler* environment that is under control of the moderator (see Fig. 2). Here, all actions are collected in a list and can be previewed. The moderator can choose to approve an action (i.e. the action is executed in the StateSpace (see next chapter)) or it can be rejected (i.e. the action is not executed and will be removed from the moderator's panel).

Of course, the moderation feature can be switched off completely. In that case, all students' actions are executed directly without further interference or delay.

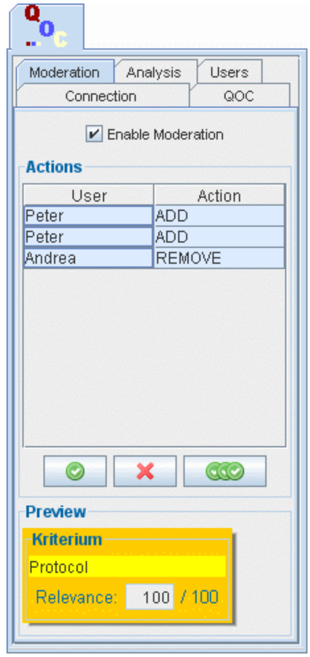

Fig. 2. Moderation interface with action preview

4 Overall Architecture

The overall architecture consists of the QOC-FreeStyler application shown on the public display, several clients that run on PDAs, an analysis engine (Prolog) and a Tuple Space (TS) server as communication and synchronisation platform (see Fig. 3). For the TS server, we use our own implementation of SQL Spaces [9].

The TS consist of several spaces that play a central role in this architecture. The *StateSpace* holds a representation of the current QOC model that is visualised by the FreeStyler application. The PDA clients may perform actions to modify or add to the model, which will be written into the *ActionSpace* first. At that point, as described in the previous chapter, actions can be moderated (i.e. previewed and possibly approved by a moderator) or conducted directly. The separation of actions and states does not only allow for an easy implementation of such moderation, but it provides a convenient way for action analysis, since all actions are persistently available to the Prolog engine (see next chapter).

The analysis engine continuously tries to match given patterns to the contents of the *StateSpace* and *ActionSpace*. If a pattern matches, the result is written to the *AnalysisSpace*, from which it can be retrieved and visualised by FreeStyler.

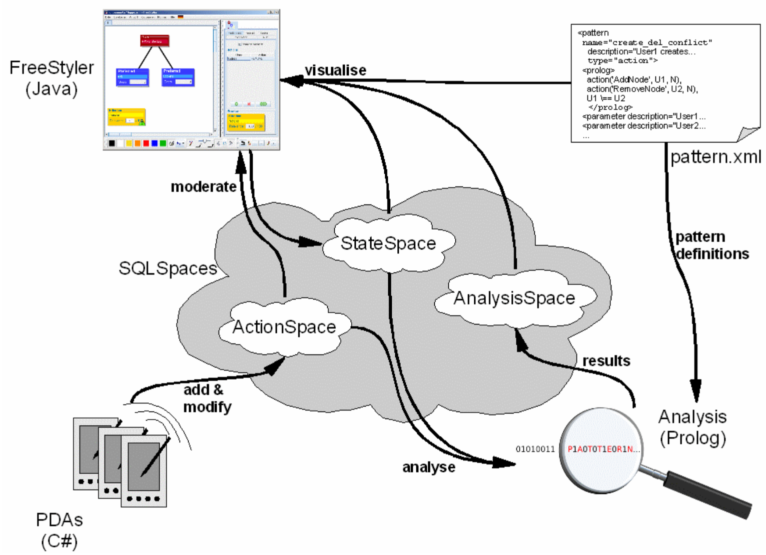

Fig. 3. Overall architecture

5 Knowledge Engineering of Cooperation Patterns

Fig. 4 shows the knowledge engineering process of cooperation patterns. A knowledge engineer uses a Prolog testing environment to create and test Prolog predicates that match interesting patterns in user actions or model states (or even a mixture of both). Once the knowledge engineer finishes the pattern creation process, the predicates are annotated with descriptions about the meaning of the patterns and of the parameters used. This information is later used by the *Awareness Display* to convey information about found patterns to the end user at run time.

The following lines are an excerpt from a *pattern.xml* file that is used by the *Awareness Display*.

```
<pattern
  name="create_del_conflict"
  description="User1 creates a node and a different User2
               deletes it"
  type="action">
  <prolog>
    action('AddNode', U1, N),
    action('RemoveNode', U2, N),
    U1 \== U2
  </prolog>
  <parameter description="User1" var="U1"/>
  <parameter description="User2" var="U2"/>
  <parameter description="Node" var="N"/>
</pattern>
```

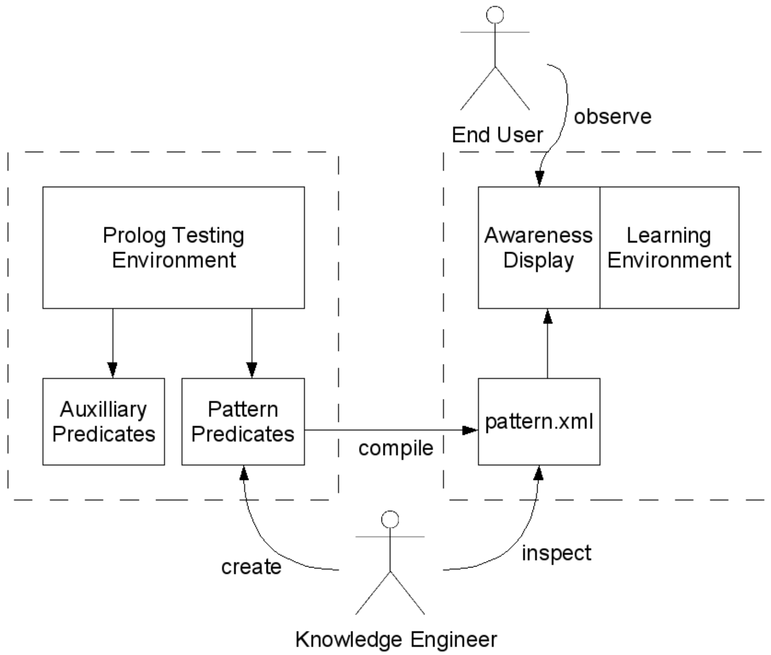

Fig. 4. Knowledge engineering of cooperation patterns

One advantage of this kind of knowledge engineering framework is the homogeneity of the interface. In the approach at hand, the knowledge engineer can create, test and describe analysis patterns in one single environment (i.e. a Prolog programming environment like SWI-Prolog[1]). He does not have to leave his familiar working environment. Additionally, by having the *pattern.xml* file, analysis patterns, their descriptions and metadata can be exchanged between users and moderators by simply copying one file.

6 Action Patterns and State Patterns

As stated above, the described framework allows for performing analyses based on information about the actual state of a model as well as analyses based on the history of user actions.

Typically, *state patterns* deal with syntactic and semantic features and characteristics of the used modelling language. These kinds of patterns describe certain constellations of nodes, edges and their attributes. For the QOC method, we identified some patterns that are potentially interesting for a moderator:

- The model contains an unconnected criterion;
- The model contains an option with no attached criteria;

[1] See http://www.swi-prolog.org, 14th April 2008.

- There is no preferred option in the model;
- A criterion has equal effects to all options;
- ... and others.

Action patterns deal with certain sequences in the history of user actions. Typically, these patterns describe some kind of significant and possibly interesting behaviour of single users or they describe occurrences of collaboration between two or more users. These patterns tend to be more domain independent than the state patterns, so that they can potentially be used with various modelling languages and learning applications.

Examples for action patterns are:

- One user creates an object, a different user deletes this object (conflict?).
- One user creates an object, a different user connect this object (collaboration?).
- One user is clearly doing most of the actions (dominating others?)

However, there are also domain dependent action patterns. E.g., for QOC, a series of actions that change the weight of an edge from positive to negative values can be quite significant and could not be detected by state patterns only.

Additionally, combinations of state and action patterns are feasible and meaningful, too. Imagine having a pattern that detects a characteristic situation in the model (state analysis) in combination with searching for possibly collaborative user actions that lead to this situation (action analysis).

Fig. 5 shows a screenshot of the FreeStyler application and the awareness component notifying the moderator of a matched pattern.

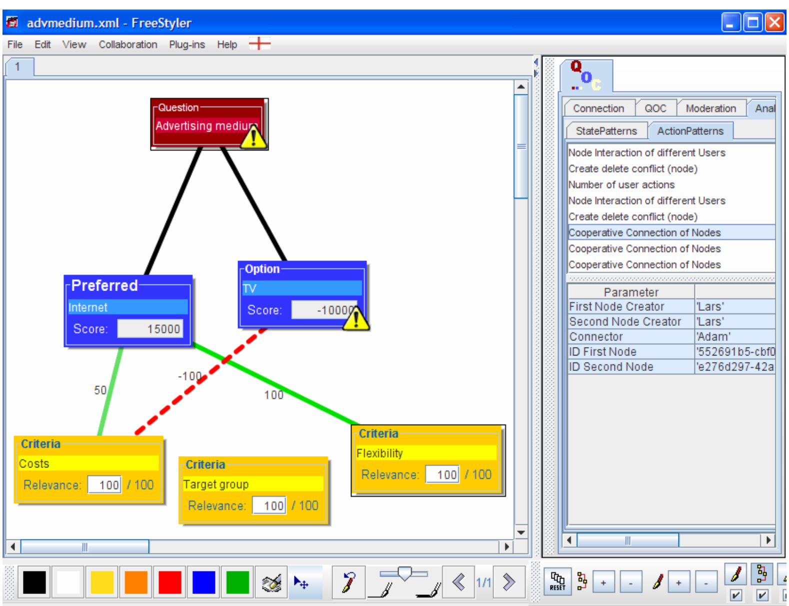

Fig. 5. QOC model and awareness display for a “Cooperative Connection of Nodes”

7 Evaluation of MobileQOC

The MobileQOC environment has been evaluated for their usefulness and ease-of-use in a study conducted in four single sessions with 19 participants altogether. In each session, one participant took the role of a moderator and four participants took the role of a discussant (one person did not show up, thus 19 persons).

In each session, the participants were given a design decision task that should be solved by using the MobileQOC environment. The setup of this study has been very similar to Fig. 1.

The four sessions have been evaluated by using questionnaires, interviews and observations. The questionnaires were built and evaluated by using the Technology Acceptance Model (TAM) by Fred Davis [13]. From the Technology Acceptance Model, the two most prominent aspects *Perceived Usefulness* and *Perceived Ease of Use* have been used in this study. The questionnaires have been designed using a 7 scale Likert scale and consisted of the following items:

Perceived Usefulness questionnaire items:

1. I think MobileQOC could improve my performance in design decisions in school or university courses.
2. MobileQOC could help me to accomplish design decisions more quickly.
3. I think using MobileQOC enhances my effectiveness in design decisions.
4. I think using MobileQOC decreases my productivity in school or university courses.
5. Using MobileQOC makes it easier to carry out design decisions.
6. I think MobileQOC slows down design decisions.
7. Overall, I find the MobileQOC application useful in school or university courses.

Perceived Ease-of-Use questionnaire items:

1. The MobileQOC application is easy to learn.
2. MobileQOC is rigid and inflexible to interact with.
3. MobileQOC is easy controllable and behaves as expected.
4. My interaction with the MobileQOC application is easy for me to understand.
5. It is hard for me to remember how to perform tasks using the MobileQOC application.
6. Interacting with MobileQOC is mentally exhausting.
7. Overall, I find the MobileQOC application easy to use.

Besides the TAM questionnaires, each session has been observed by a non-participating observer and the moderators have been interviewed on their use and estimation of the moderation and analysis features of the MobileQOC environment.

7.1 Questionnaire Results, Interview Conclusions and Observation Findings

The reliability of the questionnaire results can be considered high: The Cronbach's Alpha value for the Perceived Usefulness items (PU) is .927; the value for the Perceived Ease-of-Use items (PEU) is .776.

The results of the single Perceived Usefulness items show high values in all (non-reversed) items (the mean ranges from M=4.47, SD=1.727 to M=5.4, SD=1.298 on a 7 level Likert scale). Remarkably, the summarising item 7 gets the highest mean value.

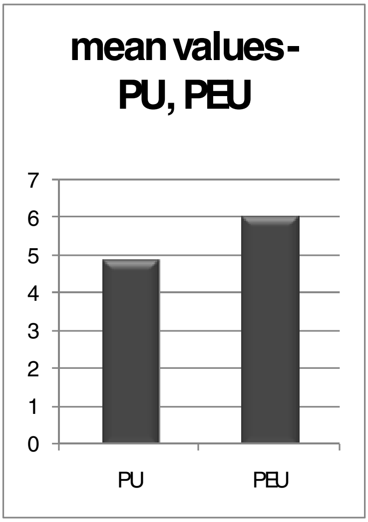

Fig. 6. Mean values of PU and PEU over all cases

The results for the Perceived Ease-of-Use items show even better results: The mean values of the non-reversed items range from M=6.0, SD=1.0 M=6.8, SD=.561 while the reversed items range from M=1.27, SD=.594 to M=3.2, SD=1.32.

Fig. 6 finally shows the mean values for the Perceived Usefulness and Perceived Ease-of-Use over all items and cases.

Overall, the usefulness and the ease-of-use can be considered as perceived well for the MobileQOC environment.

From the interviews, you could learn that the moderation features (i.e. accepting or rejecting incoming participants' action) is perceived as of little use in sessions with a small number of participants and with "well-behaving" groups, but estimated to be of high value when moderating large groups, several groups at a time or when groups are showing destructive or socially bad behaviour. The analysis features for state patterns (that mostly find flaws and shortfalls in the QOC model) are generally considered highly useful, while the action patterns (that generally detect specific collaborative features) are considered less useful for the same reasons as the moderation feature.

The observation showed that the participants' attention was not completely caught by the mobile devices or by the projected display, but they talked with each other to discuss particularities on the domain level ("What do you think the edge weight should be?") and on an organisational and social level ("You both connect these nodes [pointing to whiteboard] and we connect these nodes [pointing to whiteboard], so that everybody has to do something now..."). This goes well along with the findings of Liu and Kao [2], that appraise large shared displays as supportive for the externalization and articulation of student thinking.

8 Discussion and Outlook

In the previous chapters, we presented a learning environment to support design rationale discussion using the QOC method. Mobile devices serve as input devices to give students an opportunity to participate freely and unhindered from peers. The graph-based modelling application FreeStyler is used to collect, organise and display the contributions on a large whiteboard, acting as a shared visual focus. The paper concluded with presenting the results of a study to evaluate the usefulness and users' estimation of MobileQOC.

Moderation and analysis features support a moderator or teacher to be able to balance discussions and take care for syntactically sound models.

On a technical level, the environment bases on Tuple Spaces to provide a powerful and flexible architecture that easily integrates various programming languages, different devices and allows for sophisticated analysis components.

In further developments, we plan to generalise and extend this approach and architecture to various modelling languages like Petri Nets, System Dynamics or UML. Pre-defined Prolog predicates that are useful and meaningful for state analysis and actions analysis in various languages can be identified in this process of generalisation.

Additional agents will be used to further process the content of the *Analysis Space* in order to generate direct feedback in the form of recommendations or adaptations of the environment (instead of just displaying awareness information).

Furthermore, we plan to include the actions in the moderation queue (i.e. actions that have been committed by users but not yet approved by a moderator) into the analysis cycle. Thus, a moderator would be able to assess the impact of user actions before they are released.

References

1. Chan, T., Roschelle, J., Hsi, S., Kinshuk, M.S., Brown, T., Patton, C., Cherniavsky, J., Pea, R., Norris, C., Soloway, E., Balacheff, N., Scardamalia, M., Dillenbourg, P., Looi, C., Milrad, M., Hoppe, U.: One-to-one technology-enhanced learning: An opportunity for global research collaboration. Research and Practice in Technology Enhanced Learning 1(1), 3–29 (2006)
2. Liu, C., Kao, L.L.: Handheld devices with large shared display groupware: tools to facilitate group communication in one-to-one collaborative learning activities. In: Proceedings of IEEE WMTE 2005, Tokushima, Japan, March 2005, pp. 128–135 (2005)
3. Bollen, L., Juarez, G., Westermann, M., Hoppe, H.U.: PDAs as input devices in brainstorming and creative discussions. In: Proceedings of 4th International Workshop on Wireless, Mobile and Ubiquitous Technologies in Education (WMUTE 2006), pp. 137–141. IEEE Computer Society Press, Los Alamitos (2006)
4. Gassner, K., Jansen, M., Harrer, A., Herrmann, K., Hoppe, H.U.: Analysis methods for collaborative models and activities. In: Proceedings of CSCL 2003, Bergen, Norway, June 2003, pp. 369–377 (2003)
5. Gelernter, D.: Generative communication in Linda. ACM Transactions on Programming Languages and Systems 7(1), 80–112 (1985)
6. Lehman, T.J., McLaughry, S.W., Wycko, P.: T Spaces: The Next Wave. In: Proceedings of the 32nd Hawaiian International Conference on Computer Systems 1999, HICCS, Maui, Hawaii (1999)
7. Brecht, J., DiGiano, C., Patton, C., Tatar, D., Chaudhury, S.R., Roschelle, J., Davis, K.: Coordinating networked learning activities with a general-purpose interface. In: Proceedings of the 5th World Conference on Mobile Learning, Banff, Canada (October 2006)
8. Garrido, J.L., Noguera, M., Gonzalez, M., Gea, M., Hurtado, M.V.: Leveraging the Linda coordination model for a groupware architecture implementation. In: Dimitriadis, Y.A., Zigurs, I., Gómez-Sánchez, E. (eds.) CRIWG 2006. LNCS, vol. 4154, pp. 286–301. Springer, Heidelberg (2006)

9. Giemza, A., Weinbrenner, S., Engler, J., Hoppe, H.U.: Tuple spaces as flexible integration platform for distributed learning environments. In: Proceedings of ICCE 2007, Hiroshima, Japan, November 2007, pp. 313–320 (2007)
10. Regli, W.C., Hu, X., Atwood, M., Sun, W.: A survey of design rationale systems: Approaches representation, capture and retrieval. Engineering with Computers 16, 209–235 (2000)
11. MacLean, A., Young, R., Belloti, V., Moran, T.: Questions, options, and criteria: Elements of design space analysis. Human-Computer Interaction 6(3/4), 201–250 (1991)
12. Hoppe, H.U., Gaßner, K.: Integrating collaborative concept mapping tools with group memory and retrieval functions. In: Proceedings of CSCL 2002, Boulder, USA, January 2002, pp. 716–725 (2002)
13. Davis, F.D.: Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. MIS Quarterly 13(3), 319–340 (1989)

A Service Providing Awareness of Learning Object Evolutions in a Distributed Environment

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Abstract. In some previous works we suggested a mechanism that offers the opportunity to import, within courseware deployed within Learning Management System, some learning object stored into heterogeneous repositories. Works presented here allow teachers and curriculum managers to be aware of all divergences between the imported learning objects and their evolutions, releases and dependencies. It avoids collaboration between production stakeholders and teachers to spiral out of control by providing teachers with visualization techniques such as State Treemap and 3D relationships representation together with notification systems. The framework has been implemented in an open and LOM-based architecture that includes Moodle and the Ariadne Knowledge Pool System, thus validating our approach.

Keywords: Awareness, Learning Object Evolution, Learning Objects dependencies, Learning Object Divergence, Learning Object Conflict, Convergence, LOM.

1 Introduction

In the context of Computer Supported Cooperation Work (CSCW), several awareness tools are developed in order to help stakeholders to product content or to design a shared product [9]. On the other hand, in the context of Computer Supported Collaboration Learning (CSCL), several awareness tools are designed to help learners during their learning process [11]. In this paper, we propose an approach to help teachers and education managers to be aware of all divergences related to learning objects (LO) deployed in a curriculum and to keep this curriculum up to date. This work does not deal with LO production or use, but focuses on LO integration**.** LO creators submit LO evolutions in a learning object repository (LOR), whereas education managers import these LO in a learning management system (LMS) in order to allow teachers integrating this learning material into pedagogical designs: systems used to store and to exploit LO are de facto different. Moreover, multiple streams of activities are managed instead of giving the illusion of one stream [15]. When an author index a LO evolution into a LOR, teachers and education managers should be aware of this change, so that they are able to integrate it into curricula. However, they are most

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often unaware of a re-authoring process or a new LO release, except through too rare collaboration talks or emails. Therefore, they cannot understand what has changed, or what is going to change, and collaboration can quickly spiral out of control [18].

In this paper, we suggest an approach that offers the opportunity to curriculum managers to be aware of divergences between learning objects imported in the LMS and the matching evolutions stored in a LOR. Two kinds of visualization techniques are used: a 3D representation of LO relationships has been improved to bring out changes made during LO evolutions, and the treemap visualization technique, originally used for content production, has been adapted to give a general picture of the situation and to expose divergences. Notification systems complete the Learning Object Evolutions Awareness (LObEvA) Service. Thanks to the Learning Object Virtualization (LOV) design [2], the service is integrated in a web-based LMS whereas divergences information can be retrieved from a LOR.

First of all, kind of divergences between learning objects evolutions and information needed to take into account divergences are presented in order to identify issues to be solved. The next section tackles these issues by suggesting an additional service based on the LOV design and able to allow end-users to be aware of divergences and to help them to converge. We then demonstrate how this open architecture can be successfully implemented in a French digital campus. Finally, we conclude before exposing our future works.

2 LO Evolutions Awareness

In our context, modifications made on LO stored into LOR should be reflected on learning objects within LMS. Awareness must be provided by the system used by teachers and curriculum managers (the LMS), whereas LO evolutions and modifications are stored into a LOR. In the following sub-sections, divergences cases are identified in order to define information needed to take into account awareness.

2.1 Identifying Divergences between Learning Objects

Simple LO release. The basic use case to cope with is a succession of LO evolutions leading to a new release (see Figure 1). First of all, the teacher foo imports the LO A_1 from a LOR to his course deployed within the LMS (a). When a re-authoring process

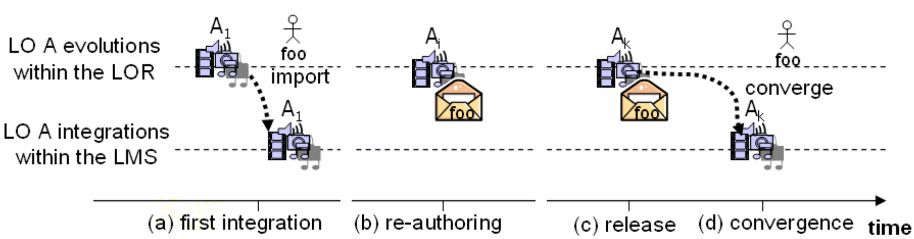

Fig. 1. Simple LO release divergence

is engaged (b), LO authors will submit succeeding LO evolutions in the repository [5]; at this step, foo should be notified of the re-authoring process. Moreover, foo should visualize divergences between A_1 and its evolutions suggested by creators. When a new release is available in the repository (c), a conflict should be detected, and foo should be notified. He could then decide to converge (d), and to replace A_1 by the new release A_k.

Competitive LO release / Format Change. Things are not so simple when authors disagree on content and start to produce various LO that aim at reaching different purposes. This case is an extension of the simple LO release (see Figure 2): two competitive branches suggest evolutions from the LO A1. Foo should be notified of all competitive branches (b) and conflicts should be detected and reported to foo (c). He would then use visualization techniques to be aware of changes related to each branch, and would choose the most appropriate release to converge (d).

This use case also applies when a LO is available through various formats.

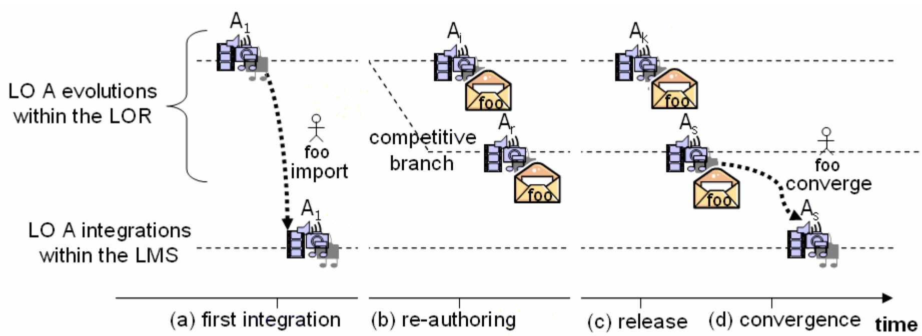

Fig. 2. Concurrent releases divergence

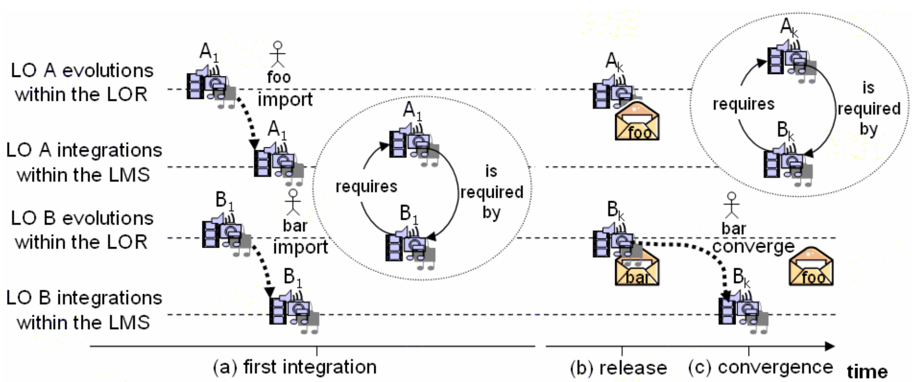

Fig. 3. Learning Object dependencies

LO dependencies. Conflicts should also be detected between LO presenting one or several relationships with others LO. On Figure 3, foo imports the learning resource A1 in a course while bar imports B1 in another curriculum (a); a relationship specifies that B1 requires A1 for pedagogical comprehension. Later, new releases of A1 and B1 (respectively Ak and Bk) are indexed into the LOR (b); if bar decides to deploy Bk (c), then a pedagogical conflict (Bk requires Ak to be well understood) should be raised and notified to foo so that he processes the convergence towards Ak.

In order to take into account and to show up these various divergences cases, information needs to be identified and stored; it is exposed in the next section.

2.2 The Needed Information

LO imported from a LOR into a LMS are labeled, within the last system, using the source LOR location and the LO id [7]. To detect divergences related to one of these LO, the following information is required:

- Qualified relationships: they allow to distinguish succeeding evolutions, format changes, and LO dependencies.
- The publication date, in order to be able to sort.
- The status of the evolution, in order to clearly identify on-going re-authoring processes and new releases.

We are then able to define where the changes have been made, when they were made and how things were changed. However, end-users need more information to decide to converge: What were the changes? Why were the changes made? Who has made the changes? [18] [12]. This information can be detailed within LO descriptors (see section 3.1).

To collect, store and exploit the above information, some questions must be raised:

1. How to store the needed information? Since this information represents the description of the LO, it makes sense to include data above into a LOR in order to be shared.
2. How can end-users be aware of divergences? Since LO are stored into LOR and exploited within LMS, architecture such as the LOV design must be set up in order to allow LO transfers between the two systems.
3. How to notify end-users about divergences? Divergences awareness can be provided on demand by visualization techniques. Users must have the opportunity to quickly identify where a divergence occurs, before visualizing details about it. Divergences awareness can also be automatically delivered through notification systems.
4. How can end-users converge? A manual and/or automatic entity must help end-users to converge and to keep their curriculum designs up to date.

In the next section, we precisely describe the big picture mentioned above and demonstrate how this framework can effectively help course managers to be aware of pedagogical material divergences.

3 How to Provide Awareness of Learning Object Evolutions

3.1 Storage of Divergences Information

The LOM standard [13] allows storing for the most of information identified in section 2.3:

- The Relation category (LOM 7) is very helpful to check any LO evolution. Combined with LO status (LOM 2.2), it enables end-users to know how and where things were changed.
- The Lifecycle category (LOM 2) helps to know when and who changes on LO content and form have been operated. Indeed, role, entity and date are filled in for each LO contributor.
- The Meta-metadata category (LOM 3) helps to know when and who has made changes on LO description by giving information on role, entity and date for each LO description contributor.

However, the LOM standard is not able to specify what changes were made and why they were made. In our previous work [6], we suggested to add a descriptor to the Lifecycle category dedicated to changes made by contributors (LifeCycle.Contribute.Changes). They are thus able to define what modifications were made on the LO and what were the motivations behind the change.

Finally, when a new LO release is available, the LO integration diverges. When is the best moment for the curriculum manager to converge? Is there only small editorial modifications? Has a chapter been completely modified? Is the hosted course still in used by students? If changes mentioned by each contributor give detailed qualitative information, global quantitative information about modifications severity would be useful. We propose a new descriptor to reach this goal (LifeCycle.ModificationsSeverity) with the following value space:

- Low: the new release presents few modifications that do not impact the pedagogical comprehension. This is the case of syntactic or spelling corrections.
- Medium: the new release has modifications with low impact to the pedagogical comprehension. It occurs when explanations were not clear enough for students in the source LO.
- High: the new release has several modifications with real impact to the pedagogical comprehension. This is the case when new concepts are introduced.

The Modifications Severity descriptor thus helps teachers and curriculum managers to decide (1) to converge when severity is low, (2) to wait the end of the teaching period or to discuss with all involved teachers before converging, when the severity becomes higher.

The improved LOM standard makes it possible to store all awareness information into LO metadata. However, it is necessary to identify learning objects that have been imported from a LOR into a LMS, and to transfer LO information between these two systems. The LOV design, presented in the next section, must be improved to provide a service related to LO evolutions awareness and convergence.

3.2 Improved Learning Object Virtualization

The LOV architecture [2] is based on ubiquitous learning standards and allows for learning objects virtualization: it offers both a single view of the whole set of resources stored into several heterogeneous LOR, and an easy access to those resources through the use of LMS. This framework offers a transparent communication between LMS and LOR and allows among other things to (a) query the LOR from the LMS and to retrieve learning objects metadata, (b) download the matching documents on the local host, (c) import the matching documents into the dedicated space of the LMS in order to deploy this resource within a learning design. For each imported LO, the Importation Service notices and stores within the LMS information such as the source LOR and the matching LO id. It's thus possible to clearly identify imported LO and to retrieve, from the LMS, their metadata.

A service dedicated to Learning Object Evolutions Awareness has been added. It allows LMS users to visualize divergences of all imported LO, and to receive notifications when a new divergence occurs. The nature of this service makes it only apply to learning resources imported from a LOR into a courseware.

Implementation details and interactions between the various systems and services of the architecture are given in section 4. Awareness visualization techniques are detailed in the next section, and give the ability of individuals to track asynchronous changes submitted by other participants over time.

3.3 On Demand Awareness of Divergences

Once divergences have been established by the new service, they must be available and accessible to curriculum designers. Visualization approaches are often exploited to ensure end-users awareness.

The 3D Relationships Representation is a visualization tool that offers a global picture of relationships related to a specific learning object [4]. Three axes are used to represent relationships: a temporal axis related to the creation date of the LO, a purpose axis expressing pedagogical objectives of the LO and a third axis linked to the LO aggregation level. This tool exploits the Relation category (LOM 7) in order to retrieve all evolutions and releases for a given LO. Relationships also include dependencies to a specific LO. The representation is here improved to indicate what were the changes made between two succeeding evolutions (see example on the right side of Figure 5).

Since the 3D representation allows the visualization of all evolutions, releases and dependencies of only one imported LO, we suggest a complementary tool based on the State Treemap approach [15] to easily visualize all imported LO that are diverging.

State Treemap. Information can be hierarchically represented with node and link diagrams (see example on Figure 4a), but this representation inefficiently uses space and is only effective for small trees. Therefore, treemap has been developed to remedy this problem [19] (see Figure 4b): only leaves are represented via recursive subdivision of an initial rectangle. The mapping between the hierarchical and the treemap representations is illustrated on Figure 4.

Even if the treemap representation can be applied to represent a large amount of information, it does not allow visualizing the status of data. State Treemap extends the treemap approach to multi-synchronous groupware systems [15]. Each leaf is colored according to the state of the leaf divergence: local up to date, local modified, remotely modified, need update, potential conflict, will conflict. Therefore, at any moment, users have a general picture of the situation and exactly know where divergences are located.

Since states defined on above are used in the context of content production, they have to be redefined to match the context of shared LO integration. State Treemap is a global visualization technique that can be applied to enhance LO evolutions awareness. Indeed, it could allow course creators to easily visualize learning objects that are diverging.

State Treemap construction applied to LO. According to divergences identified in section 2.1, states represented in table 1 have been redefined.

Table 1. LO divergences states

State Name	State Color	State meaning
up to date	(1) green	the imported LO is identical to the last evolution of the LO in the repository
re-authoring in progress	(2) orange	there exists at least another succeeding LO evolution in the repository which is not yet ready-to-use
dependency divergence	(3) violet	there exists at least one LO dependency, imported in the LMS, that diverges with the imported LO
need update	(4) red	there exists at least another succeeding LO evolution in the repository which is ready-to-use. Shades of the original red color can be used to firm up details about the highest modifications severity of LO evolutions stored in the LOR
No longer valid	(5) grey	the last succeeding LO evolution is stored in the repository with the status "unavailable"

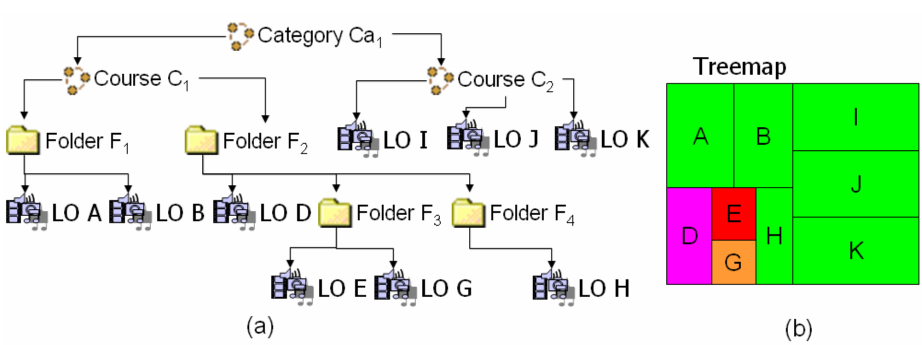

Fig. 4. Treemap construction example

The hierarchical structure of learning objects imported within a LMS is composed of categories and sub-categories containing courses: as illustrated on Figure 4a, courses C_1 and C_2 are part of the category Ca_1. Each course stores imported LO in its own file system structure. Only imported LO are represented on Figure 4; the matching treemap (see Figure 4b) includes an imported learning object E which needs to be updated, an imported learning object G with an on-going re-authoring process, and an imported learning object D that diverges with at least one LO dependency.

Moreover, small letters can be added to detail states:

- "C": competitive re-authoring. There exists at least another succeeding LO evolution in the repository with at least two concurrent branches;
- "F": format change. There exists at least another succeeding LO evolution in the repository with a differing format.

Figure 5 illustrates an example of both the treemap and the relationships representations. This way, teachers can quickly be aware of all imported LO divergences. However, these representations are only used on user demand. To provide awareness at the right time, notification systems must be provided.

3.4 Notification Systems

Several notification systems have been described in the literature: system status update [3], SMS [1], instant messaging [16], chat messaging [3], stock tickers [3], email alerts [16] [3] ... According to Caroll et al. [3], it's important to support awareness of events that impact any of the collaborators, and thereby help to explain and predict collaborators' behavior, promoting enhanced activity awareness. In the context of LO evolution, there is no need for emergency intervention. Real-time notification systems such as chat messaging, SMS or instant messaging are too pervasive. The awareness of the presence's collaborator is also excessive. Email alerts are enough to notify end users that a divergence has occurred. RSS feeds are also being considered in the new service.

Once course managers are aware of a divergence, the next step consists in ensuring the convergence process.

3.5 Convergence

Manual Convergence. The Importation Service has been improved in order to allow convergence. When a divergence occurs, teachers can manually select a succeeding LO release on the relationships representation tool in order to replace the source LO within the appropriate course in the LMS. The Evolutions Awareness service sends a request to the Importation Service in order to perform the convergence.

Teachers usually wait the end of the course period to converge, even if the improved LOM metadata schema brings significant information through the modifications severity element. They can quickly make the decision to converge when the severity is low and when there is no competitive re-authoring and no format modification being engaged.

Automatic Convergence. To simplify the convergence process, the Evolutions Awareness service is able to automatically converge when all criteria described above are combined. Let us note that this functionality must be enabled by an editing teacher.

The service allows also teachers to schedule the best moment to automatically converge: at the end of the course period. However, the automatic convergence only applies when no competitive branches or format changes are available.

3.6 Summary and Benefits

The lifecycle category of the LOM has been improved in order to allow the great amount of information needed for LO evolution awareness to be stored in metadata. This information can now be retrieved and exploited in the system used by teachers and curriculum managers, which is the LMS, thanks to the improved LOV design. End-users can benefit from on-demand visualization techniques and notifications systems to be aware of all divergences related to the LO they exploit. They also have all the information needed to make the decision to converge or not.

The introduction of the Evolutions Awareness service into the LOV architecture presents then several benefits:

- It allows teachers to keep awareness of all imported learning object divergences without continuously monitoring the content of the LOR,
- It facilitates the convergence process by enabling automatic or scheduled convergence.
- It avoids pedagogical conflicts in case of LO dependencies.
- It provides learners with up-to-date course content.

4 Implementation: Moodle and the Ariadne repository

The original LOV architecture has been implemented with two LMS and four LOR [2]. The new service focuses on the cooperation between Moodle [14] and the LOM-based ARIADNE Knowledge Pool System (KPS) [10]: Awareness is generated within Moodle by retrieving LO metadata stored in the KPS.

An example of visualization divergences is illustrated on Figure 5. Treemap representation is here generated from the file system structure of all courses including imported LO. The treemap allows the teacher to take a quick look at all divergences.

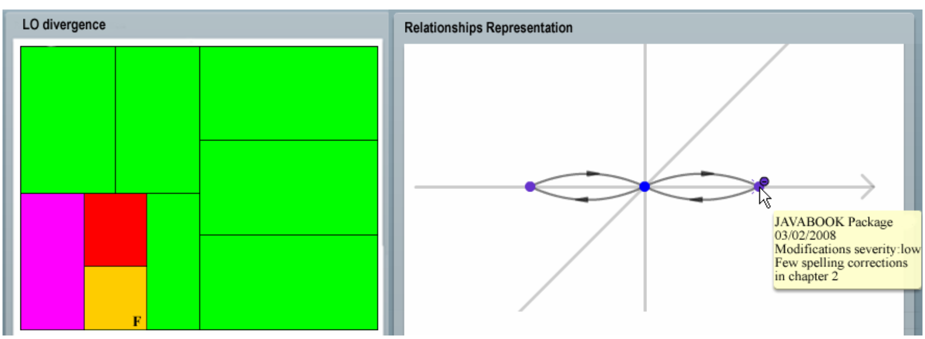

Fig. 5. Divergences visualization example

It indicates here that a learning object has at least another succeeding evolution in the repository with a different format (orange rectangle with letter “F”). It also shows that in the same folder, a learning object exists with at least one new release (red rectangle). The teacher can generate the relationships representation from this diverging LO (Figure 9 on the right side). Thus, he can see the succeeding evolutions and modifications made by authors, together with modifications severity of new releases. These elements help him to decide if he has to converge right now or not. Finally, one learning object has at least one conflict with another LO imported into the LMS (see violet rectangle).

Notifications are transparently generated by the Evolutions Awareness service through information stored into the KPS. Each 24 hours, the LMS solicits the new service to check divergences of each imported learning object. The service consults the LO properties in order to extract the location of the LOR responsible for its management, together with its matching identifier; those properties are specified by the Importation Service. The Evolutions Awareness service queries the Ariadne Web Services (AWS) to check learning object evolutions. This last browses the KPS and the matching metadata are transmitted to the new service. It also checks all LO dependencies, and generates a divergence report sent to the LMS. RSS feeds are finally generated while the teacher is notified by email.

The Evolutions Awareness service has just been developed and is now deployed within the International E-Miage (IEM) learning environment, a digital campus that delivers degrees to French and foreign lifelong learning students [8]. Each exploitation center deploys its own LMS, while shared learning resources are stored in one common KPS. Curriculum managers have access to awareness information about all imported LO divergences, while teachers are only aware of divergences of LO integrated within their courses. First results will be collected at the end of the semester and will help us to enhance the service to fulfill users’ requirements.

5 Conclusion and Perspectives

We presented in this paper an open framework able to provide teachers and curriculum managers with awareness about LO divergences in the context of LO integration process. Our proposal avoids collaboration between production stakeholders and end-users to spiral out of control. Thanks to the LOV design, visualization techniques have been set up and give a general picture of the situation, while some notifications systems facilitates teachers’ reactivity; students benefit from this system with an up-to-date course content.

The Evolutions Awareness service has been successfully implemented for a specific LMS communicating with a LOR, and has just been deployed within the various exploitation centers of an international digital campus. In order to widely benefit from this work, modifications applied to the LOM standard metadata schema should be adopted by consensus. Other metadata standards such as ISO MLR are being elaborated; a proposal will be suggested in this direction. However, success and efficiency of learning object evolutions awareness strongly depend on production stakeholders’ motivation and involvement.

When teachers look again to treemap visualization two weeks later, it should be useful to know what has changed in the interim. How the divergence has evolved? The same issue occurs with relationships representation: an historical system should provide playback and undo functionalities [17]. Moreover, undo functionality should be very useful when LO dependencies divergence occurs.

We focused our works on the LO importation process operated by teachers and curriculum managers in one LMS. However, awareness mechanisms are also interesting for steering committee members. They would like to have a global picture of the situation that includes all LMS of the digital campus. This wider hierarchical structure implies to retrieve information from the LOR together with all the LMS of the consortium. Finally, awareness techniques should also apply, like in Computer Supported Cooperation Work, during the production process.

References

1. Boari, M., Lodolo, E., Monti, S., Pasini, S.: Middleware for Automatic Dynamic Reconfiguration of Context-Driven Services. In: 11th IEEE Symposium on Computers and Communication, pp. 781–788. IEEE Press, Los Alamitos (2006)
2. Broisin, J., Vidal, P., Baqué, P., Duval, E.: Sharing and Reusing Learning Objects: Learning Management Systems and Learning Object Repositories, EDMEDIA, 8p, AACE (2005)
3. Caroll, J.M., Neale, D.C., Isenhour, P.L., Rosson, M.B., McCrickard, D.S.: Notification and Awareness: synchronizing task-oriented collaborative activity. International Journal of Human-Computer Studies 58(5), 605–632 (2003)
4. Catteau, O., Vidal, P., Broisin, J.: A 3D Representation of Relationships between Learning Objects. In: Educational Multimedia, Hypermedia & Telecommunications (EDMEDIA), pp. 4262–4271. AACE (2007)
5. Catteau, O., Vidal, P., Broisin, J.: A Generic Representation Allowing for Expression of Learning Object and Metadata Lifecycle. In: The 6th IEEE International Conference on Advanced Learning Technologies (ICALT 2006), pp. 30–33. IEEE Press, Los Alamitos (2006)
6. Catteau, O., Vidal, P., Broisin, J.: Gestion du cycle de vie au sein du LOM et de ses profils d'application. In: Technologies de l'Information et de la Communication dans l'Enseignement Supérieur et l'Entreprise (TICE), 6 p. INPT (2006) ISBN: 978-2-9527275-0-1
7. Catteau, O., Vidal, P., Broisin, J.: Learning Object Virtualization Allowing for Learning Object Assessments and Suggestions for Use. In: The 8th IEEE International Conference on Advanced Learning Technologies (ICALT 2008), 5 p. IEEE Press, Los Alamitos (2008)
8. Cochard, G.M., Marquie, D.: An e-learning version of the French Higher Education Curriculum 'Computer Methods for the Companies Management'. In: 18th IFIP World Congress Computer, pp. 557–572 (2004)
9. Détienne, F.: Collaborative design: managing task interdependencies and multiple perspectives. Interacting With Computers 18(1), 1–20 (2006)
10. Duval, E., Forte, E., Cardinaels, K., Verhoeven, B., Van Durm, R., Hendrikx, K., Wentland Forte, M., Ebel, N., Macowicz, M., Warkentyne, K., Haenni, F.: The Ariadne Knowledge Pool System. Communications of the ACM 44(5), 72–78 (2001)

11. El-Bishouty, M.M., Ogata, H., Yano, Y.: Learner-Space Knowledge Awareness Map in Computer Supported Ubiquitous Learning. In: 4th IEEE International Workshop on Wireless, Mobile and Ubiquitous Technology in Education, pp. 116–120. IEEE Press, Los Alamitos (2006)
12. Gutwin, C.: Workspace Awareness in Real-Time Distributed Groupware. PhD Thesis, University of Calgary, Canada (1997)
13. IEEE-LTSC: 1484.12.1-2002 IEEE Standard for Learning Object Metadata, 40p. IEEE Press, Los Alamitos (2002)
14. Moodle (last visited, June 2008), `http://www.moodle.org/`
15. Molli, P., Skaf-Moli, H., Bouthier, C.: State Treemap: an Awareness Widget for Multi-Synchronous Groupware. In: Seventh International Workshop on Groupware, pp. 106–114. IEEE Press, Los Alamitos (2001)
16. Preston, J.A.: Rethinking Consistency Management in Real-Time Collaborative Editing Systems. PhD thesis, Georgia State University (2007)
17. Ripley, R.M., Sarma, A., Van Der Hoek, A.: A visualization for Software Project Awareness and Evolution. In: 4th IEEE International Workshop on Visualizing Software for Understanding an Analysis, pp. 137–144. IEEE Press, Los Alamitos (2007)
18. Tam, J., Greenberg, S.: A framework for asynchronous change awareness in collaborative documents and workspaces. International Journal of Human-Computer Studies 64(7), 583–598 (2006)
19. Van Wijk, J.J., Van de Wetering, H.: Cushion Treemaps: visualization of hierarchical information. In: IEEE Symposium on Information Visualization (InfoVis 1999), pp. 73–78. IEEE Press, Los Alamitos (1999)

ALOA: A Web Services Driven Framework for Automatic Learning Object Annotation

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Abstract. Generating learning object metadata is a complex task to be done manually. An automated approach is therefore required. This work presents the concepts and ideas behind the automatic generation of metadata. We propose a Web Services driven framework for IEEE LOM-compliant automatic learning object annotation called ALOA. The primary focus has been on the flexibility and extensibility of the framework, such that new metadata generation services can easily be plugged into the basic system.

1 Introduction

Learning objects can be described by metadata in order to enable search, access, share, and reuse. This metadata could contain information about different aspects of the object: description, recommended usage, technical specifications, relation with other objects, etc. The most relevant metadata standards for describing learning objects are IEEE LOM, Dublin Core, and MPEG-7. A shared belief is that manual creation of learning object metadata is not a good approach. This is mainly due the complexity of most metadata standards. Consequently, an automation of the metadata creation process is required. In this paper, we mainly address the challenge of automatic metatada generation, and introduce ALOA; a Web Services driven framework for IEEE LOM-compliant automatic learning object annotation developed at RWTH Aachen University, Germany, with active support from the Katholieke Universiteit Leuven, Belgium in the framework of the PROLEARN project [1]. The rest of the paper is structured as follows: Section 2 explains why an automated approach is required. Section 3 briefly touches upon the various solutions aimed at automatic learning object metadata generation. Section 4 introduces the ALOA framework and outlines the design model behind it. Section 5 discusses the architecture and implementation details of the ALOA framework. Finally, Section 6 gives a summary of the paper and outlines perspectives for future work.

2 Automatic Metadata Generation

Manual creation of metadata is often supported by form-based editors. Most editors directly relate to some standard (such as IEEE LOM) and present that standard to the users. The user has then to fill in a substantial number of metadata fields. Most

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authors, however, agree on the fact that dealing with metadata cannot be a human task [5]. There are several reasons why users often do not create metadata for their learning resources. First, most metadata standards are complex. Metadata creation, therefore, is too difficult and time consuming work for content authors. Second, the benefit of creating and using metadata is not immediately appreciated. Third, expert metadata creators are considered too expensive to be employed in most educational institutions. Fourth, the current tools available for manual metadata creation are not user friendly [2]. A possible solution to this problem is the automatic creation of learning object metadata. Automatic metadata generation extracts relevant information from learning objects and the context they are stored or used in [2]. Automatic metadata generation is broken down into four aspects: content analysis, context analysis, usage analysis and structure analysis. While in content analysis, information is extracted from the learning object itself (e.g. keyword, language), context analysis involves the environment the object is used in. A learning object context provides extra information about the learning object that can be used to generate the metadata. A usage analysis for example evaluates the time spent reading a document or solving exercises. Consequently, conclusions regarding specific metadata elements can be drawn. A structure analysis involves relationship amongst objects. For example, one slide in a slide show often gives relevant context about the content of the next slide [2].

3 Related Work

The most prominent existing framework for automatic learning object metadata generation is AMG; the automatic metadata generation framework developed at the Katholieke Universiteit Leuven, Belgium. Cardinaels et al. [2] describe AMG as a framework to set up an automatic metadata generation system as a Web Service. The framework consists of two major groups of software classes that generate the metadata, namely Object-based indexers and Context-based indexers. The object-based indexers generate metadata based on the learning object itself, isolated from any other learning object or learning management system. The second class of indexers uses a context to generate metadata. The framework also has some Extractors that for example extract the text and properties from a PowerPoint-file, and a MetadataMerger that can solve conflicts between indexers and then combine the results of the different indexers into one resulting metadata record for the learning object [2]. Meire et al. [8] however note that this first version of AMG suffered from a number of limitations, among which the fact that it is limited in terms of extensibility (pluggability), and that the developed Web Services were not really interoperable between platforms. Therefore, they redesigned the AMG system, resulting in a second version of the framework that they call Federated AMG. In this last version, much attention was given to pluggability of new metadata generators and interoperability between metadata generation systems. The authors present a solution to the extensibility challenge based on the Factory design pattern. They, however, acknowledge that plugging new components into the AMG framework suffers from some limitations. As they put it: "adding new components requires recompiling and rebuilding the whole application. This is not a serious problem for us ourselves, but it might be a hindrance for other people to make additions. They have to checkout the source code, make additions, recompile and commit their changes; or they have to contact us and submit their components".

To enable interoperability between metadata generators, the authors propose the Simple Automatic Metadata Generation Interface specification, SAmgI. They further discuss the idea that several metadata generation systems (called SAmgI installations or SAmgI service endpoints) can do parts of the metadata generation job. A Federated AMG engine can then take up the responsibility of contacting several installations and combining their results into one global metadata instance. This way, one can extend the Federated AMG framework with new generators by creating one's own SAmgI installation. However, implementing a complete SAmgI installation requires some programming efforts. In fact, the implementation should conform to the abstract SAmgI specification, the XML schemas for the data types, and the WSDL (in case of a Web Service implementation).

4 ALOA and SOA

Rather than interoperability and cooperation between metadata generation systems, the primary focus of the ALOA system has been on the flexibility and extensibility of the framework, such that new metadata generation services can easily be plugged into the basic system. To achieve this, ALOA was developed based on the distributed component model Service Oriented Architecture (SOA). SOA is one of the latest trends in distributed systems engineering. It describes a new component model which relates distributed components, which are usually called services, to each other by means of formally defined interfaces [6]. In doing so, SOA provides loose coupling of services that cleanly encapsulate their functionality. Usually, a SOA is implemented by means of Web Services which enable application-to-application communication over the Internet. Web Services are self-contained, modular applications with public interfaces that are described using the Web Services Description Language (WSDL). They provide access to software components through standard Web technologies and protocols such as SOAP and HTTP, regardless of their platforms, and implementation details. A service provider develops and deploys the service and publishes its description and binding/ access details (WSDL) with the UDDI registry. Any potential client, who queries the UDDI, gets the service description and accesses the service using SOAP [7]. The communication between client and UDDI registry is also based on SOAP. Implementing the ALOA system as a SOA by means of a set of well-defined Web Services, provides the necessary encapsulation, loose coupling, and flexibility of new services entering or leaving the system at runtime. ALOA WSDL adopts a slightly modified version of SAmgI WSDL specification [8]. Two new methods, namely get- Languages and setLanguages have been introduced to support describing learning objects in different languages. And, the method getMetdata has been modified by adding the new parameter metadatatypes to make it possible to get a subset of the IEEE LOM set as the generation result. ALOA also provides a publicWeb Services API that can be used by third party applications.

5 The ALOA Framework

In the following sections, we discuss the architecture and implementation details of the ALOA framework. The ALOA framework consists of four main parts, namely ALOA core engine, ALOA components, ALOA user Interface, and ALOA configuration management interface.

5.1 ALOA Core Engine

The main class in ALOA core engine is Indexer. The Apache Axis generated Web Service stub will call the Indexer and provide it with the reference to the learning object and the list of target metadata languages. The indexer will then perform the following actions to generate metadata from the given leaning objects: (a) read all the configurations (i.e. available extractors and generators, priorities of each generator, maximum generated values for each metadata attribute) in the properties file,(b) access the learning object as an array of bytes, (c) detect the mime type of the learning object, (d) look for the available extractor that can deal with this particular mime type, (e) extract the text content and the embedded properties of the learning object, (f) contact the available generators that are capable of generating different parts of the metadata, (g) solve conflicts between different generators, (h) translate the generated metadata into the required languages, and (i) return the generation result to the Web Service stub. For the success of this process, two classes are of great importance, namely ConflictResolver and Translator. As different generators can generate different values for the same metadata attribute, it is important to have conflict resolution methods to combine the values into one. The ConflictResolver class implements different methods to solve the conflicts, taking into consideration the priorities of each generator, which can be defined via the configuration management interface (see section 5.4). The Translator class supports the generation of metadata in different languages. It uses Google Translate as its translation service. Currently, ALOA supports six languages: English, German, Arabic, French, Spanish, and Korean.

5.2 ALOA Components

The main components of ALOA are Extractors and Generators. An extractor is responsible for extracting content information from a learning object along with its embedded properties. Only one extractor can be defined for each learning object mime type. ALOA already implements different extractors for different learning object mime types such as an html extractor which uses a modified Jericho library, a pdf extractor based on the pdfBox library, a word extractor, and a ppt extractor both based on the Apache POI library. A generator is responsible for the actual metadata generation. It uses the output of an extractor to generate one or parts of the metadata. ALOA already implements several generators that integrate existing algorithms for generating metadata values, from the domains of data- and text-mining. Examples include the Yahoo! Term Extraction and Tagthe generators for keywords, the Topicalizer generator for keywords, summary, language, and difficulty level, the LingPipe generator for person names, the Balie generator for person names and languages, and the Classifier4J generator for text classification and summary.

5.3 ALOA User Interface

The ALOA user interface is a reference implementation for an application that is based on the ALOA Web Services API. It uses the API to automatically generate metadata from a learning object which is available online as html, plain text, word, ppt, or pdf. The user can define the URL location of a learning object, the target metadata languages, the subset of the metadata that has to be generated, and the output format. The ALOA user interface can present the metadata generation result in three different output formats: LOM XML, human readable HTML, and an applet version of a LOM Editor developed at RWTH Aachen. The latter format would lead to a semi-automatic approach in which both human and automatic metadata generators collaborate for instantiating LOM values.

5.4 ALOA Configuration Management Interface

As discussed in section 4, automatic metadata generation can be loosely coupled via Web Services. ALOA has a flexible SOA-based architecture that makes the framework easily extensible for new learning object types and new contexts. Developers who for instance want to extend the ALOA framework with extractors supporting multimedia learning object (e.g audio, video, image, flash) need to implement the Extractor interface. To extend the ALOA framework with new generators (e.g. generators for a specific context, or generators that apply further data/text mining techniques to generate one or parts of the metadata), the Generator interface needs to be implemented. The components (i.e. extractors or generators) can be deployed on different machines or on different application servers. Once a new component is implemented and deployed, it can be plugged into ALOA via the ALOA configuration management interface by just giving the address of the component service. The ALOA core engine will then check the availability and validity of the new component service and add it to the component list in the properties file. There is no need to recompile and rebuild the system. The ALOA configuration management interface also enables to manage the priority of the different generators plugged into the system and to define the maximum generated values for each metadata attribute. This information will be then used by the Indexer in the ALOA core engine, as discussed in section 5.1.

6 Conclusion and Future Work

In this paper, we presented a conceptual framework to automatically generate metadata information for learning objects called ALOA. ALOA already implements different components (i.e. extractors and generators) and is capable of generating a substantial part of the IEEE LOM metadata from different types of learning objects (e.g. html, pdf, ppt, word). ALOA also provides a public Web Services API that can be used by third party applications. The primary focus has been on the flexibility and extensibility of the framework. The ALOA SOA-based architecture enables that new metadata generation services can easily be plugged into the basic system.

Future work will focus on the extension of the ALOA framework with more extractors and generators from the domains of data- and text-mining. A particular focus will be on Web Services-based interactions between ALOA and AMG. In fact, ALOA and AMG can complement each other in two different ways. On the one hand, ALOA can be viewed as a new SAmgI installation that can be used by the federated AMG engine. On the other hand, AMG can be implemented as a new component of ALOA. Additionally, because we do not want to be limited to LOM, we will look at some model transformation techniques to generate metadata for other metadata schemas (e.g. DCXML, DC-RDF, MPEG-7). Also, further research of the quality (i.e. completeness and correctness) of automatically generated metadata is needed. Another research direction would be the combination of automatic metadata generation with a bottom up approach as it can be found in folksonomy-tagging systems that, in the Web 2.0 era, emerged as promising new ways for discovery and categorization [4].

All of these efforts have been made available on the ALOA project homepage [3]. There you can test ALOA and find detailed documentation on e.g. how to use the ALOA Web Service API and how to create a new extractor or generator for ALOA.

References

1. PROLEARN Network of Excellence, `http://www.prolearn-project.org/`
2. Cardinaels, K., Meire, M., Duval, E.: Automating Metadata Generation: the Simple Indexing Interface. In: Proceedings of the 14th Int. Conf. on World Wide Web. Chibo, Japan (2005)
3. Chatti, M.A., Muhammad, N.F., Jarke, M.: ALOA Project, `http://eiche.informatik.rwth-aachen.de:3333/ALOAInterface/`
4. Dahl, D., Vossen, G.: Learning Object Metadata Generation in theWeb 2.0 Era. In: Proceedings IADIS International Conference e-Learning. Lisbon, Portugal (2007)
5. Duval, E., Hodgins, W.: Metadata matters. In: Proceedings of DC. Shanghai, China (2004)
6. Erl, T.: Service-Oriented Architecture. Prentice-Hall, Englewood Cliffs (2005)
7. Gottschalk, K., Graham, S.: Introduction to Web Services Architecture. IBM Systems Journal 41(2), 178–198 (2002)
8. Meire, M., Ochoa, X., Duval, E.: SAmgI, Automatic Metadata Generation v2.0. In: Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications, pp. 1195–1204 (2007)

Reusing Collaborative Knowledge as Learning Objects – The Implementation and Evaluation of AnnForum

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Abstract. With the development and adoption of digital technologies in learning, there is an increasingly large amount of learner-generated material being stored or recorded. This learner-generated material could contain important learning resources. This paper presents our research in reusing collaborative knowledge generated in a knowledge building process as learning objects. We describe the implementation and evaluation of AnnForum – a system which can dynamically annotate and classify collaborative knowledge and detect messages which are relevant to current discussion topics and present them to the learners. With the help of AnnForum, a new knowledge building process can be built, based upon previous accumulated knowledge instead of starting from scratch.

Keywords: Semantic annotation, learning objects, domain model, collaborative knowledge, topic maps.

1 Introduction

Traditionally, learning objects refer to resources that are created mainly by teachers. These learning objects are mostly self-contained and vary in granularity. For example, a course, a simulation, or a piece of text can all be learning objects. Learning objects can be aggregated into a larger collection of content. Substantial effort has been made in annotating (with metadata), sharing, and reusing these learning objects. The benefits of reusing and sharing learning objects have been studied intensively in the last decade [1].

With the development and adoption of digital technologies in learning, there is an increasing amount of material generated by learners in their learning process. For example, in a knowledge building process, there are a large number of messages posted by learners, including problems, hypothesis, and scientific evidence [2, 3]. In an inquiry learning process, learners generate many different materials (data collected, pictures taken, models created, and hypotheses generated) [4]. This learner-generated material could potentially be valuable as learning resources.

1.1 Reusing Messages in Educational Discussion Forums

Discussion forums and bulletin boards have been widely used in web-based education and computer supported collaborative learning (CSCL), in order to assist learning and

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collaboration. Learners use discussion forums to discuss course-related issues, such as topics in their courses, learning tasks, and projects, etc. These discussion forums include questions and answers, examples, articles posted by former learners, and thus they are potentially useful for future learners [5, 6]. There are different variations of the educational discussion forum based on different pedagogies for collaborative learning. For example, some require learners to specify categories for their messages, and others use “sentence openers” to help learners with scientific thinking and message writing. By identifying relevant messages and reusing them as new learning resources, future learners can benefit from former learners’ knowledge and experiences.

However, it is not an easy task to identify relevant information from discussion forums given the thread-based structure of them. Messages posted in a discussion forum are usually organized as a tree structure with each branch as a thread. In each thread, the messages are presented in a temporal sequence. It is usually not so easy to decide whether the message is relevant by looking at the title alone, because it is not always informative. It is possible to use a full text search within the discussion forum based on keywords. However, there are always some irrelevant messages that are included in the search result. The modern information retrieval techniques and methods [7] are rarely adopted in the search for information in discussion forums.

A few efforts on reusing the messages in educational discussion forums have been made. The main method is to create a predefined structure for a discussion forum, where the structure reflects a conceptual schema of the subject domain [5]. Helic and his colleagues [6, 8] described a tool to support conceptual structuring of discussion forums. They attached a conceptual schema to a discussion forum, and the learners had to manually assign their messages to the schema. Their study shows some limitations with this method. First, some messages could be assigned to more than one concept in the schema. Second, the learners were not motivated enough to make the extra effort in assigning their messages to concepts, although it may have been beneficial to those learners to do so. Our own experience confirms the second point. We developed a plug-in for FLE3 (see 1.2), where students could choose relevant topics when preparing their messages, but they could also chose to ignore this feature. Very few students made use of this function to specify relevant topics for their message.

In our research, we choose a method that combines a (semi-) automatic annotation with a domain model, to classify the messages in previous knowledge building processes, and find the relevant messages (ranked with relevance values) and present them to learners. The learners’ feedback is used to improve the performance of the classification and matching mechanism. This method is implemented in AnnForum.

This paper uses the collaborative knowledge built with FLE3 (Future Learning Environment) in an Introductory Artificial Intelligence (AI) course as an example, to demonstrate the reuse of the collaborative knowledge as learning objects.

1.2 Collaborative Knowledge Building with FLE3

FLE3 [9] is web-based groupware for computer supported collaborative learning (CSCL). It is designed to support the collaborative process of progressive inquiry learning. The basic idea of progressive inquiry is that learners gain a deeper understanding by engaging in a research-like process where they generate their own problem, make hypotheses, and search out explanatory scientific information collaboratively with other learners.

To support the collaborative progressive inquiry process, FLE3 provides several modules, such as virtual WebTop, a Knowledge Building module, and an Administration module. The Knowledge Building module is considered to be the scaffolding module for progressive inquiry, where learners post their messages to the common workspace according to predefined categories. The categories they can use are Problem, My Explanation, Scientific Explanation, Comment, and Summary. These categories are defined to reflect the different phases in the progressive inquiry process (Figure 1).

Fig. 1. Knowledge Building in FLE3

The rest of the paper is organized as follows: Section 2 describes the design and implementation of AnnForum, including its main elements and its integration with FLE3. The evaluation of the system is presented in Section 3. Section 4 concludes the paper and discusses the implications of the research.

2 System Design and Implementation

In this section we present the main elements in AnnForum. The learner-generated material in the Introductory Artificial Intelligence course is used as an example. First, a conceptual domain model is constructed. Based on this model, the messages posted in previous knowledge building processes are annotated and classified into different categories corresponding to different concepts in the model. The teacher is responsible for constructing and managing the domain model, as well as for validating (adding/removing) annotations. The messages (including those in the current and previous knowledge building process) that are relevant to the current topic under discussion are gathered and presented to learners. The learners can then read through the messages and rank them according to their degree of relevance. In the current design, the learners do not need to perform the annotation. However, if they are willing to do so, they can use the "choose relevant topics" function when preparing a message, which is provided by the plug-in to FLE3. In the future we can also provide them with the annotation management tool that is currently designed for the teacher.

Figure 2 shows the use cases for AnnForum.

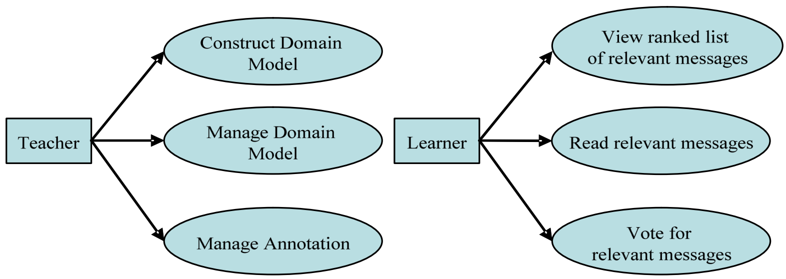

Fig. 2. Use Cases

The following two scenarios explain how AnnForum is used by learners.

- Scenario 1: A learner writing a new message.

After the learner has finished writing their message, it is submitted and appears in the knowledge building interface. AnnForum automatically annotates and classifies this message based on the domain model. In the meantime, it finds a list of existing messages that are relevant to the learner's message by computing the relevant values. The ranked list of relevant messages is presented to the learner. The annotation and relevant values are stored into AnnForum's database.

- Scenario 2: A learner reading an existing message in the knowledge building interface.

When the learner is reading the message, they click on a button called "show relevant messages". The relevant interface appears, containing a ranked list of relevant messages. These messages are retrieved from the database.

2.1 Conceptual Domain Model and Annotation of Messages

A conceptual domain model is used to describe the domain concepts and the relationships among them, which collectively describe the domain space. This domain model is usually represented by an ontology. A simple conceptual domain model can also be represented by a topic map. Topic Maps [10] is an ISO (ISO 13250[5]) standard for describing knowledge structures and associating them with information resources. It is used to model topics and their relations in different levels. The main components in Topic Maps are topics, associations, and occurrences. The topics represent the subjects, i.e. the things which are in the application domain, and make them machine understandable. A topic association represents a relationship between topics. Occurrences link topics to one or more relevant information resources. Topic Maps provide a way to represent semantically the conceptual knowledge in a certain domain.

In AnnForum we use a Topic Map to represent the domain model of Artificial Intelligence. This domain model includes AI topics and their relations, such as machine learning, agents, knowledge representation, searching algorithm, etc. These topics are described as topics in the Topic Map. Relations between these topics are represented as associations. The occurrence describes the links to the messages, where the topic was discussed in the discussion forum. The occurrence is generated by the automatic classification algorithm presented in the next subsection.

In the earlier prototypes of the system, teachers had to write XML in order to create Topic Maps for their course domains, and when a message was posted, associated topics to this message had to be selected manually by the contributors (learners/teachers). These have been proved to be rather tedious. In the newer versions, AnnForum provides a graphical interface for teachers to create a domain Topic Map interactively (Figure 3). Using AnnForum, teachers can create Topic Maps for their course domain, and load/reload them into FLE3. Because the topic map is written in XML format (XTM), it is easy for teachers to understand and maintain the topics, and the domain model can also be easily reused in other contexts. Figure 3 also shows the associations between the messages and the related topic (knowledge building) using automatic classification techniques. Teachers can also use this tool to edit and verify the associations.

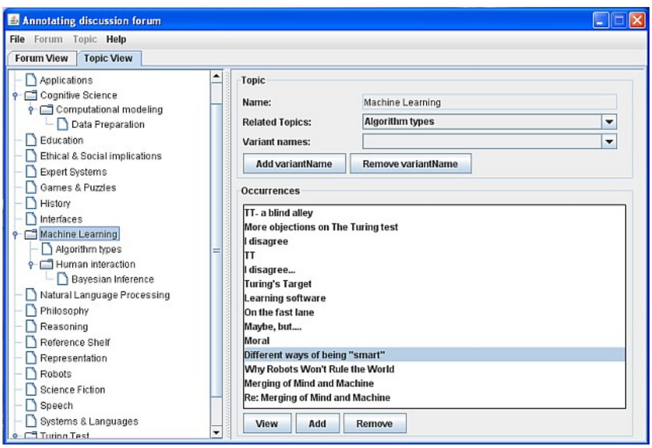

Fig. 3. AnnForum (Topic and Association Management)

2.2 Message Classification and Matching

Once the conceptual domain model is constructed, messages from previous knowledge building processes can be classified based on this model. Since these messages can be seen as a kind of document collection, we investigate the methods for classifying documents from a document collection to a conceptual model.

There are various approaches in information extraction and information retrieval that deal with the problem of document classification. For example, in information extraction, there are several approaches that use a conceptual model/schema to extract information from unstructured documents [11-13].

In AnnForum we designed an approach that combines a conceptual model and a vector-space-search algorithm that uses Vector Space Models to determine the relevance of a message to a concept in the domain model. The Keyword Recognizer identifies the occurrence of the concepts, including their basenames, and variants of the basenames, in the domain model. Relevance is determined using an algorithm that applies a weight to the keywords in the messages. The algorithm we adopted is implemented in Classifier4J (http://classifier4j.sourceforge.net/), which provides a vector-space-search engine. Below is an excerpt from the classification algorithm.

```
  //relevance value
  double result = 0;
  //prepare a message
  vectorStorage = new HashMapTermVectorStorage();
  //initiate classifier
  vectorClassifier = new VectorClassifier(vectorStorage);
  vectorClassifier.teachMatch("title", title);
  // classify title against basename of topic t
  result = vectorClassifier.classify("title",
t.getBaseName());
```

For the variants of basenames, use *t.getVariantName()*. For the content of the messages, use *vectorClassifier.teachMatch("body", body)*. Then the relevant values are compared, and the higher value is chosen as the relevance value.

The classification results are stored in a MySQL database. The database includes both the messages (title, author, timestamp, and thread information), and the concepts they are related to, with values of relevance.

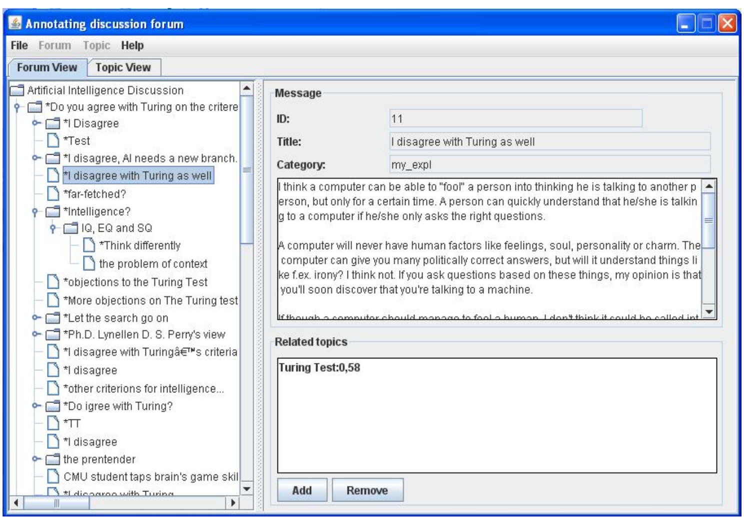

Fig. 4. Manual Annotation of Messages

Figure 4 shows an interface where teachers can manually associate messages to topics. The left panel shows the threads of the knowledge building forum. The * in front of the message title means that this message has been classified automatically. In the right panel, teachers can view the information for each message in the discussion thread (including title, knowledge building category and content) and the topics this message is related to. In the message content, the identified topics, such as "knowledge representation (KR)" and "knowledge acquisition (KA)" were highlighted with bold letters. They can also add or remove the related topics by clicking on the buttons at the bottom of the right panel.

2.3 Integration with FLE3

AnnForum is a plug-in to the FLE3 environment. It is a domain-independent tool. As shown in Figure 5, AnnForum takes the domain model and the messages as input, and puts the annotation of the messages into the database. When a new message comes, the *Classification* module decides its relevant concepts. Then it searches for the relevant messages in the database, computes the relevant values based on the relevance of the messages, and stores them in the MySQL database. The *Controller for relevant messages* module retrieves the relevant messages and sends them to the interface in FLE3. The *Controller for feedback* module learns from the feedback of the learners and adjusts the weights used in the matching algorithm accordingly. Below is the pseudo code for the weight adjustment.

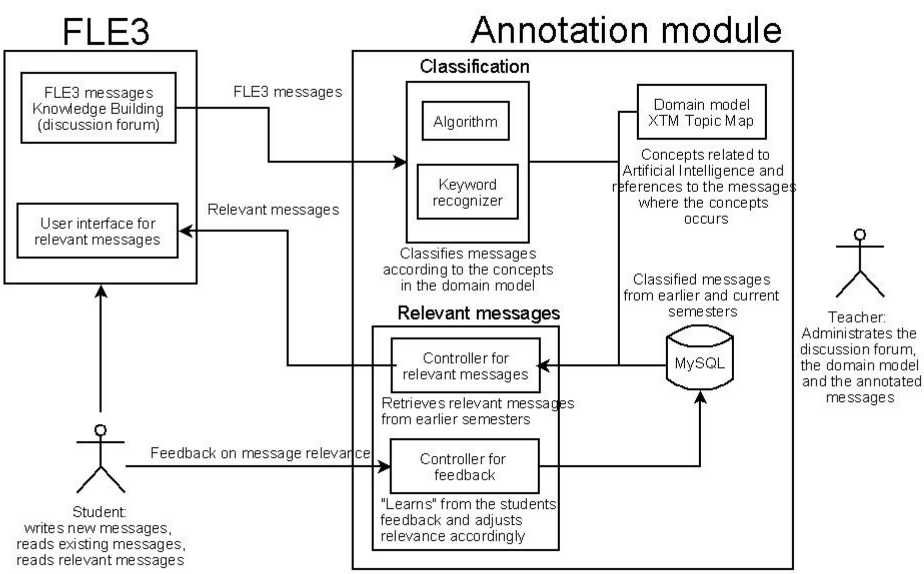

Fig. 5. Integrating AnnForum with FLE3

```
//the relevant message from last semester
Get previous message M1
//the current FLE3-message that the student was reading
Get current message M2
Get vote of user (yes/no)
Get topics L1 for M1
Get topics L2 for M2
For each topic T1 in L1
  For each topic T2 in L2
    If T1.topicName equals T2.topicName
       Increase/decrease relevance of T1 by 50% for M1
    End if
  End for
End
```

Figure 6 shows the interface where learners can browse the relevant messages and comment on them. They can also vote for the messages after reading them. The voting will affect the relevance value later.

Fig. 6. Viewing Relevant Messages (Learner's Interface)

3 Evaluation

The evaluation has three main goals: to assess the extent of the system's functionality, to assess the effect of the system on the learner, and to identify any specific problems with the system. More specifically, the evaluation aims to answer the following three questions:

- How well does the system annotate and classify existing messages based on the domain model?
- How useful are the relevant messages to the learners?
- What improvements need to be made to the system?

3.1 Carrying Out the Evaluation

Six university learners taking an information science major participated in the evaluation. All of them were familiar with the AI domain and had experience with discussion forums. The evaluation was carried out in a controlled environment where only one participant and one researcher were present. After a short introduction about the system, the participant was given a set of tasks to carry out. Data were collected by observation and interview after the tasks. The questions in the interview reflected the three goals of the evaluation.

Before the evaluation, the researchers prepared two messages and posted them into the knowledge building module in FLE3. One of the messages concerned the Turing Test and the other concerned Machine Learning. Both are important topics in AI. These two messages were posted in the category of "Problem", and served as the starting point for the discussion.

Each participant was asked to read existing messages, use the relevant message interface to check out relevant messages, and post at least two messages of their own responding to existing messages. This way, the number of existing messages grew as the evaluation progressed – the first participant had 2 existing messages to read and the last one had 10. This could be considered a simulation of a real knowledge building process, and it also made the dynamic nature of the system (annotating, classifying, and matching) more realistic. The current messages in the knowledge building module, as well as the 237 messages from previous knowledge building processes, were the source of the relevant messages.

3.2 Findings

The data from observation and interview show that all participants were very positive toward the system, and saw the added value of the relevant messages in their knowledge building process. They used the relevance value, or a combination of relevance value and the title of the messages, to decide which recommended relevant messages to read. After reading some of the messages, all six participants thought the message with the highest relevant value was the most relevant, while the one with the lowest relevant value was not quite relevant. Some also used the "thumbs up" and "thumbs down" buttons to vote for the recommended messages they read. Half of the participants responded by stating that the relevant messages they read affected the formulation of their own messages.

Perceived relevance of the recommended messages. The relevance values of recommended relevant messages were found to reflect the actual relevance to the current discussion. This indicates that the performance of the annotation, classification, and matching mechanism is acceptable. The automatic process is important because it saves learners from having to manually annotate their messages.

Perceived usefulness. The most positive aspects about providing the relevant messages include:

- The learners can build more in-depth knowledge about the discussion topic. The relevant messages provide them with different viewpoints.
- It gives the learners a feeling that the discussion is more alive, which motivates them to formulate good messages.
- The ranking list of the relevant messages is a better alternative than searching the discussion forum.
- It can reduce the possible duplication of information. Duplication of information is a problem in most big discussion forums.
- The dynamic nature of the relevant messages prevents earlier messages that are "buried" deep down in the thread from being ignored.

Improvement. The evaluation also resulted in a few ideas for improvement:

- Allowing learners to see the thread to which the recommended message belongs. This will give the learners context information regarding the message. Context information allows learners to have a feeling of presence, that is, that they are collaborating with previous learners [14].
- Allowing learners to see more information about each relevant message. Currently the system shows the title and the relevant value. The feedback from the participants indicates that showing a few opening sentences of each relevant message would help the learners to make a better judgment before going on to read the whole message. This could be implemented as a mouse-over event, which means the opening sentences of the message will be shown in a floating box near the title whenever the learner moves the mouse over the title of the message, and that the floating box disappears when the mouse is moved away from the title.
- Making the relevant messages' interface a part of the FLE3 interface with the same look-and-feel. Currently, the relevant interface is implemented as a pop-up window, which, according to the participants, disturbed the workflow.

4 Conclusion and Further Discussion

This paper presents our research on reusing collaborative knowledge as learning objects, including the design, development, and evaluation of AnnForum for this purpose. A small-scale pilot study has been conducted in order to assess the usefulness and the performance of the system, and gather information on possible further improvements. The participants in the evaluation were generally positive toward the system. The relevant values were found to reflect the actual relevance of the messages, and the system was perceived as useful. Some possible improvements were also identified through the evaluation. We are currently planning a more thorough evaluation, which will focus on the usefulness of the AnnForum to the teachers, and the influence of relevant messages on the learner's current knowledge building process [15].

In the near future we plan to test other algorithms [7] in information retrieval and document classification in order to find a better algorithm for this purpose.

The research presented in this paper has implications for searching in traditional discussion forums, and for organizational knowledge management.

The problem with traditional discussion forums is that it is difficult to find useful information about a certain topic, especially when the number of messages grows. It becomes impossible to have an overview of threads. In addition, the titles of messages usually use "RE: XXX" and do not tell the users much about the content of the message. The results from keyword-based searches are not always satisfactory. The method presented in this paper, including the dynamic annotation, classification, and matching, will be able to help users in finding relevant information from traditional discussion forums by providing them with a ranked list of relevant messages. This will also help to reduce the number of duplicated messages. Because the process is automatic, it does not give users additional overheads when they post messages.

One important research area in knowledge management is to look for better ways to handle large amounts of organizational information and knowledge, so that it is easy to represent, organize, maintain, search, and reuse them. Annotation and information retrieval have played important roles in knowledge management. We believe that knowledge management can benefit from our research in two key ways:

- Dynamic annotation and classification allows each new piece of knowledge to be automatically annotated and classified immediately when it is stored in the organizational knowledge repository.
- Dynamic matching provides users with a ranked list of relevant information and knowledge, which saves the users from having to formulize queries by themselves.

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References

1. Littlejohn, A.: Reusing Online Resources: A Sustainable Approach to E-Learning (Open Flexible Learning). Routledge Falmer (2003)
2. Scardamalia, M., Bereiter, C.: Technologies for knowledge-building discourse. Communications of the ACM 36, 37–41 (1993)
3. Scardamalia, M., Bereiter, C.: Knowledge Building. In: Guthrie, J.W. (ed.) Encyclopedia of Education, Macmillan Reference, Basingstoke (2003)
4. Hanauer, D.I., Jacobs-Sera, D., Pedulla, M.L., Cresawn, S.G., Hendrix, R.W., Hatfull, G.F.: Inquiry Learning: Teaching Scientific Inquiry. Science 314, 1880–1881 (2006)
5. Craven, M., DiPasquo, D., Freitag, D., McCallum, A., Mitchell, T., Migam, K., Slattery, S.: Learning to extract symbolic knowledge from the World Wide Web. In: Prof. of the 15th National Conference on Artificial Intelligence, Madison, Wisconsin, pp. 509–516 (1998)
6. Helic, D., Maurer, H., Scerbakov, N.: Reusing discussion forums as learning resources in WBT systems. In: Proc. of the IASTED International Conference on Computers and Advanced Technology in Education, Rhodes, Greece, pp. 223–228 (2003)

7. Singhal, A.: Modern Information Retrieval: A Brief Overview. Bulletin of the IEEE Computer Society Technical Committee on Data Engineering 24, 35–43 (2001)
8. Helic, D., Maurer, H., Scerbakov, N.: Discussion Forums as Learning Resources in Web-based Education. ACTA Advanced Technology for Learning 1, 8–16 (2004)
9. Muukkonen, H., Hakkarainen, K., Lakkala, M.: Collaborative technology for facilitating progressive inquiry: future learning environment tools. In: Proc. of International Conference on Computer Supported Collaborative Learning (CSCL 1999), Palo Alto, CA, pp. 406–415 (1999)
10. ISO/IEC 13250 Topic Maps. International Organization for Standardization (2000), http://www.y12.doe.gov/sgml/sc34/document/0129.pdf
11. Maedche, A., Neumann, G., Staab, S.: Bootstrapping an Ontology-based Information Extraction System. In: Szczepaniak, P., Segovia, J., Kacprzyk, J., Zadeh, L. (eds.) Intelligent Exploration of the Web. Springer, Heidelberg (2002)
12. Yildiz, B., Miksch, S.: ontoX - A Method for Ontology-Driven Information Extraction. In: Gervasi, O., Gavrilova, M.L. (eds.) ICCSA 2007, Part III. LNCS, vol. 4707, pp. 660–673. Springer, Heidelberg (2007)
13. McDowell, L.K., Cafarella, M.: Ontology-driven information extraction with ontosyphon. In: Cruz, I., Decker, S., Allemang, D., Preist, C., Schwabe, D., Mika, P., Uschold, M., Aroyo, L.M. (eds.) ISWC 2006. LNCS, vol. 4273, pp. 428–444. Springer, Heidelberg (2006)
14. Garrison, D.R., Anderson, T., Archer, W.: Critical thinking in text-based environment: Computer conferencing in higher education. The Internet and Higher Education 2, 87–105 (2000)
15. Kato, S., Akahori, K.: Influences of past positions on a bulletin board system to new participations in a counceling environment. In: Proceedings of ICCE 2004, Melbourne, pp. 1549–1557 (2004)

Evaluation of Interoperability between MOT and Regular Learning Management Systems

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Abstract. Adaptive Hypermedia content offers personalization; however, (re-) using such material with regular Learning Management Systems (LMS) is not yet straightforward. Ideally, materials created once should be usable anywhere. One such vehicle for reusability is represented by e-learning standards. Thus, here we describe the extension and evaluation of My Online Teacher (MOT), an adaptive hypermedia authoring system, to which compatibility with IMS Question and Test Interoperability (IMS QTI) and IMS Content Packaging (IMS CP) was added. This way, MOT authors can *use materials dedicated to learning process adaptation on any standards-compatible LMS*. In this paper we evaluate the converters from MOT to IMS CP and IMS QTI via both qualitative and quantitative analyses. This paper reports our hypothetical findings, their implementations, and the joint results of the evaluations of the converters. Finally, this work describes a significant step towards the little explored avenue of *adaptive collaborative systems*, based on extant learning standards and popular LMS.

Keywords: Interoperability, MOT, CAF, IMS QTI, IMS CP.

1 Introduction

Adaptive and adaptable hypermedia authoring is challenging, especially with respect to moving on from standalone academia systems and endeavoring to deliver the created adaptation materials to students using regular learning management systems (LMS). Previous studies [2] have shown that, whilst adaptation authoring is a "*difficult problem*", there are at least two applicable approaches to solve it: 1) a *common language*, a lingua franca, used by all authors of Adaptive Educational Hypermedia (AEH); and 2) usage of *converters* between AEH systems. In the work reported in this paper, we follow a combined approach, by developing novel *converters* [4], which use authored adaptation materials as input and produce *standardized* material (the most widely accepted lingua franca) as output.

2 Evaluation of the Converters

The converters [4] have been tested with a group of about thirty 3rd year students of a course on "Web Programming", who study Computer Science (FILS direction) at the Politehnica University Bucharest. The "Web Programming" course was partially

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delivered via two weeks of face-to-face lectures, seminars and hands-on labs, and for the rest of the term, delivered via distance learning. Before the students had to answer to questionnaires, they were made familiar, via *lectures*, with MOT [1] and CAF [3], Sakai[1], IMS QTI[2] and IMS CP[3], and via hands-on *experiments*, with authoring environments (MOT) and TEL environments (e.g., Sakai). The students collaborated in the creation of new content in MOT and carried out conversions, visualized their own products, as well as other course material stored on Sakai.

Conversions from MOT to IMS QTI and IMS CP have been performed in two different sessions, on two different days. Each session started with a presentation on how the converter works, followed by a practical demonstration on using the converters. Then, it was the students' turn to perform the conversions. Finally, the students had to evaluate their experience with the conversion systems, via questionnaires. Thus, the students played two roles in these evaluations;

1) The first role is 'author', where they created their own additional course materials in MOT and converted them to IMS QTI and IMS CP;
2) The second role as 'student', where they answered two separated questionnaires prepared in MOT and converted to IMS QTI.

For our testing purposes, it was reasonable to use students for the evaluations, as the type of system we envision towards the end of our developments will involve students as co-authors and collaborative annotators of the extant created material, in the sense of exploiting Web 2.0 techniques and trends in order to enrich and adapt material to the current student population. Thus, it is important that not only designers and educational material authors evaluate the authoring and conversion tools, such as we have done in the past, but also, that students can directly work with these tools.

2.1 Hypotheses of the MOT - CAF to IMS QTI Converter

The following set of initial design hypotheses were to be validated via the students' answers, for the CAF to IMS QTI converter:

H1.1. Conversion to standards is useful for MOT: standards are vital in the context of test and quizzes for IMS QTI.

H1.2. The converter is 'perfect' for its purpose; students believe to learn it quickly (learning curve).

H1.3. The converter is 'perfect' for its purpose; students believe to be able to use it quickly (easy to use).

H1.4. The converter's performance is adequate; time for response is acceptable (perceived user acceptance).

H1.5. The converter's performance is adequate; `time < 30 sec` for a regular UNIX server supporting multiple server processes, 2GB of RAM and 3GHz of dual CPU, for a small CAF questionnaire file (about 5 concepts with 10 attributes in total).

---

[1] http://sakaiproject.org/
[2] http://www.imsglobal.org/question/
[3] http://www.imsglobal.org/content/packaging/index.html

H1.6. The converter converts all required information from CAF.

H1.7. The converter should cover all types of questions (not just fill-in-the-blanks, as in our experiment).

H1.8. The converter is well-integrated with the other programs (that it is used with).

2.2 Hypotheses of the MOT to IMS CP Converter

The following set of design hypotheses were to be tested via the students' answers, for the CAF to IMS CP converter:

H2.1. Conversion to standards is useful for MOT: standards are vital in the context of learning contents for IMS CP.

H2.2. The converter is 'perfect' for its purpose; students believe to learn it quickly (learning curve).

H2.3. The converter is 'perfect' for its purpose; students believe to be able to use it quickly (easy to use).

H2.4. The converter's performance is adequate; time for response is acceptable (perceived user acceptance).

H2.5. The converter's performance is adequate; `time < 30 sec` for a regular UNIX server supporting multiple server processes, (2GB of RAM and 3GHz of dual CPU), for an average CAF course file (about 20 concepts with 100 attributes).

H2.6. The converter converts all required information from CAF.

H2.7. The converter is well-integrated with the other programs (that it is used with).

H2.8. CAF to IMS CP conversion is more appropriate than CAF to IMS QTI.

2.3 Quantitative Analysis of the Hypotheses

We prepared two obligatory questionnaires based on our hypotheses, in which we asked eleven questions about the MOT to IMS QTI converter and twelve questions about MOT to IMS CP converter. Due to lack of space in this paper, we have placed the questionnaires (including the questions and answers) online[4].

We applied a Chi-square test to verify if our observations match our hypotheses. We chose the chi-square test because our questionnaires used categorical data. The degrees of freedom associated with our data are calculated as follows:

```
Df = number of categories - 1
```

The Chi-square (X^2) values represent the associations between the answers of each question, i.e., X^2 will be larger if the observed results diverge from those expected by chance. As shown in Table 1 (for the MOT to IMS QTI converter) and Table 2 (for the MOT to IMS CP converter), most of the results are statistically significant, as tested with the help of the Chi-Square test (with significance level $p \le 0.05$). In the

[4] http://als.dcs.warwick.ac.uk/mot/MOT_IMSCP.pdf
http://als.dcs.warwick.ac.uk/mot/MOT_IMSQTI.pdf

Table 1. MOT to IMS QTI questionnaire statistics

Question	Chi-Square	Df	P	Hypotheses
Q1.1	24.667	3	.000	H1.1- confirmed
Q1.2	93.44	1	.000	H1.2- confirmed
Q1.3	93.44	1	.000	H1.3- confirmed
Q1.4	25.138	1	.000	H1.4- confirmed
Q1.6	0.034	1	.853	H1.6
Q1.7	25.483	3	.000	H1.7- confirmed
Q1.8	0.310	1	.577	H1.8
Q1.9	0.034	1	.853	H1.8
Q1.10	1.690	1	.194	H1.6

tables we add also the hypothesis label that is supported by the majority of answers for each question (proven significant by the Chi-square test), and if it is confirmed.

Hypotheses H1.1, H1.2, H1.3, H1.4 and H1.7 were confirmed. Hypothesis H1.6, on the equivalence of the data in CAF and in IMS QTI, was not confirmed. To understand why, we analyzed the qualitative data (the rationale given) and noticed that students oscillated between yes (meaning that the information content is similar) and no (because the structure is different). There were no direct complains about information loss. Additionally, H1.8 was not confirmed, which was tested by Q1.8 and Q1.9. By analyzing the qualitative data for Q1.8 and Q1.9, we found that the students fluctuated between preferring having the converter running in Sakai, or having the converter running in MOT. Overall, there seems to be a preference of having the converter as a separate application, but this preference is not statistically significant.

Hypothesis H1.5 which is tested by question five (Q1.5) cannot be evaluated using Chi-Square test, as it contains numerical data not categorical one. Therefore, we used a one sample T-test to test whether a sample mean (30 answers of 30 students for Q1.5) significantly differs from a hypothesized value (H1.5. 30 seconds). The mean of Q1.5 for this particular sample of students is 3.35, which is statistically significantly different ($p<0.05$) from the test value of 30 seconds. We thus infer that this group of students has a significantly lower experienced processing mean than 30 seconds.

As shown in Table 2, hypotheses H2.1, H2.2, H2.3, H2.4 and H2.6 were confirmed, and we conclude that the groups of users of MOT and its converters to Sakai are able, with a short introduction, to quickly and efficiently perform the requested conversions, and understand some of the basics of this work. Moreover, the usage of the currently implemented systems appear as straightforward, even for students, and the theoretical background on which these systems are based is comprehensible within a couple of sessions with explanations. Hypothesis H2.6 was not confirmed, for the same reason mentioned for H1.6 of the MOT to IMS QTI questionnaire; furthermore, H2.7 was not confirmed too, for the same reason mentioned for H1.8 of the MOT to IMS QTI questionnaire.

As we illustrate in the first questionnaire, question Q2.5, which matches hypothesis H2.5 cannot be evaluated using Chi-Square test, as it contains numerical data not categorical one. Thus, we applied a one sample T-test again to examine whether a sample mean (30 answers of 30 students for Q2.5) significantly differs from a hypothesized value (H2.5. 30 seconds). After applying the T-test, the mean for this particular sample of students is 5.27, which is statistically significantly different ($p < 0.05$) from the test value of 30 seconds. We thus conclude that this group of students has a significantly lower mean on the writing test than 30 seconds.

Table 2. MOT to IMS CP questionnaire statistics

Question	Chi-Square	Df	P	Hypotheses
Q2.1	15.000	3	.000	H2.1- confirmed
Q2.2	24.142	1	.000	H2.2- confirmed
Q2.3	24.142	1	.000	H2.3- confirmed
Q2.4	9.143	1	.002	H2.4- confirmed
Q2.6	3.571	1	.059	H2.6- confirmed
Q2.7	17.286	1	.000	H2.6- confirmed
Q2.8	2.286	1	.131	H2.7
Q2.9	2.286	1	.131	H2.7
Q2.10	0.143	1	.705	H2.6
Q2.12	14.286	1	.000	H2.8- confirmed

2.4 Qualitative Analysis of the Hypotheses

Both questionnaires ask for a rationale for each question, where the students were requested to explain their answers. Additionally, question Q11 in each questionnaire covers free comments on the advantages and disadvantages of the converters. Analyzing the qualitative feedback from the experiments, this showed that the converters were mainly understood, easy to use, and useful. The most common mentioned advantages of the converters are: the converters are fast, easy to use, convert various types of content in the case of MOT to IMS CP converter, converting precisely (no information is lost in the conversion process), are built based on Java (which makes it easier to plug-in in other Learning Management Systems), and allow interoperability with systems that use learning standards. A few limitations of the converters were identified; students noted the following drawbacks of the converters: the converters cannot work offline; there is a bug (the system crashes due to a misinterpretation of the file location) in uploading the CAF file, when the students use Internet Explorer v6 (but not for v7 or above; this bug was fixed by updating some libraries); MOT to IMS CP is slower than MOT to IMS QTI, and there are currently no online help guidelines.

3 Discussion

Converting material from the authoring system for adaptivity, MOT, into IMS QTI, was pushing the capacity of MOT to some extent, as the authoring system was not initially designed to edit tests and questionnaires. However, this process has its benefits. It is acceptable that using assessments together with personalized learning access has a positive impact on the learning process, because it helps in: 1) checking if the learners have understood the materials correctly or not, and 2) providing feedback for both learners and teachers. Therefore, adding standard-based assessment potentials to

TEL will enhance the learning process and give the students the chance of tracing their learning progress. Moreover, complete compatibility, not only for export from adaptive systems via CAF to IMS CP and IMS QTI, but also import, is vital. After the completion of the evaluations, from open discussions with students, as well as from discussions with other designers, it emerged that such a bilateral compatibility is essential. As a result, the import function has in the meantime also been implemented, although only peer-tested as of now. With such a function, extant standard materials can be introduced into an authoring system like MOT, where additions towards adaptation specification are possible. In this way, enriching standard-based static material from rich repositories with adaptation becomes easier.

4 Conclusion

Most adaptive learning systems focus on personalizing the delivery of course materials to individual learners. However, not enough work has been performed on applying adaptivity to collaborative learning systems, such as popular LMS. Converting adaptive content into learning standards can supply a dynamic learning process which is compatible with all systems that support these standards. In this paper we present our work of converting CAF into IMS QTI and IMS CP, in which the authored adaptive materials in MOT can be imported into well-known LMS such as Sakai.

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References

1. Cristea, A., Floes, D., Stash, N., De Bra, P.: MOT meets AHA! In: PEG 2003, St. Petersburg, Russia (2003)
2. Cristea, A., Smits, D., De Bra, P.: Towards a generic adaptive hypermedia platform: a conversion case study. Journal of Digital Information (JoDI) Special Issue on Personalisation of Computing & Services 8(3) (2007)
3. De Bra, P., Aroyo, L., Cristea, A.I.: Adaptive Web-based Educational Hypermedia, Web Dynamics. In: Levene, M., Poulovassilis, A. (eds.) Adaptive to Change in Content, Size, Topology and Use, pp. 387–410. Springer, Heidelberg (2004)
4. Ghali, F., Cristea, A.: Interoperability between MOT and Learning Management Systems: Converting CAF to IMS QTI and IMS CP. In: The 5th International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems, Hanover, Germany (2008)

Implications of Writing, Reading, and Tagging on the Web for Reflection Support in Informal Learning

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Abstract. The use of tags as user generated meta-data as well as the visualisation in tag clouds has recently received a lot of attention in research and practice. This paper focuses on supporting reflection of learners by using different presentation approaches of user-generated meta-data for reflection support. Previous research has shown that implicit interest expression can be a valuable source for reflection support. Visualising implicit or "tacit" interest in tag clouds could help learners to understand the connections of their content related activities to the tags that are assigned to the content. For grounding this potential in the social practice of using tags in teams and small communities, we conducted a three month experiment. This experiment focused on the social practices of using tags explicitly and implicitly. In this paper we analyse the data of the experiment with regard to social navigation of teams and small communities, relations of implicit and explicit interest in tags, and usages of tags on different participation levels. The findings on these dimensions of the social practice of using and sharing tags in groups help to develop a better view on the requirements of providing reflection support.

Keywords: informal learning, learning communities, social software, web2.0, evaluation.

1 Introduction

The use of tags as user generated meta-data has recently received a lot of attention in research and practice. A large number of scientific contributions focus on community driven creation of meta-data [10, 11], or on improved accessibility of contents through this kind of meta-data [12, 18]. So far, only few publications have focussed on the relations between the explicit usage of tags and their implicit usage in search queries and while accessing information [7, 16]. Particularly, contributions on applying tags in the educational domain basically address the value of tags for improving access to relevant content. From an educational perspective this covers only a limited part of learning processes, because these processes include – among others – reflection activities. Reflection is a fundamental learning activity and is needed to articulate, express, and apply knowledge appropriately [21].

In this paper we address the need of supporting reflection of learners in open environments by applying different presentations of user generated meta-data. A common

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Fig. 1. Team.sPace tag cloud (detail view)

example of such presentation is a "tag cloud", in which the tags are not only listed, but the usage of a tag is shown in its display size. I.e. tags are larger size if they are more frequently used than other tags (see Fig. 1). The frequency of a tag is therefore *encoded* in its display size.

We propose that different forms of information encoding in tag clouds can stimulate and support reflection on learning processes that are embedded in other activities. Previously, we outlined how this can be achieved [8, 9]. Furthermore, we deduced from insights in self-regulated learning [2] that reflection support might be dependent to the context in which learners are active. However, these approaches of reflection support are to this stage conceptual outlines, which require a better understanding of the social practice of the contexts in which tags are applied.

This study analyzes the differences between the explicit use of tags for bookmarking or blogging in comparison with their implicit use when reading tagged contributions. In this paper we report on our findings from a three month experimental pilot and answer the question if explicit and implicit interest expression hold different information that is potentially meaningful for learners.

2 Background

One aspect of supporting reflection through tag clouds is that the information encoding helps to visualize relations between different information types. Given our goal to help users in recognising their tacit knowledge, the interest in tags must not be restricted to the explicit use of tags, but has to take the implicit tag usage into account. So far only limited research has reported on "implicit interest expressions" [3] and the relations of interest and social practices in online communities.

We approach this gap and analyze implicit and explicit tag usage of a group of users who were using the team.sPace environment [8]. team.sPace is a web-based community portal that allows its users to share bookmarks and blog entries. Figure 2 shows a typical view of the team.sPace web-site from a user's perspective. The information presented in team.sPace portal is entirely based on peer contributions. The portal aims basically at information exchange and aggregation. Learning is not an explicit goal for using this environment. Therefore, the underlying system is not based on an explicit instructional or learning design. To this extend team.sPace shares attributes with other social networking platforms and community portals, in which users learn incidentally, too.

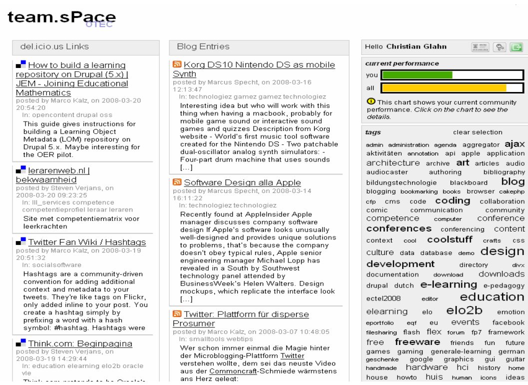

Fig. 2. User perspective of team.sPace

3 Question for Research

For supporting reflection in informal learning scenarios, we are interested in learning processes related to knowledge creation and knowledge exchange in teams or small communities. For this purpose we studied how the user's interest can be deduced from different user activities. As noted already by Claypool et al. [3] explicit and implicit references to a user's interests have to be distinguished. Implicit and explicit references are related to different types of user actions. Claypool et al. [3] have focused at understanding which user activities are relevant for deducing a user's interest. However, it has not been investigated how different user activities are related to interest expressions of a user.

Explicit interest expressions are all actions that are directly related to a user's interest and provide evidence of interest, such as user ratings, bookmarked URLs, user applied tags, or if a user writes a web-log entry about a topic. Implicit interest expressions typically do not provide direct evidence about a user's interest. Examples for implicit interest expressions are: click-troughs to a resource, the time a user spends viewing a resource, or tag selections in a tag cloud.

Understanding how tags are used is a prerequisite for raising the learners' attention on their learning interests. Therefore, our research seeks to answer the question, if a user's implicit expressions of interest in tags provide different information about a learner's interests than explicit interest expressions.

4 Related Research

Situated learning as introduced by Lave and Wenger [14] highlights the importance of competence development in a social context and the integration in a community of practice. Lave [15] states that from the perspective of situated learning, learning processes can't be seen as processes of knowledge acquisition that result in "possessing" knowledge. Instead, the concept of situated learning refers to learning as ongoing social practice, which is not defined by planned structures of curricula, rather than by the social practices, tasks, situations. Hence, learning is not context free, but *situated* in social contexts and social practices. As a consequence, knowledge and competences cannot be considered independent from the contexts and processes, in which they are developed and applied. From this perspective, learner support has to be seen as empowerment of learners, rather than overcoming their deficits [15].

This view is closely related to concepts of self-regulated learning processes, for which Butler & Winne [2] developed a model. In this model the actions of learners are interlinked with the responses learners receive on these actions from their environment. However, for designing technical support for self-organized learners this model is limited, because it models the "environment" as a "black box". In order to overcome this limitation from the perspective of technological development, we suggested earlier [8, 9] to extend this model by including principles of context aware systems [4, 5, 22, 23] on the environmental side of the model. This integration links the work on self-regulated learning with the achievements in the area of interactive and ubiquitous systems. The resulting *learning interaction cycle* is a feed forward system, in which the actions triggered by the cognitive system and the responses of the technical system affect each other. This means that both sides are not only respond the based on the actual input, but also incorporate the interaction history into their responses on the input actions. The underlying implication of this model is that technological support for self-regulated learning has to be adaptive with respect to contextual parameters of the learning activities.

Based on this theoretical model, we proposed a four-level system architecture [8]. At the lower levels this architecture is closely related to the works in the area of attention meta-data [19], whereas on the higher levels the architecture our work is related to user adaptive systems [1] and to social awareness [6, 13]. The purpose of the architecture is to provide an integrated approach for stimulating and supporting situated learning, that does not only reflect the temporal needs of learners but also allows adapting to the changing context of the learners.

Given this perspective on learning it is reasonable that reflection support should also follow the principles of the learning interaction cycle. Therefore, we assume that user-generated meta-data helps to identify explicit and implicit interests of users, which can be used to stimulate reflection on their personal learning processes. Our research has similarities to utilizing information about explicit and implicit interest of users to support their interaction with online information systems [3]; and with link sharing and social navigation [16].

Claypool et al. [3] compared implicit with explicit interest expressions in web-based content. The goal of their research was to identify if implicit expression of interest in content can be used as alternative to explicit rating of content. The authors distinguish between explicit expressions of interest, such as rating content, and implicit expressions of interest like reading content or bookmarking content. In a pilot study different kinds of user interactions have been analysed regarding their relation to a user's interest in contents. The authors identified that not all "promising" types of interactions can be used to infer the users' interest about a resource. The findings of this study were largely confirmed by a study in the educational domain [7]. Although our research also focuses on user interest, it differs from this previous research in two ways. First, Claypool et al. [3] and Farzan and Brusilovsky [7] analysed the user interests relative to single resources, while we are addressing interests regarding tags and concepts that are shared between resources. Second, the previous research was addressed only the users' interests in resources, while we analyse the conceptual differences of implicit and explicit interest on topics that are represented by tags.

Millen and Feinberg [16] have analysed the social dimension of sharing and browsing resources on the worldwide web in an organisational context. The authors were interested, if providing social bookmarking within an organisation leads to social exchange across the organisation, or if it leads to accumulation of information, with little relevance for other users in the organisation. The related field experiment was using the "dogear"-environment [17] showed that social bookmarking stimulates social exchange of information in a relatively large organisation [16]. In a way, our research takes up these findings and investigates if they can be extended to teams or smaller organisational structures as well. Additionally, we emphasize qualitative aspects of the social exchange that has been observed by Millen and Feinberg, as we focus on the developments of different kinds of interests that were developed through the general social practice regarding the content.

The studies of Claypool et al. [3] and of Millen and Feinberg [16] do not provide any implications on context dependency of their findings, because in both cases the experimental groups as well as their behaviour were treated as homogeneous. Both studies have not addressed contextual variables that might possibly affect the interest of the individual users. Hence, it is not reasonable to assume that the expression of interests is context dependent per sé.

In short, in this section we identified three gaps in research: firstly, research on implicit interest expressions has been focused on single resources, but not on tags that are used with several resources; secondly, social navigation was analysed in large user communities regarding the potential of this general concept of social activity for stimulating social exchange, but not regarding its application in teams or small communities and regarding its benefit for the individual participants; finally, user-generated metadata and social navigation have been only analysed from the perspective of homogeneous groups, but not as practices that are possibly connected to context.

5 Hypothesis

Based on these gaps in research and our research question, we define four hypotheses, to which regard we analysed the data of our experiment. The initial hypothesis of our experiment was as follows.

H1. team.sPace can support teams and small communities for social navigation.

This hypothesis implies that the users of the experimental system make use of the resources that were provided by others and that social navigation takes also place in teams or small and local communities. The underlying assumption is that the findings on social navigation of large groups and communities are also applicable in smaller groups or communities.

H2. Implicit interest expressions of the team.sPace users do not replicate the community's aggregated explicit interest that is represented in the tag cloud of the system.

This hypothesis directly addresses our main question for research. It has the important implication that the users' implicit interest is not biased by the tag cloud of the system. This hypothesis verifies our initial assumption that the use of tags in reading and searching is not biased by visualisation of the community's tag cloud. Additionally, we defined two hypothesises subordinate to H2.

H3. The implicit interest expressions of contributing users are more focused in certain tags than the interest expressions of non-contributing users.

This hypothesis refers to varying interaction patterns for users at different participation levels. We assume that non-contributing users tend to explore the different topics more than contributing users. Therefore, we expect a wider distribution of tags for non-contributing users than for contributing users.

H4. Users who contribute more to social bookmarking or blogs are more likely to replicate the tags they use for their own contributions also in their implicit interest expressions.

This final hypothesis addresses the differences of perceiving tags among the groups of users. We assume that users who actively contribute in blogs and social bookmarking are more aware about their interests and therefore are more focused in their reading habits than users who are less active. This hypothesis implies that the users' tagging habits on one side and their reading and searching habits on the other side are not independent from each other.

6 Method

For analysing the previously defined hypotheses we conducted a three month experiment using the team.sPace environment. team.sPace is a web-based community portal that allows its users to share del.icio.us bookmarks and their personal blogs among a group of users. The portal has three main sections: the first part contains a feed to social bookmarks, the second part contains the aggregated blog information, and the third part contains user and navigation tools, such as a tag cloud that can be used for information filtering. The team.sPace tag cloud does not contain all tags, but only those tags that were used at least by two users or used by a single user more than five times. The information provided in each part of the portal, is aggregated from all users of a group, who have registered sources to the information of the sections. While indexing the contributions, team.sPace excludes all contributions that were not tagged. This step assures that all contributions in the portal have tags assigned.

The experiment was conducted with members of a research department at the Open University of the Netherlands. The participants were invited according to the similarity of their research topics, while these persons were previously not collaborating intensively in the same projects. The invited participants could register themselves with team.sPace and configure team.sPace so the portal can integrate their contributions into a community feed. The participants could freely choose if and which information they contribute to this small community. Given to the types of resources this creates four groups of users: Fully contributing users who contribute blogs and bookmarks, blogging users who contribute only blog entries, del.icio.us users who contribute only bookmarks), and reading users who do not contribute at all. Within team.sPace the users can perform three different types of activities: contributing, reading, and exploring. Because all contributions in team.sPace have tags assigned, all user actions are automatically associated to tags. For the experiment only the user actions were tracked, but no feedback on the users' interests was provided.

team.sPace traces the users' explicit interests through the tags they assign to their bookmarks and web-log entries. Implicit interest is traced on conceptual browsing while users click on tags in the tag cloud; and by tracking the users' accesses of the contributions. After the experiment we analysed the explicit and implicit use of the tags which were available in team.sPace. In order to verify our hypotheses, we analysed the data in four steps.

In a first step we analysed the social navigation of the users by comparing the number of explicit and implicit tags that were used by a user. Explicitly used tags are only assigned to the contributions of a user, while implicitly used tags could have been also assigned to contributions of other users. By removing all tags from the list of implicitly used tags if they were used by a user in both ways, only those tags that were assigned to the contents of other users remain in the list. A larger number of individual tags in this list imply that a participant utilised social navigation more actively.

The second step should verify that a user's implicit interest does not simply replicate the community's explicit interest. In order to do so, we needed to show that the users did not simply use tags that were highlighted in the tag cloud. To prove that this does not only replicate the user's conscious concepts, we ranked the most relevant tags for explicit and implicit interest expressions. Both rankings were calculated for the community as well as for each user. We calculated the overlap of the 30 most relevant tags of the users' implicit interest expressions with the top 30 of the ranking of the group's tag cloud. This procedure has been repeated for the overlap of the implicit and the explicit interest expressions. A lower degree of overlap in both runs proves that the implicit interest expressions in social navigation hold potential to unveil tacit knowledge and concepts.

At the third step we analysed if the implicit interest expressions of non-contributing users are more random than those of contributing users. For this purpose we reused the relevant tags that were identified during the second step. For each user we calculated the average frequency of using one of the relevant tags and the standard deviation of this average. A lower average frequency and a low deviation mean that the tags were used more randomly by a user. In this case the user did not select the tags very often, and all values are lying in a narrow interval, whereas a focus on some tags would have been selected more often than others, which results in a higher deviation and average. We calculated the randomness of implicit interest expressions for contributing and non-contributing users.

Finally, we analysed if active users are more focused in their reading behaviour and align their implicit and their explicit interest expressions. A quick impression if the distribution is gained by calculating the overall usage of the tags that were used only implicitly, and those implicit interest expressions that were also explicitly used. In order to compare the results across the users, we represented the values relative to the total amount of implicit tags that were used by the user. As a result, a higher percentage of tags that were use only in implicit interest expressions means that the user was less aligned with the explicit interests. Of course, this relation is only meaningful for contributing participants, because by definition non-contributing participants don't express their interests explicitly.

7 Results

We invited 30 people to volunteer in the experiment. Of the invited group, twelve registered and participated in the experiment. Four participants registered their web-log feeds, nine registered their del.icio.us nicks, and three participants were only reading. All users who registered their web-log also registered their del.ico.us account. During the period of the experiment, the portal has been visited 926 times by these users. They followed 331 times a link to a contribution and selected 389 times a tag in the tag cloud. 1411 contributions were registered, of which were 1303 bookmarks and 108 were blog entries.

847 individual tags were assigned 3068 times to the contributions. In average a contribution has 2.2 tags assigned. 326 tags or 39.7% of the tags can be considered as relevant to the community, as these tags have been used more than twice in the lifetime of the experiment, either as explicitly assigned to a contribution, or implicitly while accessing an article or while using the tag cloud. The minimal threshold of three usages per tag assures that a tag was not used once and has then been read or selected incidentally. The relevant tags were assigned 2431 times to contributions and cover 79.2% of the overall explicit tag usage.

365 individual tags were assigned to contributions that were read by the participants, and 133 unique tags were accessed through the tag cloud. The average contribution that has been read by the participants had 3.7 tags assigned. 232 tags were assigned by at least two participants to their contributions. The majority of these tags are shared among less than four participants (78%). Another 30 tags were assigned more than five times by a single participant. The tag cloud in team.sPace displayed therefore 262 tags at the end of the experiment. 159 tags were read, and 97 were accessed through the tag cloud by at least two participants. 43 tags were accessed by different participants while reading and searching.

Among the relevant tags within team.sPace we identified several concept clusters. These clusters contain tags that reflect semantic similarities. An example for such a cluster is learning, which is reflected by the tags: "bildungstechnologie", "e-learning", "elearning", "e-leren", "e-pedagogy", "educationaltechnology", "learning_technology", "learningtechnology". The tags in these clusters were accessed very differently. However, a detailed analysis of these tag clusters is beyond the scope of this study.

The range and variety of this data set allows us to run the analytical steps, which have been defined in the previous section, and draw first conclusions with regard to our hypotheses.

Out of all tags the contributing participants in 36,6% of the cases used a tag more than once in their implicit interest expressions (n=8; σ=16.5%). This result takes all tags into account. With regard to the tags that were relevant to the group, 55.5% (n=8; σ=23.4%) of the tags assigned to a participant's contribution were also used in implicit interest expressions.

The 30 most frequently used tags in the participants' implicit interest expressions overlapped with the most relevant tags of the shared tag cloud in average to 40.4% (n=11; σ=11.4%). The implicit interest expressions of the non-contributing participants overlapped the communities interests to a lower extend (34.4%; n=3; σ=12.62%) than the interest expressions of the contributing participants (42.6%; n= 8; σ=10.9%). We repeated this step with the ten most frequently used tags of each participant. The average overlap of implicit interest expressions and the tag cloud was for non-contributing participants 20.0% (n=3; σ=20%), and 48.3% (n=8; σ=12.9) for contributors.

The average implicit interest of contributing participants in these tags has been expressed by 2.5 requests (n=8; σ=1.7), the average range of interest was 2 tags (n=8; σ=1.6). Compared to these results, the non-contributing participants expressed their implicit interest in average by accessing 1.6 tags (n=3; σ=0.81) with a range of 1.2 tags (n=3; σ=1.39).

With regard to the focus of interest of the participants we found that in average 52.8% of the tags were used only in implicit interest expressions (n=8; σ=19.6%). With regard to the participation to the group, we compared more active participants with those who were less active. We set the threshold for that defines more active participation to a minimum of 100 tags in implicit interest expressions. This threshold created two sub-groups of each four participants. With regard to their focus of interest, the more active participants were more interested in tags, which they did not use themselves (56.8%; n=4; σ=10.6%). In comparison, less active participants were less focused on the tags, which they did not use themselves (48.9%; n=4; σ=27.2%).

8 Discussion

Our data confirmed hypothesis H1, that team.sPace supports social navigation in teams and small groups. The low ratio of overall repetition of explicitly used tags in implicit interest expressions (36.6%) indicates that the participants were interested in the contributions provided by the other participants. As for each contribution a short description is provided in the portal, the participants are more likely to access information in which they are interested. It is not surprising that more relevant tags appeared more often (55.5%) in implicit and explicit interest expressions, as these tags were shared among the participants. These results show that explicitly used tags are not only used to structure the own contributions, but are also relevant for exploring other content that is relevant to the participants' interests. Thus, principles of social navigation also appear to apply to smaller groups.

Hypothesis H2 was supported by the experimental data. We analysed the overlap of the most frequently used tags in the participants' implicit interest expression with the most relevant tags of the team.sPace community. The relatively low overlap of the participants' implicit interest expressions with the tags presented in the shared tag cloud indicates that the tag cloud affects the actual reading habits to a limited extend. This was particularly the case for non-contributing participants. However, we identified in the ranking of implicit interest expression that all participants partially referred to semantically similar tags. This effect can be explained with the low sharing rate of tags, because the majority (78%) of shared tags have been shared by two or three participants. Therefore it is likely that another participant used different tags to label similar contents. If participants access these contents, it does not necessarily mean that they are unaware of the underlying concepts.

Hypothesis H3 was not supported by the experiment. Our data showed that the average frequency of tag usage and its deviation were lower for non-contributing than they were for contributing participants. However, the differences between the groups were too small for confirming our initial expectations. These results imply that non-contributing participants would not need different support for exploring resources of a community than other participants. For getting more detailed insights on this hypothesis additional data is necessary.

With respect to hypothesis H4, we expected that more actively contributing participants are more focused in their reading habits with respect to the tags they use themselves. The experimental results did not confirm this expectation. Instead, we found the opposite: less active contributors appear to focus more on the tags they use, while more active participants were exploring the content to a larger extent. This finding suggests that more active participants of a community may reflect more on the tags that are used within the community. Thus, more active participants seem to focus on a greater variety of contributions and related their choices of tags to their insights. As our observations were only focused on the implicit and explicit usage of tags, more research is needed to confirm this interpretation of the data.

The initial assumption made in [9] was to hide information about the implicit interests of the non-contributing participants helps them to explore the contributions of a community. Our findings rejected this assumption. Nevertheless, we identified that thresholds for distinguishing incidental tag usage and actual interests are needed. According to our data, these thresholds seem to be independent from the contributions of a participant.

9 Implications for Reflection Support

In this paper we analysed the explicit and implicit usage of tags in an open community portal. Our initial idea was to visualise a participant's interests on the different topics of the community in the tag cloud of the portal.

The goal of this study was to identify if a participant's implicit expressions of interest provide different information than explicit interest expressions. Our findings support this hypothesis. The implicit interest expressions can therefore be used to stimulate reflection on tags or concepts of which otherwise the participants would not be aware of. However, we identified three important restrictions to this primary finding.

First, for determining interest through the explicit or implicit use of tags, depends on thresholds below which "interest" is not assured. An implication of this is that not all contributions or information requests represent a participant's interest in the same way. In this respect, our data showed no differences for contributing and non-contributing participants. Defining appropriate boundaries for using tags to identify interest, remains an open question for future research.

Second, a large number of tags appear to be used for personal structuring, but seem not to be relevant to the community. This finding confirmed that it was appropriate to exclude tags from the tag cloud if they were not shared.

Third, the "unknown" tags that have been identified as interesting to a participant could be only semantic variations of the concepts that a participant is already aware of. This is not so much a restriction for reflection support, but outlines the possible demand of participants to express relations between the tags they are interested in.

The current study has only focused on the usage of tags by users in teams and small groups. Future work will analyse if integrating visualisations of explicit and implicit interest expressions actually stimulate the reflection on tags and concepts. Future research will address the effect of active and passive reflection on tag and concept visualisation, and develop a better understanding if semantic similarities make a difference for the reflection process.

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References

1. Brusilovsky, P.: Adaptive Hypermedia. User Modeling and User-Adapted Interaction 11, 87–110 (2001)
2. Butler, D.L., Winne, P.H.: Feedback and self-regulated learning: a theoretical synthesis. Review of Educational Research 65, 245–281 (1995)
3. Claypool, M., Le, P., Wased, M., Brown, D.: Implicit Interest Indicators. In: ACM Intelligent User Interfaces Conference (IUI 2001), pp. 33–40. ACM, Santa Fe (2001)
4. Dey, A.K.: Understanding and using context. Personal and ubiquitous computing 5(1), 4–7 (2001)
5. Dey, A.K.: Enabling the use of context in interactive applications. In: Computer-Human Interaction (CHI 2000), de Hague, NL, pp. 79–80 (2000)
6. Erickson, T., Kellogg, W.A.: Social translucence: using minimalist visualizations of social activity to support collective interaction. In: Höök, K., et al. (eds.) Designing information Spaces: the Social Navigation Approach, pp. 17–41. Springer, Berlin (2003)
7. Farzan, R., Brusilovsky, P.: Social navigation support in e-learning: what are the real footprints? In: Mobasher, B., Anand, S.S. (eds.) Intelligent Techniques for Web Personalisation (ITWP 2005), Edinburgh, Scotland (2005)

8. Glahn, C., Specht, M., Koper, R.: Smart Indicators on Learning Interactions. In: Duval, E., Klamma, R., Wolpers, M. (eds.) EC-TEL 2007. LNCS, vol. 4753, pp. 56–70. Springer, Heidelberg (2007)
9. Glahn, C., Specht, M., Koper, R.: Smart indicators to support the learning interaction cycle. Int. J. Continuing Engineering Education and Life-Long Learning 18(1), 98–117 (2008)
10. Heymann, P., Garcia-Molina, H.: Collaborative creation of communal hierarchical taxonomies in social tagging systems. InfoLab Technical Report, Computer Science Department, Stanford University (2007)
11. Hsieh, W.T., Lai, W.S., Chou, S.C.T.: A collaborative tagging system for learning resources sharing. In: IV International Conference on Multimedia and Information and Communication Technologies in Education (m-ICTE 2006), Seville, Spain, pp. 1364–1368 (2006)
12. Ishikawa, T., Klaisubun, P., Honma, M.: Navigation Effiency of Social Bookmarking Service. In: International Conference on Web-Intelligence and Intelligent Agent Technology – Workshops (WI-IATW 2007), pp. 280–283. IEEE Computer Society, Washington (2007)
13. Kreijns, K.: Socialble CSCL Environments; Social Affordances, Sociability, and Social Presence, doctoral dissertation, Open University of the Netherlands, Heerlen (2004)
14. Lave, J., Wenger, E.: Situated learning, legitimate peripheral participation. Cambridge University Press, Cambridge (1991)
15. Lave, J.: The practice of learning. In: Chaikin, S., Lave, J. (eds.) Understanding practice, perspectives on activity and context, pp. 3–33. Cambridge University Press, New York (1993)
16. Millen, D.R., Feinberg, J.: Using social tagging to improve social navigation. In: Workshop on the Social Navigation and Community Based Adaptation Technologies, Dublin, Ireland (2006), http://www.sis.pitt.edu/~paws/SNC_BAT06/crc/millen.pdf
17. Millen, D.R., Feinberg, J., Kerr, B.: Dogear: Social Bookmarking in the Enterprise. In: Computer-Human Interaction (CHI 2006), Montreal, Canada, pp. 111–120 (2006)
18. Michlmayr, E., Cayzer, S.: Learning user profiles from tagging data and leveraging them for personal(ized) information access. In: 16th International World Wide Web Conference (WWW 2007), Banff, Canada (2007), http://www2007.org/workshops/paper_29.pdf
19. Najjar, J., Wolpers, M., Duval, E.: Attention Metadata, Collection and Management. In: Workshop on Logging Traces of Web Activity, Edinburgh (2006)
20. Rivadeneira, A.W., Gruen, D.M., Muller, M.J., Millen, D.R.: Getting our heads in the clouds: toward evaluation studies of tag clouds. In: Computer-Human Interaction (CHI 2007), San Jose, CA, pp. 995–998 (2007)
21. Schön, D.A.: The Reflective Practitioner: How Professionals think in Action. Maurice Temple Smith, London (1983)
22. Zimmermann, A., Lorenz, A., Oppermann, R.: An Operational Definition of Context. In: Kokinov, B., Richardson, D.C., Roth-Berghofer, T.R., Vieu, L. (eds.) CONTEXT 2007. LNCS (LNAI), vol. 4635, pp. 558–571. Springer, Heidelberg (2007)
23. Zimmermann, A., Specht, M., Lorenz, A.: Personalisation and context management. User Modeling and User-Adapted Interaction 15, 3–4 (2005)

A Distributed Ontological Approach as a Basis for Software in the Context of Academic Programs

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Abstract. The implementation of a computer understandable representation of the semantics of academic programs is complex. That's why academic institutions struggle in implementing pervasive information systems that offer services to help all actors in this context. These services are demanded by, *e. g.*, students who want to plan their curricula correctly, or who want to know which courses can be used for a different academic program or at a different academic institution. In this paper, we introduce a distributed ontological approach to represent the semantics of academic programs and their examination regulations, the universities' supply, and individual results. It allows academic institutions to implement applications that offer the demanded services and that use these ontologies as a common basis.

1 Introduction

Written in a legal language, academic institutions release examination regulations and subsidiary documents that describe their academic programs. Because legal language is very hard to comprehend by humans and in this form not interpretable by computers, a great demand for decision support exists. In this context, unfortunately, there is only little automatic help — like decision support systems — realized. Results of this situation, *e. g.*, are that students often do not understand the whole descriptions of academic programs or even do not try to read them. Thus, they have questions concerning good and correct ways in planning and realizing their individual curricula. Examples are which offered courses they can take at best or which of them can be used for a different academic program, *e. g.*, in the case of a minor subject. Another interesting question is, *e. g.*, which courses can be taken for academic programs of another academic institution. Besides the computer-understandable representation of the semantics of examination regulations, another challenge is the distributed structure of academic institutions and of clusters of them. Information concerning academic programs and their examination regulations, the universities' supply of courses and the individual results of the students is often created and stored separately

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by, *e. g.*, faculties and institutions (see [1]). It has to be merged in order to be able to offer decision support applications.

In this paper, we introduce an ontological approach for the representation of academic programs and their examination regulations, the universities' supply of courses and the individual results of the students. This approach allows a distributed representation that fits to the structure of academic institutions. We explain that our approach is a very applicable basis to implement applications offering decision support in the context of academic programs.

2 The Ontological Approach

In order to represent the semantics of academic programs and their examination regulations, we have identified two important aspects: On the one hand, there is a *static* representation needed which defines the concepts of *entities* of academic programs — a conceptual model. An exemplary representation would be, *e. g.*, *modules* that can contain a couple of *courses* and *examinations*; *courses* can be used for certain *modules*, deal with specific *topics* and so on. These entities can be structured very heterogeneously comparing different academic programs (see [2]). On the other hand, there is a *dynamic* representation needed which defines a possible order of concrete entities in the course of a study. In addition, it defines conditions that regulate the possibilities in taking certain of these concrete entities. It also defines, how an entity (like a *module*) can be successfully passed, *e. g.*, by taking a couple of *courses* and calculating the average grade which has to be better than a specific grade.

The *static representation* can be modeled well using an object-oriented or an entity-relation based representation. It is a conceptualization that describes the static structure of all possible instances. The availability of a common shared conceptualization would be very useful because we have to deal with a distributed structure of academic institutions (and of clusters of them). Then, different faculties or institutions can instantiate these concepts, *e. g.*, modeling their own supply and share this information with other faculties or institutions on the web. In addition, the examination offices could use the conceptualization and these instances for representing the individual results of their students. Beside others, these aspects motivate our decision to use ontologies to represent the static representation of academic programs. The *dynamic representation* covers rules in taking and passing instantiations of the concepts that have been defined in the course of the conceptual modeling of the static representation. To do so, academic programs and their examination regulations can be represented as a kind of process (see [3]).

Our ontological approach contains a general meta-model (implemented in OWL-DL) with a set of business-rules and a software framework (see [4]). We call the approach Curricula Mapping Ontology (CMO). The framework includes a library that uses the JENA-framework (http://jena.sourceforge.net/). It can interpret instantiations of the meta-model and it ensures that they stick to the business-rules. The meta-model is a conceptual model that defines concepts that

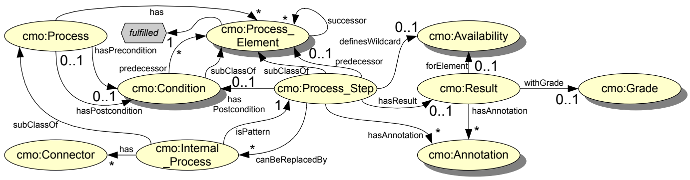

Fig. 1. Basic process and wildcard concepts of the CMO

allow the instantiation of processes including conditions that represent very complex rules — if needed. These processes represent academic programs and their examination regulations. It is intended to extend specific concepts of the general meta-model. This extended conceptual model is the static representation of academic programs. Instantiations of this individually extended meta-model form the dynamic representation of academic programs including their examination regulations. They also form representations of the universities' supply, and the individual results of the students. Given a set of individual results of a single student, the model-interpreting framework can, *e. g.*, show the possibilities of the student in continuing his academic program. Our approach is conceptualized that way that nearly arbitrary extensions of the general meta-model are allowed to define the static representation of an academic program without the need of adapting the model-interpreting framework. As long as the business-rules of the general meta-model are fulfilled, the framework can interpret all possible instantiations (the dynamic representations) of such extended meta-models synchronizing it with a set of individual results of a student.

The general meta-model of the CMO defines concepts to represent processes (see figure 1 — we use the namespace shortcut "cmo"). A process contains a set of process elements (the class Process_Element is not intended to be instantiated directly; it has to be specialized — this is shown by shadows). These elements can be conditions or process steps. Each element can have predecessors and successors in order to be able to create an order/a process. Conditions can be interpreted as TRUE or as FALSE depending on the type of their specialization and the values of their preceding elements. They can be, *e. g.*, simple logical conditions like AND — known from logic gates. They also can be more complex conditions that include the comparison of aggregations of certain values of attributes of their preceding elements with other values. An example is: "the number of passed elements > 6". It is also possible to aggregate values of the preceding elements that are self-defined within the static representation and use it in connection with a comparison like "the sum of *workload* > 16" (see [4]).

Each process step references a specialization of Availability as a so-called wildcard (property "definesWildcard"). Availability is the super class of concepts of entities of an academic program which can be defined in the course of the static modeling (like *course*, *examination*, *etc.*). The wildcard-reference defines which kind of individual results of a student can be assigned to the corresponding process step. Each result of a student therefore references an instance of Availability, too. In order to be able to assign an individual result with a certain process step, this referenced instance of the result must be of the same specialization of Availability as the instance that is referenced by the process step as a wildcard. In addition, it must reference at least the same object- and datatype properties. Additional referenced properties are allowed, too. With this methodology, it is easy to model that an entity of the academic program only has to have, *e. g.*, a certain title: A process step has to reference an instance of a specialization of Availability as wildcard. In addition, this instance only has to reference a certain title. Then, it is defined that every result that references an entity of the same concept as the wildcard can be used for this process step if this entity references at least this certain title, too. A process step can be interpreted as successfully passed or not if a result is assigned to it that references an element that fits to the wildcard as described above. It has to be interpreted as successfully passed if the grade of the result fits to its grade scale rules (see [4]). In addition, each process step and each result can reference a couple of instances of specializations of Annotation. These specializations are also part of the flexible extension of the meta-model of the CMO. For example, *date* and *term* can be defined and then be used in connection with conditions to model rules like "in the average period of a study, an additional try is allowed". The classes Availability and Annotation can be arbitrarily extended in the course of the static modeling of academic programs.

A central part of the dynamic representation of academic programs is the arrangement of process elements of a process building an order. Doing this, possible sequences and rules that describe pre- and postconditions for taking these process steps can be modeled. But some major aspects can be modeled only intricately without modular composition of processes (see requirements in [5]). These are aspects like rules to retry a step, the inner part of a step (like the inner part of a module), minor subjects, or rules to calculate the grade of the final degree. In order to be able to model these dynamic aspects of academic programs smartly, the CMO defines the concept of internal processes. An internal process is a process that can be used instead of a couple of process steps. If a process step references such a specific internal process, it is possible to replace it with the internal process instead of assigning an individual result with it.

As a normal process — introduced in figure 1 — an internal process has a couple of process elements with a specific order. In addition, it has a process step that is used as a so-called "pattern" (property "isPattern"). While replacing a concrete process step with an internal process, the framework replaces this step with the pattern. Using a connector concept, the pattern is connected with other steps of the internal process in order to map the wildcard-reference of the replaced step to specific steps of the internal process (direction: pattern $\rightarrow$ steps). In the other direction, it is used to map a result (and, *e. g.*, a calculated grade) to the result of the replaced step (direction: pattern-result $\leftarrow$ results of the steps). By connecting the pattern instead of directly connecting the concrete replaced step, a single instance of an internal process can be used in order to replace a number of process steps and function as a template.

3 Distribution

To explain how this approach can be enriched applying it distributed, we take an examination office as an example. At academic institutions, certain information is often controlled at different places (see [1]). On the one hand, it is because academic institutions have a distributed structure. On the other hand, it is because of privacy aspects (see [6]). In many institutions, the individual results of the students, *e. g.*, are only stored at the examination offices, the supply of courses of the universities is often controlled by their faculties, and so on. Often, the structure of data is not compatible among each other, or there exists no integration. Thus, the employees of the examination offices might have to check manually if a result of a student is creditable for his curriculum or if the student is able to take certain examinations. Our approach supports the distributed structure and decision making of academic institutions: OWL and the URI-concept allow applications to access unique concepts and instantiations worldwide — even if they are stored distributed. The CMO meta-model is available under http://www-is.informatik.uni-oldenburg.de/eustel/cmo.owl. Each academic institution can extend the meta-model of the CMO (or an extension of it, created by, *e. g.*, an appropriate ministry of education). It can stand for a basic static representation of its academic programs (like basic definitions of, *e. g.*, *modules*). Finally, each institution can publish it on its website. Of course, it is also possible to use a common static representation or to extend an existing one. Each of the faculties of the institutions, then, might extend such static representation, instantiate it, and publish these dynamic representations of its academic programs on the web. In addition, each faculty can create and publish ontologies containing its supply of courses. For this purpose, they have to instantiate the static representation, too. These ontologies which contain the supply of courses, *e. g.*, can be used by web applications that generate semantic linked web pages containing the calendar of events[1]. On the same basis, the examination office can create private ontologies containing the status of each student. The entities of these ontologies can reference entities of the dynamic representation of the students' academic program and the exact actual entities for that the respective student has performed results. Using the model-interpreting framework, the individual possibilities of each student to continue his studies can be determined automatically by software of the examination offices. Keeping the student ontologies private, the examination offices can offer, *e. g.*, web services that allow the implementation and connection of service applications like learning management systems that offer individual curricula planning. Another very interesting aspect is the option to model possibilities for students to integrate results/courses that they have got at other academic institutions into curricula of programs of their own institution in a very simple way. It is required that both institutions use an extension of the CMO that stands for the static representation of their academic programs. These static representations do not have to be the same. Then, it

[1] An examplary implementation can be found at:
http://pixedia.de:8080/semaver/Show_Modules.do

is very easy to extend the dynamic representation of an academic program by possibilities in taking entities of the program of the other institution. To do so, one easy way is to simply add a process step that references an entity of the other institution and define that a specific step can be replaced by this new one via an internal process.

4 Evaluation and Outlook

In order to evaluate the CMO, we have on the one hand modeled concrete academic programs with this ontological concept. On the other hand, we have implemented the framework that is able to execute and to control the model interpreting process. Our implementation uses the JENA-Framework in order to reuse its ontological capabilities. To perform the model interpretation, a set of individual results of a student has to be incrementally mapped with the process steps of the modeled academic program. Doing this, the framework can detect for each of these interpretation steps which process steps of the academic program can be assigned with which individual results. If there are multiple possibilities to do such assignment, the decision can be made manually or automatically — depending on the kind of software that uses the framework. A planning assistance tool based upon our approach that uses the framework is also under development. It can help students that want to plan their individual curricula.

References

1. Schmees, M., Appelrath, H.J., Boles, D., Kleinefeld, N.: Erweiterung eines LMS um hochschultypische Softwaresysteme. In: M. Gaedke, R. Borgeest (eds.): Integriertes Informationsmanagement an Hochschulen: Quo vadis Universität 2.0?, Tagungsband zum Workshop IIM 2007, Universitätsverlag Karlsruhe, Karlsruhe, pp. 111–127 (2007)
2. Hackelbusch, R.: Handling Heterogeneous Academic Curricula. In: Min Tjoa, A., Wagner, R.R. (eds.) Proceedings of the Seventeenth International Conference on Databases and Expert Systems Applications (DEXA 2006), September 4-8, 2006, pp. 344–348. IEEE Computer Society Press, Los Alamitos (2006)
3. Gumhold, M., Weber, M.: Internetbasierte Studienassistenz am Beispiel von SASy. In: doIT Software-Forschungstag, Stuttgart, Fraunhofer IRB Verlag (2003)
4. Hackelbusch, R.: CMO – An Ontological Framework for Academic Programs and Examination Regulations. In: Jaakkola, H., Kiyoki, Y., Tokuda, T. (eds.) Information Modelling and Knowledge Bases XIX – Frontiers in Artificial Intelligence and Applications, vol. 166, pp. 114–133. IOS Press, Amsterdam (2008)
5. Tattersall, C., Janssen, J., van den Berg, B., Koper, R.: Using IMS Learning Design to Model Curricula. Interactive Learning Environments 15(2), 181–189 (2007)
6. Witt, B.C.: Datenschutz an Hochschulen. LegArtis Verlag (2004)

Systems Engineering for Technology Enhanced Learning

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Abstract. Process models for developing diverse kinds of systems, including e-Learning systems, can be found dated back to the mid 1990. Given the current state of the art in system development in combination with experience in development of e-Learning systems, a modernization of existing approaches and an adaptation to the special needs of e-Learning development projects is required. This has been done in developing ROME, the ROstock Model for systematically developing E-Learning products and services.

1 Introduction

Technology enhanced learning requires carefully and systematically developed systems. E-Learning systems, from our perspective the educational, computational as well as organisational context of a technology enhances learning application, should be developed by teams of experts. These experts are from diverse areas e.g. computer science, pedagogy, didactics, psychology, and design. Additionally, experts from all fields related to the training content itself, e.g. medicine, law, business, are involved in system development processes. Communication between different expert groups is required in advance and during system and content development. Usually, different experts have different views on technology enhanced learning. If communication works, these interwoven fields of interest are no hindrance in system development. In contrast, the mixing of different perspectives usually adds to the complexity of the resulting TEL system. However, experience in e-Learning system development (e.g. [5], [6], [11]) has repeatedly shown that there are several aspects which aggravate inter- and intra-project communication in e-Learning system development.

In the following, process models will be introduced and analyzed regarding their suitability for the development of e-Learning systems. The Process Model ROME will be sketched. The paper closes with a conclusion and outlook.

2 Process Models for e-Learning Systems

"Process model" is a technical term in different scientific fields, e.g. in computer science (amongst others in theoretical computer science, and in software development [1]), in management and business science, but also in philosophy. Core of

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all the process models is that the model describes a sequence of elements, which occur in a special order. The elements can be activities, information and data, or artifacts. In contrast to static models, process models are always related to a temporal component. In contrast to kinetic models, where every single attribute of the model has an own relation to time, a process model as a whole has a temporal relation. Process models are means for structured analysis and design.

In the field of e-Learning system development, there are some examples of process models, each of which has a slightly different focus. Process models for e-Learning system and e-Learning content development can be traced back at least to the late 1990s. One of the early approaches has been the work of Blumenstengel [2], which is focused on hypermedia systems. Klein [9] also described a process model for content development for hypermedia courseware. As both approaches focus on the development of hypermedia systems resp. courses, they can not be used for the development of alternative system types, e.g. Intelligent Tutoring Systems. The Essen Learning Model ELM [12] is called a generic process model. When trying to use ELM in e-Learning system development (e.g. in [11]), problems occurred: the description of the steps are not fine grained enough, and there are no roles defined. Also any notion like “resources” is missing. The reference model ISO/IEC 19796-1:2005 [8] can be seen as another kind of process model. It had provided the basis for ROME, thus the description will follow in the subsequent section. Other approaches are described in [5].

3 ROME

Starting point for the resulting model are the ISO/IEC [8] and the DIN model [3]. The ISO/IEC and the DIN model are quite abstract and have an inherent complexity, as descriptions are rather dense. One result of using the models in e-Learning system development is that the models don’t lend themselves to be directly used [5]. An extension by a process model seemed to be useful. Those are the main reasons:

- Missing definitions of technical terms and methods hinder communication in interdisciplinary teams.
- Missing concretion of artifacts for documenting results of project steps lead to a broad spectrum of interpretations in heterogeneous teams and result in communication problems.
- Alternative approaches are not suggested in the reference models, but would be a nice-to-have, same as re-usability.

According to [4] and sketched in figure 1, ROME distinguishes between a macro view and a micro view. On the top level (macro view), the process model consists of phases. These phases can be seen in figure 1 on the left side. As the phases are rather abstract, they have to be specified by steps, as can be seen in figure 1 on the right side.

Additional to the phases and steps, ROME contains a role model, a resource collection, and an artifact collection. The role model contains all roles which

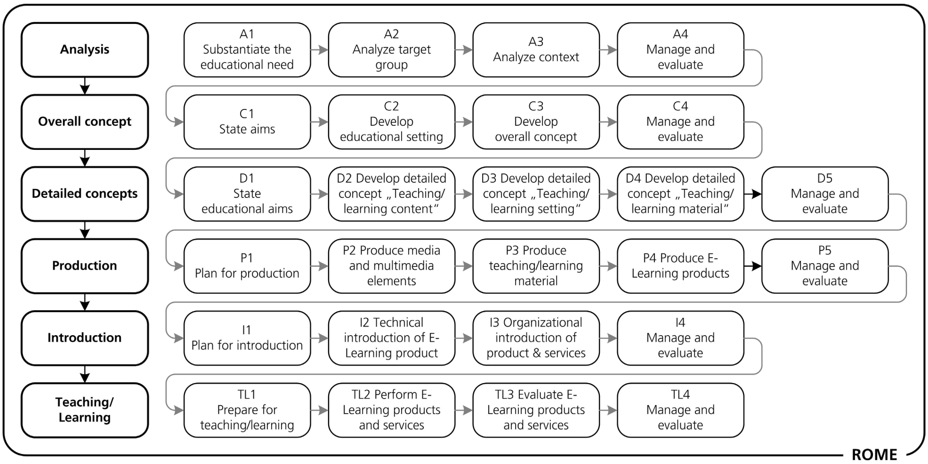

Fig. 1. ROME phases and related steps

potentially can occur in an e-learning project, e.g. media designer, computer scientist, or psychologist, but also project manager, person responsible for evaluation, etc. The artifact model is used to describe all artifacts developed in the project, starting from profile of the target group, didactic concept, up to content artifacts. Each artifact has to be equipped with date, version, and status. The latter shall help to distinguish artifacts, which still are in development, and artifacts, which are completed. The resource model can be used to describe all resources used during the project development. Resources are for example tools (e.g. authoring tools, evaluation tools) and methods (e.g. methods for information retrieval, methods like mind mapping). Each process step contains an identifier, an aim, a list of activities that have to be accomplished by this step, a list of links of incoming and of outgoing artifacts, a list of links to the resource collection, and a link to the role model.

Applying ROME in an e-Learning project starts with the definition of a development project. The project partners have to instantiate the abstract process model for their concrete purpose. The resulting project model evolves from the process model by adaptation of process steps (e.g. adding or deleting activities), by instantiation and potentially adaptation of the role model, of the resource collection, and of the artifact collection, and finally by mapping the progression of the process steps to a timeline.

4 Conclusion and Outlook

The process model ROME is based on rich experiences in the development of e-Learning products and services at the Fraunhofer Institute for Computer Graphics Rostock and the research group "e-Learning and cognitive systems" at the University of Rostock. Several research projects (e.g. [5], [6], [11]) have led to the insight that existing approaches like process models (e.g. [9], [12] and standards (e.g. [8], [3], [10]) in most cases don't lend themselves for the development of e-Learning products and services. The direction chosen by [5] has been to take an existing standard [8] and its German version [3], and develop a process model, which takes the standard's items into account and extends them as needed. Details and a direct comparison between [3] and ROME can be found in [5].

To show the transferability and viability of the approach, ROME is used in several research projects (see [5]). Currently, work goes into the direction of extending the model for special needs of certain types of projects, e.g. pure research oriented e-Learning developments. Moreover, ROME is investigated to become part of a pattern language for e-Learning system development, as described by [7] and [6].

References

1. Balzert, H.: Lehrbuch der Software Technik: Software Development. Spektrum Akademischer Verlag, Heidelberg (2000)
2. Blumenstengel, A.: Entwicklung hypermedialer Lernsysteme. wvb Wissenschaflicher Verlag, Berlin (1998)
3. DIN Deutsches Institut fuer Normung e.V. (ed.) Qualitaetssicherung und Qualitaetsmanagement im e-Learning, Beitraege zur Anwendung der PAS 1032-1, Beuth Verlag, Berlin, Germany (2006)
4. Haberfellner, R., Nagel, P., Becker, M., Buechel, A., von Massow, H.: Systems Engineering: Methodik und Praxis. In: Verlag Industrielle Organisation, 11th edn., Zuerich, Suisse (2002)
5. Hambach, S.: Systematische Entwicklung modularer E-Learning-Angebote. Fraunhofer IGD, Rostock, Germany (2007)
6. Harrer, A.: Software engineering methods for re-use of components and design in educational systems. International Journal of Computers and Applications 25 (2003)
7. Harrer, A., Martens, A.: A Step towards a Pattern Language for e-Learning Systems. In: Pahl, C. (ed.) Architecture solutions fore e-Learning Systems. IGI Global (2007)
8. ISO/IEC – Internat. Standardization Organization / Internat. Electronical Commission. Information Technology – Learning, Education, Training – Quality Management, Assurance and Metrics. Part 1: General Approach, 19796-1 Standard (2005)
9. Klein, M.: Courseware Engineering. dissertation.de – Verlag im Internet, Berlin (2003)
10. LOM. IEEE Learning Technology Standards Committee, P1484.12.1/D6.4, 04 March 2002 Draft Standard for Learning Object Metadata (2002), http://ltsc.ieee.org/wgs.html
11. Martens, A., Bernauer, J., Illmann, T., Seitz, A.: Docs 'n Drugs - The Virtual Polyclinic. In: Proc. of the American Medical Informatics Conference (2001)
12. Pawlowski, J.M.: The Essen Learning Model - a Multi-Level Development Model. In: Proc. of the Int. Conf. on Educational Multimedia, Hypermedia & Telecommunications ED-MEDIA 2000, Montreal, Quebec, Canada (2000)

Defining Adaptation in a Generic Multi Layer Model: CAM: The GRAPPLE Conceptual Adaptation Model

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Abstract. Authoring of Adaptive Hypermedia is a difficult and time consuming task. Reference models like LAOS and AHAM separate adaptation and content in different layers. Systems like AHA!, offer graphical tools based on these models to allow authors to define adaptation without knowing any adaptation language. The adaptation that can be defined using such tools is still limited. Authoring systems like MOT are more flexible, but usability of adaptation specification is low. This paper proposes a more generic model, CAM, which allows the adaptation to be defined in an arbitrary number of layers, where adaptation is expressed in terms of relationships between concepts. This model allows the creation of more powerful yet easier to use graphical authoring tools.

Keywords: Conceptual Adaptation Model; Adaptive TEL.

1 Introduction

Adaptive Hypermedia can potentially offer a rich learning experience with content adapted to the users' needs. However, this potential depends heavily on the ability of authors to create adaptive material. There exist several Adaptive Hypermedia reference models like AHAM [24] and LAOS [7] that are specifically developed for authoring. But even when using tools developed based upon these models, authoring remains a time consuming task [18]. A problem, even with graphical authoring tool like the Graph Author developed for AHA! [12] is that the adaptivity is specified in a single layer. Adaptation is based on *concept relationships* (of different *types* or *crt*s[1]) that have to be created one by one. The author will either have to use the *crts* defined by an expert or has to learn how to create new *crts* (for which there are no special design tools).

[1] Concept relationship types.

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In this paper we present the authoring approach of the GRAPPLE project, an EU FP7 STREP project aimed at bringing adaptive technology-enhanced learning (or adaptive TEL for short) to the masses, by interfacing and/or integrating an *adaptive learning environment* (ALE) with different *learning management systems* (LMSs). The authoring approach in GRAPPLE is to offer a graphical tool to create a *conceptual adaptation model* (CAM). In Section 2 we explain the structure of a CAM with multiple adaptation layers. In Section 3 we show how an author can create concept relationships (leading to adaptation), either one by one or many at a time, and how the author can create *crts* in a similar graphical way. Although the multi-layer model is loosely based upon LAOS & LAG [11] authors are not required to write "pseudo code" as they do in LAG. We discuss the translation of a CAM to actual adaptation rules executed by an adaptation engine (while the user is using the learning application), and in Section 4 we discuss some issues regarding *termination* and *confluence* resulting from the CAM to adaptation rule translation.

2 The Conceptual Adaptation Model

In the GRAPPLE project, the structure of a *conceptual adaptation model* (CAM) is even more general and flexible than in previous frameworks [7], [24]: it contains an arbitrary number of layers, which may be different for each application. There will always be a domain model (DM) and user model (UM) layer and at least one layer with adaptation aspects, so the structure of CAMs in GRAPPLE is always a generalization of the AHAM model [24], and a refinement of the LAOS model [7]. Some example adaptation layers possible in a CAM include:

- *Prerequisite* layer: in this layer the author defines a structure of prerequisites between (sets of) concepts. Each prerequisite relationship connects two sets of concepts, the first of which contains prerequisite knowledge for the second set. This would correspond to part of the information stored in the Goal Model in LAOS, the ordering of information items.
- *Task (or Goal)* layer: in this layer the author connects sets of concepts with goals or tasks. All concepts of such a set need to be studied (and mastered) in order to reach the corresponding goal or complete the associated task. This would correspond with the overall goal of a particular goal model in LAOS, i.e., the metadata describing the whole instance (e.g., an introductory course for first year mathematics students in mathematical analysis).
- *Procedure* layer: in this layer the author may define a process model that must be followed during the learning process as it corresponds to the set of steps when actually performing a learning task. This would loosely correspond to the adaptation layer in AHAM and LAOS.

The relationships defined in the different CAM layers do not yet express the actual adaptation that will take place. A prerequisite may be translated to a rule that will change the presentation of links to concepts, but it may also be translated to the conditional inclusion of a prerequisite explanation (fragment). The translation of CAM structures to actual adaptation rules is described in Section 3 below.

3 Authoring CAMs

3.1 An Illustrative Scenario

We illustrate the authoring process of a CAM by means of a scenario:

Dr. Davies[2] prepares a new on-line course on the history of art for first year undergraduate students. He essentially has two options: he can either try to define a link structure between the course pages in such a way that students never see a link to information they cannot yet understand (because of missing foreknowledge) or he can define a CAM with prerequisite relationships and then rely on the ALE to ensure that students are only guided towards pages for which they have all the prerequisite knowledge. Although it is often argued that defining adaptation (a CAM in this case) means that creating an adaptive course is more work than creating a static course, the converse is actually true: the first option, to create a static course that is such that students can only follow links to information they are ready to understand is a nearly (or perhaps completely) impossible task and would require a lot of very careful work in selecting links to show to (all) students.

At first, Dr. Davies may think that it would be a good idea to create a prerequisite relationship from "Michelangelo" to "The Last Judgment", as the students should first learn something about the artist before learning about the artist's artworks. The authoring tool allows authors to draw a prerequisite relationship between a set of (prerequisite) concepts on the left and a set of concepts on the right. In this case the drawing would look like:

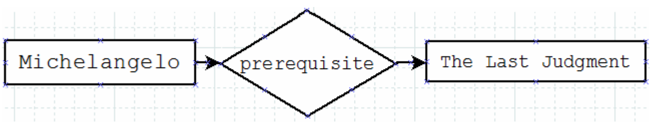

Fig. 1. Relation between Michelangelo and The Last Judgment

However, Dr. Davies then realizes that "Michelangelo" should not just be a prerequisite for "The Last Judgment" but for every artwork by Michelangelo. So he changes the drawing to and adds a constraint as follows:

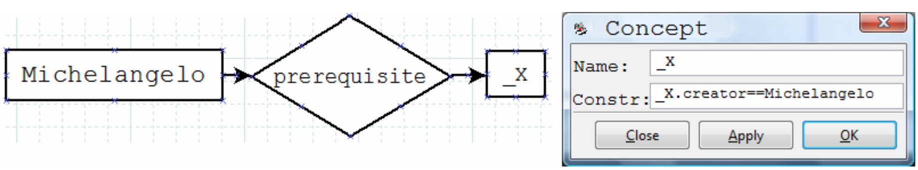

Fig. 2. Relation between Michelangelo and Placeholder Concept _X and constraints

The specific concept relationship thus becomes a partially generic one: there is still one specifically named concept but also a variable to express that the relationship

[2] Any resemblance with an existing person is purely accidental.

applies to all concepts _X that satisfy a certain condition. The underscore indicates that X is a variable and not a literal value.

Something perhaps not immediately obvious from this example is that there are two possible uses of this authoring tool (plus a combined third one):

- In the example, the "creator" attribute is a DM property, probably derived from a subject ontology. Which concepts have "Michelangelo" as prerequisite depends purely on the DM and this is thus independent of the learner taking the course.
- It is equally well possible to use an attribute from the UM in a relationship, thus creating relationships that are not only user-dependent but even dependent on the "current" instance of the user model.
- There is even a third possibility, by combining the previous two. The learning application can for instance *recommend* topics from a list that first of all depends on the DM but that also depends on the user's knowledge. For instance, only those recommended topics may be shown of which the user still has little or no knowledge.

Note that when the relationship only depends on DM information (like in the example) the replacement of _X by actual concepts could (but need not) be done at compile time, i.e. when translating the CAM into actual low level adaptation rules to be executed by the GRAPPLE ALE. When the relationship depends on UM information this is not possible.

Dr. Davies may later also go one step further in the definition of the prerequisite relationships. He may wish to state that for every artist and artwork the learner should learn about the artist before studying the artworks from that artist.
The drawing then becomes something like:

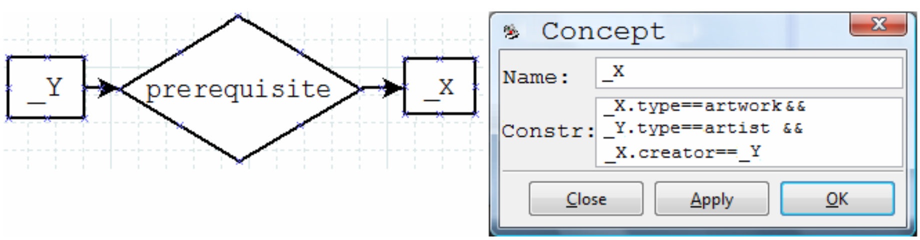

Fig. 3. Relationship for generalization of the Michelangelo example and constraints

Note that whereas creating a (set of) *specific* concept relationships does not require any knowledge of the structure of the DM or UM or any language to refer to DM or UM attributes of concepts, creating *generic* concept relationships, or *crts* does require some basic knowledge of the CAM language (to write _X.creator==Michelangelo). This language contains a still fairly high-level description of the semantics of the relationship. We consider it to be part of a *translation model* that defines how the relationships are translated to low level adaptation rules to be executed by the adaptation engine.

Each *crt* corresponds to a different layer in the CAM (and thus in the graphical presentation of the CAM editor). If Dr. Davies wishes to define a new type of relationship he can create a new layer and define a new *crt* as shown below:

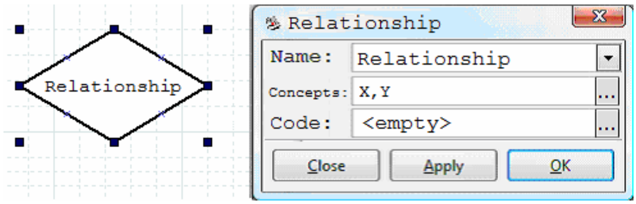

Fig. 4. Customizing a relationship

There are two ways to define the adaptation associated with the new relationship. Where it says “Code:” you can add the CAM language pseudo code for the adaptive behaviour. For instance, a statement:

```
_Y.suitability = ALL _X.knowledge > 70
```

could be used for indicating the desired behaviour for a prerequisite relationship. Although such code may look specific and implementation oriented, in reality it is not. The translation to the underlying adaptation engine may for instance define “suitability” to just be a *volatile* attribute of which the value is calculated when needed, or it may be a *persistent* attribute of which the value is updated each time the knowledge value of one of the prerequisites changes. Such implementation details are defined in a *translation model*. A single CAM may be translated to the actual adaptation language (and behaviour) of different adaptation engines, by using different translation models.

An alternative way to define the actual adaptive behaviour associated with a relationship is to just define a *method call* for a method that needs to be defined in the translation model. This approach makes the use of CAMs very powerful and generic but it also makes the behaviour dependent on a low level implementation rather than a high level specification. It is unlikely that teachers (like the imaginary Dr. Davies) will resort to writing program code for the adaptation engine.

3.2 Pedagogical Strategies in CAM

In the previous section we have seen a scenario illustrating how a teacher can create or customize an adaptive lesson. Previous research has defined interesting pedagogically sound adaptation strategies, representing different learning scenarios based on learners’ needs, preferences, some also based on complex (and controversial) pedagogical foundations, such as learning styles, for Adaptive Hypermedia[3] [1]. In this section we will explore some of these strategies in relation to CAM. More specifically we will check how, in principle, such strategies can be expressed in the new CAM. As CAM is aimed to be richer than previous attempts, it should at least be able to express the basic strategies we have defined before. CAM is more flexible, however, and can

[3] See also our strategies page: http://prolearn.dcs.warwick.ac.uk/strategies.html

express strategies beyond what is analyzed here. While trying to express the (selection of) learning style related strategies we noticed some common issues:

- It is clear that we need to have some view of the Domain Model in order for the teacher to see what the available concepts are.
- A wizard like interface for ready-made strategies could be very helpful, while still allowing customization.
- The step-wise processing as previously implicitly assumed in LAOS/LAG based systems is still desirable. Otherwise some strategies like the Breadth- and Depth-First will not be possible, as inference rules will make sure the whole content will directly be visible. Thus, rules need to be triggered one-step-at-a-time, when certain events occur (e.g., a mouse-click). It is envisioned that, if desired, it should be possible to specify rules that trigger other rules, like in AHA!, however, in a visual way.
- In the LAOS/ LAG conversions to AHA!, one could control to a certain extent what kind of menus and other guidance the student would get. This represents adaptation of the presentation layer in LAOS, and reflects on interface changes and display for the student. It is desirable that in the new CAM-based systems this control will also be present to some extent.

Rollout

The rollout strategy is a very simple strategy that allows authors to decide when a certain concept or concept part should be shown: concepts to be shown after a certain number of steps could be classified as '*showafter*', and attached the meta-data containing the number of steps after which to be shown. Similarly, concepts classified as '*showatmost'* should only be displayed at most the given number of steps as again contained in meta-data. The roll-out strategy depends upon the tree hierarchy. We note hat it is straightforward to create such a hierarchy with the introduction of a parent-child relation.

First, authors need to be able to sort the concepts in the desired hierarchy (if this is not already available, e.g., if concepts are grouped in a graph). Next, we discuss the representation of the '*showafter'* part. The strategy demands that a concept is shown after its parent has been viewed a given number of times. As a constraint on `_X`, we have the following:

```
_X.metadata == 'showafter' && _X.parent ==_Y &&
UM._Y.showcount >= _X.showafter
```

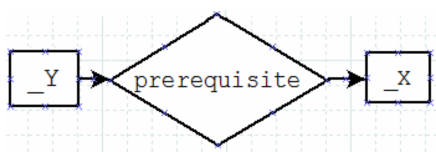

Fig. 5. 'Showafter' relationship

In Fig. 5, the relationship for 'showafter' is created via a prerequisite. This uses the prerequisite relation in its sense of condition on displaying concept `_X` based on viewing concept _Y (and some supplementary conditions, as above). However, this does not use prerequisite in terms of knowledge update.

Depending on the implementation of prerequisite relationship, the '*showatmost'* part may or may not be needed. If the implementation of the prerequisite relationship makes sure that concepts for which previously the prerequisite was fulfilled, but for which this is no longer the case, are hidden, we do not need to do anything for the '*showatmost'* part. If this is not handled by the prerequisite we have to add a relationship that hides concepts once the have passed their '*showatmost'* threshold.

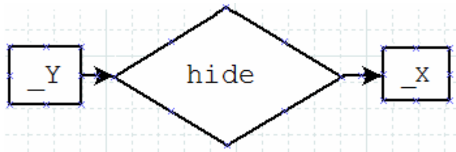

Fig. 6. 'Showatmost' via hide relation, only needed if prerequisite does not hide concepts

The constraint is then:

```
_X.metadata == 'showatmost' && _X.parent ==_Y &&
UM._Y.showcount > X.showatmost
```

Note that we also need to make sure that for each concept a count is kept in the user model. This can be done with a relationship '*countaccess'* relating a concept to itself.

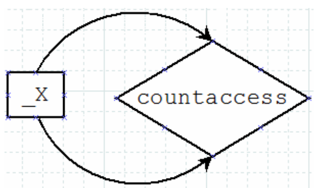

Fig. 7. 'Countaccess' relationship

The constraint will then be:

```
_X.access == true
```

The implementation of the countaccess relationship simply increases the count:

```
UM._X.showcount = UM._X.showcount+1
```

Depth First

The depth first strategy is used for sequential learners. One topic at a time is presented, and the student is allowed to go in-depth (hence, the name) in this topic first, before he proceeds with the next topic. Preferably, no menus' are shown to such students, and all they need to access is a 'next' button, taking them to their next study material, whether statically linked, or adaptively generated.

For the depth first strategy, again, the concepts have to be ordered in a hierarchy first. After this, a few relations are needed. Thus, we introduce a relation from each concept to each of its children, called *next child XOR next sibling,* see Fig. 7.

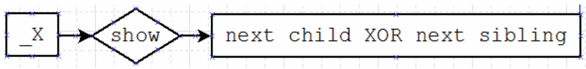

Fig. 8. The main relation implementing the 'Depth First', the logic in the constraint takes care of showing the appropriate next concept, either the next child or the next sibling

The condition must ensure that _X is the next sibling of _Y that needs to be shown, as well as update the User Model variable that keeps track of the current position of the learner within the hierarchical course. The condition shall only show the next sibling if the concept does not have any children left to be shown.

Finally we create a relationship from the root to the root, which shows first the concept unconditionally.

Breadth First

The breadth first strategy is used for global or holist learners. These learners like to see the global 'picture' first, before they dive into any topic. For such students, menus and other orientation devices are quite helpful.

Thus, implementation of this strategy has to start with the ordering of the concepts in a hierarchy. Next, we draw relations between each concept and each of its children, allowing them to show (all) the children if the parent has been shown. Finally we create a relationship from the root to the root, which shows the first concept unconditionally.

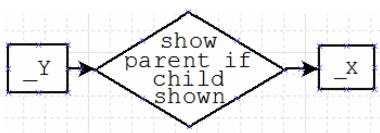

Fig. 9. The relation shows _Y if _X has been shown the condition is: _Y.parent==_X

4 Termination and Confluence in Multi-layer CAMs

The authoring process (for the concept structures and the adaptation) which is focused on the creation of concept relationships, appears to be fairly simple. Using different layers for different *crts* makes understanding the conceptual structure relatively easy too. However, this simplicity is partly an illusion. Depending on how the concept relationships are translated (using a translation model) to the low level adaptation rules for the adaptation engine, the (graph-like) structure of concept relationships of a single layer may already cause problems, and the combination of concept relationships from different layers may cause even more problems. We illustrate this with some examples.

Consider a simple structure where A is a prerequisite for B, B is a prerequisite for C and C is a prerequisite for A. This may cause a problem or not, depending on how prerequisites are used in the learning application.

- When “A is a prerequisite for B” results in links to B being recommended only after learning enough about A it is possible that the cycle of prerequisites causes the links to A, B and C to never become recommended to the learner. (Needless to say this is a problem.)
- When “A is a prerequisite for B” means that a short explanation of A will automatically be inserted into a page about B to compensate for the missing foreknowledge then there need not be a problem. If A is accessed first it will contain a prerequisite explanation of C, possibly preceded by a prerequisite explanation of B. (In this way the cycle does not cause a problem.)

Problems with undesirable structures like cycles are relatively easy to detect within a single layer. The problems become much more unpredictable when looking at the adaptation rules that result from translating the concept relationships from all layers together. The most common types of problems are *termination* and *confluence*.

4.1 Termination Problems

A simple example of where rule execution can run out of hand is when an author creates *knowledge propagation* relationships. A page that is essentially about Michelangelo may contain a brief description of some of his masterpieces, like “The Last Judgment”. Our imaginary Dr. Davies may draw a “10% knowledge propagation” relationship from “Michelangelo” to “The Last Judgment”. However, there may also be a generic rule that states that whenever you learn something about an artwork you also learn something (maybe also 10%) about the “creator” (artist) of that artwork. It is possible that the *knowledge propagation crt* has a translation model that will cause the translation of such a cycle to be an infinite loop of rule executions. (Each knowledge increase of “Michelangelo” may involve a knowledge increase of “The Last Judgment” and vice versa.) Disallowing cycles within a layer guarantees that there are no *termination problems* within that layer. However, even when each layer is without termination problems the interaction between rules of different layers may still cause an infinite loop.

The *static analysis* proposed in [24] results in conditions that may be too restrictive to apply them in multi-layer CAMs. The authoring tool might well disallow the creation of harmless concept relationships just because the static analysis detects a cycle, even when no infinite loop would be possible (when actually considering the conditions of the rules and the possible effect of the actions of the rules).

So rather than performing such static analysis, it is possible to apply a heuristic that is applied at runtime (in the adaptation engine) and that will ensure that there are no *termination problems*:

- The first step is to perform static analysis to ensure that no termination problem can be caused by the rules associated with the relationships of any single layer.
- The second step towards a solution for termination is to assign a (different) *priority* to each layer. (This is not to be confused with *execution phases* of

AHAM [24]. This is similar to priorities for adaptation strategies in the LAG language [5], [11].)
- The third step is to disallow updates to an attribute A of a concept C when C.A has been updated already by a rule associated with a higher priority layer or when an update to C.A already triggered the execution of a rule at a higher priority layer. (Note that just ensuring C.A has not been updated by a rule of a higher level is not enough. The C.A updates as a trigger is really a necessary additional condition.)

Although this method ensures that infinite loops are not possible, it makes the behaviour of the adaptation engine dependent on the choice of the priorities of the layers. We expect such problems to be rare, but nonetheless a system designer should determine the proper priorities for the "predefined" layers that are made available to authors (who do not define their own *crts* and translation models).

4.2 Confluence Problems

Confluence problems occur when more than one rule tries to update the same attribute of the same concept. The order in which such updates are performed may determine the resulting UM state.

- Static analysis can be used to ensure that there are no confluence problems within a single layer.
- In addition to this analysis we again assign a (different) *priority* to each layer and we disallow updates to attributes of concepts that were already updates at a higher (priority) level.

Like for termination, the assignment of priorities to layers may potentially influence the outcome (the UM instance) of the adaptation rule execution.

5 Related Work

Authoring of adaptive hypermedia is notoriously difficult work [2]. Research on improving this process ranges from ontology-based authoring [20], to integrating standards and their representations [16], [19] , using data mining techniques [23], web services [21], interfacing techniques between authoring systems [10], adaptation languages [11].

The current work is based on prior developments of adaptive hypermedia frameworks, like AHAM [24] and authoring frameworks for adaptive hypermedia, such as LAOS [7] and LAG [5]. Moreover, it is based on systems for adaptive hypermedia delivery, such as AHA! [12] and for authoring of adaptation, such as MOT, My Online Teacher [8], APels [13], ACCT [14].

Finally, this research is based on evaluations of authoring processes for adaptive hypermedia, as performed with various groups of students, in various locations, and with different versions of constantly improving tools [9], [4], [6], [10], [17], [15], [3]. Such research shows that, whilst having a higher flexibility and multiple layers for authoring is advantageous [3], [5] it is difficult for authors to actually program the adaptive behaviour of adaptation strategies [6], and it's thus much easier to have them reuse strategies at a higher granularity level, in a graphical interface [3]. As the best paper of the 4th International Workshop on Authoring of Adaptive and Adaptable Educational Hypermedia (A3H) shows [22], a template-based approach of a graphical nature is easier to handle by teachers, who in this way can better make use of the flexibility that the CAM GRAPPLE tool is offering.

6 Conclusions and Further Work

In this paper we proposed the structure of Conceptual Adaptation Models, as used in adaptive learning applications within the GRAPPLE project. We have shown that a graphical authoring tool helps authors in creating conceptual structures (of concept relationships) that guide the translation of CAMs to the adaptation rule language used by an adaptation engine. Using very similar graphical interface elements, an author can define a single *specific* concept relationship instance, a *generic* concept relationship or a new *concept relationship type* and its meaning, using a simple expression language.

The simple graphical approach to authoring does not alleviate the typical problems of *termination* and *confluence* in the generated adaptation rules. We briefly showed run-time heuristics that help avoid these problems in practice.

The graphical CAM authoring tool will be further developed in the coming months, and its usability evaluated with course authors. Within the GRAPPLE project work is proceeding in parallel, on the user modelling services and the adaptation engine. The progress of these components will determine the specification and implementation of *translation models* and a compiler from CAMs to low level adaptation rules.

Acknowledgment

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References

1. Brown, E., Cristea, A., Stewart, C., Brailsford, T.: Patterns in Authoring of Adaptive Educational Hypermedia: A Taxonomy of Learning Styles. International Peer-Reviewed On-line Journal Education Technology and Society, Special Issue on Authoring of Adaptive Educational Hypermedia 8(3) (2005)
2. Brusilovsky, P.: Developing adaptive educational hypermedia systems: From design models to authoring tools. Authoring Tools for Advanced Technology Learning Environment. Dordrecht (2003)
3. Conlan, O., Wade, V.P.: Evaluation of APeLS - An Adaptive eLearning Service based on the Multi-model. In: De Bra, P.M.E., Nejdl, W. (eds.) AH 2004. LNCS, vol. 3137. Springer, Heidelberg (2004)
4. Cristea, A.I.: Evaluating Adaptive Hypermedia Authoring while Teaching Adaptive Systems. In: Handschuh, H., Hasan, M.A. (eds.) SAC 2004. LNCS, vol. 3357. Springer, Heidelberg (2004)

5. Cristea, A.I., Calvi, L.: The three Layers of Adaptation Granularity. In: Brusilovsky, P., Corbett, A.T., de Rosis, F. (eds.) UM 2003. LNCS, vol. 2702. Springer, Heidelberg (2003)
6. Cristea, A.I., Cristea, P.: Evaluation of Adaptive Hypermedia Authoring Patterns during a Socrates Programme Class. International Peer-Reviewed On-line & Print Journal Advanced Technology For Learning 1(2) (2004)
7. Cristea, A., de Mooij, A.: LAOS: Layered WWW AHS Authoring Model and their corresponding Algebraic Operators. In: WWW 2003, The Twelfth International World Wide Web Conference, Alternate Track on Education, Budapest, Hungary (2003)
8. Cristea, A., de Mooij, A.: Adaptive Course Authoring: My Online Teacher. In: ICT 2003, International Conference on Telecommunications, Papeete, French Polynesia (2003)
9. Cristea, A.I., De Mooij, A.: Evaluation of MOT, an AHS Authoring Tool: URD Checklist and a special evaluation class. In: CATE 2003, Rhodos, Greece (2003)
10. Cristea, A.I., Stewart, C., Ashman, H., Cristea, P.: Evaluation of Adaptive Hypermedia Systems' Conversion. In: HT 2005, Salzburg, Austria (2005)
11. Cristea, A., Verschoor, M.: The LAG Grammar for Authoring the Adaptive Web. In: ITCC 2004, Las Vegas, US. IEEE, Los Alamitos (2004)
12. De Bra, P., Smits, D., Stash, N.: The Design of AHA! In: ACM Conference on Hypertext and Hypermedia, Odense, Denmark, p. 133 (2006)
13. De Bra, P., Brusilovsky, P., Conejo, R. (eds.): AH 2002. LNCS, vol. 2347. Springer, Heidelberg (2002)
14. Dagger, D., Wade, V.P., Colan, O., Developing Adaptive Pedagogy with the Adaptive Course Construction Toolkit, ACCT. In: AH 2004 (2004)
15. Dagger, D., Wade, V.P., Evaluation of Adaptive Course Construction Toolkit. In: ACCT, A3EH, Adaptive Authoring for Educational Hypermedia, Workshop AIED (2005)
16. Gutierrez, S.: Authoring of Adaptive Sequencing for IMS-LD. In: A3EH, 5th Adaptive Authoring for Educational Hypermedia, Workshop AH 2007, Corfu, Greece (2007)
17. Hendrix, M., Cristea, A., Joy, M.: Evaluating the automatic and manual creation process of adaptive lessons. In: ICALT 2007, Niigata, Japan (2007)
18. Hendrix, M., Cristea, A., Nejdl, W.: Authoring Adaptive Educational Hypermedia on the Semantic Desktop. International Journal of Learning Technology, IJLT (2007)
19. Boticario, J.G., Santos, O.C.: A dynamic assistance approach to support the development and modelling of adaptive learning scenarios based on educational standards. In: A3EH, 5th Adaptive Authoring for Educational Hypermedia, Workshop AH 2007, Corfu, Greece (2007)
20. Martin, B., Mitrovic, A., Suraweera, P.: Domain Modelling with Ontology: A Case Study. In: A3EH, 5th Adaptive Authoring for Educational Hypermedia, Workshop AH 2007, Corfu, Greece (2007)
21. Meccawy, M., Stewart, C., Ashman, H.: Adaptive Educational Hypermedia Content Creation: A Web Service based Architecture. In: A3EH, 5th Adaptive Authoring for Educational Hypermedia, Workshop AH 2006, Dublin, Ireland (2006)
22. Muñoz, F., Ortigosa, A.: An Adaptive Course on Template-based Adaptive Hypermedia Design. In: A3EH, 5th Adaptive Authoring for Educational Hypermedia, Workshop AH 2006, Dublin, Ireland (2006)
23. Vialardi, C., Bravo, J., Ortigosa, A., Empowering, A.E.H.: Authors Using Data Mining Techniques. In: A3EH, 5th Adaptive Authoring for Educational Hypermedia, Workshop AH 2007, Corfu, Greece (2007)
24. Wu, H.: A Reference Architecture for Adaptive Hypermedia Applications, doctoral thesis, Eindhoven University of Technology, The Netherlands (2004) ISBN 90-386-0572-2

Imperfect Answers in Multiple Choice Questionnaires

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Abstract. Multiple choice questions (MCQs) are the most common and computably tractable ways of assessing the knowledge of a student, but they restrain the students to express a precise answer that doesn't really represent what they know, leaving no room for ambiguities or doubts. We propose Ev-MCQs (Evidential MCQs), an application of belief function theory for the management of the uncertainty and imprecision of MCQ answers. Intelligent Tutoring Systems (ITS) and e-Learning applications could exploit the richness of the information gathered through the acquisition of imperfect answers through Ev-MCQs in order to obtain a richer student model, closer to the real state of the student, considering their degree of knowledge acquisition and misconception.

1 Introduction

Valid and continuous assessment is necessary for effective instruction to improve student learning [6]. To obtain a measure of the student knowledge acquisition on a particular subject (or to collect the opinion of an individual in a more general survey), Multiple Choice Questions (MCQs) are arguably the most common method applied in Computer Aided Assessment (CAA) [10], thanks to their intuitive interaction and computability. MCQs can be used as a way of evaluating the results of the learning process (grading), or as a formative assessment that identifies working areas to be treated next or to be considered as acquired.

In a MCQ, the student must answer with a precise indication of the correct choices even if, as usually occurs, she[1] is not entirely convinced by her own choice. It is normal for a student, when passing a MCQ test, to find herself in a situation where a question appears to be ambiguous according to the options presented. She may be able to recognize some of the options as incorrect, but not be able to establish the correctness of all of them. When in doubt, a student must make a blind choice among the answers that are not completely wrong.

This type of situations cannot be treated accordingly by classical MCQs. They lack of a way for students to express ignorance, imprecision and uncertainty. By

[1] We will refer to the student/learner as a woman.

P. Dillenbourg and M. Specht (Eds.): EC-TEL 2008, LNCS 5192, pp. 144–154, 2008.

imposing precise answers classical MCQs influence student's output. Noise resulting from the adaptation of imprecise and uncertain answers is gathered and considered in the diagnosis of the student knowledge model; invaluable information as to the current state of knowledge of the student is then lost and replaced by a crisp rendition of the student's response.

An ITS has to help the learner achieve the course's objectives in its quest for knowledge acquisition by first diagnosing her current state of knowledge, which will be used as a basis for proposing activities. An ITS could exploit such information to represent the state of knowledge acquisition: the concepts that have not been fully acquired by the students, the concepts that the students themselves are certain they possess and the concepts that the students have wrongfully considered as acquired (misconceptions) could be identified.

Knowledge is a messy concept and there are several types of imperfections [1] that must be dealt with if we want to assess its acquisition. In this article, we present Evidential MCQs (Ev-MCQs)[3], a generalisation of MCQs through the application of belief function theory [11] that allows evaluated learners to express a more flexible answer, closer to their real state of knowledge. We validate their use in the context of knowledge evaluation on a group of students from junior school, and we measure the amount of noise we were able to prevent thanks to the expression of imperfect answers.

2 Background and Previous Work

Several concerns regarding the use of MCQs in assessment have been criticized. They allow guessing, adding random noise to assessment data; they rely on the recognition of the correct answers; they only treat a superficial level of knowledge; they don't allow the assessment of partial knowledge nor the detection of dangerous misconceptions. A handful of techniques have been developed in order to correct them. Classical Test Theory, Computer Aided Testing (CAT) and Item Response Theory (IRT) are among the proposed techniques to treat the evaluation of students with different levels of knowledge [10]. The particular features of each item (question) presented to the students (discrimination power, difficulty, guessing factor) are used in order to estimate the level of the trait being evaluated. Based on previous answers the method selects the most idoneous item to be presented next, getting closer to the real level of the student.

From an educational viewpoint, it is important to identify the degree to which a student is sure or confident about the correctness of her responses [7]. If the recognition of the ignorance of the correct answer is important, the detection of misinformation is essential. Some authors working in CAA [15] propose the extension of classical MCQs by allowing the student to specify a degree of global confidence on their answers (by choosing a label) or select alternative possible choices (by suggesting an alternative choice that could be the correct answer to the question). MCQs with confidence measurement [2,5,7,8] allow the students to express their trust on their answers (selecting an appropriate confidence level from a list), motivated by a scoring scheme that rewards honesty and penalizes guessing. The selection of the confidence level has an underlying probabilistic interpretation that assumes that a student would want to maximize the probability of obtaining more marks. These MCQs minimize guessing, encourage reflection and self-awareness, and improve validity and reliability of the evaluations [5]. They have been validated by comparing them to more traditional assessment types [4] and have been successfully applied in medicine [8] and computer networks [2]. Moreover, they have been found to be less biased than regular MCQs [7].

These approaches provide some flexibility, but they are still too restrictive to represent imperfect and partial knowledge. Even if some of their marking is inspired on probabilities and Shannon's Theory of Information [5], their aim is mainly the establishment of a scoring scheme, not the formative assessment of knowledge levels and misconceptions. Furthermore, no treatment or interpretation of the imperfections of the answers is proposed. They recognize severe misconceptions (high levels of confidence on wrong answers), but a lower level of granularity in the expression of the confidence would allow the expression of doubts among the choices, the differentiation of uncertainty, indecision and ignorance, and the diagnosis of different types of misconceptions within the same answer. Even if confidence on the global answer to a question can be expressed, local imprecision and uncertainties of the particular choices remain hidden.

3 Taking the Most Out of a MCQ

Uncertainty and imprecision are two inherent aspects of human knowledge and they should be considered in an automated learning process. Following a formative assessment approach, they should appear in different stages of learner diagnosis. Formative MCQs must help in the acquisition of this imperfect information by allowing flexible assessment (first stage) and providing approximate reasoning inferences (second stage). In this section, we present some ways we can maximize the expressivity of the students answering a MCQ: choice indexing, choice preference quantification, general confidence assessment and distractor identification.

3.1 Choice Indexing

One of the most common ways of modeling student knowledge acquisition is with an *Overlay Model* [16], based on the model of the domain knowledge presented as an ontology (network of related concepts). An instance of the domain ontology is considered for every student; every concept is qualified according to the learner's knowledge level. By indexing the concepts treated on the learning resources, an ITS can infer the current state of knowledge of the students, either by implicitly analyzing the resources accessed by the students or by explicitly assessing student knowledge through an evaluation.

In a MCQ, questions are indexed according to knowledge they evaluate. Since a student has to give a precise response, only one piece of evidence can be inferred from her answer. A good MCQ [10] should have good distractors, wrong

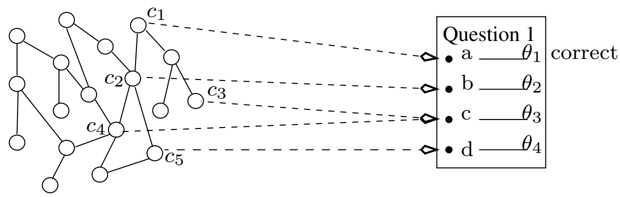

Fig. 1. Choice indexing in MCQ

answers that are not preposterous. The identification of the concepts related to the distractors allows the diagnosis of possible misconceptions.

We propose to index the concepts treated on the questions at the choice level (see figure 1). This way, the selection of the correct answer of an item would give information as to the acquisition of the concepts related to that choice, and the selection of an incorrect choice would identify the concepts that could have been misunderstood. Moreover, if we allow imprecise answers that point to several choices in a single item (as proposed in the following subsections), we would get multiple pieces of information from a single MCQ.

The intensity of the relationships between concepts and choices can be described by use of conditional belief functions, a generalisation of conditional probabilities in the context of belief function theory [11]. By applying the Generalized Bayesian Theorem [12] the student model can be diagnosed.

3.2 Choice Preference

A precise and absolute answer would introduce noise into the assessment process: if we want to assess the acquired knowledge why force a student to a clear cut answer if her knowledge is imprecise? We propose to let her express her choice preferences by assigning weights representing her belief on the proposed choices. This type of interaction can easily be accomplished by using sliders.

3.3 General Confidence

We concur with the works on confidence assessment in MCQ (presented on section 2). If the student is not sure of her answer, a good assessment tool would have to let her express this uncertainty. We want to acquire her feeling of knowing [9], of agreeing with her own answer. Alternately, we can see this as an estimation of her ignorance of the correct answer to the question at hand. The expression of general confidence can be done by explicitly letting the student provide a confidence value, or by implicitly inferring it according to the underlying uncertainty and imprecision representation theory.

3.4 Choice Elimination

Another aspect that we consider to be very informative is the ability to eliminate one or more choices. The identification of distractors is important because, in the context of choice indexing, it ratifies the misconception of the concepts involved.

4 Belief Function Theory

In this section we present the basic notions of belief functions and their relationship with probabilities; we will use this measures to interpret the weight assignments given by the students to represent their choice preferences on their imperfect answers.

First we define a **frame of discernment** Θ as the set of possible exclusive values that a variable can take. For instance we can use $\Theta = \{\theta_1, \theta_2, \theta_3, \theta_4\}$ to represent the set of possible choices θ_i of a given question.

Belief function theory (also called evidence theory) [11], generalizes probabilities by abandoning the additivity constraint. A Basic Belief Assignment (BBA) is a mapping $m : 2^\Theta \to [0, 1]$ distributing a unit of belief mass to the subsets of Θ such that $\sum_{A \in 2^\Theta} m(A) = 1$. A subset $A \subset \Theta$ such that $m(A) > 0$ is called a **focal element**. The value $m(A)$ represents the fraction of belief (mass) on the elements of the subset $A \subset \Theta$.

Total ignorance is represented by the vacuous belief function, which assigns the belief mass unit to the frame itself. Partial ignorance is represented by $m(\Theta) > 0$.

A measure $bel(A)$ from 2^Θ to $[0, 1]$ of a subset $A \in \Theta$ represents the total belief on the elements contained in A. We have $bel(A) = \sum_{B \subseteq A} m(B), \forall A \subseteq \Theta$.

A measure $pl(A)$ from 2^Θ to $[0, 1]$ of a subset $A \in \Theta$ represents the belief that could be transferred to A. We have $pl(A) = \sum_{A \cap B \neq \emptyset} m(B), \forall A \subseteq \Theta$.

Uncertainty is easily represented in belief function theory, since different amounts of beliefs can be assigned to different focal elements. Imprecision is specified by the assignment of belief masses to subsets of the frame, not necessarily singletons. Different levels of imprecision can then be expressed.

The case where all focal elements are all singletons is called the Bayesian belief assignment, the particular case of probabilities. We have $bel(\theta_i) = pl(\theta_i) = P(\theta_i)$. Probability only allows the representation of uncertainty. Total ignorance is represented as equiprobability and there is no way to specify partial ignorance nor imprecision.

5 Representation and Interpretation of Imperfect Answers

In [3] we presented a way to express imperfect answers by applying belief function theory to MCQs (evidential MCQs - **Ev-MCQs**). Here, we consider only MCQs where only one of its choices is correct; MCQs with multiple responses can be viewed as a set of of truth or false questions (hence, single response MCQs). One unit of belief mass has to be distributed by the evaluee, so that each choice that seems plausible can be selected to a certain degree. The student is not forced to assign all of her belief mass to a single option, she can distribute it as she wants. She is neither forced to distribute all of her belief mass, she can leave some mass unassigned ($u = 1 - \sum_{\theta_i \in \Theta} m(\theta_i)$) indicating her ignorance or lack of confidence on her answer (see figure 2). In Ev-MCQs the expression of general confidence is then bound to the choice preference. The acquired freedom allows the student

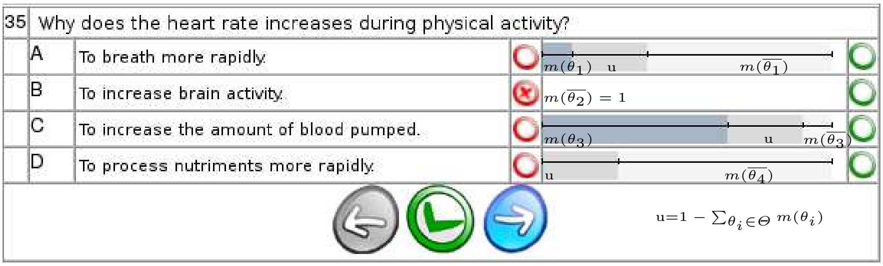

Fig. 2. An Ev-MCQ imperfect answer

to point at some of the choices that otherwise she wouldn't consider. Moreover, the student is able to identify incorrect choices (the set of $Distractors$) in her view (choice b in figure 2), so that the unassigned mass u will not be assigned to Θ, but to $\Theta \setminus Distractors$.

We can represent an answer to the question as a belief mass assignment among the elements $\theta_i \in \Theta$. The unassigned mass can be associated to Θ itself. We will only have singletons and the frame itself as possible focal elements of the BBA that represents the answer. All the BBAs expressed through Ev-MCQs are normalized.

A classical MCQ would assign a weight of 1 to the selected choice θ_{sel} and 0 to the others. Ev-MCQs generalize classical MCQs, a precise and certain answer will concur with a classical MCQ answer.

If we were to interpret the weights as probability masses, the imperfect answers would be expressed through probability distributions, and a tool allowing the expression of these answers would have to respect the additivity constraint. Choice elimination would be possible by fixing the value of the probability of a choice to 0 so that the masses would be distributed among the rest of the choices. Since it is not possible to express a degree of partial ignorance directly, it is necessary to express it in terms of another probability distribution over a universe having two possible states {Confident, Ignorant}. The two distributions would be independent of each other, and a combination of the two would give us a final answer that would take into account general confidence and choice preference. Nevertheless, the complexity and interactivity of a tool permitting such an answer would need to be studied carefully.

6 Normalization of Imperfect Answers and Noise Prevention

The purpose of the expression of imperfect answers is to obtain answers closer to the imperfect notions the students have. We estimate that the student diagnosis process suffers from the consideration of a noise caused by the constraint of expressing precise and certain answers via classical MCQs, and that rich information as to the current state of knowledge of a student is lost in the adaptation of imperfect notions to a single choice answer. Ev-MCQs can help to avoid such noise.

We define the process of *normalization* of an imperfect answer as the selection of a single choice as the answer to a MCQ, taking into account the BBA expressed by an imperfect answer of an Ev-MCQ, representing the answer of the same student through a classical MCQ interface. Choice preference, choice elimination and global confidence on the answer would need to be considered on the selection of the choice for the normalized answer.

In Smets' interpretation of belief function theory [13], an operation called the pignistic transformation is applied to BBAs in order to obtain a pignistic probability distribution to qualify each of the singletons on the frame of discernment:

$$BetP(\theta_i) = \sum_{\theta_i \in A,\, A \subseteq \Theta} \frac{m(A)}{|A|}$$

In the case of EvMCQ, we have for each choice:

$$BetP(\theta_i) = m(\theta_i) + \frac{m(\Theta)}{|\Theta \setminus Distractors|}$$

For example, in the case of figure 2, we have $\Theta = \{A, B, C, D\}$, $Distractors = \{B\}$, and $m(\Theta) = u = 0.3$:

- $BetP(A) = m(A) + m(\Theta)/|\{A, B, D\}| = 0.1 + 0.3/3 = 0.2.$
- $BetP(B) = 0.$
- $BetP(C) = m(C) + m(\Theta)/|\{A, B, D\}| = 0.6 + 0.3/3 = 0.7.$
- $BetP(D) = m(D) + m(\Theta)/|\{A, B, D\}| = 0 + 0.3/3 = 0.1.$

We consider that each answer to a question contributes to one unit (1) of information. In the case of a precise and certain answer, that unit of information is assigned to the selected choice. In the case of an imperfect answer, the unit of information is distributed among the considered choices, and we use the $BetP$ values of each choice as a way of measuring the information fragments.

If R_{norm} has only one element, we select it as the student's normalized answer. If R_{norm} has several choices, we assume that the student would select one of them randomly.

We define $BetP_{norm}$ as the highest value of $BetP$, and we call R_{norm} the subset of choices having a $BetP$ value equal to $BetP_{norm}$[2]. In the case of figure 2, $BetP_{norm} = 0.7$, and $R_{norm} = \{C\}$.

We define a measure of *prevented noise* as the difference of information of the selected choice between the normalized answer (1) and the imperfect answer ($BetP_{norm}$):

$$Noise = 1 - BetP_{norm} \tag{1}$$

In our example, we have: $Noise = 1 - 0.7 = 0.3$.

[2] In fact, since the imperfect answers are expressed by the students by clicking into a bar, we consider a sensitivity threshold in the comparison to $BetP_{norm}$.

7 Experimentation

In order to validate the use of Ev-MCQ, we conducted an experimentation in the context of knowledge evaluation of a group of 113 students from junior school. Two 7th grade (5ème) classes and two 8th grade (4ème) classes were confronted to a 45 minute evaluation consisting of 30 questions dealing with the biology courses. Table 1 shows the distribution of the groups and the type of evaluation assigned to them. Half of the students passed a classical MCQ evaluation (groups A, C, E, G), and half an Ev-MCQ evaluation (groups B, D, F, H).

We used the $BetP$ value of the correct choice in order to note the performance on the tests. This way, a classical MCQ answer can have only 0 and 1 as possible scores, and an Ev-MCQ answer can have any value in the interval [0,1] as its score. The evaluations are graded under 20.

The average performances of each group are presented on the next to last column of table 1. The last column shows the average score of the normalized answers for Ev-MCQ evaluations. The weighted average of the scores is 16.05/20. From the results presented on table 1, we can see that the type of evaluation doesn't have a considerable impact on the performance of the students. We can also see that difference between the score of the normalized and unnormalized answers for the Ev-MCQ evaluations is negligible.

Table 2 describes the imperfect answers expressed by the 58 students from the 4 groups who passed the Ev-MCQ evaluation. Columns 2, 3 and 4 summarize the type of answers given by each group, presenting the percentage of absolute answers (correct or incorrect precise and certain answers), uncertain answers (having a choice clearly preferred to the others - $|R_{norm}| = 1$), and undecided answers (having $|R_{norm}| > 1$). Columns 5 and 6 present the mininimal and maximal prevented noise percentages per item. Columns 7, 8 and 9 present the number of students for each group and the mininimal and maximal prevented noise percentages per student. Finally, on the last column, we have the average percentage of noise prevented for each group.

We can see that approximately three quarters of the answers given were absolute (the weighted average of the questions having absolute answers is 77.1%). This means that if the students of groups B, D, F and H would have had to

Table 1. Group distribution and performance

Grp.	Class	#Students	MCQ type	Grade avg. /20	Norm. grade avg. /20
A	7th	14	Clasical MCQ	15.70	-
B	7th	15	Ev-MCQ	16.03	16.311
C	7th	15	Clasical MCQ	16.27	-
D	7th	15	Ev-MCQ	16.52	16.82
E	8th	13	Clasical MCQ	16.15	-
F	8th	14	Ev-MCQ	14.64	14.75
G	8th	13	Clasical MCQ	16.97	-
H	8th	14	Ev-MCQ	16.15	16.23

Table 2. Imperfect answers given through Ev-MCQs

Grp.	Answers			Item noise%		# Students	Student noise%		Noise
	%Abs	% Unc	%Ind	Min	Max		Min	Max	Avg.
B	82	4	14	0	19.1	15	0.7	17.9	6
D	73.6	24.6	1.8	0	26.6	15	0.3	11	5.5
F	75	17.6	7.4	0	22.3	14	1.3	28.7	9
H	77.6	17.6	4.8	0	16	14	0	13.9	6.1

pass the evaluation with classical MCQs instead of Ev-MCQs, they would have had to adapt their answers for one quarter of the questions, losing in the process important information as to their imperfect state of knowledge.

The magnitude of the adaptations for each group is given on the last column. The weighted average of prevented noise is 6.61%. This measure gives us the amount of information lost and replaced by noise because of the inflexibility of classical MCQs.

This is just an average of the performances. It includes the results of the absolute answers given by students with good performances along with the indecise and uncertain answers given by the students with relatively poor performances.

The impact of imperfect answers can be seen more clearly by analyzing the particular cases of students with high amounts of noise prevented. These are the students with low feeling of knowledge whose cognitive state is very fragile and needs to be treated. We can see for example on the next to last column on table 2 the single maximum level of noise prevented from the answers of one of students from each group (17.9%, 11%, 28.7% and 13.9%).

Thanks to the increased information gathered through EvMCQs different degrees of misconceptions can be recognized, so that an pedagogical application (e.g; ITS) can undertake the necessary measures to correct them.

On the fifth and sixth column, we can see the minimum and maximum noise prevented by a single question. The acquisition of imperfect answers allow us to recognize which items cause the more unease to students, and detect possible problems with the way questions are presented.

8 Conclusion and Future Work

In this article, we analyse the ways in which classical MCQs can be extended in order to obtain more information from a single answer, by taking advantage of the flexibility provided by an uncertainty and imprecision management theory. Choice preference, confidence assessment and choice elimination are identified as possible extensions to classical MCQs.

We presented the way Ev-MCQs, a generalization of classical MCQs applying belief function theory to the interpretation of imperfect answers expressed as weight assignments over the choices, allow for a closer representation of the real state of knowledge of a student.

We validated the application of Ev-MCQs in the context of knowledge evaluation through experimentation, and we verified its main purposes: increased flexibility of expressivity and noise prevention. Results showed how Ev-MCQs allowed the acquisition of approx. 25% of imperfect answers without constraining the expression of precise and certain answers, and how Ev-MCQs prevented the replacement of an average of 6.61% of the total information with a form of noise issued from the adaptation of the imperfect answers.

One of the more important aspects of the imperfect answers we presented on this article is the subject of our current research. If the expression of imperfect knowledge is very important as we have shown, the representation of imperfect answers through BBAs allow us to exploit the reasoning capabilities of belief function theory. Student modeling is possible through the use of BBAs to represent the state of knowledge of the different concepts covered on the domain model of a pedagogical application (*Overlay model*).

We are currently working on a student modeling framework that uses Ev-MCQs as a means for evaluating learner knowledge. Choices are linked to domain concepts through conditional belief functions, and the Generalized Bayesian Theorem [12] is applied to infer[14] the current state of knowledge. This work will be the subject of future publications.

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References

1. Bouchon-Meunier, B.: La logique floue et ses applications. Addison-Wesley, Reading (1995)
2. Davies, C.: There's no confidence in multiple-choice testing. In: 6th Inter. CAA conference, pp. 119–130. Loughborough Univ., UK (2002)
3. Diaz, J., Rifqi, M., Bouchon-Meunier, J.: Evidential multiple choice questions. In: PING Workshop at UM 2007 (2007)
4. Farrell, G.: A comparison of an innovative web-based tool utilizing confidence measurement to the traditional multiple choice, short answer and question problem solving questions. In: 10th Inter. CAA conf., pp. 176–184. Loughborough Univ., UK (2006)
5. Gardner-Medwin, A.R., Gahan, M.: Formative and summative confidence-based assessment. In: 7th Inter. CAA conf., pp. 147–155. Loughborough Univ., UK (2003)
6. Gronlund, N.: Assessment of Student Achievement. Ally & Bacon (2005)
7. Hassmen, P., Hunt, D.P.: Human self-assessment in multiple-choice testing. Journal of Educational Measurement 31(2), 149–160 (1994)
8. Khan, K.S., Davies, D.A., Gupta, J.K.: Formative self-assessment using multiple true-false questions on the Internet: feedback according to confidence about correct knowledge. Medical Teacher. 23(2), 158–163 (2001)

9. Koriat, A., Goldsmith, M., Schneider, W., Nakash-Dura, M.: The credibility of children's testimony: Can children control the accuracy of their memory reports? Journal of Experimental Child Psychology 79(4), 405–437 (2001)
10. McAlpine, M.: A summary of methods of item analysis. CAA Centre, Luton (2002)
11. Shafer, G.: A Mathematical Theory of Evidence. Princeton University Press, Princeton (1976)
12. Smets, P.: Belief functions: the disjunctive rule of combination and the Generalized Bayesian Theorem. International Journal of Approximate Reasoning 9, 1–35 (1993)
13. Smets, P., Kennes, R.: The transferable belief model. Artificial Intelligence 66, 191–234 (1994)
14. Smets, P., Kennes, R.: The Application of the Transferable Belief Model to Diagnostic Problems. International Journal Intelligent Systems 13, 127–158 (1998)
15. Warburton, B., Conole, G.: Key findings from recent literature on Computer-aided Assessment. In: ALT-C 2003. Sheffield, UK (2003)
16. Wenger, E.: Artificial Intelligence and Tutoring Systems. Morgan Kaufmann Publishers, Inc., San Francisco (1987)
17. Zadeh, L.A.: Fuzzy Sets as a basis for a Theory of Possibility. Fuzzy Sets and Systems 1, 3–28 (1978)

Towards a Semantic-Rich Collaborative Environment for Learning Software Patterns

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Abstract. Current approaches to learning software patterns are based on individual use of different learning systems and tools. With this 'fragmented' approach it is very hard to provide support for context-aware learning and offer personalized learning experience to students. In this paper, we propose a new approach to learning software patterns that integrates existing Learning Management Systems, domain specific tools for software modeling and relevant online repositories of software patterns into a complex learning framework that supports collaborative learning. This framework is based on the semantic web technologies.

Keywords: Semantic web, ontologies, collaborative learning, software patterns.

1 Introduction

The major concern of today's software engineering education is to provide students with the skills required for solving different kinds of software problems both on their own and as members of a development team. In addition, it is essential that students learn how to exploit previous successful experiences and knowledge of other people in solving similar problems. This knowledge about successful solutions to recurring problems in software design is also known as software patterns [1],[2]. Software patterns are becoming increasingly important in software engineering.

However, teaching and learning software patterns is not an easy task. It is rather a complex process that requires significant efforts from both educators and students. In order to secure high-quality learning in this complex engineering field, a learning platform needs to meet the following requirements:

1. Enable students to learn at the pace and in a place that best suits them as well as provide them with the content and learning activities that are related to the learning objectives and students' characteristics, knowledge, skills and experiences.
2. Integrate software development tools that would enable students to experience patterns-based software development in the context of real-world problems. Such tools should enable students to do practical examples and experience how the theory they have learned can be applied in practice.

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3. Include collaborative tools such as discussion forums, chat, and tools for software artifacts exchange. Since software development is intrinsically a team oriented work, students should get used to collaborative style of work as well as learn what constitutes a successful team.
4. Enable seamless access to online repositories of software patterns and communities of practice that will provide students with right-in-time access to the relevant online resources, that is, to the software patterns relevant for the problem at hand.
5. Provide tools for informing teachers about students learning activities, their usage of learning content and other valuable information that could help them improve the learning content and/or the chosen teaching approach.

Even though the above mentioned kinds of tools do exist today, they are not used in an integrated way [3]. Instead, current approaches to learning software patterns are based on individual use of these tools. The major problem with this 'fragmented' approach is in its lack of means for enabling exchange of data about the activities that students performed within individual learning tools and learning artifacts they have produced during those activities. Besides, with such an approach it is very hard to provide support for context-aware learning services and offer personalized learning experience to students.

In this paper, we propose a new approach to a learning environment for software patterns that leverages existing Learning Management Systems (LMSs), domain specific tools for software modeling and relevant repositories of software patterns available online. All these elements connected together establish an integrated learning framework, called DEPTHS (DEsign Patterns Teaching Help System) that supports collaborative learning of software patterns. We propose the use of Learning Object Context Ontology (LOCO) framework [4] as an ontology base for the integration. The framework integrates a number of learning-related ontologies, such as user model ontology, a learning content ontology, and domain ontologies. We leverage the LOCO framework in the following manner: domain ontology is used for representing the domain of software patterns, whereas the learning context ontology is extended to allow for capturing and representation of learning contexts of different kinds of systems and tools that DEPTHS integrates.

This approach promises to be beneficial for all participants in the learning process:

- Teachers would spend less time developing lessons. Instead they would (re)use the existing online resources. DEPTHS would secure the ease of locating relevant online resources for the course the teacher develops.
- DEPTHS will improve students' learning effectiveness and efficiency by recommending relevant resources from online repositories as well as by recommending the most suitable peer(s) to collaborate with.
- Integration of knowledge about all learning related activities performed within any educational tool integrated in this framework should provide solid base for improving the quality of important educational aspects (e.g., adaptation and context-awareness).

The following section presents a typical usage scenario of DEPTHS. Section 3 gives an overview of the LOCO ontological framework as well as the extensions we made to meet the specific needs of DEPTHS. An extensive description of the DEPTHS architecture is given in Section 4, whereas Section 5 focuses on the implementation details. Before concluding the paper, we outline the related work (Section 6).

2 Running Example

It is possible to develop many scenarios for learning software patterns in the DEPTHS framework. Due to the limited size of this paper, we describe only one, which is based on a problem-based learning approach with collaborative learning support. In this scenario (Fig. 1), a teacher defines a specific software problem that has to be solved in a workshop-like manner. Workshop is a peer assessment activity with a huge array of options, such as allowing students to review and assess each other's solutions. The teacher provides an informal description of the problem, a task to be accomplished and a set of learning resources that could help students to solve the problem.

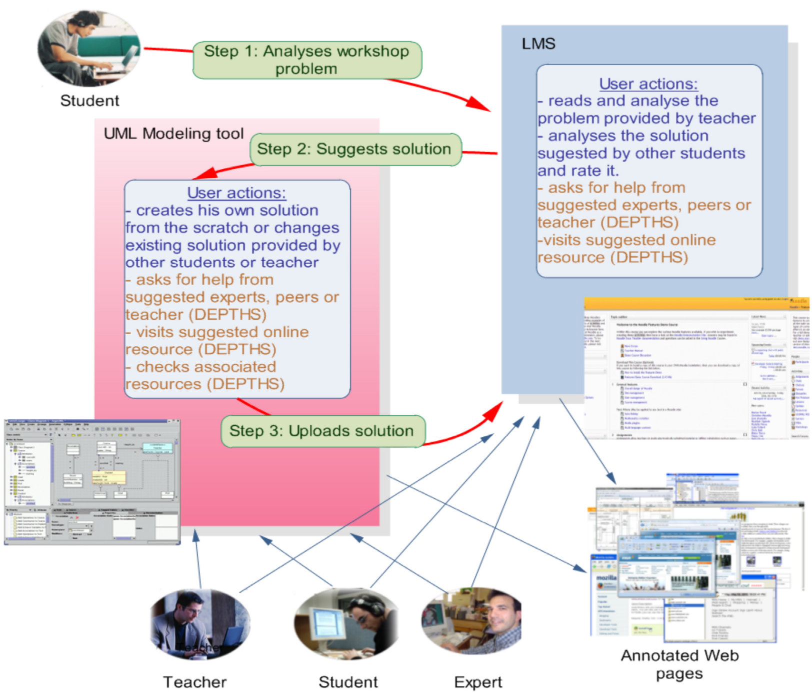

Fig. 1. An example learning scenario with DEPTHS: problem-based learning with collaborative learning support (DEPTHS in parenthesis indicates DEPTHS specific functionalities)

Students are typically supposed to provide a graphical representation of their solutions (i.e., the designed software models). A student can draw his/her own solution from scratch, use some other student's solution, and/or use a partial solution provided by the teacher in the problem's description. If one of the last two options is selected, an appropriate solution (often in the form of a diagram) would be loaded within the student's modeling tool and the tool would keep track of all changes that the student would make and tag them with other color on the diagram. Based on the student's current learning context, DEPTHS would suggest him/her to consult online resources that it estimated as potentially useful for the student's current situation. It would also find and suggest other students, experts and/or teachers that could be contacted in order to get additional support. The system would do this both proactively and on the student's request. As DEPTHS provides seamless integration of all of its tools, the student is able to send a message to or chat with peers regardless what tools of the DEPTHS framework they are using at that moment.

3 Ontological Foundation

DEPTHS is based on the Learning Object Context Ontology (LOCO) ontological framework [4]. LOCO allows one to formally represent the notion of learning context which is defined as a specific learning situation, determined by the learning activity, the learning content, and the student(s) involved. To support DEPTHS, we use ontologies of the LOCO framework to interrelate information about learning objects, learning activities and learners collected from various tools relevant for learning software patterns, as specified in the introduction.

The core part of the LOCO framework is the LOCO-Cite ontology, which comprises a number of classes and properties aimed at formally representing learning context. In addition, this framework integrates a number of learning-related ontologies, such as: User Model ontology, Learning Design ontology, Learning Object Content Structure ontology, Domain ontology [4]. To address the requirements of the DEPTHS framework, we fully adopted the LOCO-Cite ontology, and connected it with the ontology of software patterns domain.

3.1 The LOCO-Cite Ontology

The LOCO-Cite ontology allows for semantic representation of the data about a student's overall interactions with learning content and other students during different learning activities. Based on this data, DEPTHS can perform context-aware retrieval of software patterns resources from online repositories and its own repository of software artifacts (which contains artifacts produced and shared by other students); identify and draw students' attention to the related threads in discussion forums; and identify peers that could help in a specific situation.

Activities are very important part of the learning process in DEPTHS as they lead to realization of learning objectives. Examples of such activities are reading lessons, visiting online pages, participating in a workshop or doing an assignment, solving design problems, quizzing and collaborating with other participants. In the LOCO-Cite ontology, these activities are recognized and grouped as three basic types of activities: reading, doing an assessment, and collaborating. However, we found that the LOCO-Cite ontology does not allow for capturing and representation of some specific types of activities and events typically occurring within software modeling tools. Accordingly, we extended this ontology with a set of classes and properties, to enable collecting data about user interactions in software development tools, in a similar way as described in [3].

3.2 Domain Ontology

Since DEPTHS is devised as an environment for teaching/learning software patterns, it leverages an ontology of software patterns as its domain ontology. DEPTHS uses this ontology to annotate relevant learning resources and extract metadata that is subsequently used for finding resources appropriate for a student's current learning context. In this way, DEPTHS can easily connect diverse kinds of learning resources, and use this links to further improve its context-aware support by being able to mash-up knowledge scattered in different activities.

Rather than developing new design pattern ontology from scratch, we decided to (re)use an existing ontology. Among the available ontologies of the design patterns domain [5],[6],[7],[8], we have chosen the set of ontologies suggested in [8] to serve as the domain ontology of the DEPTHS framework. Comparing these with the other ontologies, we found that they provide a very intuitive and concise way to describe design patterns and patterns collections, and more information on usability knowledge and the contextual factors that impact this knowledge. This approach to pattern representation allows for federating distributed pattern collections.

4 System Architecture

In this section, we present a high-level architecture of our DEPTHS framework. The framework comprises five basic components: a Learning Management System (LMS), a Collaborative Learning Modeling tool, a Teachers' Feedback tool, Online Repositories of Software patterns and a Semantic Management System (Fig. 2). In the rest of the section, each of these components is addressed in turn.

4.1 Learning Management System

Today's LMSs have an extensive set of tools and features aimed at facilitating the learning process (e.g., quiz, assignment, chat room, discussion forum, and glossary). However, they do not fully address the requirements of a comprehensive learning framework such as DEPTHS. One of those requirements is the integration of the usage tracking data from all the systems/tools students use. We address this requirement with the LOCO framework (see Section 3). As most of the existing LMSs use classical databases for data storage, it is necessary to transform the data stored in their databases into semantically enriched data compliant with the LOCO-Cite ontology. The transformed data is stored in the **Repository of Learning Object Contexts (LOCs)** which is fully based on the LOCO-Cite ontology**.**

Apart from the existing collaborative learning support that is usual in most LMSs (such as discussion forums and chat-rooms), we found that it would be very useful if student(s) had a tool for collaborative annotation of learning content (such as tagging, commenting and highlighting). The more the content is annotated, the easier it becomes to later find it and retrieve it. Accordingly, we decided to integrate such a collaborative tool in the LMS that is used in our framework.

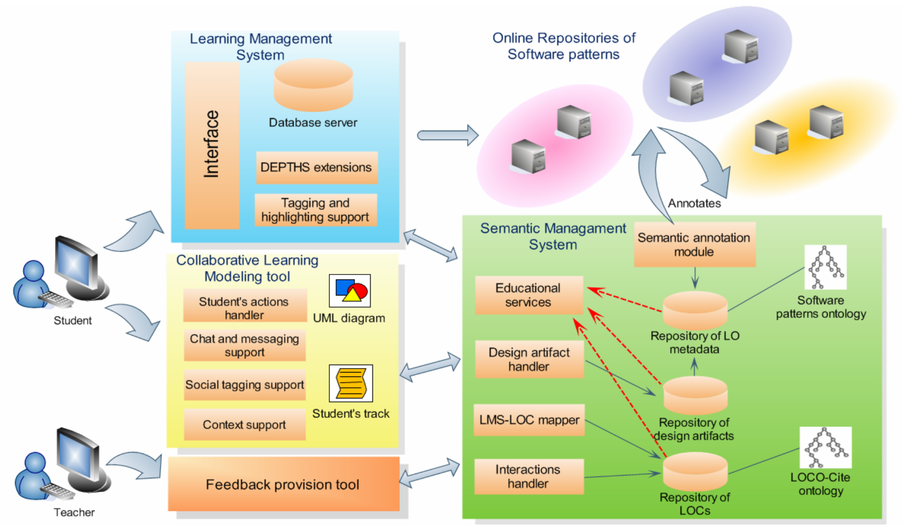

Fig. 2. The architecture of the DEPTHS learning framework

4.2 Collaborative Learning Modeling Tool

We have identified that the framework for software engineering education should necessary have the support for software modeling using diagrams, especially UML (Unified Modeling Language) diagrams. However, most of the existing software modeling tools does not provide all necessary support for collaborative learning. We refer here to the set of features that should be supported by these tools, beside those that they usually include:

- An easy way for presenting a description of the suggested solution.
- Collaborative Tagging support module enabling students to create either social (public) or private annotations of learning content (e.g., publicly available online resources on the Web, design diagrams, and forum messages). That way, a student begins to create a network of content that can be later accessed and searched, for example, through a tag cloud view.
- A chat room and messaging tools that support collaboration with other students even if they are not using the same tool in the given moment.
- Ability to keep track of students' actions during learning sessions (**Student's actions handler**). These tracks are sent to the **Interactions handler** (see section 4.5) which is responsible for integrating them into the **Repository of LOCs** where they are stored for later analysis.
- Context-aware learning. Based on a student's learning context the system should suggest him/her the most suitable learning content, publicly available online resources on the Web, similar problems, or discussion threads that could be useful for the specific problem he/she is facing. This should basically help students to better comprehend relations between the acquired theoretical knowledge and experiences of others with the practical problems at hand.

4.3 Feedback Provisioning Tool

In order to help a teacher to improve the learning experience of his/her students, DEPTHS incorporates a tool that provides teachers with feedback about all kinds of activities their students performed during the learning session. This tool is also built on top of the LOCO framework, so that it has access to the learning context data created in all learning tools used in DEPTHS. The feedback tool provides teachers with contextualized feedback and relevant information about students' learning.

4.4 Online Repositories of Software Patterns

One of the main advantages of this framework is that it leverages existing online learning resources, rather than requiring teachers to create new ones. There are a plenty of such repositories which could be used, such as Yahoo! Design Pattern Library[1], Portland Pattern Repository[2], and Hillside.net Pattern Catalog[3].

DEPTHS leverages the domain ontology to provide both teachers and students with resources from these repositories that are relevant for the current teaching/learning context. In particular, the domain ontology is used for annotating semanticaly the resources available from these repositories and the resulting semantic metadata is stored in the **Repository of LO Metadata** (see Fig. 2). This metadata is used for indentifying the resources relevant for any given learning situation. An additional advantage of DEPTHS is that these resources are made accessible from which ever tool of the DEPTHS framework a teacher or a student is using. Moreover, students are able to tagg and highlight these resource. We believe that these content annotation activities can not only improve some typical activities in learning (e.g. revisiting learning material, personal note taking, and connecting with peers), but also provide valuable data that can quaranty higher quality of context-aware learning.

4.5 Semantic Management System

This module is the integration point of the whole framework. In particular, it leverages the semantic web technologies to support integration of all the above mentioned modules. In order to acomplish this, it uses a set of repositories and a set of software compentents. In particular, it comprises the following three reporitories:

- **Repository of LO metadata** stores semantic metadata about online resources available from online repositories, as well as about internally created content, such as software design diagrams, discussion forum postings and chat messages besides regular lessons used in the courses under study. This metadata consists of topics defined in the software pattern ontology and we refer to it as semantic metadata as it formally defines the semantics of the learning content it is attached to.
- **Repository of design artifacts** keeps students' solutions in different formats: a reusable format, and a format suitable for presentation in the LMS.
- **Repository of LOCs** stores learning objects' context-related data in accordance with the LOCO-Cite ontology.

[1] http://developer.yahoo.com/ypatterns/index.php
[2] http://c2.com/ppr/
[3] http://www.hillside.net/patterns/onlinepatterncatalog.htm

In addition, Semantic Management System integrates the following components:

LMS-LOC mapper has the role to transform data from the LMS database of logs of learners's activities into the format compliant with the LOCO-Cite ontology and to store the resulting data in the Repository of LOCs. This data mapping is performed throughout each learning session in order to keep the semantic repository updated (with data about the events occuring durign that session).

Semantic annotation module is used for annotating online repositories of design patterns, as well as, diagrams (created by students) stored in the Repository of design artifacts. This module automatically extracts metadata based on the domain ontology and stores them in the Repository of LO metadata.

Design artifact handler manages the diagrams in the Repository of design artifacts. It takes diagrams from the modeling tool and stores them in the Repository of design artifacts in different formats. It is also responsible for keeping track of different versions of the same diagram.

Educational services provide all necessary support for context-aware learning and are accessible from all tools integrated in the DEPTHS framework. These services are based on Semantic web technologies, and include (but not limited to):

- Finding web resources relevant for the student's current learning context.
- Recommending learning artifacts (discussion posts, chat messages, workshop submission…) related to the current context.
- Finding potential collaborators among experts and peers.

5 Implementation of DEPTHS

In this section, we describe the tools that we are using to implement the proposed framework and argument our decision to use specifically these tools.

5.1 Learning Management System

As the LMS component of the DEPTHS framework (Section 4.1), we have decided to use Moodle[4] LMS for many reasons. First, Moodle is a popular open-source LMS, which requires only hosting costs, and thus provides us with an inexpensive but reliable learning environment. In addition, the open source nature of this system enables us to extend it with Semantic Web technologies. Moodle also has an extensive set of tools and features.

However, one of the most eminent advantages of Moodle that influenced our decision is that it facilitates collaborative work, that is, it is designed under the social constructivist theory. This theory argues for a student-centered environment where learners are able to work independently, reflect on their own work and on the work of other students, while at the same time being connected to a group of learners with whom they can share ideas and reflect on each other's work [10]. As we indicated in the introduction, getting the students involved in the learning process is essential to effective learning of software patterns.

[4] http://moodle.org/

However, the manner in which Moodle stores data about students' interactions with the system is inappropriate for DEPTHS. Rather, DEPTHS requires semantically enhanced interactions data, that is, RDF data stored in a format compliant with the LOCO-Cite ontology. In order to resolve this issue, during the initialization of the system, we do the mapping of the interactions data stored in Moodle's database into the required ontological format and store the resulting RDF data into the Repository of LOCs (see Section 4.5). This task is performed using D2RQ[5] – an open source platform that facilitates the mapping of relational databases into ontological models. This way a lot of valuable data that currently resides in Moodle database are made accessible to DEPTHS in the form of RDF statements. Later, throughout each learning session, DEPTHS uses Sesame[6] Java API to update the semantic repository with data about the events occurring during that session. Apart from updating the Repository of LOCs, DEPTHS uses Sesame API to query this repository in order to retrieve the data required by its educational services (see Section 4.5). As two distinct technologies are used (PHP for Moodle and Java for DEPTHS), we use PHP/Java bridge[7] to provide the connection.

We have decided to integrate OATS (The Open Annotation and Tagging System) [11] in Moodle in order to provide students with a tool to collaboratively create and share knowledge, by using highlights, tags and notes. OATS is an open source tool which was created to further enrich the functionalities provided by an LMS. The aim is to motivate students to enagage more and move beyond passive consumtion of e-learning content towards active production [12]. We have already made an extension of the LOCO-Cite ontology to enable formal representation of events occuring in collaborative content annotation tools such as OATS and we intend to use it to capture and store data about students interactions with OATS into the Repository of LOCs.

This way DEPTHS employs Moodles advantages but also adds some new possibilities provided as DEPTHS's educationsl services, among which the most important are: finding web resources that could be useful in the current learning context, finding relevant internaly produced resources stored in DEPTHS repositories, and finding appropriate peers.

5.2 Semantic Annotation of Learning Content

Among many available tools for content annotation that we have tested, we decided to use the KIM framework[8], a semantic annotation platform, that provides an automatic semantic annotation, indexing and retrieval of documents. Semantic annotation in KIM is based on the provided domain ontology (i.e. the ontology of software patterns, see Section 3.2) that makes KIM aware of the concepts from the software patterns domain. As a result, we use KIM annotation facilities to automatically annotate diverse kinds of learning artifacts with relevant domain topics. This further facilitates

[5] http://www4.wiwiss.fu-berlin.de/bizer/D2RQ/spec/
[6] http://www.openrdf.org/
[7] http://php-java-bridge.sourceforge.net/pjb/
[8] http://www.ontotext.com/kim/index.html

semantic interlinking of diverse kinds of learning artefacts: online resources, lessons from the LMS, students software models, and exchanges messages. Thus, enables us to integrate previously fragmented knowledge artifacts students used or created in learning activities.

5.3 Domain Modeling Tool

ArgoUML is a Computer-Aided Software Engineering (CASE) tool suitable for the analysis and design of object-oriented software systems. It allows for designing all kinds of UML diagrams. Another advantage of ArgoUML is that it supports open software standards which facilitate exchange of UML diagrams among students, as well as presentation of these diagrams in Moodle.

Due to its open-source nature, ArgoUML can be extended to enable capturing of user interaction data and storing that data in the common ontological format of the DEPTHS framework (i.e. the LOCO-Cite ontology). We are using Sesame Java API to extend ArgoUML, so that it continually updates the Repository of LOCs with data about events generated during students' interactions with the tool. Subsequently, we are going to extend ArgoUML, so that it can make use of the DEPTHS's educational services, such as finding solutions to the similar problems suggested by other students or finding appropriate online resource about design patterns that could be used in the student' current context.

5.4 Feedback Provision Tool

Finally, we have decided to integrate LOCO-Analyst in the DEPTHS framework. This tool provides teachers with contextualized feedback regarding all kinds of activities their students performed during a specific period of time [4]. It is built on top of the LOCO framework so we can easily use it in this framework without any intervention on it.

6 Related Work

The framework proposed in this paper is related to two favored research fields: collaborative learning of software engineering and the Semantic web. Even though extensive work has been done in both research fields, to the best of our knowledge there were very few attempts in developing collaborative learning environments through integration of existing tools based on the semantic web technologies.

The approach proposed in [13] presents an intelligent tutoring system, called COLLECT-UML, the goal of which is to support the acquisition of both problem-solving skills and collaboration skills. In this environment, students construct UML class diagrams that satisfy a given set of requirements. COLLECT-UML supports collaborative learning and provides feedback on both collaboration issues and task-oriented issues. Our framework provides similar approach to the learning process, that is, students learn through the practical problem-based examples in collaboration with other students. However, our framework offers higher learning potential as it provides access to the relevant learning resources and facilitates context-aware learning.

Many authors have indicated the great advantages that Semantic web technologies can bring to education. For example, Devedzic [14] stated that for semantic interoperability of educational content and applications on the Web, it is necessary to root them in the technologies of the Semantic Web. He has proposed educational servers which exploit learning technology standards, ontologies and pedagogical agents to support interaction between clients (authors and students) and servers (hosting educational content and services). A similar approach is described in [15] where the author suggests the use of semantic web technologies for representing knowledge about resources, learners and services. The author in this work suggests a service-based architecture for establishing personalized e-learning, where personalization functionality is provided by various web-services. While strongly agree with this approach, we are going a step further. In DEPTHS we provide a domain specific tool which is necessary, especially in software and other technical engineering education.

In [3], the authors suggested the approach similar to the one presented in this work. They have developed MICE – a learner-centered platform for regulating learners' programming styles when studying a programming language using an integrated development environment. It also integrates an LMS and a set of tools for communication and collaboration among users. Even though MICE follows a similar approach to integration of existing tools, it still lacks access to the online resources that is available in our framework. Besides our framework promises additional support for collaborative learning as it offers social tagging support.

7 Conclusion

This paper has introduced DEPTHS, a collaborative learning framework that we are developing to better support education in the domain of software patterns. We have argued for the integration of existing, proven learning systems and tools in this framework in order to provide an effective collaborative learning environment. Such a framework requires a flexible underlying ontology-based model to support such integration. We have found that the LOCO ontological framework exactly addresses this requirement. Currently, we are using two kinds of ontologies of the LOCO framework: learning object context ontology (the LOCO-Cite ontology) and domain ontology (an ontology of software pattern).

DEPTHS can improve student's collaboration work by recommending resources that are related to the goal the student is currently working on, by providing tools for collaboration in solving practical exercises and by suggesting peers to collaborate with. By allowing for knowledge sharing among different educational tools and online repositories, we provide students with a context-aware learning environment. We believe that this is a promising direction that will contribute to further improvements in software engineers' education.

Our present and future work is primarily focused on working further on the implementation of the DEPTHS framework. So far, we have been primarily working on data collection and integration and the next step is to develop educational services (explained in Section 4.5) that will leverage that data to provide students with enhanced learning experience (such as the one described in the learning scenario of Section 2).

References

1. Alexander, C., Ishikawa, S., Silverstein, M.: A Pattern Language: Towns, Buildings, Construction. Oxford University Press, New York (1977)
2. Gamma, E., Helm, R., Johnson, R., Vlissides, J.: Design Patterns: Elements of Reusable Object-Oriented Software. Addison-Wesley, Reading (1995)
3. Jovanović, J., Rao, S., Gašević, D., Devedžić, V., Hatala, M.: An Ontological Framework for Educational Feedback. In: Proc. of the 5th Int'l Workshop on Ontologies and Semantic Web for Intelligent Distributed Educational Systems, USA, pp. 54–64 (2007)
4. Jovanović, J., Gašević, D., Brooks, C., Devedžić, V., Hatala, M., Eap, T., Richards, G.: Using Semantic Web Technologies for the Analysis of Learning Content. IEEE Internet Computing 11(5) (2007)
5. Dietrich, J., Elgar, C.: A formal Description of Design Patterns using OWL. In: Proc. of ASWEC, IEEE Comp. Soc. (2005)
6. Montero, S., Diaz, P., Aedo, I.: Formalization of web design patterns using ontologies. In: Proc. of 1st Int'l Atlantic Web Intell. Conf. (AWIC), Spain, pp. 179–188 (2003)
7. Kampffmeyer, H., Zschaler, S.: Finding the Pattern You Need: The Design Pattern Intent Ontology. In: Engels, G., Opdyke, B., Schmidt, D.C., Weil, F. (eds.) MODELS 2007. LNCS, vol. 4735, pp. 211–225. Springer, Heidelberg (2007)
8. Henninger, S.: A Framework for Flexible and Executable Usability Patterns Standards. In: 31st IEEE Software Engineering Workshop (SEW-31), USA, pp. 23–34 (2007)
9. Coplien, J.O.: Software Patterns. SIGS Books, New York (1996)
10. Dougiamas, M.: A journey into constructivism (1998), `http://dougiamas.com/writing/constructivism.html`
11. Bateman, S., Farzan, R., Brusilovsky, P., McCalla, G.: OATS: The Open Annotation and Tagging System. In: The Proc. of the 3rd Annual Int'l Scientific Conf. of the LO Repository Research Network, Montreal (2006)
12. Fischer, G., Ostwald, J.: Transcending the Information Given: Designing learning Environments for Informed Participation. In: The Proc. of ICCE Int'l Conf. on Computers in Education, New Zealand (2002)
13. Baghaei, N., Mitrovic, A., Irwin, W.: Supporting collaborative learning and problem-solving in a constraint-based CSCL environment for UML class diagrams. Int'l Journal of CSCL 2(2-3), 150–190 (2007)
14. Devedžić, V.: Next-generation Web-based Education. Int'l Journal for Continuing Engineering Education and Life-long Learning 11(1/2), 232–247 (2003)
15. Dolog, P., Henze, N., Nejdl, W., Sintek, M.: Personalization in Distributed e-Learning Environments. In: Inter'l WWW Conf., pp. 170–179. ACM Press, New York (2004)

Tinkering or Sketching: Apprentices' Use of Tangibles and Drawings to Solve Design Problems

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Abstract. The articulation of practice and theory is a central problematic in a dual apprenticeship system that combines working in a company and attending courses at school. Design problems are proposed by teachers as a way to address theoretical concepts in a practical context. The difficulties encountered by apprentices while creating paper based sketches motivated the development of a tabletop warehouse simulation providing apprentices with a Tangible User Interface in the form of a small-scale model. We compare drawings and tangible representational modalities with regards to three phases of design problem solving. Tinkering with tangibles is described as an easy way to engage into the problem. The physical properties of tangibles facilitate the extraction of features relevant for verification. The limited expressiveness of tangibles allows apprentices to focus on the search for a solution rather than on the representation of the problem space.

Keywords: Tangible Computing, Problem- and Project-based Learning, Practice Fields, Initial Vocational Training, Field Studies.

1 Introduction

Vocational training in Switzerland concerns 70% of the 15 year old people after obligatory schooling. Training is organized to a large extend following a dual approach: apprentices spend four days per week working in a company and attend courses in a professional school on the fifth day. Compared to a model that implies vocational schools only, the dual model presents the advantage that businesses financially profit from the apprentices' work [1] and apprentices practice their trade in an authentic setting. Professional schools propose general courses (e.g. foreign languages or commercial law) as well as trade-specific courses. In addition, practical training for specialized aspects of the profession is provided by professional associations four weeks in a year.

A field study conducted at the beginning of this research in the field of logistics showed that the distribution of the apprenticeship over two different locations poses the problem of the articulation of practical and conceptual knowledge. Schools attempt to teach generalities: despite the efforts teachers invest in explaining and contextualizing textbook examples, apprentices are not able (or willing) to transfer generalities into

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their practice. From the teachers' point of view, the central problem posed by schooling with logisticians comes from their limited abstraction, reading and comprehension capabilities. It is for instance difficult for apprentices to imagine the effect of everyday practice on the behavior of a global logistics chain. It is also difficult for them to reason about numerical relationships, for example between storage surfaces and monetary flows or between the weight of a pallet and the maximum height a forklift is allowed to lift it. School is described by apprenticeship masters (who are responsible for the apprentices in companies) as something irrelevant for the apprentice's daily practice. At the best, they recognize that conceptual knowledge might be useful in the later career of the apprentice. At the workplace, apprentices don't have the opportunity to apply the general skills they are taught in school. Especially in the beginning of the apprenticeship, apprentices are mostly involved in the manual aspects of the profession (e.g. moving boxes, packaging goods). Organizational decisions (e.g. about the layout of a new warehouse), which would require the application of theories taught in school, are taken by the employees already in place. In addition, intellectual work is sometimes negatively perceived in predominantly manual professions (e.g. car mechanics, logistics, woodworker, etc.). In short, the dual system is missing a place where reflection on practice is encouraged and supported. There are however occasions where school activities aim at bridging the "abstraction gap" between practice and theory. The warehouse layout exercise which we describe in this paper precisely aims at embedding conceptual knowledge into an ill-defined design problem.

The differing nature of in- and out-of-school learning is well described by Resnick's Presidential Address to the American Educational Research Association [2]. Out of school learning (including at the workplace) is situated, distributed over people and tools whereas schooling is conceived as individual "mentation" on symbolic representations which (are supposed to) transfer to a wide array of situations. Unfortunately, transfer doesn't happen, what is learned in schools is not useable in the workplace. The remedies proposed by situated learning ([3], [4]) to the problems faced by traditional schooling are well articulated in the ideas of *practice fields* [5] and *authentic learning environments* (see synthesis in [6]). These approaches advocate in favor of learning situations which are similar to the situations where knowledge will be used, feature ill-defined activities, provide access to expert performance, provide multiple roles and perspectives, support collaborative construction of knowledge, promote reflection and articulation. During the past two years we have worked in close relationship with two teachers from a professional school to design a tabletop small-scale simulation for logistics. The design was guided by the principles outlined by the practice fields approach. The general objective of our intervention is to enable teachers to propose problem-solving activities to the apprentices which are as close as possible to the real context of a warehouse.

2 Research Question

Design problems are ill-defined problems [7]: they have multiple solutions which are not contained in the description of the problem and which may be evaluated by multiple criteria. Many real world problems faced by professionals belong to this category. Solving ill-defined problems is similar to a design process rather than a systematic search and the application of well-known procedures. Problem-solvers have to define and frame the problem first and do epistemic monitoring which includes looking for a match between the current definition of the problem and idiosyncratic memories, personal histories, emotional memories and problem-related memories. Design problems are particularly difficult to solve because the quality of a solution cannot be evaluated by standard criteria. Rather, the problem solvers have to define the nature of the problem and deduce relevant evaluation criteria by themselves. Besides individual differences with regards to the expertise in the domain, the problem representation is one of the factors which predict successful problem solving: "An important function of designing for problem solving is deciding how to represent the problem to novice learners" ([7], p. 69). Decisions concern the fidelity of the problem representation (e.g. does it present the same complexity as its real-world counterpart) as well as the modality and medium of the representations used.

The particular problem we are interested in is the design of a warehouse. Solving the problem consists of determining the shape, size and placement of different areas (loading docks, merchandise control, storage, administration, order preparation) by taking into account various constraints. The storage area has in turn to be organized as a spatial configuration of shelves and alleys. Paper and pencil is so far the preferred medium to tackle design problems during the logistics apprenticeship. However, teachers report that apprentices have difficulties in reading and constructing layouts on paper. The aim of our contribution is to illustrate the impact of a tangible external representation on how apprentices solve a warehouse design problem. Our hypothesis is that a small-scale model of the warehouse is better suited for apprentices because it supports the concrete, contextualized and enactive mode of reasoning they use in their daily professional life.

Three properties of tangible user interfaces ([8], [9]) are especially promising in a pedagogical context [10]. First, tangible user interfaces include physical action in the repertoire of learning activities with computers. Not surprisingly the added value of sensori-motor experience is often described in projects involving young children [11]. Children may learn through the manipulation of objects by what Piaget called empirical abstraction [12], the idea that one accommodates behavioral schemes in response to resistance from the physical world. The greater "richness" of interaction in terms of perceptual modalities is also put forward as a potential benefit of tangible user interfaces. The deep immersion into concrete physical experience and the full embodiment of representations might however be counter-productive if the goal of the activity is to foster reflection [13]. The problem might be that the learners get stuck in the action with the tool "ready-at-hand" rather than seeing the concept which it represents (the tool is "present-at-hand"). Similarly, research on manipulatives used in mathematical education has shown that focusing on the manipulative rather than on what it represents is detrimental to learning [14]. Second, the coupling of tangible user interfaces with augmented reality (the system projects information on top of physical artifacts) allows for a very close mapping between tangible input and digital output, between the physicality of an object, the manipulations it affords, and the abstraction of visualization. Third, tangible user interfaces naturally support face to face collaborative activities, allowing multiple users to interact with the system at the same time.

3 Method

We follow the approach outlined by the Design-Based Research Collective [15] which consists in testing and building working theories to make sense of a field of investigation through an iterative design and intervention cycle. Wang and Hannafin [16] summarize the key points of the approach as 1) it aims at refining both theory and practice 2) through interventions which are grounded in theories and take place in real-world settings 3) with an active participation of the participants in the design 4) through iterative cycles of analysis, design, implementation and redesign 5) by the use of an array of methods from field observations to controlled surveys 6) leading to results which are articulated to the specific context of the studies. Our investigation follows these principles rather than a series of tightly controlled laboratory studies. Given the exploratory nature of our hypothesis we do not base our quest for answers on the statistical refutation of hypotheses but rather on a systematic description of observational data.

3.1 Material

A tabletop small-scale warehouse model is built by placing wooden shelves on a 2 by 1.5 meter table, we called TinkerTable. Metallic pillars are used as architectural constraints and rectangular cardboard elements represent specialized areas of a warehouse, like offices and technical rooms. All objects are tagged with fiducial markers (similar to a 2 dimensional bar code) which enable a camera to track their position on the table [17]. The whole model is scaled at 1:16 which allows building the equivalent of a 32 by 24 meters warehouse. The physical warehouse is augmented through a video projector and a mirror placed above the table (see Fig. 1). A gallows carries the camera, the video projector and a mirror. The purpose of the mirror is to augment the distance between the projector and the table, in order for the projection to cover the

Fig. 1. Left: The TinkerTable system with the table and the gallows. Wooden shelves are arranged on the table. Right: Five apprentices discuss and draw a forklift's path on the floor of the warehouse.

whole surface of the table. The table is covered with whiteboard material, which allows users to draw by using regular whiteboard markers.

Augmentation through the projector enables the system to draw on top and around the wooden shelves as they are moved on the table. The simplest augmentation consists of drawing the navigation path around each shelf. When two shelves are placed too close, the navigation path disappears and signals that a forklift can't navigate between the shelves. It is therefore possible for users to find the ideal spacing between shelves (i.e. the corridor width) by trial and error. Other features of the layout are represented as well, for instance whether a given shelf is accessible from the loading dock or how long it takes for a forklift to reach the shelf.

3.2 Data Sources

The TinkerTable was tested with apprentices on six occasions which differ according to the location (at the professional school, at the university), the group of students and the teachers involved and the type of augmentations provided by the system. All sessions started with the layout of a warehouse by the apprentices. The warehouse was then used as a basis to address further topics in logistics (e.g. optimal placement of goods in the warehouse, optimal picking path for forklifts). The activities were videotaped and sound was recorded with ad hoc microphones. The warehouse layout exercise consists of accommodating as many shelves as possible in the given area by taking into account architectural constraints (pillars), placing and dimensioning an administrative area, and placing loading docks. The layout was evaluated by counting the number of accessible pallets and discussing the quality and usability of the warehouse (e.g. navigation, average path length to reach shelves, etc.). The layouts produced by apprentices during these sessions were however not formally sanctioned by a mark.

To enable a comparison with the traditional version of the warehouse layout exercise, we conducted an observation during a problem solving session in a class from another school which never used the tabletop simulation. The observation included short interviews with five groups of apprentices and the collection of drawings produced by the apprentices during the design task. This warehouse layout exercise was done in class during four one hour sessions. Groups of three to four apprentices were given the task to design the layout of a warehouse which accommodates a given number of constraints (number of pallets, number of pallets in one shelf, dimension of a shelf, width of alleys, areas for administration and technical rooms, etc.). As an outcome, apprentices delivered a 2D plan of the warehouse, answered a set of arithmetic questions (e.g. how many people are needed to run the warehouse given the time required to pick pallets and the number of movements per day) and had to justify their design. This small report was assessed by a mark.

3.3 Data Analysis

Although the two situations we described differ in a number of ways, we found that an analysis of the drawings produced on paper and the comments gathered during the interviews reveal the potential advantages and disadvantages of the tangible approach. To facilitate and systematize the comparison, we organize the description of each situation into three sections which correspond to the phases of design problem solving described by Chandrasekaran [18]: Propose, Verify, Modify. Accordingly, the Propose subtask consists of proposing potential solutions. The Verify subtask checks whether relevant design specifications are satisfied. If this is not the case, a diagnosis is performed and the Modify subtask is activated to change the design accordingly. These different phases do not take place in a strict sequential order during problem-solving, and apprentices usually move freely from one to the other, iterating between proposal and verification phases.

4 Results

We now report examples and observations which illustrate how the representational modality affects apprentice's problem-solving process.

4.1 Paper Modality

Propose. The apprentices are given a set of constraints which can't directly be mapped onto the problem space: their first task consists of computing the storage area required for the warehouse given the available constraints (store 1500 pallets on shelves with 6 levels of a given width). Once the initial computation is done, apprentices can determine the scale of their drawing given the size of the paper or the size of the rectangle they chose to represent the warehouse. The problem then consists of segmenting the space by taking into account the relative surface and the arrangement of the areas (e.g. the order preparation zone should be connected with the loading docks). Coming up with a good solution satisfying these constraints seems to pose

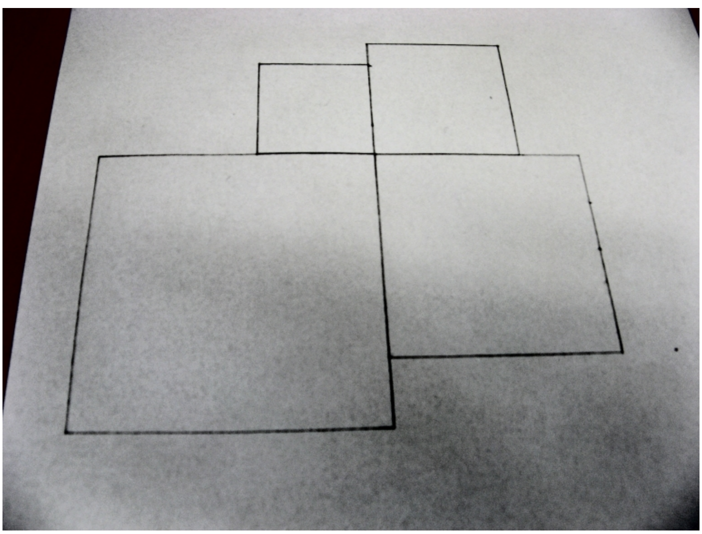

Fig. 2. Spatial warehouse configuration which respects surface constraints but without integration into a rectangular shape

great problems to the apprentices, who tend to reproduce the layout of the warehouse they work in at their company. Moreover, dealing with proportions seems to be difficult for them: the typical and intuitive shape of a warehouse is a rectangle, with a ratio of two-third between its width and length, and apprentices naturally tend to (and should) create warehouses following this pattern. The challenge here comes from the fact that the instructions they have only describe the area of the different rooms, which means that their width and length have to be defined to get the given surface and fit altogether in a rectangle. Fig. 2 shows an example of a group of apprentices who had problems in arranging the rooms in rectangles of the correct surface and finally simplified the problem by using only square rooms and thus creating a warehouse with an unpractical shape.

Verify. Evaluating a design drawn on paper implies that the apprentices imagine the work processes, simulating in their head the typical trajectory of a pallet in the warehouse, as well as its implications on the job of workers. It appears that apprentices have problems in doing this as they are often not able to identify clear weaknesses of their designs. The implementation phase gives a clear illustration of the difficulty

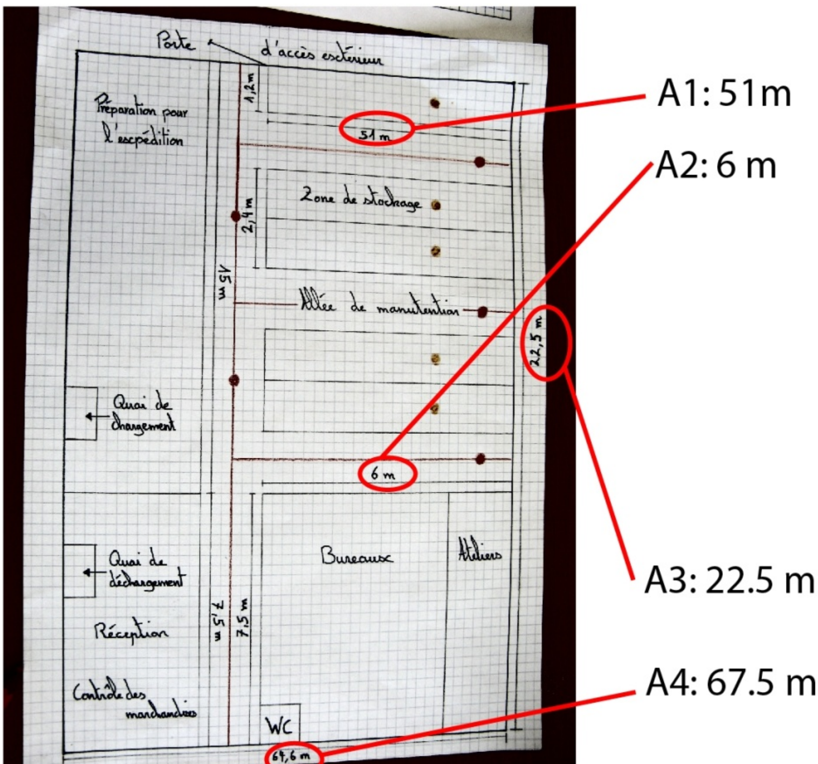

Fig. 3. An example of a completed warehouse layout with labeling inconsistencies. (A1) and (A2) are geometrically equal but have been given different values. (A3) and (A4) represent the outside dimensions of the warehouse: the labels define (A4) as being longer than (A3) which is geometrically clearly wrong.

faced by apprentices to handle the abstract representation of a warehouse on paper. Drawing a layout while respecting the relative proportions of the rooms and objects represented was a challenge for most of the groups we interviewed. A closer look to their productions reveals inconsistencies between the layout and a real warehouse. Fig. 3 is an example of a layout on which a group of apprentices we interviewed was working. Two observations are worth noting: the same distance is labeled with two different values, 6m and 51m, and the width (horizontal axis) is labeled as being smaller than the height (vertical axis). Beyond the spatial inconsistencies, the teachers report that apprentices often have difficulties evaluating the quality of their solution with regards to warehouse efficiency.

Modify. Sketching was observed only on few artifacts produced by the apprentices. By their blurriness and fuzziness, sketches signal openness for change and would allow for exploration of the design space. However, it looks like apprentices try to draw the final plan during their first (and only) proposal. They use drawings as a way to communicate a solution rather than a way to build it. Accordingly, their drawings are done with much emphasis on precision (i.e. using a ruler to draw lines, following the grid on the paper). Drawing "perfect" warehouses leaves no room for modification. Revisions of the design, when they exist, are implemented by drawing a new version of the layout.

4.2 Tangible Modality

Propose. During the observations of apprentices designing a warehouse using the TinkerTable, we noticed that they tended to start implementing their solution almost immediately, without much discussion. Compared to the paper condition where they spend more time thinking about the global organization of the warehouse, the physical objects encourage them to act immediately. The proposal takes place at a more local level, based on the shelves already present on the table. Once the first few shelves are placed by one apprentice, the others simply extend the row of shelves by following the same direction. The implementation phase appeared to be facilitated by the use of physical objects and augmentations. Apprentices can use the shelves' physical resistance as a help for alignment and spacing. Finally, it is worth noting that sometimes several apprentices simultaneously place shelves in different locations on the table.

Verify. Ensuring that the width of the alleys was large enough to allow forklifts to access the content of the shelves was achieved in various ways. In some cases, the system projected circles in front of each shelf. The color of the circles indicated whether the content of the shelf was accessible or not from the loading docks. In some other cases, no information was provided, and apprentices had to use either a projected grid to estimate the distance between the shelves or use a small-scale model of a forklift as a measuring device. These techniques were used for fine-tuning (in order to minimize the space used by alleys), as apprentices were able to visually estimate the optimal width an alley while placing the shelves on the table.

Estimating proportions using physical objects was not a problem for apprentices. It seems that the concrete three-dimensional shape of the shelves helped apprentices to build a representation of the situation that could be easily linked to their experience. For example, on one occasion an apprentice critiqued the position of a shelf a peer just added by saying: "It doesn't work like that, if there are several forklifts working, it won't be wide enough!" The instructions that were given to the apprentices were to design a warehouse with the biggest storage capacity, without worrying about work efficiency as an evaluation criterion. This comment was thus triggered from the experience of this apprentice, who had the feeling that putting this shelf at that place would be a problem for the workers. This example illustrates how the concrete representation provided by the small-scale model allowed apprentices to think about the warehouse they were building as an authentic workplace.

Modify. As mentioned previously, apprentices were not taking a global approach for designing the layout of the warehouse but were mainly acting at a local level, adding one shelf at a time. The revision phase was thus spread over the whole activity, with apprentices often trying several possibilities before adding a shelf. One interesting property of the tangible approach is that it allowed them to quickly test whether a given position would be acceptable for a shelf. However, global revisions did not happen naturally and apprentices tended to stick to their initial design decisions. The teachers had an important role to play in discussing the production of the apprentices to point out different ways of considering the problem and thus orienting them towards another solution. This was made possible by the fact that the first design iteration was done rather quickly which saved time to try out other options and discuss them through debriefing sessions.

On one occasion, a teacher was discussing with a group of apprentices about the position where the reception and expedition docks should be placed. Each apprentice proposed and commented on different ideas, and one of them took his own company as an example, which triggered a ten minutes long exchange with the teacher. After watching the videotape of this example, the teachers were positively surprised as they felt that this apprentice would not have engaged in such a detailed description in a traditional classroom situation. It is also worth noting that these explanations took place around an empty table and that gesturing was used to "draw" an invisible warehouse.

5 Discussion

The observations and interviews allowed us to identify main differences between the tangible and paper-based problem representations that influence problem-solving activities.

The first difference concerns the extraction of information from the problem state for verification. The level of metaphor differs among the two forms of representation: the tangible objects give a concrete representation of a warehouse, in three dimensions, compared to the more abstract and two-dimensional representation offered by the drawings. The cognitive effort required from the apprentices to work on a paper-based representation of a warehouse is thus stronger, as this form of representation implies a transformation in dimension (from 3D to 2D) and scale compared to the tabletop environment which just implies a change of scale from a real warehouse. In the tabletop environment the scaling is facilitated because the wooden shelves serve as a measuring unit to estimate the size of the warehouse, the relative area of the office, the width of the alleys. The three dimensional nature of shelves, plastic pallet and miniature forklift allows to use familiar objects to estimate distances. On the contrary, on paper, all objects are represented as rectangles without a perceptual property that allows differentiating among them. Labels placed on the rectangles allow disambiguating the meaning of the representations, but do not afford the direct comparison of proportions. These examples illustrate the fact that a drawing of a warehouse layout on paper is a disembodied representation for apprentices, who do not seem able to relate it to a real situation.

The second difference concerns the production and modification of design proposals. Apprentices are not at ease with sketching. One of them told us in a quippy comment: "we are not architects". As a consequence they do not use sketching (i.e. making rudimentary drawings without paying much attention to details) as a way to explore variations of their current design. The ability to explore design options by sketching requires that designers apprehend the object without attending too much to details. This abstraction allows them to manipulate the essential features of the problem. Buxton's observation that "[…] it takes the same kind of learning to acquire the skills to converse fluently with a sketch as it takes to learn to speak in any other foreign language" [19, p.118] concurs with the difficulties that we observed. Tangible shelves are a much less generic expression media compared to pencils. It is not possible to express a design proposal with tangible shelves without actually implementing it in full detail. In other terms, tangible shelves present a minimal level of metaphor as they resemble very closely to their real counterpart [20]. The small scale model we use relies on a metaphor where the user doesn't need to make an analogy between the virtual and physical world: the effects of moving a wooden shelf are similar in both cases. The metaphor has a positive impact on the ability of apprentices to tackle the design activity: they do not need to maintain the semantic link between the representation and what is represented. Rather than proposing the "big picture", they proceed in a bottom-up construction of the solution by incrementally adding shelves on the table.

The placement of a shelf is often accompanied by some tinkering, which allows the apprentice to test small variations on the current state of the solution. Especially when they reach a bottleneck (e.g. there is not enough room to place a shelf at the end of a row, a pillar is in the way), these variations trigger a bigger re-arrangement of the warehouse.

6 Conclusion

It appears from our observations that apprentices benefit in two ways from the realism of the small-scale model. First, the 3D representation facilitates the evaluation of the design because relevant spatial features are made salient. Second, the limited expressiveness of the 3D representation, allows apprentices to concentrate on trying out solutions rather than on creating the artifact to represent the solution. We do not claim however that apprentices should stay confined in the concrete manipulation of tangibles. Rather, we think that tangibles act as a scaffold which allows apprentices to engage with the problem. The pitfalls of tangible interfaces pointed out by Marshall [13] still have to be avoided by appropriately supporting reflection. For instance, teachers perform epistemic monitoring and verify the design through discussions with the apprentices. Those discussions are a privileged way to illustrate theoretical concepts, because they are embedded in the authentic context of a design problem.

Current extensions of the TinkerTable system include the ability for the system to recognize draw-erase pen annotations on and around wooden shelves. The goal is to enable apprentices to switch back and forth between tangible manipulation and pen-based sketching as well as formal calculations. We recently observed a combination of the two media in a small informal experiment that we conducted in a doctoral course for computer scientists. Students were asked to design a warehouse. Contrary to the apprentices, who built an entire warehouse before entering verification, the computer science students built a small shelf module with tangibles and then used pencil and paper to do calculations to check whether the module could be replicated across the warehouse. This fluid alternance between local and global problem-solving examplifies well the type of skills we try to help apprentices acquire.

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References

1. Mühlemann, S., Wolter, S.C.: Bildungsqualität, demographischer Wandel, Struktur der Arbeitsmärkte und die Bereitschaft von Unternehmen, Lehrstellen anzubieten. Wirtschaftspolitische Blätter 54, 1 (2007)
2. Resnick, L.B.: The 1987 Presidential Address: Learning in School and out. Educational Researcher 16(9), 13–20+54 (1987)
3. Brown, J.S., Collins, A., Duguid, P.: Situated cognition and the culture of learning. Educational Researcher 18, 32–42 (1989)
4. Collins, A., Brown, J.S., Holum, A.: Cognitive apprenticeship: Making thinking visible. American Educator 15(3), 6–11 (1991)
5. Barab, S.A., Duffy, T.: From practice fields to communities of practice. In: Jonassen, D., Land, S.M. (eds.) Theoretical foundations of learning environments, pp. 25–56. Lawrence Erlbaum, Mahwah (2000)
6. Herrington, J., Oliver, R.: An instructional design framework for authentic learning environments. Educational Technology Research and Development 48, 23–48 (2000)
7. Jonassen, D.H.: Toward a design theory of problem solving. Educational Technology Research and Development 48(4), 63–85 (2000)
8. Fitzmaurice, G.: W.: Graspable User Interfaces. Ph.D. thesis, University of Toronto (1996)
9. Ishii, H., Ullmer, B.: Tangible bits: towards seamless interfaces between people, bits and atoms. In: CHI 1997: Proceedings of the SIGCHI conference on Human factors in computing systems, pp. 234–241. ACM Press, New York (1997)
10. O'Malley, C., Stanton-Fraser, D.: Literature review in learning with tangible technologies, Nesta FutureLab Series, report 12 (2004)
11. Price, S., Rogers, Y.: Let's get physical: the learning benefits of interacting in digitally augmented physical spaces. Journal of Computers and Education 43, 137–151 (2004)
12. Glasersfeld, E.: von: Abstraction, re-presentation and reflection. In: Steffe, L.P. (ed.) Epistemological foundations of mathematical experience, pp. 45–67. Springer, Heidelberg (1991)

13. Marshall, P., Price, S., Yvonne Rogers, Y.: Conceptualising tangibles to support learning. In: Proceeding of the 2003 conference on Interaction design and children, July 01-03, 2003, Preston, England (2003)
14. Uttal, D.H., Scudder, K.V., DeLoache, J.S.: Manipulatives as symbols: A new perspective on the use of concrete objects to teach mathematics. Journal of Applied Developmental Psychology 18, 37–54 (1997)
15. Design-Based Research Collective: Design based research: An emerging paradigm for educational inquiry. Educational Researcher 32(1), 5–8 (2003)
16. Wang, F., Hannafin, M.J.: Design based research and technology enhanced learning environments. Educational Technology Research & Development 53(4), 523 (2005)
17. Fiala, M.: ARTag, A Fiducial Marker System using Digital Techniques. In: IEEE Proc. CVPR. San Diego (June 2005)
18. Chandrasekaran, B.: Design Problem Solving: A Task Analysis. AI Magazine 11(4), 59–71 (1990)
19. Buxton, B.: Sketching User Experiences. Getting the design right and the right design. Morgan Kaufmann, San Francisco (2007)
20. Fishkin, K.P.: A taxonomy for and analysis of tangible interfaces. Personal and Ubiquitous Computing 8(5), 347–358 (2004)

Design of an Annotation Tool to Support Simulation Training of Medical Teams

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Abstract. The design of an educational tool for training observational skills of medical practitioners is presented. Using simulators is becoming more and more frequent in the training of medical teams and as a part of such training video often plays an important role providing a way of showing, in retrospect, what happened during critical incidents. Learning to identify and analyze teamwork in critical care is difficult and our objective has been to create a tool to train participants in such skills rather than developing yet another tool for researchers or specially trained observers. The tool is a simple annotation tool for letting users mark problematic and good team behavior which visualizes annotations on a timeline. One central idea is that individual annotations are shown collectively thereby visualizing possible differences and gaps in different users' observations.

Keywords: Annotation tool, educational tool, design, medical teamwork.

1 Background: Critical Care Teams and Simulation Training

To prepare medical teams for the challenges of critical care, simulation training of health care personnel working as teams to solve realistic cases but with a manikin is becoming more and more wide-spread. This paper presents the design of a prototype which aims at supporting such training. The time pressure and dynamic nature of critical care contexts places high requirements on the medical teams. Clear communication is important for interdisciplinary teams to function well and for avoiding adverse events [3, 9]. For a medical team to work efficiently, clear leadership is also crucial. Team members need to have an understanding of how decisions are made with the group; resuscitations with a clearly identifiable trauma team leader have been found to enhance trauma resuscitation performance [10]. Clear leadership is, however, something that is often lacking in resuscitation teams and may be highly dependent upon team composition and experience level [14]. The quality of teamwork in critical care can have serious consequences for patient safety; in a retrospective review of US malpractice cases more than half of the deaths that occurred were judged to have been avoidable under conditions of better teamwork [13]. This is of course worrying and even worse is that experience does not seem to be a guarantee for developing efficient leadership. Cooper and Wakelam reported that some leaders had very low performance ratings despite a great deal of experience [5]. A challenge is that even

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very experienced medical practitioners may not have a clear and shared model for analyzing the teamwork and communication making improvement difficult or even impossible. Skills in analyzing, and in consequence improving, suboptimal teamwork may therefore be limited. In the worst case awareness, of this knowledge gap is lacking.

The quality of teamwork, leadership and communication is typically discussed in simulation courses. Simulation in medicine is a rather young but a rapidly growing area [7]. At the Center for Education in Pediatric Simulators (CEPS) at the Södersjukhuset hospital in Stockholm, simulation courses are organized for pediatricians, anesthesiologists, obstetricians, nurses, and midwives. The courses are intensive one-day courses starting with lectures and followed by simulations and debriefing and feedback sessions. The participants work in interprofessional teams to practice solving complex, authentic cases: the medical teams provide newborns (a small manikin) arriving from the delivery room with intensive care. Much emphasis is on learning the medical guidelines, resuscitation procedures, and equipment. But the importance of clear communication, leadership, and, teamwork is also emphasized. During debriefings immediately following each simulation, video recordings of the simulations are watched and the teams analyze the teamwork with their instructors. The technology that is used at most simulation centers is typically standard, old-fashioned VCR equipment. Watching the videos may be illuminating and provide an occasion for learning when the team members are not immersed in a challenging task, especially if facilitated by instructors [8]. However, the full potential of the use of video recordings has hardly been reached yet.

Several advanced tools for the analysis and annotation of video data exist today, e.g., The Observer™, Transana™, and MEPA (Multiple Episode Protocol Analysis), and DiViDU [12]. Some simulators that are used have software which can synchronize event logs (e.g., patient status and measures taken by the team) with the video recordings and which thereby can provide feedback on the performance of teams – see, e.g., the Laerdal SimBaby™ software. Video recordings have also been used to study adherence to guidelines and have shown that these are not always consistently followed [4]. Video recording of resuscitation work with the objective of evaluating teams and in the context of quality assurance projects has been done by, e.g., [6]. Also, besides software, a number of guidelines and protocols exist for assessing medical work. E.g., the Advanced trauma life support (ATLS)-based protocols provide a common language and framework for trauma [3], behavioral marker systems for teamwork in neonatal resuscitations [8, 14], and the ANTS system which is a guide for the assessment of non-technical skills in anesthetic practice [1]. However, none of the software and conceptual tools mentioned are suitable for the uses we envision. They are simply too complex for our intended user group and use situation where very little if any time exists for training. Our focus is primarily on education rather than on evaluation, assessment or quality assurance. And it is on teamwork and communication rather than on adherence to medical guidelines (which exist e.g., for resuscitation procedures).

To summarize *the problem*, clear leadership and communication is essential to efficient team work but even experienced practitioners may lack competence in making observations about and analyzing critical care team work. The existing conceptual models and annotation software are too complex and not adapted for being used by healthcare personnel taking part in simulation-based team training courses.

The purpose of this work is to create a tool to be used in simulation training with the objective of supporting users in developing skills in making observations and analyzing teamwork and communication and which can support the users in establishing a common view concerning the observations and analyses.

2 The Design of the Annotation Tool

The tool discussed here provides the possibility to make annotations about the teamwork and communication, but our goal has not been to develop yet another tool for researchers doing interaction analysis nor for developing models for special committees or specially trained observers with expertise in crisis resource management. And rather than being an advanced research tool, it is inspired by the telestrator devices used by sports commentators on television. Today the analysis of the video recordings is to a large degree an instructor-led activity. Our aim was to create a tool which would instead push participants into becoming more active observers. One issue affecting the design of the computer-based tool itself was that almost all course participants have limited time available since almost all participants have full-time jobs to return to. Moreover, the target population has a low motivation to engage in using new computer software tools requiring that new tools have a low threshold for getting started with.

Fig. 1. The simple version with oversized buttons allowing users to easily mark critical (red button with exclamation mark) or good (green button with plus sign) team performance as well as add marks for questions (yellow button with question mark)

The objective was to be able to annotate the teamwork and communication in the simulations in a coarse way and that the annotations could form a basis for discussion and analysis. The prototype is a simple annotation tool for “flagging” critical incidents on video recordings; users can make markings of problematic and good team behavior which are stored with the recordings. The markings can be made in different ways and different versions are currently tried out. The simplest version lets users mark team performance as either problematic (red) or good (green) as well as mark whenever questions arise which could be discussed, see Fig. 1. What is categorized as good or as problematic is not predefined in this version but up to annotators to decide freely.

Since leadership, teamwork and communication are essential parts of simulation courses, the use of the tool should support the learning of a common model or framework taught in the courses. As part of this work a conceptual model was developed capturing some of the key team behaviors required for successful teamwork and communication in neonatal resuscitation teams and which could be used in the debriefing sessions and be the foundation for the annotation in the planned tool: the APCER model, described in [11]. The model covers key issues concerning efficient medical teamwork and team communication and was designed to include a number of observable behaviors. The objective was to make key issues more explicit and to provide a shared conceptual tool for discussions during debriefings. An alternative design therefore uses a version of the model so that users can mark each APCER behavior as well-performed or as improvable, see Fig. 2 which shows the simple buttons replaced by the behavior buttons. Users can click either + or – buttons corresponding to each behavior. To exemplify such behaviors, team leaders might share their plans clearly to the team by thinking aloud and team members confirm and repeat ordinations clearly both rendering green + marks. Or the teams may evaluate their work too rarely or not call for help in time which may result in red – marks. Both kinds of annotations are presented as green and red markings on a timeline in the interface, as can been seen in Fig. 3. Many red markings at the beginning and towards the end reveal that the annotators considered some aspects of the team performance problematic and not living up to the desired criteria at these occasions. The timeline and its markings thus give a quick overview of how a particular simulation was perceived and attention can easily be directed to those parts which appear interesting.

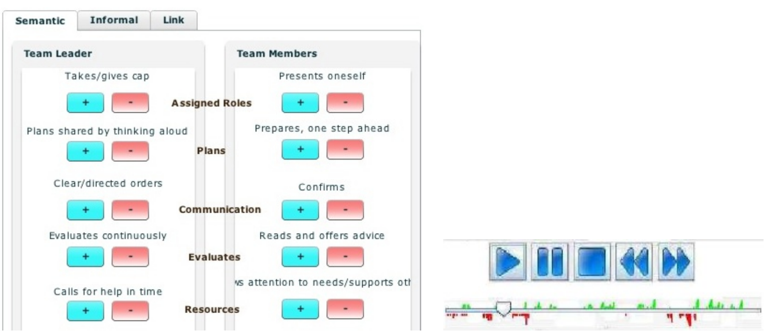

Fig. 2. Using the APCER behaviors on the left users can annotate the simulations and these are represented as green markings above and red below the timeline at the bottom of the screen

Practicing the process of annotating is in itself the primary educational goal rather than to obtain a perfect documentation of video material. With the tool, participants are able to train their skills in identifying critical incidents individually right after having taken part in an simulation. Afterwards when the entire team meets again and watches the recording, the annotations of the whole team are collectively presented with the video recording, i.e., the recordings now not only show the video but also a visualization including the annotations of each participant. In the “Player mode”, the annotations are shown as well as basic statistics about the occurrence of the various behaviors, see Fig. 3. The annotations make different perspectives clearly visible – when parts are marked in different ways these will stand out visually on the timeline. The tool is also intended to be used for the training of instructors in their feedback skills; the tool gives hints about how different instructors’ observations overlap and differ.

Fig. 3. In the Player mode the video recording is shown with information about each annotation as well as statistics about all annotations concerning the particular simulation

3 Concluding Remarks

Few tools for analyzing team performance in simulations are appropriate for learners who are not especially trained observers or researchers. While a number of advanced annotation tools do exist, these are typically intended for experts; either in interaction analysis or someone especially appointed and trained for observing, documenting or assessing the behavior of the medical teams. The annotation tool discussed here has in contrast been created with the objective of creating a tool for learners, i.e., the course participants or for course instructors/facilitators who want to train their skills in analyzing teamwork and communication. The simplicity of the tool has been emphasized in order to develop a tool which could be used with only a short introduction by users with little time and motivation for learning new tools - user studies are currently being carried out to evaluate how successful that goal has been. As many annotation tools instead appear to focus on “the learning material” to be annotated it is only natural that ‘usability’ is defined as cases where manual annotation does not “disturb” learning activities and to view annotation performed by software agents as a promising direction [2]. Here, however, annotation cannot disturb learning – annotating itself is what is to be learned. The point of the tool is not primarily to make the final, complete assessment (other tools are better for this). But rather to engage participants in the process of annotating and thereby hopefully reflection on team performance by showing the annotations of several users and by visualizing differences and interesting sections in the recordings. The timeline visualizes all annotations of a simulation giving a useful overview of how a simulation has been perceived by an entire group of users. This kind of tool could potentially also be useful in other contexts where video recordings are used for educational purposes, e.g., for leadership or so called standardized patient exercises in medical education or for behavior management in general.

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References

1. ANTS. Framework for Observing and Rating Anaesthetists' Non-Technical Skills - Anaesthetists' Non-Technical Skills (ANTS) System Handbook v1.0 [cited July 20, 2007] (2004), http://www.abdn.ac.uk/iprc/ants_papers.shtml
2. Azouaou, F., Chen, W., Desmoulins, C.: Semantic Annotation Tools for Learning Material. In: CAiSE 2005. Porto, Portugal: FEUP edicoes (2005)
3. Bergs, E.A.G., Rutten, F.L.P.A., et al.: Communication during trauma resuscitation: do we know what is happening? Injury 36(8), 905–911 (2005)
4. Carbine, D.N., Finer, N.N., Knodel, E., Rich, W.: Video Recording as a Means of Evaluating Neonatal Resuscitation Performance. Pediatrics 106, 654–658 (2000)
5. Cooper, S., Wakelam, A.: Leadership of resuscitation teams: "Lighthouse Leadership". Resuscitation 42, 27–45 (1999)
6. Finer, N.N., Rich, W.: Neonatal resuscitation: toward improved performance. Resuscitation 53(1), 47–51 (2002)
7. Gaba, D.M.: The future vision of simulation in health care. Quality & Safety in Health Care 13, i2–i10 (2004)
8. Halamek, L.P., Kaegi, D.M., et al.: Time for a New Paradigm in Pediatric Medical Education: Teaching Neonatal Resuscitation in a Simulated Delivery Room Environment. Pediatrics 106(4), e45 (2000)
9. Helmreich, R.L., Merritt, A.C.: Culture at Work in Aviation and Medicine - National, Organizational and Professional Influences: Asgate (1998)
10. Hoff, W., Reilly, P., et al.: The Importance of the Command-Physician in Trauma Resuscitation. Journ. of Trauma-Injury Infection and Critical Care 43(5), 772–777 (1997)
11. Karlgren, K., Dahlström, A., Lonka, K., Ponzer, S.: A new educational annotation tool for supporting medical teams to improve their teamwork and communication. In: ICEM/ILE 2007 – The International Council for Educational Media: "Educational Media & Innovative Practices" in conjunction with Innovative Learning Environments, Nicosia, Cyprus (2007)
12. Kulk, R., Janssen, J., Gielis, A.-M., Scheringa, E.: DiViDU - Learning from Professional Practice through Online Video. In: World Conference on Educational Multimedia, Hypermedia and Telecommunications 2005. AACE, Chesapeake (2005)
13. Risser, D.T., Rice, M., et al.: The potential for improved teamwork to reduce medical errors in the emergency department. Annals of Emergency Medicine 34(3), 373–383 (1999)
14. Thomas, E.J., Sexton, J.B., Helmreich, R.L.: Translating teamwork behaviours from aviation to healthcare: development of behavioural markers for neonatal resuscitation. Qual. Saf. Health Care (13), i57–i64 (2004)

A Domain-Specific-Modeling Approach to Support Scenarios-Based Instructional Design

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Abstract. Over recent years, Model-Driven-Engineering has attracted growing interest as much as a research domain as an industrial process that can be applied to various educational domains. This article aims to discuss and propose such an application for learning-scenario-centered instructional design processes. Our proposition is based on a 3-domain categorization for learning scenarios. We also discuss and explain why we think Domain-Specific Modeling techniques are the future new trend in order to support the emergence of communities of practices for scenario-based instructional design. The originality resides in the support we propose to help communities of practitioners in building specific Visual Instructional Design Languages with dedicated editors instead of providing them with yet another language or editor.

Keywords: Instructional Design, Learning Scenario, Educational Modeling Language, Model Driven Engineering, Domain Specific Modeling, Visual Instructional Design Language.

1 Introduction

Over the last years, the Model-Driven Engineering (MDE) principles [1] have been applied and acclaimed as of great interest within various educational disciplinary fields: adaptable learning materials generation [2], Computer Supported Cooperative Work [3], user modeling [4], etc. In this paper, we focus on application of MDE theories and practices for learning-scenario-centered instructional design processes.

Current context analysis about languages, tools and techniques for learning scenarios [5] highlights the need for user-friendly end-user languages and tools, and implementation tools to help designers in setting up Learning Management Systems. We are interesting in providing end-users, acting as both teachers and designers (sometimes mentioned as 'practitioners'), with dedicated Educational Modeling Languages (EML) or Visual Instructional Design Languages (VIDL) [6], and tools. These editor-tools have to help them specify learning scenarios with their own terminology, graphical formalism, and editing preferences, without leaving aside computerizing trends concerning the produced scenarios (reuse, interoperability, etc.).

Our past experiences about graphical representations of learning scenario [7] and scenario transformations between different EMLs [8], lead us to deal with MDE

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techniques and finally to a new orientation we are currently experimenting: Domain-Specific Modeling (DSM) [19] as a new approach for modeling and formally specifying learning scenarios. This paper aims to present and discuss the potential of DSM techniques and tools when applied in our instructional design context. We purposely propose a conceptual framework underlying our approach: a categorization based on a domain-oriented separation of concerns.

The next section briefly presents the MDE in order to understand its underlying concepts. We then discuss the MDE application to the specific context of the learning-scenario-centered instructional processes. We then present our 3-domain categorization for learning scenarios and our orientation towards Domain-Specific Modeling. Before the conclusion we illustrate and discuss our first results about the use of DSM tools to specify VIDL and build dedicated editors.

2 Model-Driven Engineering Principles

The Model Driven Architecture (MDA) is a framework for software development adopted by the Object Management Group in 2001 [9]. It aims to provide a solution to the problem of software technologies continual emergence that forces companies to adapt their software systems every time a new 'hot' technology appears. The solution proposed consists of separating the enterprise functionalities of an information system from the implementation of those functionalities on specific technological platforms, and also by using an intensive model-based design and development.

The MDA approach sorts models into three classes. The Computation Independent Model (CIM) where the used vocabulary is the business one, helping to specify exactly what the system is expected to do. The Platform Independent Model (PIM) leads to independence from specific platforms but should be expressed in a computational way, so as to be suitable for use with a number of different platforms of similar type. Finally, the Platform Specific Model (PSM) links the specifications in the PIM with the details that specify how this system will be implemented on a specific platform. Mappings between PIM and PSM can be accomplished by means of model transformations. MDA aims at automating these model transformations as much as possible. Finally, code can be generated from the PSM.

The Model Driven Engineering is a more general and global approach, aiming to apply and generalize MDA principles for every technological space (object-oriented space, XML documents, grammarware, etc.). It is founded on these principles:

- Capitalization: models are to be reusable,
- Abstraction: domain models have to be independent from implementation technologies in order to more easily adapt application business logic to them,
- Modeling: models are no longer contemplative (to document, communicate, etc.) but in a productive way (they are machine-interpretable),
- Separation of concerns: the MDE is generally illustrated with the separation of concerns between domain and technology but other separations are possible.

To dispose of productive models, they must be well-defined, i.e. corresponding to a specific meta-model. Productive models can be handled, interpreted with MDE tools [10]: meta-model/language definition tools, transformation tools, code generation tools, weaving tools, generation of domain-specific model editors, etc.

3 Model-Driven Engineering and Instructional Design

3.1 Past and In-Progress Research

Many research works focus on the definition of EML [5] and also discuss IMS-LD [11] considered as the current standard for specifying scenarios. IMS-LD models are formally described into XML documents because of the standard objectives (interoperability, reuse, etc.). Some works explicitly claim their MDE positioning:

The **CPM language** [12] is a UML-based visual language dedicated to the definition of Problem Based Learning situations by specific designers. CPM models act as a support for communication within a multidisciplinary design team. The CPM language is concretely provided as a UML profile. Model transformations from CPM activity diagrams to IMS-LD-compliant scenarios have been studied.

The **Bricole project** [13] propose a transformation model application to set up an LMS from any IMS-LD-compliant scenario by transforming the IMS-LD source scenario (graphically modelled with the **ModX** tool) into another graphical LMS specific scenario (**Gendep** tool) that is interpreted to automatically configure the LMS via a specific service web based API.

The **LDL language** [14] is a CSCW domain-specific language aiming to specify such dedicated scenarios. This language is concretely proposed as a specific XML binding but recent works aim to provide it with a visual formalism.

MOT+LD formalism [15] providing an extension of the MOT notation and dedicated edition tool to conform to IMS-LD standard for defining learning scenarios.

Other research works aim to provide teacher-designers with an automatic graphical representation of IMS-LD scenario (XML document). The concrete technique uses imperative transformations from XML to a **UML4LD** representation (UML profile dedicated to IMS-LD) via the Objecteering tool [7].

Recent works [16] also proposed a graphical environment, MDLD (Model-driven Learning Design Environment), in order to help learning designers to generate units of learning (XML) conformed to IMS-LD by graphically specifying BPEL-oriented modeling (BPEL is an abstract language for modeling business process execution).

3.2 Discussions

The models produced/transformed into MDE processes correspond to the learning scenarios in instructional design processes and are generally defined/specified thanks to an EML. Whatever the formalism used (graphic, textual, etc.) we can consider that every EML can describe its underlying terminology as a meta-model.

The final system, in a MDE process, corresponds to the learning situation aimed in an instructional design process. The difference is that this learning situation relies on both human and system artifacts, not only code (instructional design processes do not aim to produce code but units of learning that can be deployed into LMS that pre-exist them). For example, learning-scenarios are generally either automatically interpreted by LMS (via an import facility), or used by LMS experts to manually configure LMS. All EML or VIDL languages can be compared from many point of views, so many separations of concerns can be applied to distinguish one learning scenario from another. For example, [17] distinguish five features to compare VIDL languages: stratification, formalization, elaboration, perspective and notation system.

We also want to highlight the omnipresence of the business learning domain: whatever the EML/VIDL used to express a learning scenario (very specific domain scenarios, standards based scenarios, ...) they all are expressed with a more or less abstract/specific learning syntax (concepts/relations) and semantics. All these business domains reflect some specific particularities: pedagogical approaches / theories, didactic domains, etc. This notion of « business learning domain » materialize the vocabulary/language shared by pluridisciplinary design teams; every learning design community shares its own business learning domain.

Another key point concerns learning scenarios visual representation. It appears to be as important for domain-specific learning scenarios, as for understanding shared scenarios complying to standards, as for helping the manual configuration of LMS.

Finally, all those points led us to the idea that a simple CIM/PIM/PSM application is not relevant because of the business omnipresence and the overall visual interest for representing scenarios. This is why we propose a new domain-specific approach.

4 The 3-Leaf Domain-Clover

4.1 Proposition

Our approach proposes three categories for learning scenarios and languages from a separation of concerns reflecting different communities of practices sharing a comparable business learning domain towards specific objectives.

- **Practitioners-centered Scenario (PS)**: the vocabulary is the one shared by a pluridisciplinary design team; it expresses their common vocabulary (e.g. in relation to some pedagogical theories as well as specific references to the LMS they use). Objectives of such scenarios are to ease the definition of the learning scenario, to act as a design guide, and a support to thinking/communicating.
- **Abstract Scenario (AS)**: the vocabulary aims to be independent from any LMS in order to support the interoperability of scenarios. This abstraction also usually reflects a high-level abstraction of the vocabulary used from pedagogical theories and didactic fields. Objectives aim at supporting pedagogical diversity and innovation, while promoting the exchange and interoperability of scenarios.
- **LMS-centered Scenarios (LS)**: the vocabulary is specific to a dedicated LMS or other e-learning platforms. The objectives are to act as a guide for the manual or semi-automatic configuration of the technical dispositive by humans as well as for automatic configuration by machines when possible.

In addition we propose to split each categorization into two parts:

- One part for **human-directed interpretation**, and dedicated visual formalism (human-readable textual/graphical notation),
- And the other one for **machine-directed interpretation** (machine-interpretable formal notation, i.e. no ambiguous semantics).

Although these two parts can be used as a new feature to compare VIDLs/EMLs, we think that they are both useful and have to be both provided by any instructional design language. This approach is conformed to the MDE paradigm where models have to be productive, not only contemplative. Learning scenarios have to be both contemplative (for human interpretation) and productive (for machine execution in order to realize simulations, predictions, transformations, etc.). These dual-characteristics for a learning scenario have to be taken into account when designing a new VIDL/EML (a kind of model/view pattern). As an example it guarantees that transformation will be not needed to visually represent a XML-formatted scenario or to let the computer interpret a diagrammatic-view of a scenario.

In our thinking the three categorizations (PS/AS/LS) share fuzzy frontiers between each other. Also, we do not think instructional design processes handling learning scenarios must systematically follow all these categorizations. We do not propose a systematic way to transform scenarios from one to another. On the contrary we think that designers must be free to decide which EML/VIDL is useful according to their objectives and target public (human or machine interpretation).

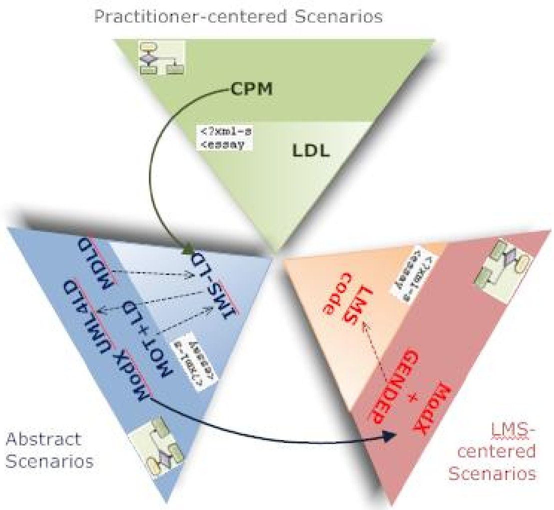

Fig. 1. The three-leaf domain-clover annotated with a projection of current research works

Key point concerns the transformation from one type of scenario to another. When source and target scenarios are from different EMLs, the transformation is extra-domain; it necessary happens from one category to another but also between different EMLs from the same category. The interest of such transformations is to gain the objectives of the targeted categorization, when changed, or to exchange and reuse scenarios with other communities of practices that do not share the same business learning domain. On the contrary, when source and target scenarios share the same abstract syntax (metamodel) but differ from the used concrete syntax (notation), the transformation is intra-domain. This kind of transformation is useful to adapt to a different target public and objectives by changing the format of the learning scenarios.

4.2 Illustration

We illustrate our proposition into the figure 1. We also position into this figure the research work (languages and tools) briefly presented in section 3.1.

CPM and LDL are practitioners-centered languages; CPM being more a VIDL because of its human-directed notation than LDL which only offers a machine-interpretable formalism for now [18]. Also, the CPM tooling proposes a service that transforms CPM activity diagrams to IMS-LD scenarios.

The abstract category with a machine-oriented formalism suits the IMS-LD standard well. We position the MOT+LD proposition in the same category but with a human-directed notation (the MOT+ formalism has been extended to consider IMS-LD vocabulary). Works about UML4LD are both a visual formalism for IMS-LD (abstract category with human notation) and a transformation mechanism from IMS-LD scenarios to UML4LD ones. Because the MDLD environment offers an abstract language (but not dedicated to learning scenarios) to model chunks of learning processes that are then transformed into IMS-LD, we position it in this same category.

Finally, works about the Bricole Project propose the ModX tool to model scenarios in both abstract and LMS-centered visual notations, and the GenDep tool to ensure the transformation between these two formalisms. We also add that CPM and ModX tools can save the produced scenarios in a machine-interpretable formalism (XMI).

4.3 Tooling Needed to Support the Proposition

The 3-leaf domain clover we propose can be considered as, and used as, a theoretical tool for classifying existent VIDL/EML or tools as we used it in the previous illustration subsection. It also concretizes our vision of current communities of practices about learning scenarios. The 3-leaf domain clover is a model of this vision.

Our research works aim at supporting the emergence of communities of practices from this model. But to reach this goal, our proposition needs concrete tools and techniques to support and ease the emergence of such communities:

1. Tools for defining domain-oriented VIDL/EML (metamodeling technique concepts/relations specification plus techniques to define both machine-interpretable and human-readable formalisms). Although these tools will be used by MDE experts, members of the pluridisciplinary team would have to participate in expliciting their vocabulary and the visual notation they want.
2. Tools/techniques for defining learning scenarios corresponding to domain-oriented VIDL/EML previously created (eg. graphic editors). These tools will have to be as user-friendly as possible for being used by practitioners.
3. Tools/techniques for intra & extra transformations of learning scenarios. Indeed, we do not aim at clustering instructional design actors within communities that do not communicate. We contrarily claim that bridges between these communities are an important point of our proposition.

Although current instructional design research proposes some VIDL and various kind of user-friendly editors [6], there is no research work that proposes the tooling we have highlighted, none of them technically addresses the support of emergent VIDL-based communities of practices. We think that the Domain-Specific Modelling (DSM) research field provides tools and techniques supporting most of these needs.

5 Towards Domain-Specific Modeling for the Instructional Design

5.1 DSM Domain and Tools

The Domain-Specific Modelin [19] is a software engineering methodology for designing and developing systems, most often IT systems such as computer software. It involves the systematic use of a graphic Domain-Specific Programming Language (DSL) to represent the various facets of a system. We are interested by these graphical DSL, also called Domain-Specific Modeling Languages (DSML).

Several technical approaches coexist presently to support the specification of DSML [20]: commercial products like MetaCase/MetaEdit+ [28], the Microsoft DSL tools (based on the Software Factories vision)[27], and academic propositions or open-source projects [24] like VMTS, TIGER, EMF, GEF, GMF, etc. [29].

All these DSM tools propose metamodeling techniques capable of expressing domain-specific vocabularies (abstract syntaxes), and propose facilities to construct various notations (concrete syntaxes). These editing frameworks are supporting the techniques and many more customizations with minimal programming effort. As a result, these tools can generate powerful and user-friendly dedicated editors for DSM languages. They are kind of meta-CASE editors capable of generating CASE tools. The final editors give domain-designers the ability to graphically specify models from their domain, and propose some persistence facilities to load and store these models in a machine-interpreted format. This machine-directed format is always independent from the notation used to visually represent the model.

5.2 Using DSM Tools

It seems obvious that DSM tools meet most of the needs we need in order to support our domain-oriented proposition for the Educational Modeling Languages and learning scenarios. Concretely, needs previously numbered 1/, 2/ and 3/a (intra-transformations) are supported (cf. §4.3). DSM principles are also convenient with our 3-leaf domain-clover and more generally seem able to support the emergence of VIDL/EML communities of practices as well as providing practitioners with user-friendly visual editors for specifying learning scenarios.

In order to understand the potential of DSM tools use, let us illustrate examples of concrete results one can expect to get according to our 3-leaf domain clover:

- A VIDL specific to a team of practitioners that usually designs scenarios following a constructivist approach (pedagogy), for the mathematics field (didactic), and with some references to concepts particular of Moodle platform they use to use (Technology Enhanced Learning system).
- A VIDL specific to IMS-LD that proposes a multi-layered and diagram-oriented editor to visually specify IMS-LD scenarios that are directly build as XML-files conformed to the IMS-LD standard.
- A VIDL specific to the Moodle platform (on the contrary of the first example that is not entirely specific to an environment) that is used by practitioners, expert of this LMS, to conceptualize and specify their distant courses before operationalizing them into the Moodle platform.

Although DSM tools support most of the needs we mentioned, we also need tools for supporting some bridges between the future communities. Concretely, these tools would have to transform learning scenarios produced by a DSM-based instructional design editor (in conformance with a dedicated VIDL) to another format compatible with another one DSM-based editor (dedicated to another VIDL). Such transformations tools exist from the Model-Driven Engineering domain: ACCELEO [25], Merlin [26], etc. Some works have already experimented some of these tools: the ATL [21] tooling has been used to transform learning scenarios conformed to a Project-based and collaborative pedagogy, towards Moodle-specific scenarios [22]. We plan to experiment more with these transformation tools. For now we illustrate in the following section the first results we get from the experiments of one DSM tool.

6 Illustration and First Results

6.1 Context

We are currently experimenting the Graphical Modeling Framework (GMF) [23] to support the DSM approach for learning scenarios. GMF is an Eclipse project. Its goal is to form a generative bridge between EMF and GEF, other Eclipse meta-modeling projects, whereby a diagram definition is linked to a domain model as an input to the generation of a visual editor.

Among the various case studies we have experimented with GMF, we sketch the following one. Some practitioners have expressed these pedagogical expressiveness and notation needs: a UML UseCase-like diagram that permits to express performing relations between roles and learning activities at a high-level of abstraction. Also, the practitioners would like to express precedence/following relationships between the learning activities. Because the UML UseCase diagram is not able to express time-related relationships between use-cases, our experiment work consisted in providing these practitioners with a dedicated visual editor, built using GMF, able to express such scenario representation. Also, we decided to provide them with a specific VIDL guarantying that the produced models will be both human-readable for them but also machine-interpretable for further usages.

6.2 The VIDL and Editor Designed

A basic domain model for the « Learning Design Use Case » view has been defined. It is illustrated into the following figure 2 (a diagram-view of the concrete domain model whose native format is XML).

According to the GMF engineering process, we have successively designed a graphical definition model (defining the figures, nodes, links, etc. that will be draw into the final usecase-like view), a tooling definition model (specifying the palette, creation tools, actions, etc.), and a mapping definition model (binding all the previous models with the domain one).

Finally, after a code generation step, a specific editor (embedding the VIDL dedicated to the practitioners' requirements) is generated and fully operational. The figure 3 shows an example of a scenario graphically realized with this editor (the human-readable « view »). Concretely, the scenario is serialized in a machine-interpretable format (XMI) depicted in the figure 4.

We planned three different experimentation for the next months to study more deeply the GMF potential added value. Two of them concern the Practitioners-directed

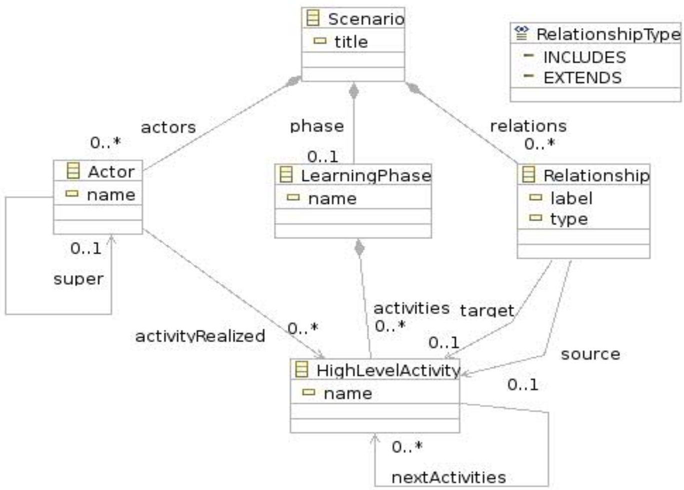

Fig. 2. The “Learning-UseCase” meta-model (or domain model) experimentation

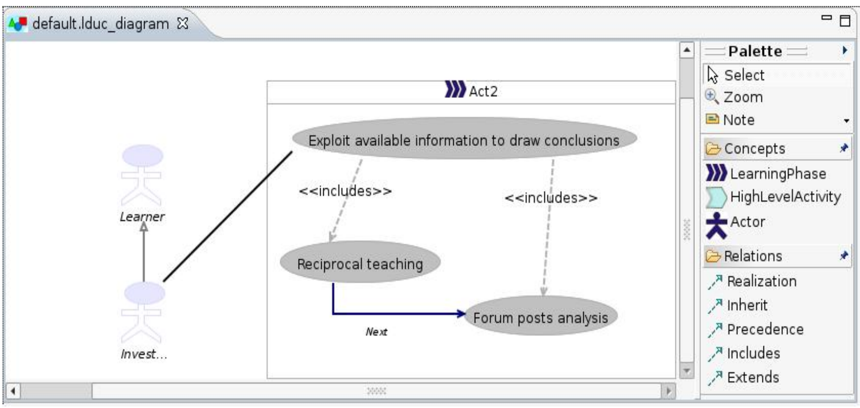

Fig. 3. Model designed with a specific editor generated with the GMF DSM meta-tool

```xml
<?xml version="1.0" encoding="UTF-8"?>
<lduc:Scenario xmi:version="2.0" xmlns:xmi="http://www.omg.org/XMI" xmlns:lduc="lduc">
  <phase name="Act2">
    <activities name="Exploit available information to draw conclusions"/>
    <activities name="Reciprocal teaching" nextActivities="//@phase/@activities.2"/>
    <activities name="Forum posts analysis"/>
  </phase>
  <actors activityRealized="//@phase/@activities.0" name="Investigator" super="//@actors.1"/>
  <actors name="Learner"/>
  <relations label="includes" source="//@phase/@activities.0" target="//@phase/@activities.1"/>
  <relations label="includes" source="//@phase/@activities.0" target="//@phase/@activities.2"/>
</lduc:Scenario>
```

Fig. 4. The model in the serialized format (XMI)

Scenarios category from our 3-leaf domain clover model. The third one concern the LMS-directed Scenarios category: we want to study the added value of providing experts of the LMS used in our university with a dedicated VIDL and visual editor.

7 Conclusion

This article has presented and discussed a specific Model-Driven Engineering application for scenario-based instructional design. The originality of our proposition resides in the three categories for learning scenarios and languages: they reflect different communities of practices sharing a same business learning domain towards specific objectives. We also propose a two-part division for each category to distinguish the targeted public: human or machines.

We have then argued our current orientation about Domain-Specific Modeling (DSM) techniques and tools to support our proposition. DSM is a model-based approach that gives domain experts the freedom to use structures and logic that are specific to their learning domain. Another originality of our research position is that we do not aim to provide practitioners with yet another Visual Instructional Design Language (VIDL) with its dedicated editor but we aim to provide them with techniques and tools that help and support them in specifying and building the VIDL and editors they need.

We have also illustrated our first results about the use of the Graphical Modeling Framework from the Eclipse projects. These first results have proved the ability of such DSM tools to build specific VIDL and to generate user-friendly dedicated editors. We are currently improving our experiments of the DSM tools. We are also experimenting model transformations tools in order to support the design of 'bridges' between different learning scenario communities of practices.

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References

1. Schmidt, D.C.: Model-Driven Engineering. IEEE Computer 39(2) (2006)
2. Dodero, J.M., Díez, D.: Model-Driven Instructional Engineering to Generate Adaptable Learning Materials. In: Proceedings of ICALT 2006, Kerkrade, The Netherlands. IEEE, Los Alamitos (2006)
3. David, B.T., Chalon, R., Delotte, O.: Model-Driven Engineering of Cooperative Systems. In: 11th International Conference on Human-Computer Interaction (HCII 2005), Las Vegas, Nevada, USA (2005)
4. Marinilli, M.: Model-Driven User Adapted Systems and Applications. PhD Thesis (2005)
5. Kinshuk, S.D.G., Patel, A., Oppermann, R. (eds.): Special issue: Current Research in Learning Design. Journal of Educational Technology & Society V(9)-1 (2006)
6. Botturi, L., Todd Stubbs, S.: Handbook of Visual Languages for Instructional Design: Theories and Practices. Information Science Reference (2007) ISBN-13: 978-1599047317
7. Laforcade, P.: Visualization of Learning Scenarios with UML4LD. Journal of Learning Design 2(2), 31–42 (2007)

8. Laforcade, P., Nodenot, T., Choquet, C., Caron, P.-A.: Model-Driven Engineering (MDE) and Model-Driven Architecture (MDA) applied to the Modelling and Deployment of Technology Enhanced Learning (TEL) Systems: promises, challenges and issues. In: Pahl, C. (ed.) Architecture Solutions for E-Learning Systems (2007)
9. OMG: MDA specification guide version 1.0.1. Report – omg/03-06-01 (2001)
10. Bézivin, J., Gérard, S., Muller, P.-A., Rioux, L.: MDA components: Challenges and Opportunities. In: Metamodelling for MDA (2003)
11. IMS: Learning Design Version 1.0 Final Specification. Technical report (2003)
12. Laforcade, P.: Towards a UML-based Educational Modeling Language. In: Proceedings of ICALT 2005, Kaohsiung, Taiwan, pp. 855–859 (2005)
13. Caron, P.-A.: Web services plug-in to implement “Dispositives” on Web 2. In: Duval, E., Klamma, R., Wolpers, M. (eds.) EC-TEL 2007. LNCS, vol. 4753. Springer, Heidelberg (2007)
14. Martel, C., Vignollet, L., Ferraris, C., David, J.-P., Lejeune, A.: Modeling Collaborative Learning Activities on e-Learning Platforms Advanced Learning Technologies. In: Proceedings of ICALT 2006, Kerkrade, The Netherlands, pp. 707–709. IEEE, Los Alamitos (2006)
15. Paquette, G., Léonard, M., Lundgren-Cayrol, K., Mihaila, S., Gareau, D.: Learning Design based on Graphical Knowledge-Modeling. Educational Technology & Society 9(1), 97–112 (2006)
16. Dodero, J.-M., Tattersall, C., Burgos, D., Koper, R.: Non-representational authoring of learning designs: from idioms to model-driven development. In: Leung, H., Li, F., Lau, R., Li, Q. (eds.) ICWL 2007. LNCS, vol. 4823. Springer, Heidelberg (2008)
17. Botturi, L., Derntl, M., Boot, E., Figl, K.: A Classification Framework for Educational Modeling Languages in Instructional Design. In: Proceedings of ICALT 2006, Kerkrade, The Netherlands. IEEE, Los Alamitos (2006)
18. Martel, C., Vignollet, L., Ferraris, C.: LDL for Collaborative Activities. In: Handbook of Visual Languages for Instructional Design: Theories and Practices, Information Science Reference (2007) ISBN-13: 978-1599047317
19. Kelly, S., Tolvanen, J.-P.: Domain-Specific Modeling, March 2008, p. 427. Wiley-IEEE Computer Society Press (2008) ISBN: 978-0-470-03666-2
20. Jouault, F., Bézivin, J., Consel, C., Kurtev, I., Latry, F.: Building DSLs with AMMA/ATL, a Case Study on SPL and CPL Telephony Languages. In: Proceedings of the 1st ECOOP Workshop DSPD. Nantes, France (2006)
21. Allilaire, F., Bézivin, J., Jouault, F., Kurtev, I.: ATL - Eclipse Support for Model Transformation. In: Proceedings of the Eclipse Technology eXchange workshop (eTX) at the ECOOP 2006 Conference. Nantes, France (2006)
22. Abdallah, F., Toffolon, C., Warin, B.: Models transformation to implement a Project-Based Collaborative Learning (PBCL) scenario: Moodle case study. In: Proceedings of ICALT 2008, Santender, Spain. IEEE, Los Alamitos (to appear, 2008)
23. Eclipse, The Eclipse Graphical Modeling Framework (retrieved, January 2008), `http://www.eclipse.org/gmf/`
24. Taentzer, G.: Towards Generating Domain-Specific Model Editors with Complex Editing Commands. In: Proc. International Workshop Eclipse Technology eXchange (eTX), Satellite Event of ECOOP (2006)
25. ACCELEO (retrieved, April 2008), `http://www.acceleo.org/pages/using-acceleo-with-gmf/`
26. MERLIN (retrieved, April 2008), `http://merlingenerator.sourceforge.net/merlin/index.php`

27. Microsoft DSL tools, `http://msdn.microsoft.com/vstudio/DSLTools/`
28. Kelly, S., Lyytinen, K., Rossi, M.: MetaEdit+: A Fully Configurable Multi-User and Multi-Tool CASE Environment. In: Constantopoulos, P., Vassiliou, Y., Mylopoulos, J. (eds.) CAiSE 1996. LNCS, vol. 1080, pp. 1–21. Springer, Heidelberg (1996)
29. Pelechano, V., Albert, M., Muñoz, J., Cetina, C.: Building Tools for Model Driven Development. Comparing Microsoft DSL Tools and Eclipse Modeling Plug-ins. In: III Taller sobre Desarrollo de Software Dirigido por Modelos. MDA y Aplicaciones (DSDM), Sitges (Spain) CEUR Workshop Proceedings, vol. 227 (2005) (in English) ISSN 1613-0073

A Heuristic NLP Based Approach for Getting Didactic Resources from Electronic Documents

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Abstract. The development of Computer Supported Learning Systems is a hard task and, therefore, they are not as broadly used as expected yet. Some authors have claimed that tools for generating learning material in automatic or semiautomatic way are needed. This paper describes how didactic resources can be semi automatically generated from electronic documents using ontologies and Natural Language Processing techniques. Gathering atomic didactic resources and combining them is essential to get results that match human instructors' expects. Several didactic resource similarity measuring methods have been implemented and tested.

Keywords: Computer Supported Learning Systems, Semi Automatic Domain Acquisition, Didactic Resources, Ontologies.

1 Introduction

Although the *domain module* has been the deepest studied module in the development of Computer Supported Learning Systems (CSLSs), the content authoring process still remains as a complex task, especially for teachers and instructors not expert in the computational field. . Up till now some efforts had been done with the aim of facilitating instructors work [1]. Brusilovsky *et al.* [2] propose differentiating teachers and computer specialists works: *"while the construction of the core systems has to be done by expert developers, the teacher add their favourite contents (e.g., explanations, examples, exercises, etc.)"*. The same approach has been also applied in the construction of some algebra tutors [3, 4]. Although some authors like Murray [5] pointed out the need of tools that facilitate the construction of the domain module in a semi automatic way, not much work has been yet oriented to fulfil this objective.

Advances in AI methods and techniques from Natural Language Processing (NLP) and heuristic reasoning allow extracting the domain knowledge of a CSLS from existing documents [6]. The work presented in this paper focuses on the identification of the Didactic Resources (DRs) related to the topics included in a domain ontology. Textbooks for primary school students written in Basque language and provided by the *Gipuzkoako Ikastolen Elkartea*[1] have been used as starting point. Some experiments

[1] http://www.ikastola.net/

P. Dillenbourg and M. Specht (Eds.): EC-TEL 2008, LNCS 5192, pp. 197–202, 2008.

have been conducted comparing automatic identification and classification of DRs and human experts' behaviour in those tasks. The paper starts with a brief description of the process of identification and creation of didactic resources from documents. Later, the evaluation results are detailed. Finally, some conclusions and future work are pointed out.

2 Generation of Didactic Resources from Electronic Documents

The generation of didactic resources from electronic documents relies on the identification of the patterns, i.e. syntactic structures, which are most frequently used when defining new topics, describing theorems or proposing exercises. The approach presented here is domain independent, since the only domain-specific knowledge used is the domain ontology, which has been previously gathered from the electronic document in a semi automatic way [6]. First, a linguistic analysis is performed on the document obtaining the *part-of-speech* information. This information, the original document and the domain ontology previously gathered from the document [6] are used in the next step, DR identification, in order to find fragments of the document that correspond to DRs. The identification of the DRs is carried out using a grammar, i.e. a set of rules that defines the different patterns or syntactic structures observed in the analysed documents. The result of the DR identification process is a set of atomic DRs, i.e. sentences that contain a DR. In this step, each DR is annotated with the kind of DR (example, definition …) and the domain topic(s) it relates to.

Table 1. Algorithm for DR composition

```
while Not changesDone
      newDRList ← new DRList()
      iterator = drList.iterator()
      while iterator.hasNext()
            currentDR ← iterator.next()
            currentDR ← joinConsSimilDRs(currentDR,iterator)
            assureCohesion(currentDR)
            newDRList.add(currentDR)
      end
      drList ← newDRList
end
```

The obtained DRs are usually quite simple, so they are enhanced following the algorithm in Table 1. On the one hand, consecutive DRs are combined if they are similar. On the other hand, and in order to keep the cohesion of the DRs, previous fragments are added to each DR if these DRs contain references to previous DRs or sentences. The composite DRs are built as an aggregation of DRs of lower granularity and keep the information about why they were composed (cohesion maintenance, similar DRs) and the similarity rates. This process is repeated until no more changes are performed in the DRs and it is crucial in order to get really reusable DRs. It is based on similarity measures between DRs, which are determined by two aspects: the similarity of their topics, i.e. the domain topics they reference, and the resemblance of the types of DRs. The methods that determine the similarities return a value in the [0, 1] range. Two DRs are considered similar if the obtained topic similarity and the DR type similarity are beyond the corresponding threshold values.

Content similarity measuring methods determine if two DRs are similar according to their content, i.e., the topics of the domain they reference. Four methods have been implemented and tested:

- **Same Topics Method:** It determines that two DRs are similar if the first one references all the domain topics mentioned in the second DR and vice versa.
- **Share Topic Method:** Two DRs are considered similar if the first one makes reference at least to one of the domain topics mentioned in the second DR.
- **Cosine Method:** Cosine measure is one of the most used means of calculating the similarity of two texts. The cosine measure is given by the formula (1), where *d* and *d'* are the vectors used to model each text. In this work, each vector element contains how many times the corresponding domain topic is referenced in the DR.

$$\cos(d, d') = \frac{d \bullet d'}{|d||d'|} \quad (1)$$

- **Ontology Based Method:** The Cosine Method does not consider the semantic relationships among the domain topics. Thus, this new method has been developed based on the work of Hughes and Ramage [7]. They present the application of random walk Markov chain theory for measuring lexical relatedness. A graph of topics is constructed from the ontology[2]. The random walk model posits the existence of a particle that roams this graph by stochastically following local semantic relational links. The particle is biased toward exploring the neighbourhood around a target topic, and is allowed to roam until the proportion of time it visits each node in the limit converges to a stationary distribution. In this way, topic specific probability distributions can be computed over how often a particle visits all other nodes in the graph when "starting" from a specific topic. The relatedness of the two documents is computed as the similarity of their stationary distributions. In this case, the vectors containing the stationary distributions of the two DRs are computed using the formula (1) to get their similarity.

Two different means of determining the similarity of two DRs considering the type of resource (example, definition, etc.) have been used:

- **Same Resource Type Method (SRTM):** Each detected DR has a list of patterns that have been used to gather it. This method considers that two DRs are similar if the first pattern of the list of each DR assigns them the same category.
- **Didactic Ontology Method (DOM):** This method is similar to the Ontology-Based content similarity measure method. It uses a didactic ontology [8, 9], which represents the different kinds of DRs and relationships between the types of DRs, to compute the similarity between two DRs.

[2] Wordnet is used in the referred work.

3 Evaluation

When developing the application, all the found patterns were considered and included in the grammar in order to get a 100% recall, i.e. percentage of real DRs detected, even if that might affect the precision (percentage of correctly identified DRs). It is easier for the instructional designers to discard invalid DRs than building undetected ones.

Table 2 and Table 3 summarize the results of the evaluation of the above mentioned similarity measuring methods. As it can be observed, all the combinations have been proved. The column SRTM details the results obtained with the Same Resource Type method while the DOM column contains the performance of the Didactic Ontology Method. The Same Topics Method, Share Topic Method, Cosine Method and Ontology Based rows detail the results for those content similarity measuring methods. Table 2 details the aspects considered positive for the evaluation, i.e, percentage of valid DRs (VALID DR %) and the percentage of DRs for which the related topics have been correctly identified (TOPICS %). Table 3 shows the negative aspects, i.e., the percentage of DRs that should be enhanced by combining them with preceding fragments (ENHANCED %) and the percentage of DRs that have been joined and should be split (SPLIT %).

Table 2. Performance of the distance measuring methods: Positive Aspects

		SRTM	DOM
SAME TOPICS METHOD	**TOPIC %**	82.63%	88.64%
	VALID DR %	82.63%	83.57%
SHARED TOPIC METHOD	**TOPIC %**	91.49%	**92.50%**
	VALID DR %	91.40%	**94.17%**
COSINE METHOD	**TOPIC %**	88.89%	90.00%
	VALID DR %	88.02%	90.83%
ONTOLOGY BASED METHOD	**TOPIC %**	90.29%	**92.22%**
	VALID DR %	91.03%	**92.86%**

Table 3. Performance of the distance measuring methods: Negative Aspects

		SRTM	DOM
SAME TOPICS METHOD	**ENHANCED %**	32.39%	30.99%
	SPLIT %	0.00%	0.00%
SHARED TOPIC METHOD	**ENHANCED %**	14.03%	9.87%
	SPLIT %	3.92%	6.90%
COSINE METHOD	**ENHANCED %**	19.35%	17.43%
	SPLIT %	4.48%	7.48%
ONTOLOGY BASED METHOD	**ENHANCED %**	12.56%	**7.59%**
	SPLIT %	5.41%	**4.12%**

The results of Same Resource Type Method (SRTM) combined with any of the content similarity measuring methods are quite satisfying if the VALID DR % and the TOPIC % aspects are considered. The obtained scores for TOPIC % range between 82.63%, which is achieved by the Same Topics Method, and 91.49%, which obtained by the Share Topic Method. The VALID DR% varies between 82.63% (Same Topics Method) and 91.40% (Share Topic Method). However, it was observed that many of the obtained DRs should be enhanced (12.56% - 32.39%) when comparing the results with the instructional designers output.

The Didactic Ontology Method (DOM) has significantly improved the results, excepting for the Same Topics content similarity method, which has proved to be too restrictive. All the other content similarity measuring methods have improved the results, either by getting a better VALID DR % and TOPIC % rates or by reducing the ENHANCED % and SPLIT % rates.

The Cosine Method and the Share Topic method obtain better classification rates (VALID DR % and TOPIC %). However, the DR composition and organization is not the most accurate, i.e. they have got higher SPLIT % and ENHANCED % rates. Furthermore, they have got higher SPLIP % rates. The SRTM is too restrictive; it considers two DRs similar if they both are the same kind. However, DOM uses a Didactic Ontology to decide if two DRs are similar and allows more DRs to be composed. Thus, combined with Share Topic Method or the Cosine Method, they have generated some DRs that do not fit human instructors' preferences and should be split.

The most precise method is the Ontology Based content similarity measuring method combined with the Didactic Ontology Method. Even though it does not achieve the VALID DR % of the Shared Topics Method (92.86% vs. 94.17%), the obtained DRs better suit human instructors' preferences as it can be deduced from the low ENHANCED % (7.59% vs. 9.87%) and SPLIT% rates (4.12% vs. 6.90%). The Ontology Based Method does not only consider topic references but the semantic relationships among the topics. In the same way, the Didactic Ontology Method considers the relationships among the different kinds of DRs. The combination of these two similarity measuring methods provides DRs with high cohesion and that fit better the human instructors' output.

Future work includes the development of a graphical user friendly application that will allow the supervision of the results to any human instructor. The integration of the work here presented in Elkar-DOM [10] will facilitate the whole process of DR generation. Also, and in order to promote the reuse of the generated DRs, the semi automatic generation of metadata for annotating and building them as Learning Objects (LOs) is being analysed.

4 Conclusions and Future Work

In this paper a domain independent method for semi automatically generating didactic resources (DRs) from documents has been described. The method relies on the use of ontologies and NLP techniques. A grammar defining the patterns or syntactic structures that may identify DRs has been developed after the analysis of several textbooks in Basque language. This grammar is applied on electronic documents and the obtained atomic DRs are combined in order to get more accurate ones, i.e. closer to the

DRs the human instructors identify. Several similarity measure methods that determine which DRs must be composed have been tested.

In addition to being domain independent, this approach is also valid for other languages with little work, i.e., a lemmatizer/tagger for that language must be used and the grammar adapted to recognize the corresponding syntactic structures.

Future work includes the development of a graphical user friendly application that will allow the supervision of the results to any human instructor. The integration of the work here presented in Elkar-DOM [10] will facilitate the whole process of DR generation. Also, and in order to promote the reuse of the generated DRs, the semi automatic generation of metadata for annotating and building them as Learning Objects (LOs) is being analysed.

Acknowledgments

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References

1. Murray, T., Blessing, S., Ainsworth, S. (eds.): Authoring Tools for Advanced Technology Learning Environments. Kluwer Academic Publishers, Dordrecht (2003)
2. Brusilovsky, P., et al.: Interactive Authoring Support for Adaptive Educational Systems. In: 12th International Conference in Artificial Intelligence in Education. IOS Press, Amsterdam (2005)
3. Arroyo, I., Schapira, A., Woolf, B.P.: Authoring and Sharing Word Problems with AWE. In: 10th International Conference on Artificial Intelligence in Education. IOS Press, San Antonio (2001)
4. Ritter, S., et al.: Authoring Content in the PAT Algebra Tutor. Journal of Interactive Media in Education 9 (1998)
5. Murray, T.: Authoring Intelligent Tutoring Systems: An analysis of the state of the art. International Journal of Artificial Intelligence in Education 10, 98–129 (1999)
6. Larrañaga, M., et al.: Acquisition of the Domain Structure from Document Indexes Using Heuristic Reasoning. In: Lester, J.C., Vicari, R.M., Paraguaçu, F. (eds.) ITS 2004. LNCS, vol. 3220. Springer, Heidelberg (2004)
7. Hughes, T., Ramage, D.: Lexical Semantic Relatedness With Random Graph Walks. In: Joint Conference on Empirical Methods in Natural Language Processing and Computational Natural Language Learning, Prague (2007)
8. Meder, N.: Didaktische ontologien. In: Globalisierung und Wissensorganisation: Neue Aspekte für Wissen, Wissenschaft und Informationssysteme (2000)
9. Leidig, T.: L3–Towards an Open Learning Environment. ACM Journal of Educational Resources in Computing 1(1), 5–11 (2001)
10. Larrañaga, M., et al.: Towards Collaborative Domain Module Authoring. In: IEEE International Conference on Advanced Learning Technologies 2007 (ICALT 2007) (2007)

Fostering Self-Directed Learning with Social Software: Social Network Analysis and Content Analysis

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Abstract. Self-directed Learning (SDL) is an old pedagogical concept facing new challenges engendered by the emerging social software. We aim to explore the issue how SDL is facilitated in online cross-cultural collaborative settings – iCamp Trial2 involving faculty and students from four European academic institutions. Empirical data of two relatively active groups were meticulously analyzed with the use of social network analysis and content analysis. Results showed the online collaborative learning environment empowered by social software could potentially enhance that SDL of some but not all the students. The actual impact is stipulated by several critical factors such as the students' intrinsic motivation and initial anxiety about the learning situations. Initial formal structure is essential. Revision of Henri scheme is implied.

Keywords: Self-directed learning, Cross-cultural collaboration, Social software, Content analysis, Social network analysis.

1 Introduction

Self-directed learning (SDL) is a pedagogical notion with a long and rich history. Numerous studies have been conducted in a variety of domains to validate, augment and improve our understanding how SDL works for whom under which conditions (e.g., [1], [2], [6], [8], [9], [10]). Empirical evidence has accumulated that mature adult learners can demonstrate high SDL competencies by specifying their own learning needs and goals, identifying learning resources, planning the course of actions, managing the workflow, and evaluating learning progress as well as outcomes. Besides, it is recognized that SDL, which is traditionally seen as individualistic, has its social aspect (e.g., [8], [10]). Group learning processes can foster individuals' SDL abilities because feedback from collaborators with different backgrounds can stimulate the learners to reflect on their own learning activities and regulate them accordingly. Divergences in values and experiences are more salient in cross-cultural collaborative settings than their single-culture counterparts. Hence, investigating SDL in such settings is deemed intriguing. Thanks to the proliferation of social software, the scope of cross-cultural studies becomes very flexible, ranging from a bi-national dyad to a multi-national huge community. Indeed, the internet is seen as "*one of the most powerful and important self-directed learning tools in existence*" ([3], p.120; cf. [2]).

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SDL has been extensively researched and documented in the pre-digital world, and it is promising to explore whether and how it has been affected by new ICT [2]. The relationship between self-directed learning and heavily-guided learning that occurs in formal education/training tends to be strengthened with the widespread use of social software. The concomitant question is which types of social software are more effective in advancing SDL competencies. When learning is embedded in a formal setting with specific purposes and requirements, the institutional expectations should then be addressed. Learning contracts provide a means for negotiating resolutions between these external needs and expectations and the learner's internal needs and interests [7].

In summary, SDL is an old concept that takes on new challenges in face of emergent ICT, especially social software. We endeavour to explore two major issues:

- How SDL is facilitated (or hindered) in an online cross-cultural collaborative setting?
- Which types of social software support the development of SDL competencies?

These issues will be investigated in the context of our research project iCamp (http://www.icamp.eu), which aims to create an infrastructure for collaboration and networking across systems, countries, and disciplines in higher education. Pedagogically it is based on social constructivist learning theories. Three validation trials of different foci and scales are implemented within the lifetime of the project. Whereas the first trial was primarily exploratory, the second (Trial2) is formative evaluation and aims to *validate how SDL can effectively be supported with the use of social software in online cross-cultural collaborative learning settings*. In accomplishing a group project collaboratively on a selected topic, students are required to create, reflect on and revise their Personal Learning Contracts (PLC) under negotiation with their facilitators and peers. A major goal of Trial2 was to advance students' SDL competencies, including their skills in deploying technological tools to collaborate, their interaction skills with international partners in a foreign language, their abilities to locate learning resources, and their autonomy to negotiate and make relevant decisions.

2 Trial2 Structure, Activities, and Evaluation Methods

2.1 Participants

Four European Higher Education institutions constitute the trial sites of Trial2: Czech Republic, Poland, Slovenia, and Turkey. There are three major roles:

- *Facilitators*: Five faculty members from the trial sites proposed different project topics about which they are knowledgeable, and facilitated groups of students to accomplish the projects selected;
- *Students*: 24 undergraduates and postgraduates majoring in computer science, electrical engineering, sociology, and management;
- *Research team*: They were responsible to coordinate and monitor the progress of the trial, and provide technical and pedagogical supports;

Seven student groups, with the size ranging from two to five, were formed. Each group worked on a specific topic and was supervised by a facilitator.

2.2 Preparation and Execution Stages

Trial2 commenced in April 2007 with groundwork preparations: Facilitator recruitment, development of pedagogical scenarios and evaluation schemes, and selection and adaptation of technical tools, and student recruitment. A blog entitled "iCamp Trial2 Weblog" has been developed as an information hub. After the Preparation stage, Trial2 entered the Execution stage consisted of four phases: launching, first, second, and third.

Launching Phase (October 2007). Trial2 was launched by introducing the iCamp Trial2 Weblog to the students who were required to accomplish several tasks prior to the actual project work:

- *Initiating personal tool landscap*e. Students were recommended to deploy a selection of open-source applications that support learning activities of Trial2, including Wordpress (weblog), xowiki, videowiki, Scuttle (social bookmarking), Feed-on-feed (aggregating feeds), x-Lite (IP telephony), iLogue (developing learning contract), myDentity (email forwarding), Doodle (meeting planner), Flickr (sharing photos), and Objectspot (learning object repository). Students were required to manage and configure some of the tools to meet specific needs;
- *Making self-introduction*. Students were required to create a personal weblog and to attend a kick-off videoconference where they briefly introduced themselves;
- *Registering for a project of interest*. On the Project Wiki there were links to a set of wiki pages with each of which containing the title of a project, the name of the facilitator and a brief description of the project. A student registered for her preferred project by putting her name, email addresses and link to personal weblogs on the corresponding wiki page.

First Phase: Project Group Formation (Nov 2007). Students were basically free to choose whichever project theme they found interesting. To ease information search, the *feeding mechanism* for aggregating contents from different sources in one place was introduced. For instance, if a student subscribed to her group-mates' and facilitator's blogs, she could then view the contents of these blogs from her own blog. Towards the end of the First Phase the students were asked to fill in the *Periodic Reflection Survey#1* to indicate how they perceive the trial context (including people, tools, the project topic, resources, etc). The rationale was to encourage the students to reflect on their learning environment.

Second Phase: Project Specifications and Learning Contracts (Dec 2007). With the help of the project facilitator, students had to decide clearly the content and context of their project, identify goals and objectives to be achieved, specify tasks and who was responsible for which tasks, and select criteria against which they would be evaluated. These discussions took place asynchronously (e.g. email), and synchronously (e.g., IP telephony). When agreements on project specifications had been reached, the students had to develop their personal learning contracts (PLC) in their blog or with the tool iLogue. Students could use the contract template and fill it with their own aims, tasks, tools, resources, and evaluation criteria. After the students had drafted their PLC, the project facilitator commented on it. Group members should also peer-review each other's PLC. Basically towards the end of this phase students should 'freeze' their PLC, though they could still slightly revise it when they got a better understanding about their project work and learning environment.

Third Phase: Project Attainment and Evaluation (Jan 2008). This phase focused on achieving project goals and evaluating project outcomes. Students continued to communicate and interact with different tools for teamwork coordination, activities regulation and resolution of social issues. Towards the end of the project, students were asked to fill in the *Periodic Perception Survey#2* to indicate how their personal and group landscapes (i.e., tools usage, interaction patterns, etc.) changed and to what extent their learning goals were attained.

2.3 Evaluation Methods and Instruments

We employ mixed-method evaluation approach to capture qualitative and quantitative data from different sources with different techniques (Table 1). The artefacts (e.g. blog messages, emails) produced in the processes of accomplishing the given tasks are significant sources of data. Due to the space limit, we can only present the data relevant to the research questions of interest in this paper.

Table 1. Evaluation instruments and data sources

Tool	Source	Brief descriptions
Background survey	Students	Administered prior to the start of Trial2; pre-trial knowledge and experience about SDL, tools and collaboration
1st Reflection survey	Students	Administered in the mid-phase of Trial2; tools usage pattern and tools acceptance
2nd Reflection survey	Students	Administered in the end-phase of Trial2; tools usage pattern, perceived value of learning contract; self-rated SDL abilities
Emails	Students Facilitators	Archives collected in batches after the completion of Trial2 to derive communication patterns; students shared their emails on a voluntary basis
Blogs	Students Facilitators	Archives of personal learning contracts and other blog messages
1st Online Inter-view	Students	With the use of a videoconference tool; conducted in the mid-phase; reflection on different aspects of Trial2 up to the time
2nd Online Inter-view	Students Facilitators	With the use of a videoconference tool; conducted in the end-phase: reflection and evaluation of all aspects of Trial2
Weblog feeds	Students Facilitators Researchers	Automatic logging; data management skills
myDentity	Students Facilitators Researchers	Automatic logging of email transactions, but capturing only those sent with the specific account: name@icamp.eu
Assessment	Facilitators	Grades given to individual students based on their performance in different tasks

3 Results

A pool of 15 project themes was offered to 24 students; this high project/student ratio led to a highly uneven distribution, e.g. some projects attracted several students from the same country and some were not appealing to any student. Consequently, some students were advised to take their second or even third choice to balance the student/facilitator and country/group ratio. These group reshuffles inevitably undermined the motivation of some students, though the exact extent could not be estimated. Eventually, seven groups with the size of two to five students with different project themes were formed, but the original group numbers were retained. We monitored the activities of the groups by regularly visiting the blogs of individual students and holding videoconferences with the facilitators. Two groups - Group3 and Group11 - were identified to be relatively more active. Empirical data of these two groups are reported below: first at the group level with the use of sociograms and then at the individual level with the use of content analysis of email contents.

3.1 Content Analysis Method

To validate whether the involvement in group activities can enhance the learner's SDL competence, we apply content analysis to the group's email archives. Specifically, we have followed the analytic scheme proposed by Henri [5], which yields both quantitative and qualitative data. Henri identified five key dimensions for analysing computer-mediated asynchronous text-based discussion (i.e. computer conference). While Henri's scheme may not be suited to all evaluation purposes such as analysis of online debate (cf.[4]), it fits reasonably well to an informal discursive environment like Trial2 where the participants were basically free to initiate, sustain or change any subject of discussion. Each email was divided into 'message unit', which represented one 'relatively separate idea', and coded using unique identifiers. Each message unit was then classified according to the categories defined in the coding scheme. Here are some brief descriptions about such categories

- Participation: it refers to the nature of communication; we have defined five types: Coordination (CO), Social (SO), Task (TA), and Technical (TE);
- Interactivity: it differentiates between units that are explicit, implicit or independent. Explicit interactions can be either a direct response (DR) or a direct commentary on someone else's message (DC). Implicit interactions are defined as including a response to (IR) or a commentary on (IC) a prior message without explicitly referring to it.
- *Cognitive*: it comprises two sub-categories: reasoning skills and information processing. Reasoning skills include Elementary clarification (RE), In-depth clarification (RI), Inference (RF), Judgement (RJ), Strategy (RS). Information processing includes Surface (PS) and In-depth (PI).
- Metacognitive: it includes metacognitive knowledge and metacognitive skills (for detailed descriptions, see Henri [5]).

In addition, we introduced another term: *Unclassified (UN)* for classifying message unit that cannot be fit in any defined categories.

3.2 Analysis of Project Group11

Group level: Group11 consisted of five students. One was studying in an academic institute in Slovenia (*p11s5*), two in Turkey (*p11s4, p11s5*), and the other two in Poland (*p11s1*, *p11s2*) where the facilitator *fa11* and local site coordinator (*lc*) were working as well. Based on the batches of emails we received from this group, we can analyse its communication patterns with the use of *sociograms* – an important technique in Social Network Analysis (SNA) [11], which is an approach that focuses on the study of patterns of relationships between actors in communities. The sociogram is generated from the actor-by-actor matrix. Here the term 'actor' is used to refer to both students and facilitators and local coordinators. We use different shapes and colours to refer to different types of actors, e.g., students (*p11s1..5*) are represented as red circles, the facilitator (*fa11*) as the blue diamond and the local site coordinator (*lc*) the yellow rectangle. The size of a link between 2 nodes represents the frequency of communication, while the size of a node represents its activeness.

Sociograms in Figure 1 can well illustrate the communication patterns of Group11. Specifically, we divided the message units into 3 consecutive one-month periods. The number of message units falling in each period was 7, 34 and 63, respectively.

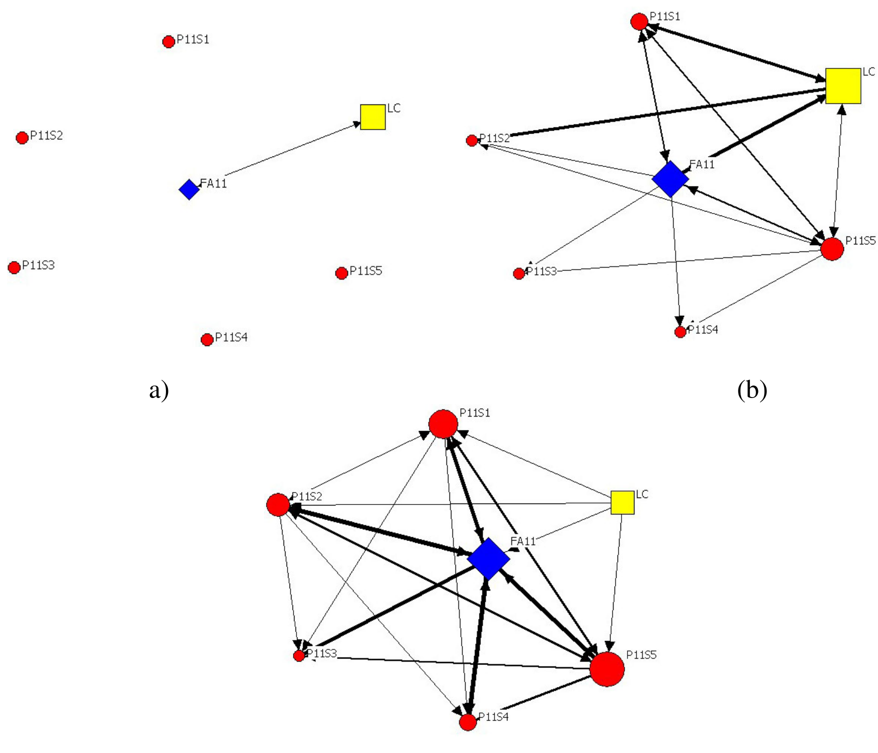

Fig. 1. Sociograms for email exchanges in early (a), mid (b), end (c) phase of the trial

In the Early phase (Figure 1a), emails exchanges occurred only between the facilitator *fa11* and the local site coordinator *lc*. The students did not send any emails at all. It seemed that the students only started working in the Mid-phase (Figure 1b) when the number of students participating in the group activities, the number of email exchanges and also the frequency of communication increased. Actually, the number of message units doubled in the End phase (Figure 1c). In the Mid phase, only *p11s1* and *p11s5* sent some emails, but in the End phase, emails were exchanged and circulated among all the students except *p11s3*. The sociograms clearly show that the facilitator has played a crucial role in the group communication. The local site coordinator (*lc*) was also active in this group.

Furthermore, we segmented the emails exchanged by the Group11 members over a three-month period (Oct 2007 to Jan 2008) into 105 message units and found that 32.7% of the message units were coordination (CO). These CO units were about meeting organisation. 12.5% were technical-related (TE), only 16.4% were social (SO), task-related unites constituted 38.46% of the message units. Most of the social units were from *p11s5* and related to the greetings such as "Have a nice Monday morning" or "I wish you a greet week start".

Concerning the interactivity dimension, 71.15% of message units were classified as independent statement (IS). The very high percentage of independent statements showed that there were not many interactions by emails among the students. The number of interactive units (both implicit and explicit) was 28.85%. Among the interactive units, 4.81% were implicit and 24.04% were explicit. These interactions were mostly started by the active actors, i.e. *fa11*, *lc*, and *p11s5*. Those active actors appeared to respond to every message directed to them.

The message units that were categorized as task-oriented (TA) were further analysed according to cognitive and metacognitive dimensions. Concerning the subcategory of Reasoning Skills, 40% were Elementary Clarification (RE), 2.50% were Judgement (RJ), Strategy (RS) made up 12.50% and the rest 45% were unclassified (UN). None of the messages was classified as In-depth Clarification (RI). 45% were classified as Surface (PS), only 10% were In-depth (PI) according to the sub-category of Information Process, and 45% were unclassified.

Individual level. The sociograms shows that *p11s5* and *p11s3* were the most and least active students, respectively. Whereas the former initiated and responded to a number of emails, the latter just received emails from the others and did not send any email at all. In the interview, *p11s5* confirmed that *p11s3* did not participate in any group learning activities.

To identify the trajectory of *p11s5*'s communication patterns over time, we observed how the distribution of the types of her email message units has changed over two periods of time, namely Nov-Dec and Dec-Jan. Figure 2a shows how her major types of participation have evolved. Interestingly, the number of coordination (CO) message units increased whereas the number of social (SO) and task (TA) dropped. This may imply that *p11s5* has assumed the leadership role in Group11 to orchestrate the activities in the group, e.g. arranging group meetings, assigning subtasks to fellow group-mates, and interfacing different parts of the project.

The trajectory of Interactivity (Figure 2b) has also changed with a slight drop of independent message units (i.e. no link to other messages) and a slight increase of direct as well as indirect ones (i.e. implicit or explicit links to other messages). It may imply that *p11s5* could relate her messages better to her group-mates'. In fact, a similar trajectory can be observed in *p11s1* and *p11s4*, indicating the interactivity of this group has improved over time. This desirable trend is corroborated with the sociograms (Figure 1) shown above. In contrast, *p11s2* and *p11s3* remained inactive all the time.

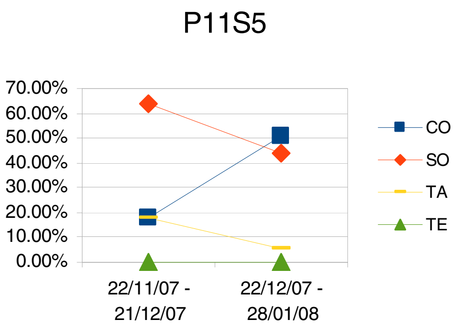

Fig. 2. (a) Participation trajectory

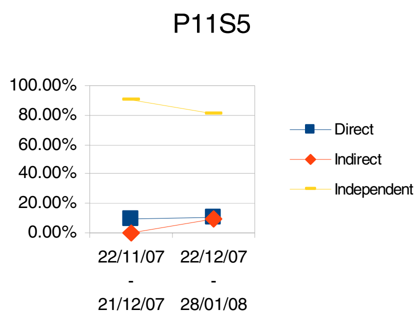

Fig. 2. (b) Interactivity trajectory

3.3 Analysis of Group3

Group level. With the similar approaches described above, we have also analysed data of Group3. This group consisted of three students. One was studying in an academic institute in Poland (*p3s1*), two in Turkey (*p3s2, p3s3*) where the facilitator *fa3* was working as well.

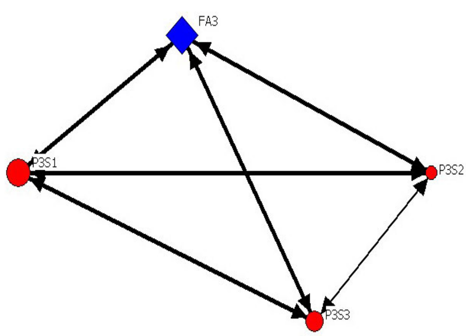

Fig. 3. Group3

Figure 3 illustrates the communication patterns of Group3 members based on their email exchanges over the three-month period of Trial2. In this group, the facilitator played the most important role in group interactions. Unlike Group11, all the three students were rather active; they exchanged emails quite regularly and all of them contributed their parts in the group work. The general communication pattern of this group as indicated by the emails remained more or less the same with variations in the strengths of the edges (i.e. links) among the nodes (i.e. actors), getting stronger over time. The most active student *was p3s1*, who played the leading role in this group.

44.9% of the message units were coordination (CO). 9.18% were technical-related (TE), 9.18% were social (SO), 36.73% of the message units were task-related (TA). The CO units related to the meeting organisation. The social units concerned not only about the greetings but also about complaining and explanation as some member missed the task deadline. For instance, *p3s2* was late in preparing his tasks and his group-mates blamed him for that. Then *fa3* intervened by saying "About …, we are on holidays and we cannot force … to work in an official holiday, therefore you need to adjust yourself according to institutional regulations".

Concerning the interactivity dimension, 80.61% of message units were classified as independent statements (IS). The number of interactive units (both implicit and explicit) was 19.39%. Among the interactive units, 5.10% were implicit and 14.29% were explicit. With regard to the sub-category Reasoning Skills, Elementary Clarification (RE) made up 38.89%, Judgement (RJ) constituted 13.89%, 5.56% were In-depth Clarification (RI), and the rest 41.67% were unclassified. 50% of the message units were classified as Surface (PS), only 8.33% were In-depth (PI), and 41.67% were unclassified according to the sub-category of Information Process.

Individual Level. Figure 4(a) and (b) show that the trajectories of Participation and Interactivity of the most active member *p3S1* of this group. She showed the decreasing trend of coordinating the group activities and became more task-oriented. A contrasting trend was the social dimension with *p3s1* putting more efforts in sustaining the inter-relationships with her group-mates.

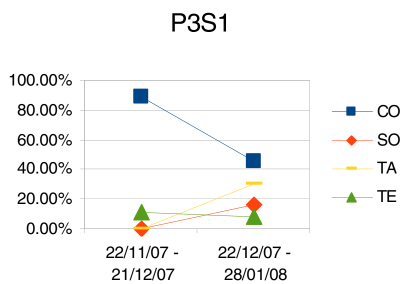

Fig. 4. (a) Participation trajectory

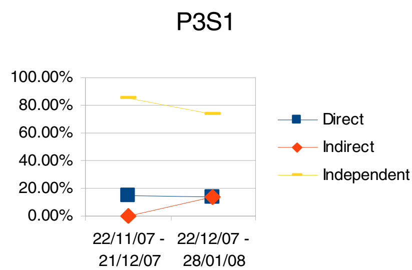

Fig. 4. (b) Interactivity trajectory

3.4 Feedings

The feed log file has provided some interesting information. Table 2 shows the actions, the number of such actions and the number of the actions done by the iCamp staff from November 2007 to February 2008 found in the feed log file.

Table 2. Usage of the feeding function

	No. of actions	From the research team
Activated plugin	18	5
Sent subscription offer	68	11
Accepted offer	49	30
Request subscription	94	51
Replied	23	16

This means that over the four-month period, there were 18 "activated plugin" actions, five of them were done by the iCamp research team. Users should activate the "feed" plugin in order to use the feeding function. And then, if they want others to read their feeds, they should send subscription offers. If they want to read feeds from the others, they should request subscription. The "replied" action refers to the reply on a post made by another user. There were only seven "replied" actions by students during the whole Trial. It means that weblog was used mostly for posting information. Students did not see it as a "discussion forum". About the two active groups, in Group3 all the students received feeds from each other and also from the iCamp Weblog. However, in Group11, only *p11s1*, *p11s2* and *p11s5* used the feeding function and they only received feeds from their facilitator *fa11*.

4 Discussion

With reference to our two major issues posited earlier on in the Introduction, the empirical data seem to suggest that the collaborative learning environment can facilitate SDL competencies of some but not all the students. Situating those students, who were intrinsically motivated to explore new learning environments, in the online collaboration setting like Trial2 can further strengthen their already quite well-developed SDL competencies, which manifested in terms of their skills in deploying technological tools to collaborate, their interaction skills with international partners in a foreign language, their abilities to locate learning resources, and their autonomy to negotiate and make relevant decisions. These SDL competencies were well exemplified by the outstanding performances of the two most active students in Group3 *(p3s1)* and Group11 *(p11s5)*.

In the Background survey, *p11s5* indicated that she has had very good experiences in teamwork and online courses in which the main communication tools were blog and email. She participated in Trial2 because she wanted to test new tools, learn a specific topic from different perspectives, and to meet new friends. She had a reasonably good understanding of SDL, as shown by her corresponding response in this survey. Besides, *p11s5* has developed three versions of personal learning contracts (PLC) with each version being revised based on the feedback from the facilitator *fa11* as well as on her ongoing reflection on the project tasks. The quality of her PLC was high in terms of clarity, comprehensiveness and feasibility. She negotiated with the facilitator about the evaluation criteria against which she would be assessed by the end of the trial. Such negotiation ability is deemed a significant milestone in SDL. Furthermore, *p11s5* knew how to use and has tried out all of the recommended social software tools with some help from her facilitator and peers. She knew how to set the feeding and has done so with most of the provided tools. She also had a clear idea about the purposes of most of the provided tools and intended to use them after the trial. She also demonstrated her perseverance in pursuing her goal of accomplishing the project task despite the initial frustration engendered by the non-responsiveness of her group-mates. In the second Reflection Survey and the second Interview (see Table 1), *p11s5* affirmatively indicated that her SDL competencies have been improved in different aspects.

While *p11s5* was a successful showcase of the positive impact of a collaborative learning environment with the support of social software, there were some unsuccessful cases. Unfortunately, the data of these students were not accessible as they refused to share anything with us. Hence, we cannot understand what factors have hindered them from engaging in the trial. Further, while some students appreciated the value of PLC as a useful tool for them to plan their activities and thus invested efforts in developing one already in the early phase of the project, some other students created their PLC only in the end phase. As shown in the interviews, quite a number of students did not grasp the concept of PLC, nor did they bother to seek the related information actively. Indeed, we believe that initial learner anxiety and confusion about learning contract often places the learner in a "zone of discomfort". Some students may be able to overcome such discomfort whereas the others are overwhelmed by it. Presumably, once learners have worked through their initial fears and concerns, they may become motivated to implement their own plans. Indeed, learners typically need some initial guidance from the facilitator if they are to make good use of the contract as a learning resource.

With regard to the question about the tool usage, results of the two Reflection Surveys show that the students predominantly used weblog in the trial for sharing their experiences with group-mates and documenting their PLC. Given its ease of use, publishing a PLC to a blog presumably is a good means to invite feedback from fellow members of a group sharing some common goals. However, it did not work well in Trial2 in general, because of the relative poor communications among the group members. Indeed, without social inputs, the role of social software like blog, wiki and forum in promoting SDL by channelling timely feedback to individual learners is compromised. Similarly, the need for the feeding mechanism, which supports an all-in-one-place view, was low, given the small group size and limited content. In contrast, synchronous communications proved effective in generating the momentum in the group to collaborate. However, they tended to fall back on using emails as the main communication tool. It may be attributed to the fact that emails are seamlessly incorporated in their everyday life and they are so familiar with it. While a number of the students use social software like Facebook for social interactions, using social software for achieving learning tasks is still something new to some of them. It may take them some more time to accept such alternative functions of these emergent technologies and deploy them creatively.

Cross-cultural online setting made it especially challenging for the trial participants, who had never met before, to collaborate. The initial and some persistent non-responsiveness of some group-mates to emails and low posting frequency in blogs were particularly frustrating because they were key means to share ideas and reach consensus. The lack of such shared information jeopardized the students' SDL opportunities to pursue their own needs and goals.

5 Concluding Remarks

The challenging tasks for our research team are to design appropriate learning scenarios, to capture data with effective tools, and to integrate a large volume of multi-source qualitative data. Some lessons have been learnt in the trial. First, an unstructured open environment may scare a number of students, who are so used to traditional guided learning, and de-motivate them from getting involved in the early stage, rendering it even harder for them to join in later because of the issue of bootstrapping. Hence, some form of formal structure and scaffolding from facilitators are deemed essential. Second, data collection procedure may interfere with the students' learning processes. The design of our online cross-cultural collaborative learning was relatively complex and inherently messy. As the trial participants were widely distributed in different sites, it was extremely difficult for the evaluators to track the tool usage on a fine-grained level. Some in situ observations could in principle be done but practically rather implausible, because the students performed their project tasks on flexible schedules and places (e.g. late in the evening at home). In fact, we did employ some automatic data logging instruments (e.g. myDentity – an application for tracking email transactions). Unfortunately, some students failed to follow the instruction; the data thus collected were incomplete. Consequently, we had to rely mostly on subjective, self-reported data, despite our awareness of the limitation of this methodology. Nonetheless, the empirical data collected with the surveys could be triangulated and substantiated by other data sources such as interviews. Third, we have encountered the difficulties of categorizing quite a number of message units. It may suggest that the framework of Henri [5] needs to be revised and augmented to meet our specific need. In particular, it is necessary for us to find the nuances between computer conferences, to which Henri's scheme is relevant, and our specific trial setting.

In summary, the learning environment designed for the iCamp Trial2 was complicated and messy as it was embedded into some regular academic courses. Not only institutional but also cultural differences influence the participants' performances and behaviours. Under these situations, it is extremely difficult to disambiguate causality. Nonetheless, we identify some interesting observations and attempt to illustrate them with the data of four case studies. Presumably social software has potential to facilitate individuals' SDL competencies, but the realization of such potential is stipulated on a set of critical factors with one of them being social inputs or contributions from members of the community of interest. The other factors are to be further defined by more empirical data.

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References

1. Brookfield, S.D.: Understanding and Facilitating Adult Learning. Jossey-Bass (1986)
2. Candy, P.: Linking thinking – self-directed learning in digital age (accessed on 08/01/08) (2004)
3. Gray, D.E.: The internet in lifelong learning. International Journal of Lifelong Education 18(2), 119–126 (1999)
4. Gunawardena, C.N., Lowe, C.A., Anderson, T.: Transcript analysis of computer-mediated conferences as a tool for testing constructivist and social-constructivist learning theories. In: Proc. of the Annual Conference of Distance Teaching and Learning (1998)
5. Henri, F.: Computer conference and content analysis. In: Kaye, A. (ed.) Collaborative learning through computer conferencing: The Najaden papers, pp. 117–136. Springer, Heidelberg (1992)
6. Hiemstra, R.: Self-directed learning. In: Husen, T., Postlethwaite, T.N. (eds.) The International Encyclopedia of Education, 2nd edn. Pergamon Press, Oxford (1994)

7. Hiemstra, R.: Learning contracts, http://home.twcny.rr.com/hiemstra/contract.html
8. Kerka, S.: Self-directed learning myths and realities no.3. ERIC Clearinghouse on Adult, Career and Vocational Education (ED365818) (1999)
9. Knowles, M.S.: Self-directed Learning: A Guide for Learners and Teachers. Cambridge Book (1975)
10. Maehl, W.H.: Lifelong learning at its best. Jossey-Bass (2000)
11. Scott, J.: Social network analysis: A handbook. Sage, London (1991)

Capture of Lifecycle Information to Support Personal Information Management

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Abstract. Re-use is a key aspect of today's Learning Resource creation. Authors often re-use objects, which they had originally created. Additionally organization of documents has become a complex task and users tend to have more and more problems to manage documents stored on their local computers. With our approach we combine these two aspects by supporting users in their Personal Information Management with information, emerging from re-use processes. We propose a framework capable of capture, management and utilization of this so called lifecycle information and present our implementation for PowerPoint presentations. A first evaluation shows promising results and demonstrates the feasibility and validity of our approach.

Keywords: Re-Use, Metadata Generation, Lifecycle Information, PIM.

1 Introduction and Motivation

Nowadays, re-use is a key aspect of the creation of Learning Resources as well as knowledge documents. Processes like authoring, re-authoring and re-use of images, texts, slides or other parts of these resources provide for the emergence of multiple types of information. This information – if captured and processed – can help to support retrieval, authoring or management of the documents involved.

It is a known fact that users tend to have problems organizing documents stored on their local computers [12]. Modern PIM (Personal Information Management) tools try to support users here. With the above mentioned information, PIM applications like desktop search tools, semantic desktops or dedicated information management tools can be enhanced.

Authors of Learning Resources and knowledge documents usually do not want to create metadata or additional information for their documents. Therefore we propose to acquire this so called *lifecycle information* without explicit user interaction but by monitoring actions users take anyway when working on their resources. In [7] we have presented a framework for capture, utilization and management of lifecycle information (LIS.KOM). In this paper we present the application of our approach for

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the capture of lifecycle information in PowerPoint. Among others the captured information can be used to support management of the documents involved. To increase the readability we refer to Learning Resources, when meaning both Learning Resources and knowledge documents. In the following we present our notion of lifecycle information and discuss how lifecycle information can be used to support PIM (Section 2). After a discussion of related work (Section 3) we present the overall architecture of the LIS.KOM framework (Section 4). Finally we discuss first evaluation results (Section 5), summarize and give an outlook on future work (Section 6).

2 Lifecycle Information for PIM

Lifecycle information is a special kind of metadata. However, in contrast to the common notion of metadata it is not related to a specific object but emerges from a certain process. Therefore it is only available while the corresponding processes take place. That means that lifecycle information has to be captured during these processes - or else is lost. In order to identify information emerging from processes, the processes themselves must be identified. A detailed description of the analysis of a Learning Resource's or knowledge document's lifecycle and a thorough view on lifecycle information and the corresponding processes can be found in [7] and [8]. In the following we describe how lifecycle information can be used to support PIM.

Boardman [1] defines PIM as "Management of personal information", where "personal information" means information a user possesses and not information *about* a user. PIM is not only related to e-mail and bookmarks, though these concepts are strongly associated with it, but to all kinds of information (or codified knowledge) in a user's possession. That includes various information and document types, like pictures, videos, audio files, text files or presentations. PIM tools are often designed to support one specific type of information only (like management tools for images or audio files). Nevertheless there are applications like Semantic Desktops, which aim to cover several information types.

Lifecycle information can constitute valuable input for those applications. When content is re-used, the source document and the document the content has been re-used in (target document) are often very closely related. In most cases a relation that connects both documents on a semantic level can be assumed. Thus the possibility is high that the source document might again be interesting if the target document is re-opened, e.g. for a revision. These relations between documents can be captured as lifecycle information.

There are two main possibilities to use lifecycle information to support PIM presented in the following. The first possibility is to provide information about source and target documents for his currently opened document to the user. The related documents can then be made accessible directly from the working context of the user.

The second possibility to utilize lifecycle information for PIM is an external application for the retrieval, browsing or search of documents. To achieve this, document management systems or desktop search engines like Beagle++ [4], could be extended. Lifecycle information like relations between documents would add nicely to the already featured full-text search, enrichment with contextual information and social recommendations Beagle++ provides. Search results could be extended with links to re-used or otherwise related resources or a visualization of document relations could be rendered. Of course it is also possible to utilize the lifecycle information in an independent application, for example a relation browser or file system explorer.

3 Related Work

There are quite some interesting approaches in current research that are related to our work. With the *Ecological Approach* McCalla (et al.) laid the foundation for our approach [9], [2]. *Contextualised Attention Metadata* [3] is used to store the attention a user pays to different Learning Resources in different applications. It is e.g. utilized for ranking and recommendations of Learning Resources [13], learner modelling [11] or even for knowledge management [15]. The main difference to our approach is that the information is collected user-centric instead of document-centric. *Semantic Desktops* are tools which, among other things, aim to improve the PIM on a greater scale. Tools like Gnowsis [14] or Haystack [6] try to provide a holistic solution for Personal Information Management, often mixed with social aspects. *Desktop search engines* like Google Desktop or Beagle++ [4] try to make information stored on a local computer search- and retrievable. In *TeNDaX* [5], a system for the collaborative creation and editing of documents, user actions are stored as transactions in a database. Thus it is possible to track copy and paste relations between documents. However, other kinds of lifecycle information are not considered. Mueller proposes in his approach a system for "*consistent management of change*", i.e. for improved versioning of documents [10]. The approach takes relations both, within and between documents into account and tries to provide versioning functions on a semantic level. However, re-use or lifecycle information is only marginally considered.

4 LIS.KOM Framework

As stated in [7] a system is needed which allows the collected lifecycle information to cross system borders. That means that information gathered in one system has to be transported to a different system in order to be fully utilizable. The LIS.KOM framework (Figure 1) provides these features. The main component of the framework is the LIS.KOM Server. Here, the captured lifecycle information is stored, processed and provided for utilization. Local components can connect to the central server via a web service API to either send the lifecycle information captured or obtain processed information. The LIS.KOM Client, located on a user's computer, is responsible for the handling of the connection to the server and the synchronization of the locally cached lifecycle information. Due to the local storage the LIS.KOM Client works even in an offline case. The Client provides an API for add-ins and applications that utilize the lifecycle information as well as for those that capture information. Capture is done by the ReCap.KOM add-ins. They are plugged into the different applications where information should be captured, e.g. authoring and office applications, repositories or Learning Management Systems. The utilization can be either done with a standalone application (LIS.KOM Utilization Tool) or in turn by means of add-ins (ProCap.KOM) for existing applications like office tools, repositories, desktop search tools or Semantic Desktops.

We have implemented the LIS.KOM client as well as a ReCap.KOM add-in for PowerPoint and are currently working on the implementation of the LIS.KOM server.

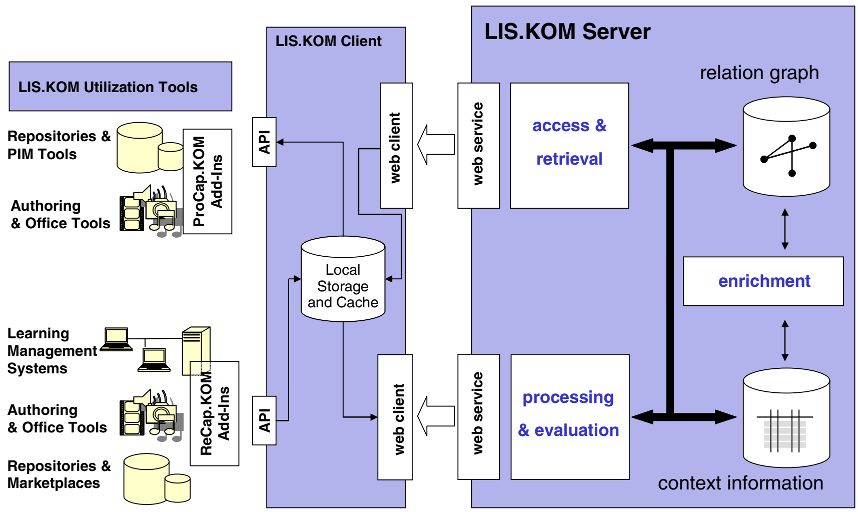

Fig. 1. LIS.KOM framework

5 Evaluation

The goal of this evaluation was to prove the validity of lifecycle information captured with our framework. We deployed a ReCap.KOM capture module for PowerPoint on the computers of 4 test persons. We focused on the capture of relations emerging during the creation, re-use and editing of PPT presentations. We captured *provision relations* when elements were re-used within PowerPoint, *asset relations* when an external asset, e.g. an image, was (re-)used in a PowerPoint presentation and *variant relations* each time a presentation was saved under a different name. The main purpose of this evaluation was to test if the tool works with respect to the *validity* of relations captured. To achieve this, the source and target document were examined by an expert. A relation was found valid if it was traceable by the expert. It was not the goal of this evaluation to judge the *significance* or *importance* of relations captured.

The evaluation was done for 6 weeks in a realistic usage scenario, i.e. the test persons used PowerPoint as they would have without being test persons. Since the capture of information happened completely in the background it can be assumed that the test persons have not been influenced by it in any way. Because of the naturally different amounts of working time, working styles and re-use behaviour the amount and types of relations captured were quite different. Table 1 shows the results of the evaluation with the types of relations captured, their respective quantity, the distribution among the test persons and their validity. It is remarkable that one test person opened and created significantly more presentations than the others. Altogether there were 58 provision (i.e. re-use) relations for 29 different documents collected. This shows that there is actually a high amount of reuse happening when PowerPoint presentations are created.

Relations were captured on slide level. About 75% of the provision relations were valid, 19% invalid and 6% inconclusive. Relations were marked as inconclusive when the validity of a relation could not be determined. This was the case if a target slide (a slide a relation pointed to) did not exist anymore, due to the fact that the test persons were not forced to keep all versions and revisions of their presentations.

Table 1. Number and Distribution of Captured Relations and their Validity

Relation Type	Total	Distribution (Testperson 1-4)	Valid	Invalid	Inconcl.
Provision (total)	58	3 I 5 I 0 I 50	43	11	4
Prov. - Slides	38	3 I 0 I 0 I 35	31	7	0
Prov. - Text	12	0 I 5 I 0 I 7	9	3	0
Prov. - Shapes	8	0 I 0 I 0 I 8	7	1	0
Variant	16	2 I 4 I 1 I 9	16	0	0
Asset	23	18 I 0 I 5 I 0	23	0	0

We identified three reasons for invalidity of relations:

1. The evaluation scenario was not closed. I.e. there was the possibility that other users without ReCap.KOM adds-in changed the presentations leading to invalid relations. This problem does not occur in a closed evaluation scenario where all users have the mandatory add-ins installed.
2. Some of the invalid relations were caused by a minor event handling issue that we have solved meanwhile. We estimate that about 25% of the invalid relations were invalid due to this error.
3. Lastly, invalid relations were captured when slides or shapes were re-used for structural or formal reasons only. This constitutes the biggest challenge. To solve this we need to analyse the content of related slides to judge if the relation is valid. A similar problem occurs if a slide is re-used and then the contents of the slide are deleted successively. Here, a measurement to judge when a relation is not valid anymore is needed.

Asset and variant relations were captured with a reliability of 100%. The overall validity of captured relations was around 85%.

6 Conclusion and Future Work

In this paper we have shown that it is feasible to capture lifecycle information for Learning Resources which are created with standard office applications. We have proposed and developed different possibilities to utilize this information. The evaluation has shown that there is a significant amount of re-use when presentations are created and that the resulting relations can be captured with high reliability. The next step, beside the improvements of the capture in PowerPoint, will be the connection of the LIS.KOM Client to the LIS.KOM Server. Thus we can change from a personal to a community environment, where lifecycle information und thus their value can be shared with other users. More evaluations will be conducted to determine the significance of relations and to test our approach in a community scenario. Due to the modular nature of the LIS.KOM framework it is easily possible to implement further add-ins for other document types, like e.g. MS Word.

References

1. Boardman, R.: Improving Tool Support for Personal Information Management, PhD thesis, Imperial College London (2004)
2. Brooks, C., McCalla, G.: Towards Flexible Learning Object Metadata. Proceedings of Int. J. Cont. Engineering Education and Lifelong Learning 16(1/2) (2006)
3. CAMs, Conceptual Base Scheme (2007), http://ariadne.cs.kuleuven.ac.be/empirical/attentionCAM%20schema_Document_v1.5.pdf
4. Chirita, P., Gavriloaie, R., Ghita, S., Nejdl, W., Paiu, R.: Activity Based Metadata for Semantic Desktop Search. In: Proceedings of the 2nd European Semantic Web Conference (2005)
5. Hodel, T., Hacmac, R., Dittrich, K.R.: Using Text Editing Creation Time Meta Data for Document Management. In: Proceedings of Conference on Advanced Information Systems Engineering (2005)
6. Karger, D., Bakshi, K., Huynh, D., Quan, D., Sinha, V.: Haystack: A General Purpose Information Management Tool for End Users of Semistructured Data. In: Proceedings of CIDR (2005)
7. Lehmann, L., Hildebrandt, T., Rensing, C., Steinmetz, R.: Capturing, Management and Utilization of Lifecycle Information for Learning Resources. In: Duval, E., Klamma, R., Wolpers, M. (eds.) EC-TEL 2007. LNCS, vol. 4753. Springer, Heidelberg (2007)
8. Lehmann, L., Hildebrandt, T., Rensing, C., Steinmetz, R.: Utilizing Lifecycle Information for Knowledge Document Management and Retrieval. In: Proceedings of the 7th International Conference on Knowledge Management (2007)
9. McCalla, G.: The Ecological Approach to the Design of E-Learning Environments: Purpose-based Capture and Use of Information About Learners. Journal of Interactive Media in Education 7 (2004)
10. Mueller, N.: An Ontology-Driven Management of Change. In: Proceedings of the conference on Wissens- und Erfahrungsmanagement, LWA (Lernen, Wissensentdeckung, Adaptivitaet) (2006)
11. Najjar, J., Wolpers, M., Duval, E.: Towards Effective Usage-Based Learning Applications: Track and Learn from Users Experience(s). In: Proceedings of the IEEE ICALT 2006 (2006)
12. Nejdl, W., Paiu, R.: I know I stored it somewhere - Contextual Information and Ranking on our Desktop (2005)
13. Ochoa, X., Duval, E.: Use of Contextualized Attention Metadata for Ranking and Recommending Learning Objects. In: Proceedings of the CAMA 2006 (2006)
14. Sauermann, L.: The Gnowsis Semantic Desktop for Information Integration. In: Proceedings of the IOA Workshop of the WM 2005 Conference (2005)
15. Wolpers, M., Martin, G., Najjar, J., Duval, E.: Attention Metadata in Knowledge and Learning Management. In: Proceedings of I-Know 2006 (2006)

A Model of Re-use of E-Learning Content

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Abstract. Re-using e-learning content is a solution often proposed against the high-cost of the creation high-quality e-learning material, a solution with a neglectable price. In this paper we propose a content distribution model that addresses the long term evolution of content pieces whose quality raises along with re-uses. A realization of this model is presented for the ActiveMath learning environment platform.

Introduction

E-Learning content, on the one hand, is known to be expensive to realize; on the other hand, its potential for reproduction is much greater than paper-published content. Thus, the idea of long-term development and re-use of content has emerged and has been attempted and studied for example in [1,2,3]. We have found, however, very few studies that address the management of the long-term evolution of content linked to re-use actions such as aggregation, transmission, and publication. That is, re-use seems to be considered as a single shot action whereas a significant quality evolution can be obtained as a result of several re-uses.

This paper advocates the notion of a **content-collection** corresponding to the organization of content projects in **shared directories**, along with the mechanism of **item-inclusion**, and the approach of **semantic content**. Together, these notions allow the project-based maintenance, connecting to author communities, and the assembly and preview actions for the purposes of specific learning experience where re-used content appear as a coherent entity.

This paper starts with an ideal re-use scenario and surveys current practice of re-use. It follows with the various relations of an author to them in the re-use paradigm. Related work and open questions conclude it.

1 A User-Story of Re-use

Let us imagine an author who is assembling the content for next year's course. For this purpose, a new content-collection is set-up. It starts as an inclusion of last year's project but the author wishes to replace parts and does not wish to affect last year's content. So his collection *extends* last year's collection, by referencing it.

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The author also wishes to include the interactive exercises of this fellow he exchanged with since last workshop as well as the high-quality real-world examples of a big industrial project he encountered in his professional associations' online community. To be able to evaluate the content elements, he needs to see web-pages that describe the content projects, that point to public demoes and that provides the IPR statements; these information pages allow him to track the online spaces where these content projects happen and document how to include them.

Using the simple *import* facility of his authoring learning platform, he can see the *books* of these content projects and can browse the content within the realm of his own server. When he starts to assemble the contents of the first lessons, he quickly realizes that his students will need more technical instructions for the interactive exercises of the fellow, and also that some of the real-world examples refer to concepts that are formulated differently than the formulations he wishes.

These adjustments are possible for him since he knows how to change the sources of the documents that can be copied and processed by his authoring tools. Doing this, he creates an *appropriated* version of each of the three collections the course he prepares is based on. The content project of this year is first built with just a few *books* that imitate the books of last year and slowly get adapted to incorporate the two new content projects and further explanations.

After the modifications, the author can upload his course to the server of the school. This means uploading all four collections to this server (three base collections and the collection of the new course). Students will see it as a coherent single course. Advanced users of the school's server, e.g. remote teachers, will still be able to click through until the original collections, following an information page with *copyright information*.

Figure 1 presents the view of the working-space of the author, in the central rectangle, with imported collections linked to their external *repositories*, and with a link to the target learning environment.

Because his way of working has clearly identified the derivative nature and the origin of each content collections he is based on, our author can incorporate in the new course, a few months later, corrections to last year's course or revisions to the industrial examples. Similarly, he is able to transmit the enriched technical instructions he wrote so that his fellow considers them for inclusion in his project's repository...

2 Elements of Re-use

By re-use we mean the action of taking an *existing* piece of content with the activity of the creation of content different than the original one.

The authoring activity naturally happens within the context of several **spaces**, such as the composition space (world of the editor) and the preview space (a small learning platform) and it may lead to a publication space (for other authors) or a staging space (for the learners).

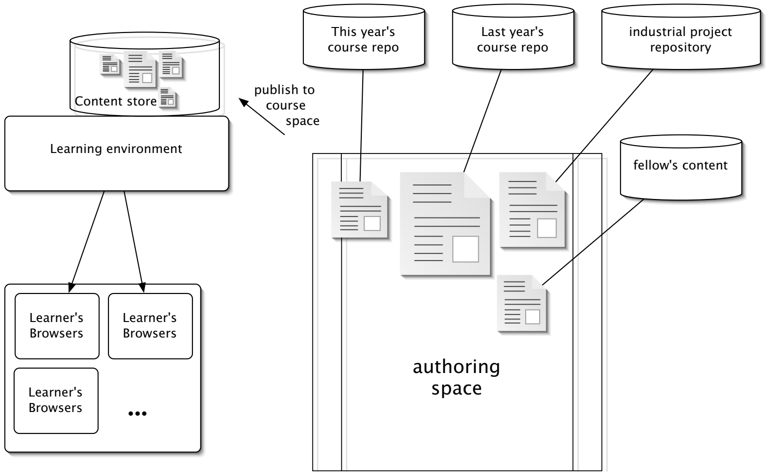

Fig. 1. Projects' organizations of the author creation process of the user-story

Re-use sheds a new light on these spaces since one such set of spaces is needed for each content project; therefore transport methods between these spaces is needed, for example from the originating author's publication space to the composition, staging, and publication spaces of the recipient authors. This paper articulates re-use under the perspective of the many relationships between authors and these spaces which are mostly all visible on the web.

Central to the re-use actions is the granularity of the content-items manipulated. The finer it is, the more management actions may be required but the more freedom for re-organization it allows; the coarser it is, the easier the content items are to exchange, but the higher the risk to require the creation of a new version. ActiveMath has chosen a very fine-grained approach where individual mathematical content paragraphs such as a definition, a motivation, or an example, are the content items. Most other tools have the granularity of a page (typical of content-management-systems or wikis), or of a book (typical of a desktop document). Items are combined into larger pages or books using the item-inclusion paradigm, that is, books are *assembled* (or *aggregated*) in table-of-contents hierarchies. This approach is what we call **item-inclusion**.

Another important aspect of re-use is the nature of the material and its content-encoding. The nature of the material varies from simple pictures to complete web-sites, the nature of the content-encoding varies from final-delivery executable materials (such as a multimedia CD or a video exploration), to the full authoring sources. Each of these dimensions impact strongly the re-use possibilities. For example, lack of authoring sources (or available software to edit it), means the sole possibility of acceptance or rejection *as-is* for re-use.

Because web-delivery technologies are changing rapidly, it is common for the authoring sources to be much more abstract. One way to abstract is to write **content semantically**. For ActiveMath this has meant that all formulæ are encoded using the OpenMath standard and that all content-items are given a mathematical and pedagogical role (e.g. exercise, definition...). We refer to [4] for more details about the knowledge representation of ActiveMath. This gives the advantage that mathematical notations are homogenous since they are separated from the content.

Re-using a piece of e-learning content within another setting is a fundamental action to evaluate many of its facets. If the origins are sufficiently traced, it is possible to stimulate evolutions of the content pieces following this re-use and thus enable long-term **quality management**. Several such workflows which combine quality assessment, content composition, and usage have been studied in the e-Quality project, see, e.g. [5].

Last but not least, the **consistency** of the resulting learning experience is desirable for learners so as not to raise the load on extraneous memory. This fundamental aspect of the re-use result has to be proofed by re-using authors.

3 Current Practice in Re-Using

In this section we attempt to classify the current practices that can be called re-use in e-learning. We catalogue the weaknesses and strengths of each.

Classical Re-Use: Verbatim Inclusion. The simplest form of re-use is achieved by importing the file of someone else, not changing it, and including it within his authoring space. This practice is common, for example, for the re-use of pictures from clip-arts libraries. Verbatim inclusion works much less well as soon as changes are needed.

Classical Re-Use: Copy-and-Paste. Most of the time, re-use is based on the usage of the *copy-and-paste* paradigm. The evaluation of the WINDS authoring tools states: *Reusability is not measurable in our system as it is based on the copy and paste method that can be applied on various levels – learning unit, material, content block and index.* [6]

Re-use through copy-and-paste can beof great help for imitation, which is an important activity to learn to author.

Re-use based on copy-and-paste and subsequent modification is clearly insufficient for the quality development. This practice generally looses the the trace of the inclusion (from where to where in the re-authored work). It thus prevents transmission of further enhancements.

Classical Re-Use: linking. The simplest form of re-use in web-publishing is realized by the usage of a hyperlink from the published text into another.

Linking is a method that is very easy for authors and keeps good tracks of the origin (hence can take advantage of enhanced versions). However, when followed by learners, it looses almost fully the users' context within the learning environment and the practing of sending learners to uncontrollled sites has attracted mistrust as in [7].

Classical Re-Use: Copy and Branch of Large Bodies. The operation of *branching* is, typically, achieved when moving from one project to another by duplicating the document then arranging the various parts. The branching practice could be best of breed in principle but needs, in general, to be combined with further edits: for example, re-using a textbook chapter or the slides of a whole lesson will very likely lead to modifications. Analysis of differences so as to flow back and forth enhancements, as described in the user-story above, may become difficult with such a practice because of the grain size. Indeed the usage of a differencing tool is then required but rarely practical.

Classical Re-use: Channel-based as in News-Feeds. One of the common practices of web-based re-use is the practice of newsfeed aggregation where one *aggregates* news from several sources and merge them in one news-page. The resulting stream of news includes both locally created news texts as well as remotely fetched news-texts. They are generally presented in a chronological manner and serve targets such as web-logs or groups' news pages. This paradigm is most commonly exercised by the abonnement to RSS-channels, which are simple URLs of RSS or Atom documents, two XML formats which describe a timed sequence of news items. Channel based re-use is very easy to activate: one needs only drop the URL into the configuration of the aggregator. Channel based re-use is not appropriate for e-learning contents and the same unpredictability as linked re-use is there, finally modifying an included news item is not a normal practice.

4 Project- and Inclusion-Based Re-use

In the previous section, we surveyed widespread re-use practice and saw their strengths and limits. In this section, we propose a model to content sharing and re-use for e-learning that appears to gather advantages of each method described above. To our knowledge, this model is new although it seems to be closely implementable in Connexions (but see section 9.1).

We propose to organize re-use along *content projects*, which we shall call, in ActiveMath, *content collections*. More or less they are created at organization time, when a content goal is formulated and have a lifetime as long as the evolution of the intended learning experience (which may span several years). Content projects have a broader scope than single books. An example would be described in the user story in section 1 as the project of industrial examples.

To realize a re-use action of a content project, the learning environment using them needs to define the ability to *import* items of a content project, that is the actions to bring within the scope of includable content another content collection. Such an action does not mean the inclusion of the whole content within the current authored work. Further, we propose that learning environments allow imported content to be *included* within the realization of another content collection, that is its content-elements become part of a larger entity, for example content items become part of a *book* navigation artifact. Other actions with content projects include the browsing evaluation, download, appropriation, and publication, all of which are tasks of an authoring support tool.

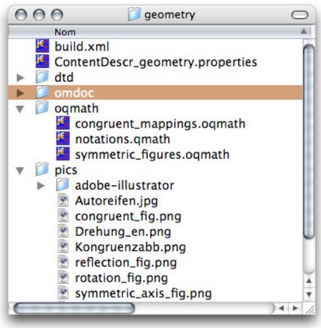

Fig. 2. A file-explorer view of a typical content collection

ActiveMath's content collection implement this pattern: to the eyes of the ActiveMath learning environment, all content elements are contained in a collection, they are directories that contain a descriptor, server-content-files, as well as static web-resources. The screenshot in figure 2 depicts a file-explorer view of a typical collection ActiveMath: the content files in the `omdoc` directory, the authoring sources of them (the `oqmath` files), the current syntax-specification (`dtd`), a content-descriptor, and a directory of pictures (`pics` and their sources `adobe-illustrator`). This collection contains the enough information for a *build process* to be run which will compile the sources and upload them to the server as is described in [8].

Content collections should, at best, be focussed on a theme, they should have a long lifetime and carry a community of authors and consumers interested in it; this is strongly different than single documents shared in learning-objects'-repositories.With such a long lifetime, quality and evolution can be managed at the project level and different views can be exchanged about the usage of the content. As a result, content projects may come with their own versioning repository, their own download space, their own web-pages and their own community space.

Designating a content project as the **contents of a shared directory**, without having the need to move them around, thanks to the inclusion mechanism, allows the proper management of content-items while keeping a common file organization shared between contributors of the content project. Thus, the recipient of a re-use action is able to identify that the files he changes are coming from a project shared with some other people to which he may be able to offer his modifications. This location tracking is precisely what is missing in the copy-and-paste or the copy-and-branch practice which lead to an unmanaged proliferation of almost duplicates.

Advantages of the linking paradigm of re-use remain in a learning environment that allows reference-based inclusion. Indeed, the inclusion within a book's table-of-contents is a single line in ActiveMath's OMDoc. This inclusion is stronger than linking since it really inserts the content-item within the scope of the other items. Moreover the fine granularity as well as a semantic nature of contents help to make this re-organization consistent since they allow, each, paragraph level re-use or modification, (mixing reused and own items on a page) as well consistent math-notations even though the source is of a fully different origin.

5 A Simple First Approach: A Shared Authoring Server

It has been suggested several times that single global server, such as that of Wikipedia or Connexions would allow the re-use story of section 1) to be easily realized. The biggest issue of this approach is the impact of a content change.

There is no reason that a given content author changes a Wikipedia page, or any other *central server* page, for the purposes of his intended teaching experience alone; Wikipedia pages are meant for the humanity and not for a particular classroom or book audience.

In the ActiveMath learning environment, for example, the impact of a change can be quite radical: the addition of an exercise anywhere suddenly makes it selectable by its tutorial component [9], or displayable by the search tool. We see, thus, the (current) impossibility to manage appropriate *scopes* to restrict impacts of changes.

Finally, a shared server suffers the same issues as the linking re-use paradigm with respect to loss of context of the learners which have to leave their learning platforms for another.

The approach of a global server, however, has a clear interest as a content commons for the instructors and authors who wish to discover and share content items. The shared platform allows easy cross-linking and easy searching, two important facets of the re-use of new materials. This shared platform is what made the success of the Connexions project [10] which, however, does not try to provide an adaptive experience to the learners but helps the author realize a document that they can deliver to the learners within a different serving environment. Most probably, domain-oriented author communities are the best host to such content-commons but the need to *export* from a content collection on a content commons to one's own learning environment remains.

6 How Can an Author Re-use Content?

Having described the spaces where the content projects and their sources can be stored, we now try to concretize the user story with successive approach steps an author may have towards the re-use of a content project. They are connection relations between an author and a content collection.

6.1 Remote Browsing

Remote browsing is the simple relation of the author's web-browser to be a client of a learning platform server running anywhere in the world. Such a connection relation is appropriate for discovery but requires the author to understand what is content in the web-experience he is having in order to know what he will be able to re-use. The author also cannot see how a content he would re-use would be integrated with other content items. Having identified the content items of interest, he is able to identify the content project he wishes to be re-using and can enter one of the connections relations below.

6.2 Web-Service Content Channel

Similarly to RSS channels, the idea of this connection method to a content storage is to use a simple remote protocol as single method of access to the content. Using this approach the author's learning-platform, for example an authoring-preview server, is configured to request anything concerning the content collection through this channel. In learning platforms, there seems to be few implementations of such a method.

ActiveMath implements this approach currently using the bare-bones XML-RPC protocol, a simple and efficient remote method invocation mechanism through *http*. It has been tested successfully, reaching 300 queries per second.

The web-service approach works fine for a small amount of queries and it is very easy to add a new collection, since it simply requires to add the URL of the web-service to the configuration.

6.3 Download of the Collection

A simple way to load a collection which avoids all network fragility is to simply download the collection in full, for example as an archive or through a *checkout* of a versioning server. Following the configuration of the learning platform to load this content collection, it needs to be *loaded*, that is, the *index* for this collection needs to be built which may be time consuming. This connection relation, being lengthy to set up, is not appropriate for a simple discovery of the content but provides the biggest safety. Also, it opens the door to appropriations:

6.4 Appropriation of Collections

It has been our experience that re-use is only acceptable to most authors if the right to modify is granted as well (the derivation right in [11]), along with the rights to redistribute (at least to one's learners) the modified content. The necessity to support the modification of content collections that are re-used is important. We call appropriation, the action of starting to modify a collection that is re-used since it is the action of *making own* this content collection. To our knowledge, appropriation only works with a downloaded copy of the content-collection and is thus an action only possible when one has really decided to try to re-use a content-collection. Once appropriated, the content collection would best be re-published, in order to be offered for further re-use:

7 Sharing of Content Project on the Web

In the previous section, we have described three methods above to access a content and its storage through the web. We now turn to describing the essential ingredients required for a publication on the web so that other authors can easily re-use a collection (even an appropriated collection).

As fundamental ingredient of a publication on the web is a single identifier which should not change. The first role of such a string is to be used as an identifier to let the content storage identify its items, as well as let other content items reference it. The second role is used in discussion about collections and items. It is important that people may refer to a collection or a content item anywhere in electronic communication. The third role, if care is taken that this identifier is an HTTP URL, follows the *namespace document* practice of [12].

Here is information we expect to be found behind such a URL:

– a license that specifies the rights for re-use
– a list of names of copyright holders
– identifiers of the content projects this project relies on
– a list of all the resources involved in the collection
– list of the various storage connection configurations which allows the collection to be re-used
– optionally links to a community space of the content development, to courses or other events that make use this content collection, to usage reports, ...

All this information can be encoded within IMS Content Packaging manifests [13] (IMS-CP) which, by its XML nature, may provide this double role of machine processable file as well as browser-renderable document.

With such an information behind a content-collection manifest an author could be able to simply drag-and-drop the link with this URL into his authoring interface's configuration in order to let his authoring platform suggest connection methods and *be connected* to this content collection to use it.

8 A Web of Versions for Peer Productions

Creating a new version of a content collection published on the web can be done in two ways:

– A minor and compatible version change should probably be published at the same location with simple updates of the storage. Simple web modification tracking, similar to bookmark tracking, can be used to detect changed manifests, indicating a changed content.
– A major version change, for example between the course of one year to another, should probably best be made as a branch, allocating a new collection URI. Such a version change is the same as building and publishing an appropriated collection with a few modifications. Licenses that allow derivation allow this to be done by anyone in the world, who can choose to publish on the web an archive of the appropriated content collection.

The web of versions has content-package-manifest as nodes and dependencies or new versions between collections as links. In this web of version, a very important activity is the navigation between the various collections while shopping for the appropriate content to be re-used. For this, the ability to access a content-collection as easy as a link-click is very important. In this navigation, access may mean simply *browse about*, that is to read the small information about it, to try it in preview servers (linked from this information), or to start using it in one's own platform.

Updating a content collection can be done in several ways: if it is a minor version change, an update or download is only needed. A major version change yields a change in URL: the new content collection needs to be connected to, the old version probably needs to be removed, and updating references to this collection means changing the collection-identifier.

To help the management of such identifiers, the OMDoc language used in ActiveMath has integrated the *development graph* [14]: this namespace management methodology requires that each document be endowed with *imports* elements which provide the full collection name of *theories* that are referenced. References within the document can thus use only the short *theory-name*. Major updates of relations, whereby one changes the URL of a content-collection, are done by only changing the imports. Because imports are recursive, this needs to be done once per content collection.

9 Conclusions

In this paper, we have presented approaches to organize content projects, to publish, to store, and to serve them, in order to facilitate re-use of content and long term quality management. Our approach is unique under several perspectives which we describe.

9.1 Originality of the Approach

We propose to rely on a very fine granularity of content items, which we suggest be as small as a motivation, a definition, or an exercise and be used as elementary units of inclusion. Opposite to this fine granularity we propose content projects which carry connection methods, ownerships, and authoring practice to be large and long lived.

This decoupling seems, in particular, to be lacking in all learning object repositories and many approaches that speak about learning objects where re-use is too often considered at the individual document level without a notion of a package derived from another.The large granularity of the projects may be key to the constitution of the communities' focus which, otherwise, may become scattered around too many resources. Both [5] and [2] indicate the community constitution as essential factor for re-use to happen.

Our approach considers the appropriation tasks deeper than [3] which proposes limited re-factoring methods activated by menu entries; instead, our approach insists that arbitrary modifications should be authorable in the appropriation process and let the differencing and versioning tools act, if need be, to identify or visualize the modifications. This task is best served, as of today, by source formats using source versioning tools.

The Connexions content common, seems to be closest to achieve our user-story. Although it provides combination and branching, it seems not to support the *merging* or *return* of adaptations to help in quality management.[1] Another major difference to ActiveMath is the granularity of the item of content reorganization: Connexions' modules seem to be rather expected to be full pages making them harder to combine.

[1] A private communication with authors of the Connexions project seems to indicate a growing feature-set that allows fine-grained combination (through the course composer) and management branches and differences.

The ability for *anyone* to publish a new version is provided legally by licenses that allow derivation and technically simply by putting it on the web with a description of its source. This facility opens considerably the door to contributions for anyone with a web-space who can publish what he has considered appropriate for his context and usage.

The decentralization and distribution facet is slowly appearing in projects which re-use Wikipedia material: indeed the needs of school for a predictable, high-quality material has justified such an institution as SOS Children to fund the delivery of an offline set of wikipedia articles in a DVD form.[2]

9.2 Open Questions

Aside of completing implementation and large scale evaluation of our approach, open research questions remain:

It appears that, technically, the web-service channel approach could be relaxed to exploit simple web-of files using a process of compilation and map of XML content. This avenue could enable authors to use their normal web-space to publish their content-collections by a simple upload (such as FTP) and let other authors enjoy the same *lightweight installation* that the web-service channel offers, with local download of "only the files needed" for appropriated items to be edited.

The right to derive in public only. Our experience has shown that authors that invested body and soul in the creation of content find it hard to let anyone change their work freely and redistribute it even though the license stipulates well the requirement to quote the original author; the most common justification is that authors wish to *know what will happen to their content*.

A potential avenue to solve this is to request the *notification of usage and change*. Global web-availability of the displayed content with links to the collections' identifiers may be sufficient to answer this: reverse links queries, as supported by current web search engines, may reveal the usages; it would enable an author to see where a content project is used, to browse it, and, if need be, to request the removal of his authorship. A mix of legal and technical investigation is required in order to make the derivation right less feared about.

The Right Brick of E-learning Peer-Production? Yochai Benkler in [15] analyzes the ingredients that have allowed the peer productions spaces to exist and grow as large as we know them (e.g. open-source software or the Wikipedia initiatives). Among the major ingredients are the possibility of a very fine grain contribution and its affordance. We claim that the contribution of a delta posted on a static web storage satisfy these requirements and thus believe that this framework can allow decentralized peer-production.

[2] See `http://schools-wikipedia.org/`.

References

1. Robson, R., Collier, G., Muramatsu, B.: Reusability framework. Technical report, Reusable Learning Project (2006), http://www.reusablelearning.org/
2. Busetti, E., Dettori, G., Forcheri, P., Ierardi, M.G.: Promoting teachers' collaborative re-use of educational materials. In: Innovative Approaches for Learning and Knowledge Sharing, Proceedings of ECTEL 2006 (2006), http://www.springerlink.com/content/n25p524n4514/
3. Meyer, M., Hildebrandt, T., Rensing, C., Steinmetz, R.: Requirements and an architecture for a multimedia content re-purposing framework. In: EC-TEL, pp. 500–505 (2006)
4. Melis, E., Büdenbender, J., Goguadze, G., Libbrecht, P., Pollet, M., Ullrich, C.: Knowledge representation and management in activemath. Annals of Mathematics and Artificial Intelligence, Special Issue on Management of Mathematical Knowledge 38(1-3), 47–64 (2003), http://monet.nag.co.uk/mkm/amai/index.html
5. Montalvo, A.: Conceptual model for odl quality process and evaluation grid, criteria and indicators. Technical report, e-Quality Project (2005), http://www.e-quality-eu.org/
6. Kravcik, M., Specht, M., Oppermann, R.: Evaluation of winds authoring environment. In: De Bra, P.M.E., Nejdl, W. (eds.) AH 2004. LNCS, vol. 3137. Springer, Heidelberg (2004)
7. Moravec, J.: US senator: Ban wikipedia from schools (2007), http://www.educationfutures.com/2007/02/15/us-senator-ban-wikipedia-from-schools/
8. Libbrecht, P., Groß, C.: Experience report writing LeActiveMath Calculus. In: Borwein, J., Farmer, W. (eds.) MKM 2006. LNCS (LNAI), vol. 4108, pp. 251–265. Springer, Heidelberg (2006), http://www.activemath.org/pubs/bi.php/Libbrecht-Gross-Experience-Report-Authoring-LeAM-MKM-2006
9. Ullrich, C.: Course Generation as a Hierarchical Task Network Planning Problem. PhD thesis, Saarbrücken (2007)
10. Henry, G., Baraniuk, R.G.: Peer to peer collaboration using connexions. In: American Society for Engineering Education Annual Conference & Exposition Salt Lake City, Utah (2004), http://cnx.org/aboutus/publications
11. Creative Commons: Choose a license (accessed, April 2008) http://creativecommons.org/license/
12. Jacobs, I., Walsh, N.: Architecture of the world wide web. Technical report, World Wide Web Consortium (2004)
13. Smythe, C., Jackl, A.: IMS Content Packaging Information Model v1.1.4 (2004), http://www.imsglobal.org/content/packaging/
14. Mossakowski, T., Autexier, S., Hutter, D.: Development graphs – proof management for structured specifications. Journal of Logic and Algebraic Programming 67(1-2), 114–145 (2006)
15. Benkler, Y.: The Wealth of Networks. Yale University Press (2006), http://www.benkler.org/wealth_of_networks/

Knowledge Services for Work-Integrated Learning

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Abstract. In order to support work-integrated learning scenarios task- and competency-aware knowledge services are needed. In this paper we introduce three key knowledge services of the APOSDLE system and illustrate how they interact. The context determination daemon observes user interactions and infers the current work task of the user. The user profile service uses the identified work tasks to determine the competences of the user. And finally, the associative retrieval service utilizes both the current work task and the inferred competences to identify relevant (learning) content. All of these knowledge services improve through user feedback.

Keywords: technology enhanced learning, task detection, contextualized retrieval.

1 Introduction

Work-integrated learning (Lindstaedt & Farmer, 2004) (Smith, 2003) happens very frequently (often without being noticed) during social interaction while knowledge workers collaboratively create or refine digital artefacts, communicate aspects of their work, or examine existing documents. The role of a knowledge worker, embodied in social interaction, is subject to continuous change: at one point in time, a knowledge worker acts as a learner, at another point in time she acts as an expert (teacher), and then again she is simply getting her work done – all depending on her expertise with regard to the subject matter at hand (Lave & Wenger, 1991).

The design of computational support for work-integrated learning is at the core of the EU-funded integrated project APOSDLE (Advanced Process-Oriented Self-Directed Learning Environments, www.aposdle.org). The APOSDLE approach (Lindstaedt et al., 2007) is to support learning and teaching episodes tightly integrated into the work processes by taking into account the work context, such as the task at hand, and the prior knowledge of the knowledge worker. Workers are provided with knowledge artefacts relevant to their work context, thus raising their own awareness of learning situations, content, and people that may be useful for learning at that point in time. This context-aware knowledge delivery takes place within the usual computational work environment of the user, raising her awareness about relevant resources without having to switch to dedicated learning or knowledge management systems.

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One major challenge within the project is to not rely on specifically created (e) Learning content, but to reuse existing (organizational) content which was not necessarily created with teaching in mind. We tap into all the resources of an organizational memory which might encompass project reports, studies, notes, intermediate results, plans, graphics, etc. as well as dedicated learning resources (if available) such as course descriptions, handouts and (e) Learning modules. The challenge we are addressing is: How can we make this confusing mix of information accessible to the knowledge worker in a way that she can advance her competencies with it? (Lindstaedt & Mayer, 2006).

While we have addressed APOSDLE's support for the role of the expert in (Lokaiczyk et al., 2007) and the support for the role of the learner in (Bonestroo et al., 2007) in the following we specifically focus on the support for the role of the worker, specifically the work context-aware identification of relevant documents and people.

Within the field of technology enhanced learning (TEL) user context awareness has been extensively studied within mobile learning applications. In these applications user context is determined to a large extent by the physical location of the user (Naismith et al., 2004). However, there are many more learning situations which can benefit from contextualized support. Examples of such situations include but are not limited to situated learning (Lave & Wenger, 1991) within the context of communities of practice, self-directed learning and informal learning (Eraut, 2004). Within the case of work-integrated learning the relevant user context is constituted specifically by the current work task the user is attempting to complete.

User context determination plays a crucial role in the overall approach. In order to be able to provide the user with information, learning material and links to people relevant to her task at hand, the system needs to identify the work task reliably. The goal is to identify a user's current work task based on the user's interactions with her work environment (key strokes, mouse movements, applications used, etc.) and the metadata and content of the resources accessed (mail messages, documents, links to people, etc.). The identified task then updates the user profile and causes a number of activities to be started pro-actively: re-computation of a user's learning goal and learning goal histories, search of knowledge artefacts relevant to the learning goal, search of people relevant to the learning goal, and the dynamic creation of learning events. The results of these searches are displayed in the form of resource and people lists unobtrusively to the user.

In this contribution we give a detailed account on the technological approaches involved in completing this complex context-aware retrieval process from context identification to information delivery. Section 2 gives an overview of this process and introduces the three key knowledge services which are combined to implement it. In Section 3 we shortly give an insight into the role of semantic models within the system. The introduced key knowledge services are then detailed as follows: Section 4 elaborates on how tasks are detected, Section 5 details the computation of learning goal gaps, and in Section 6 the retrieval approach itself is described. We close with an outlook on evaluations currently under way and some ideas for future work.

2 Key APOSDLE Knowledge Services

Figure 1 below illustrates the information flow through the system and the key knowledge services provided by APOSDLE. We distinguish two alternative paths: the 'Learning Tool Path' (steps 6a and 7a in Figure 1) uses the available user information to dynamically create *learning events* (for more details on this path please refer to (Bonestroo et al., 2007)). The 'Related Resources Path' (step 6b of Figure 1) uses associative retrieval to find knowledge artefacts that are related to the knowledge worker's current situation. This contribution explains in detail how this related resource path is supported.

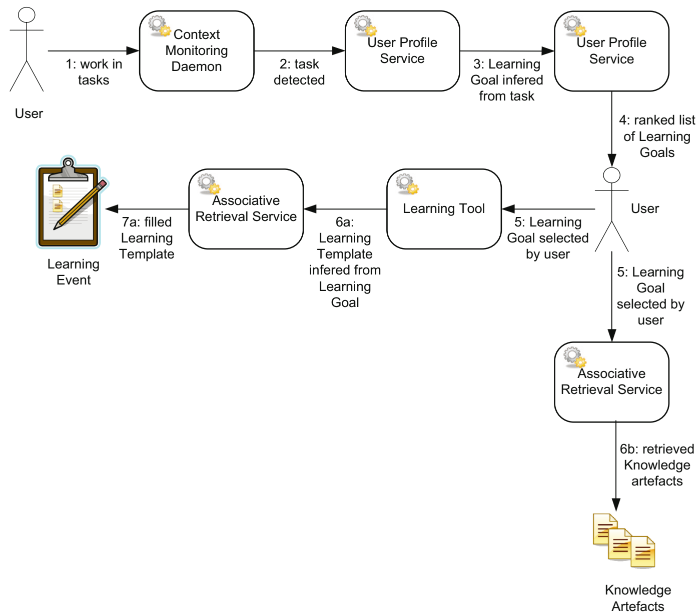

Fig. 1. Information flow and key knowledge services within APOSDLE

Based on low level system events the *Context Monitoring Daemon* (CMD, see Section 4) detects the current task a knowledge worker operates in (steps 1 and 2 in Figure 1). The CMD is a background service installed on the client computer. The CMD gathers low-level system events and maps them to tasks from the task model using machine learning algorithms. The goal of the CMD is to automatically identify the current user's work task.

The detected current task of the user is then stored in the User Profile of the user which is accessed using the *User Profile Service* (UPS) (steps 3 and 4 in Figure 1). The UPS is part of the APOSDLE Platform running on the server side. It serves as a repository for user-related information and as an engine enabling the system to infer information about the user. The UPS utilizes a history-based user profile representation where activities of users are stored together with a timestamp. Based on this history of user activities the UPS infers information about the user as described in more detail in Section 5. The user is able to overrule the *learning goal* suggested by the UPS (step 5 in Figure 1).

Based on the selected learning goal a search is triggered engaging the *Associative Retrieval Service* (ARS, see section 6) (step 6b in Figure 1). The ARS is used for context-based retrieval of resources for work-integrated learning. It incorporates semantic similarity between concepts in the domain model, content based similarity between knowledge artefacts and semantic annotations of knowledge artefacts.

3 The Role of Semantic Models within APOSDLE

This section explains the three model structures and their relationships which provide the basis for reasoning within APOSDLE:

- Domain model – provides a representation of the learning domain in OWL (Web Ontology Language) format
- Task model – provides a representation of the work tasks to be supported in YAWL (Yet Another Workflow Language) format
- Learning goal model – provides a mapping between domain concepts, tasks and general learning goal types in OWL (Web Ontology Language) format

Domain Model

The objective of the domain model is to provide a semantic description of the learn domain of an APOSDLE environment. The domain is described in terms of concepts, relations, and objects that are relevant for this domain. Technically speaking the domain model is an ontology that defines a set of concepts which are relevant for the domain. These concepts are also used for semantic annotation of documents (or parts thereof). In the following we will refer to the combination of a document (or part thereof) together with one or more domain concepts as a knowledge artefact. This annotation process can either happen automatically (using text based classification algorithms) or manually. These semantic annotations are used later within the Associative Network to retrieve relevant knowledge artefacts.

Task Model

The objective of the task model is to provide a formal description of the tasks the knowledge worker can perform in a particular domain. The YAWL workflow system (van der Aalst & ter Hofstede, 2005) is used as conceptual basis for the task modelling. This formal description is used in various ways within APOSDLE. One aspect is the task prediction, which needs a set of predefined tasks. Another important aspect is the dependant task-competence mapping forming the *learning goal model* (below).

Learning Goal Model

Learning goals constitute a mapping between tasks and domain concepts in order to realize an adaptive system. A learning goal describes knowledge and skills needed to perform a task. It is defined as a discrete element of a cognitive activity (learning goal type) connected with a domain model element. The formalisms employed are based on Competence-based Knowledge Space Theory (Korossy, 1997) and they provide several advantages for APOSDLE. One important advantage is that it allows the computation of learning goals through a learning need analysis by comparing knowledge needed to execute a task and the knowledge state of the user. Another one is the possibility to infer a user's learning history by examining the work task she has engaged with in the past (task-based learning history). A final advantage of utilizing Knowledge Space Theory within APOSDLE is that the mappings afford the computation of prerequisite relationships between learning goals. This allows APOSDLE to identify learning goals which should be mastered by the user on the way to reaching a higher level learning goal.

APOSDLE Knowledge Base

The APOSDLE Knowledge Base (AKB) contains the three different models briefly discussed above, and the meta-model schema interrelating them. Within this AKB each model is stored in its original format (OWL, YAWL) and also within the meta-model schema. The meta-model schema is an ontology represented in OWL. The advantage of keeping the models in both representations is that within the original representation (for example, YAWL for tasks) reasoning about processes is possible while within the OWL representation reasoning about the overall model is supported.

4 Task Detection - From Low Level User Events to Work Task

Our approach to context awareness in based on a common architecture by Baldauf et al. (2007) which includes the use of agents in three layers separating the detection of context, reasoning and actions based on context.

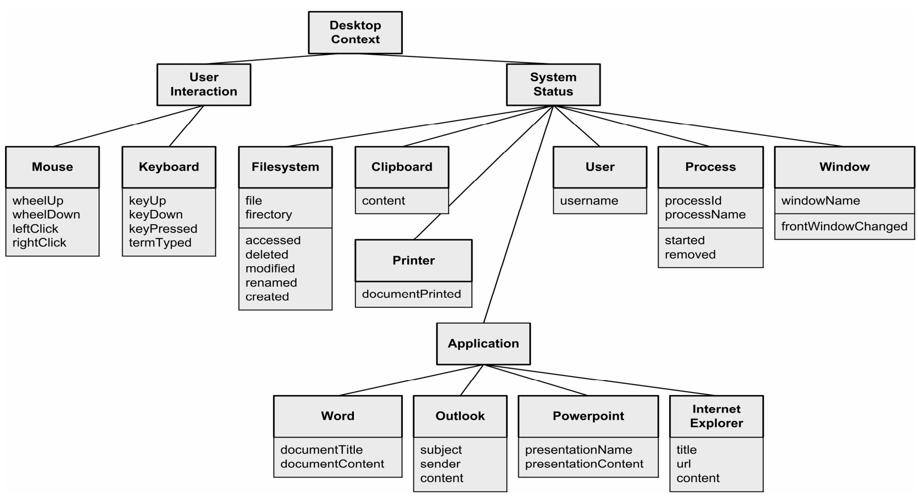

Fig. 2. Taxonomy of work context sensors

Layer 1, the monitoring of user events, is implemented using the CMD. This knowledge service observes a set of system sensors to gather operating system events, which reflect the user's interaction with the computer desktop during the working process. These sensors include e.g. information about the foreground and background applications, the user's input to these applications, the files opened during the work process and the textual features of the desktop, such as window titles and website content. A taxonomy of the implemented sensors is shown in Figure 2. These system level events, which are collected in an unobtrusive way, are then logged with a time-stamp and correlated to the current work task of the user.

Layer 2, the context reasoning layer, is realized as a machine learning classification. During the training phase task executions by a number of different users are captured and labelled. These captured execution logs are then utilized to train a classifier, which is able to distinguish between the different tasks assuming that they significantly differ in their execution log (see Figure 3). This assumption depends of course on the definition of the work process and the task granularity but has a plausible foundation. Knowledge workers often use different applications or files for different process steps in the working process. Consequently, the usage of a particular file, application or term during the work process can be exploited as an indication for the execution of a particular work task from the task model.

During run-time the CMD tries to automatically classify the work task of the user. A prediction is made, if the following conditions apply:

1. The user changes its role from worker to learner (switches from a Non-APOSDLE application to APOSDLE)
2. The detected task is included in the adjusted work process
3. The self-assessment of the classification is above a defined threshold
4. The predicted task is not already manually set by the user
5. The time span to the last prediction is above a certain threshold

The user will be presented then the currently detected task. Here the user can decide how to proceed. If the user chooses 'yes' or 'no' the internal training process will be enforced with this decision. If the user chooses 'set always' she fully trusts the automatic task detection and this task will be always automatically set. This information is fed back to the Automatic Task Detection module.

Beside the automatic task detection the user still has the ability to manually set her current work task and optionally a sub-task as a fallback or in case she wants to learn independently from the current work task.

The whole approach already shows a good precision in an a posteriori analysis, but a low recall. Therefore, we decided for the current version to rely on the one hand on the a posteriori prediction model and on the other hand to incrementally extend this model with new training instances produced by the user during her APOSDLE usage. This makes the task prediction an online learner with a self-improving classification model.

The idea could be further extended by taking into account other implicit or explicit user feedback mechanisms, which were taken care of at design time but are still in their infancy. They will be taken into account for the design of the third prototype. In addition, an extensive real-world user study is necessary to show the real benefit of automated task prediction in terms of performance or quality increase during the work process.

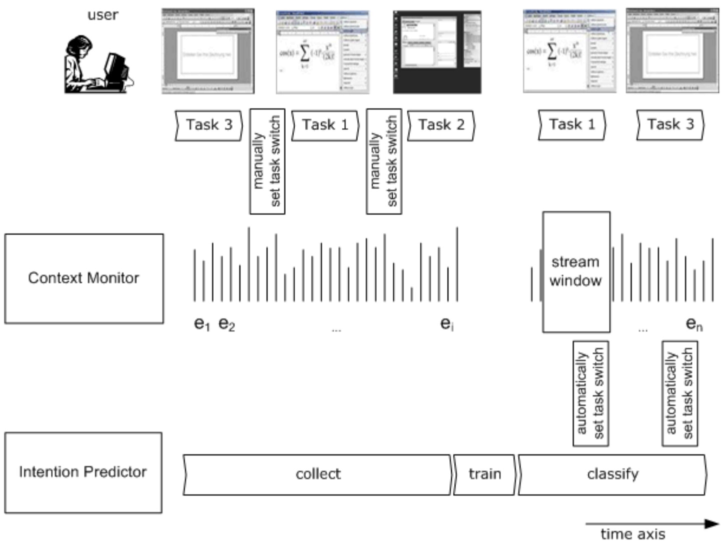

Fig. 3. Task detection as classification challenge

5 Competency Gap Calculation - From Task to Learning Goals

Once a task is set in the APOSDLE sidebar, the inference mechanisms of the User Profile Service (UPS) provide a ranked list of learning goals. By default, the highest ranking learning goal is used for further computations. However, the list of learning goals is displayed in the sidebar, where the user has the possibility to over-rule the ranking, and to select a lower ranking learning goal that she wants to tackle. Once a learning goal is set, the UPS performs another inference, namely the computation of experts with respect to a given learning goal. As for learning goals, a ranked list of experts is computed by the UPS.

The calculations of the UPS are based upon on the models for tasks, learning goals and a mapping of tasks and learning goals, which assigns to each task all learning goals that are required for performing the task. A learning goal is formally represented by a pair composed of a domain model element and a learning goal type. The task-learning goal mapping as been defined by Knowledge Engineers is stored in the Structure Repository. Algorithms for realizing the inference task (as recommending experts, generating a ranked list of learning goals, etc.) are all implemented within the User Profile Service. Note, that especially the algorithms for computing the learning need of a user and detecting experts strongly rely on a proper and clear concept of what a learning need or an expert actually are. Briefly they can be written down informally as follows: A 'learning need' is the discrepancy between the learning goals that are needed by a user to execute a task at hand, and the learning goals that a user has 'demonstrated' in the past, according to her user profile.

Technically, the learning need is a list of learning goals. The UPS applies a ranking algorithm for sorting the learning goals according to theoretical assumptions, from the 'most urgent' to the 'least urgent' for the user to acquire. This ranked list of learning goals is presented to the user. Within the conceptualization of the second APOSDLE prototype, an expert is a person who has 'demonstrated' a learning goal more often than the learner herself in a task execution.

The inferences in the UPS are all based on the task-learning goal mapping. In any situation, the context of the user is determined by the task at hand, and by the task history of a user, i.e. by all tasks that the user has executed in the past. Each time a user executes a task, all learning goals that are assigned to the task are added to the learning history of the user. This means, the learning history of a user is inferred from her task history by counting the number of how many times the user has "applied" a learning goal in a task execution. The computations of the learning need, the ranking of learning goals, and the ranking of experts that are suggested to the user in a concrete situation are based on the learning history of the users. The algorithm for ranking the learning goals takes into account the basic assumptions of the Competence-based Knowledge Space Theory (Korossy, 1997), and extension of Doingon & Falmagne's Knowledge Space Theory (Doignon & Falmagne, 1999). Moreover, the ranked list of learning goals has the following characteristics: Learning goals that never have been applied, or that have been applied less frequently are ranked higher than learning goals that have been applied more frequently. Learning goals that are "more important" in the learning domain, i.e. learning goals that are assigned to more tasks than others, are ranked higher.

In addition to the aforementioned inference functionality the UPS also provides a partial representation of the user's 'current context' to the Associative Retrieval Service to be used for context-based retrieval. The current context consists of domain model elements, which have either been decided by the UPS to be highly relevant for the user's current work task and learning need, or which have actively been selected by the user. To provide the Associative Retrieval Service with relevant domain model elements, the UPS generates a ranked list of learning goals. The sidebar displays them to a user who then can select one learning goal out of this list. All further inferences are based on this selection. Thus the most important domain model for a user's current context is the domain model connected to the selected learning goal. All other domain models connected to learning goals also presented in the sidebar will be provided as additional context information allowing the Associative Retrieval Service to broaden its query when needed.

6 Retrieval - From Concepts to Knowledge Artefacts

The Associative Retrieval Service (ARS) creates a network representation, based on textual similarities, of a collection of knowledge artefacts for retrieval. This well explored approach is enhanced with techniques from knowledge representation and reasoning by analogy, resulting in a network model for finding similarities in a collection of knowledge artefacts by both, content based and knowledge based similarities. Within the APOSDLE project this network representation is referred to as the *Associative Network* (see Figure 4). In this Associative Network every concept from the domain model and every knowledge artefact present in the system are represented by a node. These nodes are associated by means of their similarly and by the semantic annotations of knowledge artefacts with concepts. The use of a network representation as underlying structure for the retrieval process allows for both, exact search for filling learning templates (step 6a in Figure 1) and associative search for resource retrieval (step 6b in Figure 1).

For processing the information in the network representation we employ a processing technique called spreading activation. Spreading activation originates from cognitive psychology (cf. (Anderson, 1983)) where it serves as mechanism for explaining how knowledge is represented and processed in the human brain. The human mind is modelled as a network of nodes, which represent concepts and are connected by edges. Starting from a set of initially activated nodes in the net, the activation spreads over the network (Sharifian & Samani, 1997). During search, energy flows from a set of initially activated information items over the edges to their neighbours. The information items with the highest level of energy are seen to be the most similar to the set of nodes activated initially. A detailed introduction to spreading activation in information retrieval can be found in (Crestani, 1997). A description of our studies on the topic can be found in (Scheir & Lindstaedt, 2006), (Scheir et al., 2007a), (Scheir et al., 2007b).

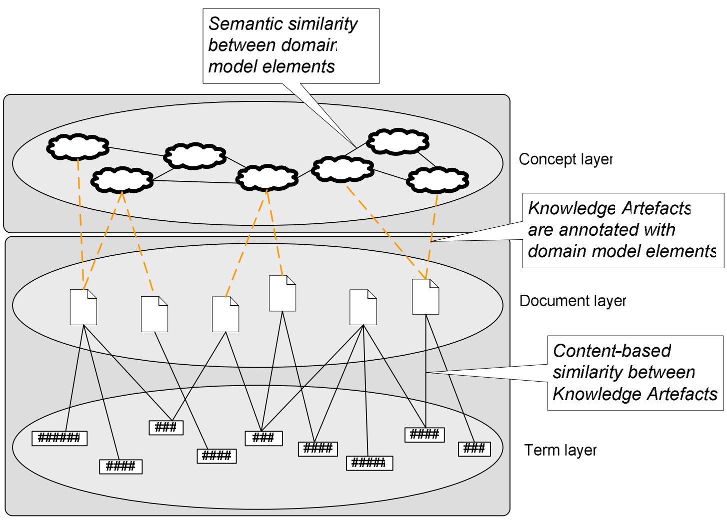

Fig. 4. Semantic and content based similarity within the associative network. Concept layer and document/term layers are connected by semantic annotations.

7 Conclusion and Outlook

The second APOSDLE prototype was completed in Spring 2008. Currently the installations of the four domain specific environments at our four application partners are under way. EADS (Paris, France) is employing APOSDLE for the support of their software based flight simulation department. The Darmstadt Chamber of Commerce and Industry (Germany) applies it to the support of the REACH guidelines for chemical industries. ComNetMedia (Dortmund, Germany) aims at introducing new requirements engineering processes into their organization. And ISN (Graz, Austria) will be employing the system for the support of their consulting processes in innovation management. In each organization the end users receive training for the use of the APOSDLE system.

The evaluation will be conducted in two phases: First, a workplace evaluation takes place in which we observe and interview users of the application partners during system use. Secondly, the individual key knowledge services (as described in this paper and a few additional ones) will be evaluated in detail in controlled environments.

This paper introduced three knowledge services which were implemented within the second prototype of the APOSDLE environment. These services aim at (1) identifying a user's work context (task), (2) infer the competences she has displayed during the use of the system, and (3) use both the task as well as the competences to identify content within the organizational memory of the organization which could help advance the competences of the user. Together they build a complex retrieval process to support work-integrated learning. Evaluations are currently under way and first results can be reported at the conference.

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References

Anderson, J.R.: A spreading activation theory of memory. Journal of Verbal Leaning and Verbal Behaviour 22, 261–295 (1983)

Baldauf, M., Dustdar, S.: A Survey on Context-Aware Systems. TUV-1841-2004-24, Technical University of Vienna (2004)

Bonestroo, W., Ley, T., Kump, B., Lindstaedt, S.N.: Learn@Work: Competency Advancement with Learning Templates. In: Memmel, M., Ras, E., Wolpers, M., Van Assche, F. (eds.) Proceedings of the 3rd Workshop on Learner-Oriented Knowledge Management, RWTH, Aachen, pp. 9–16 (2007)

Cristani, M., Cuel, R.: A survey on ontology creation methodologies. International Journal Semantic Web Information Systems 1(2), 49–69 (2005)

Doignon, J., Falmagne, J.: Knowledge Spaces. Springer, Heidelberg (1999)

Eraut, M.: Informal learning in the Workplace. Studies in Continuing Education 26(2), 243–247 (2004)

Korossy, K.: Extending the theory of knowledge spaces: A competence-performance approach, Zeitschrift für Psychologie, vol. 205, pp. 53–82 (1997)

Lave, J., Wenger, E.: Situated learning. Legitimate peripheral participation. Cambridge University Press, Cambridge (1991)

Lindstaedt, S.N., Ley, T., Mayer, H.: APOSDLE - New Ways to Work, Learn and Collaborate. In: Proceedings of the 4th Conference on Professional Knowledge Management WM 2007, Potsdam, Germany, März 28-30, 2007, pp. 381–382. GITO-Verlag, Berlin (2007)

Lindstaedt, S.N., Mayer, H.: A Storyboard of the APOSDLE Vision. In: Nejdl, W., Tochtermann, K. (eds.) EC-TEL 2006. LNCS, vol. 4227, pp. 628–633. Springer, Heidelberg (2006)

Lindstaedt, S.N., Farmer, J.: Kooperatives Lernen in Organisationen. In: CSCL-Kompendium - Lehr- und Handbuch für das computerunterstützte kooperative Lernen Oldenbourg Wissenschaftsverlag, München, Germany (2004)

Lokaiczyk, R., Godehardt, E., Faatz, A., Görtz, M., Kienle, K., Wessner, M., Ulbrich, A.: Exploiting Context Information for Identification of Relevant Experts in Collaborative Workplace-Embedded E-Learning Environments. In: Duval, E., Klamma, R., Wolpers, M. (eds.) EC-TEL 2007. LNCS, vol. 4753, pp. 217–231. Springer, Heidelberg (2007)

Naismith, L., Lonsdale, P., Vavoula, G., Sharples, M.: Literature Review in Mobile Technologies and Learning (Literature Review No. 11): University of Birmingham (2004)

Scheir, P., Lindstaedt, S.N.: A network model approach to document retrieval taking into account domain knowledge. In: Schaaf, M., Althoff, K.-D. (eds.) LWA 2006. Lernen - Wissensentdeckung - Adaptivitдt, 9.-11.10.2006 in Hildesheim. Universitдt Hildesheim, pp. 154–158 (2006)

Scheir, P., Pammer, V., Lindstaedt, S.N.: Information Retrieval on the Semantic Web - Does it exist? In: LWA 2007, Lernen - Wissensentdeckung - Adaptivitдt, 24.-26.9. 2007 in Halle/Saale (accepted for publication) (2007)

Scheir, P., Ghidini, C., Lindstaedt, S.N.: Improving Search on the Semantic Desktop using Associative Retrieval Techniques. In: Proceedings of I-MEDIA 2007 and I-SEMANTICS 2007, Graz, Austria, September 5-7, 2007, pp. 221–228 (2007)

Sharifian, F., Samani, R.: Hierarchical spreading of activation. In: Sharifian, F. (ed.) Proc. of the Conference on Language, Cognition, and Interpretation, pp. 1–10. IAU Press (1997)

Smith, P.J.: Workplace Learning and Flexible Delivery. Review of Educational Research 73(1), 53–88 (2003)

Van der Aalst, W.M.P., ter Hofstede, A.H.M.: YAWL: Yet another workflow language. Information Systems 30(4), 245–275 (2005)

Designing Software for Pupils with Special Needs: Analysis of an Example for Complementary Action Design

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Abstract. Designing learning-software for a special target group should not only focus on the pupils but also on the teacher. The propagation of using computers for everyday teaching should take into account teachers' possible lack of technical competence. Thus, there are two gaps which have to be bridged: One for the pupils using a computer to learn and the other for the teacher preparing tasks within this learning environment.

1 Introduction

It is known for a long time that computers can be used as effective learning tools to support the acquisition of basic learning skills of pupils with cognitive disabilities [1]. Yet, in spite of the fact that computers can support the growth of self-determination, of independence, and integration skills [2] and allow for *positive changes in inter- and intrapersonal relationships, [...] and cognitive capabilities [...]* [3], there is only few applicable software available. One reason is that software for pupils with special needs is not a profitable field for developers with pecuniary interest. Furthermore, the majority of teachers getting involved in using computers do not possess technical expertise to design and implement software for this target group.

Abbott [4] says that *researching the effectiveness of technology to support learning by those defined as having special educational needs is essentially no different from researching the needs of all other learners.* Bradburn and Pearson [5] find that although requirements for specific groups may be conflicting or changing over time, the inclusive design is the more crucial aspect. Considering not only technical but pedagogical and contextual aspects and intended outcomes and needs is a key for successful solutions. Using the complementary action design strategy [6] for the project LMMP (Learner supporting Multi-Media Platform for pupils with cognitive disabilities) [7], researchers, teachers and software developers collaborate to develop of a full-fledged learning platform for pupils with cognitive disabilities. Since the idea for the project has been generated by the teachers themselves it gives a good example of how software and

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learning scenarios can be designed and implemented in the classroom in a meaningful and successful way by making use of the different expertise of teachers, researchers and programmers in a complementary way.

2 The Software Design Process

The main objective of the design process was to integrate the computer into daily practice to support existing learning procedures without mandatorily redefining teaching practice. We realised this by bringing together teachers for pupils with special needs, computer scientists and psychologists. By regular meetings of the core group and frequent contact between software developers and teachers we obtained short cycles of our incremental development process: *design and description* of a learning module, *implementation* by programmers, *evaluation* in schools, *feedback* by teachers, leading back to a redesign phase.

An important role in the development process is given to the project's wiki. Downloads of the latest software are provided to the core group and to interested teachers from the outside. The Wiki contains the manual with a detailed description of the installation routine, different applications and learning modules. Since it is an essential feature of a wiki that everyone can edit the content, our goal was to encourage the teachers to participate in writing the manual and help to improve the quality of both the software itself and the documentation by using the wiki as a living document [8]. Although the teachers of the core development team knew each other from regular project meetings we also expected that the wiki will boost the community building. Generally, it can be said that even teachers who were not familiar with wikis before, accepted and practiced the collaborative way of editing. Approximately 100 users registered to the wiki within several months whereas 10% contributed to the wiki in different ways.

Figure 1 shows a network visualisation [9] of the contributions made to the wiki from the start in September 2006 to March 2008. Each month is represented by one slice starting with the first month on the left. The software developers are represented by dark (blue), the teachers by light (green) circles, pages as small squares. The more a user contributed to the wiki the bigger the circle is. A user's history over the months can be identified by a linear line from left to right. Lines of users registered later start at this point in time. During the first 10

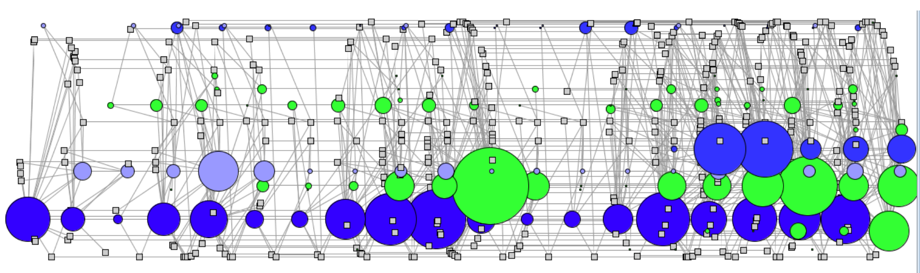

Fig. 1. Analysis of the contribution made to the wiki's content

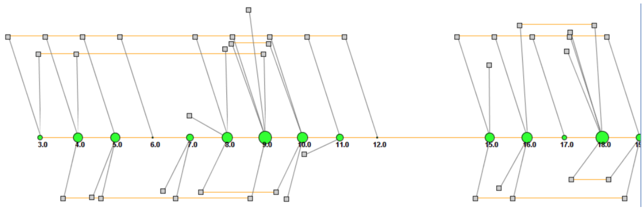

Fig. 2. Analysis of the contributions made by one teacher to the wiki

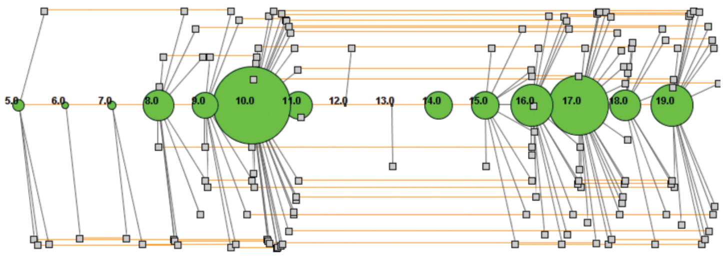

Fig. 3. Analysis of the contributions made by one teacher to the wiki

months most of the wiki's content was generated by software developers. The big circle in the 10^{th} month represents a teacher who started to look deeper into the software and its documentation and improved the installation instruction and the user manual. But it took another five months until more teachers started to actively contribute to the wiki. It can be observed that while the end of the software development phase draws near and the final version will be built, more teachers start contributing actively. During the last three months we could see a clear change from developer to teacher dominated activity.

In a more fine grained analysis of the teacher's editing behaviour we contrast two diagrams showing specifically one teacher and all the pages he edited in each specific month. Again the circles represent the teacher's activity in one month, while different versions of the same wiki page are connected with a horizontal *lifeline*. The diagram shows easily if a teacher edits one page repeatedly or if several pages are edited within one time interval. Figure 2 shows a teacher with a contribution behaviour that is oriented towards a selected set of pages that are of high interest to him. This can be seen in the strong presence of page lifelines in the diagrams with only a few interspersed edits on pages on irregular basis. The main concern of this teacher was with the wiki main page, the online manual for the software, and the puzzle tool. There is also an activity hiatus between months 12 and 15 that shows a non-consistent contribution to the collaborative space. Figure 3 shows a very active teacher who works both on a multitude of pages some of them frequently over time, but also some irregular at specific moments. The activity has been fluctuant in the first months, yet was established at a high level in the latter months of the analysed dataset.

3 Conclusion and Outlook

Developing software is usually dominated by specifications, definitions and interfaces. In our project we followed a completely different approach with a teacher driven design and description phase and immediate feedback from school practice. From our experience LMMP is a good example of a software developing process where teachers are becoming proactive since they are unsatisfied with existing possibilities of using technology and aiming at using computer-supported learning to improve their way of teaching. The crucial point is in fact the process itself. The self-conception of teachers to be responsible for all aspects of instruction and teaching is one of the main obstacles when it comes to using computers. The expertise of the teacher is insufficient to become software developer, specialist for new technology and user in one person. Hence, complementary expertise is needed for a successful design process of tomorrow's learning environment in which computer-supported learning plays a feasible and meaningful role.

We believe that encouraging the teachers to *actively* participate in this process and implementing an interdisciplinary community that shares common goals and interests from different perspectives are key factors for the success of the developed software. However we do not assume that this concept is arbitrarily scalable and might lead to a working open developer community, e.g. like open source projects. But apart from extending the software itself a further research in the reasons and premises why teachers became motivated to participate and contribute actively are recommended.

References

1. Iacono, T.A., Miller, J.F.: Can microcomputers be used to teach communication skills to students with mental retardation? Education and Training in Mental Retardation 24, 34–44 (1989)
2. Wehmeyer, M.L.: National survey of the use of assistive technology by adults with mental retardation. Mental Retardation 36, 44–51 (1998)
3. Parette, H.P.: Assistive technology devices and services. Education and Training in Mental Retardation and Developmental Disabilities 32, 267–280 (1997)
4. Abbott, C.: e-Inclusion: Learning Difficulties and Digital Technology. Futurelab Series, Bristol (2007)
5. Bradburn, E., Pearson, E.: From inclusive guidance to inclusive online teaching practive – a tool to help planfor student diversity. In: Proceedings of 6th IEEE International Conference on Advanced Learning Technologies, pp. 540–541 (2006)
6. Lingnau, A., Kuhn, M., Harrer, A., Hoppe, H.U.: Empowering Teachers to Evolve Media Enriched Classroom Scenarios. Research and Practice in Technology Enhanced Learning 2(2), 105–129 (2007)
7. Zentel, P., Lingnau, A., Ratzke, E.: A multi-media software environment for children with cognitive disability. In: Proceedings of Society for Information Technology and Teacher Education International Conference, Chesapeake, VA, AACE (2007)

8. Cress, U., Kimmerle, J.: Systemic and Cognitive Perspective on Collaborative Knowledge Building with Wikis. International Journal of Computer-Supported Collaborative Learning (in press, 2008)
9. Harrer, A., Zeini, S., Ziebarth, S., Münter, D.: Visualisation of the dynamics of computer-mediated community networks. In: INSNA Sunbelt Conference (2007)

Adaptation in the Context of Explanatory Visualization

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Abstract. Explanatory visualization is a promising approach that has been used in many tutoring systems. This paper presents an attempt to assess the value of adaptation in the context of explanatory visualization. It shows that a system employing a user model and tracking users' progress gives students an opportunity to interact with larger amount of material in the same amount of time.

Keywords: adaptation, adaptive explanatory visualization, evaluation, systems comparison, user study, working memory.

1 Introduction

For more than thirty years, many researchers have explored the use of computers in education. Many of the endeavors focused on developing various kinds of educational tools to facilitate teaching and learning programming. Intelligent tutoring systems (ITS) for programming and program visualization tools [1,2,9,15] were amongst the earliest examples of such applications. ITSs have employed artificial intelligence techniques to model the state and dynamics of the student's programming skills and provide them with individualized guidance in the problem-solving process. In contrast, program visualization systems have supported exploration approach instead of tutoring. They attempted to scaffold students' own intelligence by helping them to better understand the behavior of complex programming constructs. For over ten years those two directions evolved independently. At the end of the 1980s, the pioneer work of Reiser et al. [13] has initiated a new trend in this field of research. An increasing number of researchers have attempted to build systems combining both tutoring and visualization components. This translation from classic ITSs to intelligent learning environments seeks to combine both guided tutoring and learning by exploration.

Many intelligent and adaptive systems for programming, that include both tutoring and visualization functionalities [10,12,17,19], have been created to date. However, in most cases those functionalities are independent and do not affect or reinforce each other. One potential approach to achieve true integration of tutoring and visualization making it more than a sum of its parts is adaptive visualization, originally suggested in [3]. The idea of adaptive visualization is to apply the model of student knowledge maintained by the ITS component to

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produce visualization adapted to the current level of student's knowledge. It has been argued, that the properly adapted visualization can help to focus student's attention on the least understood programming constructs and thus improve learning outcomes [4].

While being implemented in several systems, the benefits of adaptive visualization have yet to been properly evaluated. To date, some implementation attempts show no evaluation [3], employ a simulated study [4], or report a classroom study with no control group [5]. This paper presents our attempt to advance the adaptive visualization research agenda by exploring the added value of this technology in a controlled study.

The reminder of this paper is structured as follows. Section 2 introduces the system used in the evaluation. Section 3 provides details of the experiment. Section 4 presents the results. Section 5 provides discussion on the findings. A summary and discussion of future plans conclude the paper.

2 The Object of Visualization

cWADEIn[1] [6] is a Web-based tool for students in the introductory C programming language oriented courses[2]. The system addresses the problem of explaining the evaluation of expressions (excluding pointer arithmetics). This problem is both relatively complicated and rarely addressed by visualization tools. cWADEIn supports twenty four operators covering simple arithmetic, comparison, increment/decrement, logic, and assignment operations. The system tracks the progress of the student and uses adaptive visualization and adaptive textual explanations.

In cWADEIn, a visualization of a single operation can have one or more of the following five stages (examples given in parentheses):

– Reading a variable (`A % 3`)
– Production of the value (`0 || -4`)
– Writing a variable (`A = 10`)
– Pre inc/dec (`++A`)
– Post inc/dec (`A--`)

Each stage includes several steps, many of which are animated. The system adapts the speed of animations to the progress the student has done so far with the operator in question. The more progress the higher the pace of animations. Eventually, animations get collapsed into single-step actions.

Some visualizations can be difficult to understand when presented on their own. To address that problem, cWADEIn uses natural language explanations associated with most of the visual events. Each explanation is constructed from one or

[1] The previous name of the system was WADEIn II. It has been renamed to cWADEIn since a new version, named jWADEIn and supporting the evaluation of expressions in the Java programming language, has been developed.

[2] E.g. *Data Structures and Programming Techniques* course offered by the School of Information Sciences at the University of Pittsburgh.

more fragments of text. Each fragment addresses a different idea. The system decides which fragments to present based on its knowledge of the student's progress.

cWADEIn models two types of concepts: explicit and implicit. The system visualizes the progress the student makes with explicit concepts. The progress made with implicit concepts is tracked, but not visualized. All operators are modeled as explicit concepts. Implicit concepts include (1) reading a variable, (2) implicit casting, and (3) logical value representation.

The user interface of cWADEIn (Figure 1) is divided into four areas: Goals and Progress (A), Settings (B), Navigation (C), and Blackboard (D). Goals and Progress area contains a list of explicit concepts, along with progress indicators (skillometers) which allow users to monitor their progress. The Settings area allows user to select the expression to be evaluated and set the initial values of variables. The Navigation area allows users to go through the evaluation process on a step-by-step or operator-by-operator basis, either forward or backward. Finally, the Blackboard area is where the evaluation takes place. All visualizations and explanations are presented there.

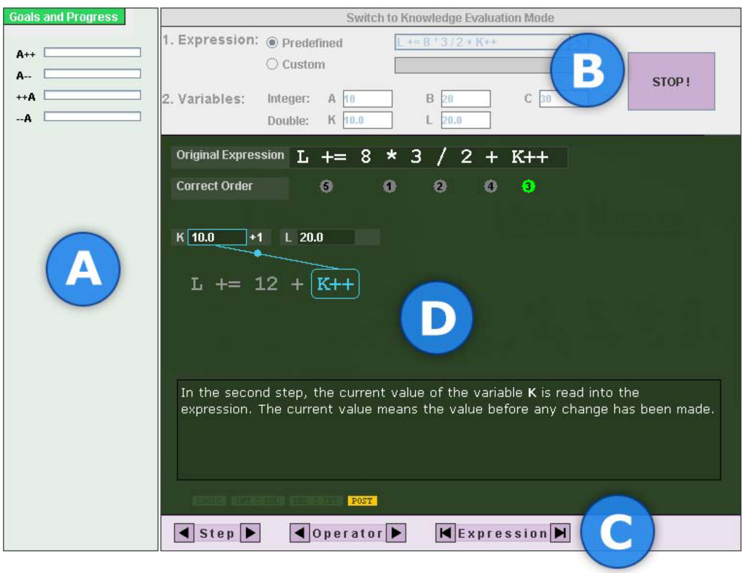

Fig. 1. The user interface of the cWADEIn system is divided into four areas: Goals and Progress (A), Settings (B), Navigation (C), and Blackboard (D)

The system features two mutually exclusive modes: Exploration and Knowledge Evaluation. In the Exploration mode the student can step-through the evaluation, observe the visualizations, and read the associated explanations. In the Knowledge Evaluation mode the student is asked questions at every step of the evaluation – starting with a question about the order of evaluation, checking their knowledge of the operators precedence.

3 Experiment

3.1 The System

For the purpose of the experiment, cWADEIn could be launched with adaptive mechanisms enabled or disabled. As described in Section 2, the adaptive version attempted to tailor its behavior to the student's progress. The non-adaptive did not modify its behavior. Animations were always played using the same speed and fragments of explanations were never hidden. Additionally, the progress indicators were not showing the student's progress. They were still displayed, but only as a reminder of current learning goal (i.e. concepts to be mastered). Only the Exploration mode was employed in the experiment.

3.2 Subjects

Fifteen subjects were recruited for the cWADEIn study at the University of Pittsburgh. Nine of the subjects were students in different Bachelor's of Science programs; five of the subjects were students in different Bachelor's of Art programs; one of the subjects was in the Masters of Information Science and Telecommunications program. The only graduate student was subsequently excluded from the statistical analysis as an outlier – their gain score was more than three standard deviations below the mean gain score in both of the two experimental trials (i.e. they learnt very little). Cook's distance depicted in Figure 2 shows the influence that the subject would have had on the analysis results (subject 2) and provides support for the exclusion (Cook's D > 0.8). Nine of the subjects were female and the age range of all subjects was 18–25 ($M = 20.5$, $SD = 1.7$).

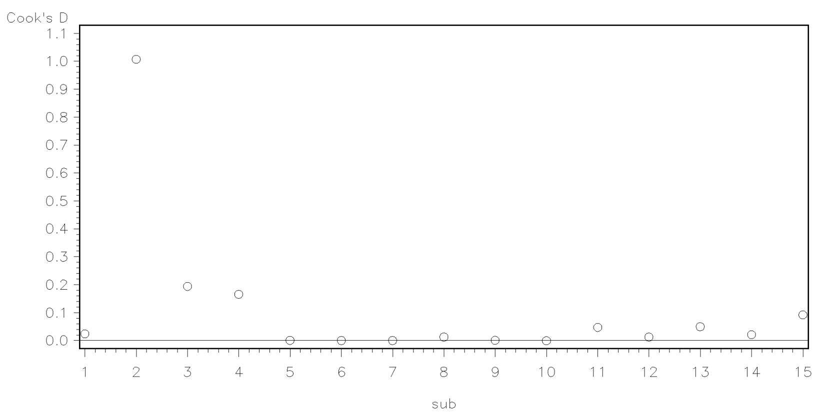

Fig. 2. Cook's distance showing the influence of every subject's scores

The majority of the regular users of the cWADEIn system come from a Data Structures and Programming Techniques course at the School of Information Sciences. The school receives applications from people with different backgrounds and no assumption on the level of technical proficiency are to be made. Because of that the following two recruitment requirements were enforced: (a) none of the subjects could be a student in the Computer Science program and (b) all subjects could have at most *very limited* programming skills (1 on a scale of 0-5). Effectively, eleven subjects never programmed before and three had very limited programming experience.

3.3 Protocol

Figure 3 shows the timeline of the experiment (the anticipated durations of each phase are given in minutes). After filling in the entry questionnaire and performing the MODS task (see Section 3.4), each subject was given an introduction to the study and a short training to minimize the effect of the unfamiliarity with the system. During the training, subjects were asked to attend the evaluation of several expressions to know what to expect with regard to visualization and explanations. Ten expressions with three simple arithmetics operators (+, −, and ∗) were used. Subjects were free to finish the training when they felt ready, but not before they attended the first three expressions and at least one of the more structurally complex ones.

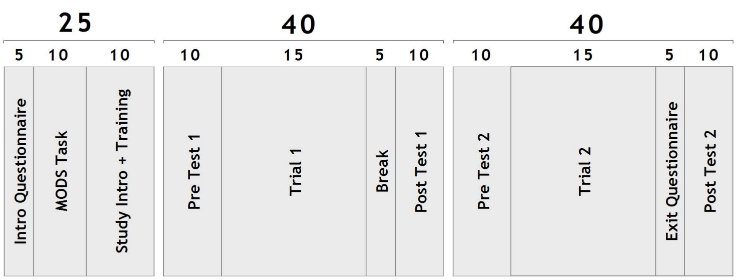

Fig. 3. The timeline of the experiment (time shown in minutes)

After training, subjects were asked to perform two 15-minute learning tials using the cWADEIn system – one with the adaptive version and the other with the non-adaptive version. Initially, the trials were scheduled to be 20-minute long, but after a few pilot subjects we decided to cut them 5 minutes shorter. Each trial was framed as preparation for an in-class test on the C programming language expressions. Subjects were made aware of the dual nature of the problem involving semantics and precedence of the operators. Six subjects completed their first trial using the non-adaptive version, with the other eight starting with the adaptive version, to control for any possible learning effects. A total of twelve operations from the twenty four supported by cWADEIn were used in the experiment. The selected operations were divided into two sets to accommodate the two trials (Table 1). The operator sets were designed to be equal in overall difficulty and orthogonal with respect to knowledge transfer. For instance, assignment operators were cumulated in one set. Distributing them between the two sets would increase the likelihood of inter-trial dependency. Thirty expressions were associated with each operation set. They were available as elements of a drop down list and ordered by difficulty, with the easier ones at the top. Subjects were aware of the ordering but were not forced to follow it.

Table 1. Operators used in each of the set along with the operation group they belong to

Set	Group	Operator
1	comparison	<, >=, !=
	modulo	%
	increment	++A, A−−
2	parenthesis	()
	assignment	=, +=, *=
	logical	||, &&

Prior to starting each task, subjects were given a pretest. After the task was finished subjects had to take a break of an approximate length of five minutes. That time lag was introduced to control for some portion of recency effect. In the case of the first trial that break was a scheduled break in the experiment. In the case of the second trial the break was in a form of the exit questionnaire. A posttest was administered after the break. The corresponding questions on pretest and posttest checked the understanding of the same operator. The tests were designed not to give away the answers. Both the semantics and the precedence of operators was tested, with a greater emphasis on the former.

Apart from questionnaire and test responses, user interface events and gaze data protocols were collected. The Tobii 1750 [16] remote eye tracker was used. The eye tracker calibration routines were part of the experiment, but constituted only a minor portion of the whole experiment time. The discussion of eye tracking results is beyond the scope of this paper. The whole experiment took between 1.5 and 2 hours. That variation was due to the difference in the time it took subjects to solve the tests and fill out the questionnaires (those were not time constrained) and the fact that subjects could finish both learning tasks when they felt ready (before fifteen minutes passed).

3.4 Working Memory Capacity

The task of understanding evaluation of expression evaluation is symbolic in nature. Working memory capacity may have an impact on performance. To measure subjects' sensitivity to the increase in the memory load we used the modified digit span task (MODS) [7]. This task emphasizes individual differences in working memory and reduces impact of other individual differences, e.g. prior knowledge and usage of compensatory strategies. It was administered right after the entry questionnaire (demographics) and before study introduction and the first pretest.

In each trial of the MODS task, a subject was presented with a string of letters and digits. Their task was to remember the digits for later recall. To suppress subvocal rehearsal subjects were asked to read all characters aloud as they appeared on the screen. A metronome tick sound was used to help time the articulation. Each letter was presented for 0.5 sec. The presentation time for digits was lengthened to 0.91 sec to help to encode them in the memory. The number of letters preceding each digit was three or four (selected randomly). This variation was introduced to mask the position of the next digit.

Each of the subjects started with three digits and went through stimuli with four, five, and six of them, which yields a total of four conditions. All subjects went through four trials per condition, which yields a total of 16 trials (not counting the three training ones). The total length of the stimulus was between 12 and 30 characters.

Each subjects started each trial with a screen showing 30 empty boxes (Figure 4). The stimuli presentation begun after they acknowledged their readiness by clicking the "Ready" button. After the entire stimulus was presented all boxes were cleared and recall prompt was presented. This prompt highlighted boxes previously occupied by digits. The subjects had to provide the digits in the order they were originally presented. Backtracking was not possible. They could skip a digit they didn't remember by using the letter X.

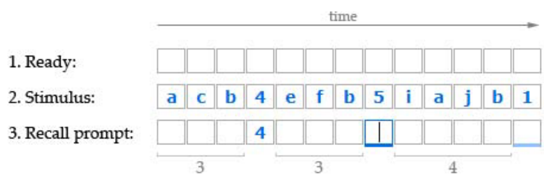

Fig. 4. A sample trial in the MODS task (set size 3)

4 Results

We used an alpha level of .05 for all statistical tests. All p-values reported are two-tailed. All results were obtained using SAS System version 9.1 [14].

4.1 Pretest-Posttest Difference

The response variable in our comparison was the difference between the posttest and pretest scores, that we will be referring to as *gain score* and denote as δ. The two independent variables were the system version and the trial order. Both variables were within-subject and dichotomous.

The system version (non-adaptive and adaptive) was counterbalanced. Subjects were randomly assigned to the two possible orderings. In order to check if that assignment generated equivalent groups we used a paired t-test to compare the pretest scores. We found no significant difference between the mean score of the first group ($M = 2.57$, $SD = 2.24$) and the second group ($M = 4.57$, $SD = 3.13$), $t(13) = .48$, $p = .642$, $\hat{g} = 0.24$.

In an attempt to differentiate subjects with respect to their working memory capacity we calculated an index w for each of them. We did that by averaging the partial recall proportions from the MODS task for set sizes four, five, and six. We excluded set size three due to its small influence (almost no variability in the partial recall proportions; Table 2). We used w as a between-subject covariate ($\rho_{\delta,w} = 0.36$).

Table 2. Partial recall proportions for all set sizes used in the MODS task. Standard deviations express the distinguishing power of each set.

Set size	3	4	5	6	w
Mean (SD)	0.99 (0.02)	0.93 (0.08)	0.77 (0.16)	0.65 (0.15)	0.79 (0.08)

To test the effect of both factors on the gain score we fitted the following linear mixed model

$$y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + b_{ik} + e_{ijk} \quad (1)$$

where μ is the overall mean, α_i is the effect of system i, β_j is the effect of trial j, γ_k is the working memory for subject k, b_{ij} is the random effect of subject j assigned to system i, and e_{ijk} is the random measurement error. We assumed random effects to be normally distributed and independent of each other. We used the variance component structure for the random effect covariance matrix. We used the Kenward-Roger correction for degrees of freedom and standard errors, a method suggested for repeated measures data with small sample sizes [8]. Figure 5 shows studentized conditional residuals diagnostic panel indicating no clear departures from the assumptions of normality. The model above is the most parsimonious one; all higher order terms were not significant.

Working memory index w was a significant covariate, $F(1, 12) = 14.27$, $p = .003$. The trial order explained a significant amount of variability in δ. Subjects achieved higher gain scores on the second trial ($M = 20.43$, $SD = 4.18$) than they did on the first one ($M = 15.50$, $SD = 4.20$), $F(1, 12) = 10.46$, $p = .007$. There was no difference between the mean gain score achieved by subjects with the adaptive version of the system ($M = 17.35$, $SD = 5.05$) as compared to the non-adaptive version ($M = 18.57$, $SD = 4.69$), $F(1, 12) = 1.48$, $p = .247$. If the difference between the two systems existed it might had been masked by the ceiling effect. It is possible that fifteen minutes was still too much for the learning task in the case of our, quite simple domain. Some evidence of ceiling effect is provided by the fact, that eleven out of the total of twenty eight trials were finished before time by subjects themselves.

We also looked at the difference between posttest and pretest scores to assess if cWADEIn helped subjects in improving their understanding of the domain. The results of a paired t-test indicate that they got a significantly higher score

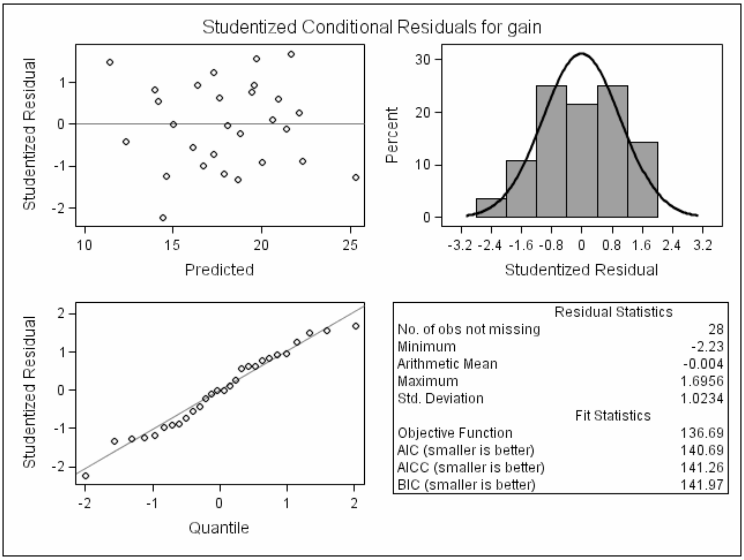

Fig. 5. Model 1 fit assessment. No apparent patterns in the residuals cloud. The distribution of the residuals reasonably well follows the shape of the normal distribution.

on the posttest ($M = 21.54$, $SD = 5.46$) than they did on the pretest ($M = 3.57$, $SD = 2.86$), $t(27) = 19.73$, $p < .001$, $\hat{g} = 8.67$.

4.2 Material Exposition

In addition to investigating the gain score difference, we checked the amount of material subjects were exposed to. For that purpose, we used the interaction logs collected during the experiment. Due to space limitation, we present only one metric of material exposition: the rate of expression evaluations exploration. If we treat the events of exploring the evaluation of an expression as independent, the total number of them will be Poisson distributed. We choose to compare rates instead of total numbers to control for the total session time.

We fitted the following generalized linear mixed model

$$\log y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + \log \tau_{jk} + b_{ik} + e_{ijk} \tag{2}$$

where μ is the overall mean, α_i is the effect of system i, β_j is the effect of trial j, γ_k is working memory for subject k, τ_{jk} is the session time for subject k in trial j and entered the model as an offset variable, b_{ij} is the random effect of subject j assigned to system i, and e_{ijk} is the random measurement error. We assumed random effects to be normally distributed and independent of each other. We used the variance component structure for the random effect covariance matrix. We used Kenward-Roger degrees of freedom approximation. Studentized conditional residual plots showed a good fit of the model. The variance of the Pearson residuals was 0.71 indicating no problems with overdispersion [11], a common problem with count data. Again, that is the most parsimonious model; all higher order terms were not significant.

Subjects working with the adaptive version of the system explored expressions with a rate significantly higher ($M = 1.94$ per min., $SD = .46$) as compared to the non-adaptive version ($M = 1.53$ per min., $SD = .68$), $F(1, 24) = 7.65$, $p = .010$. Subjects were also exploring expressions significantly faster in the second trial ($M = 2.03$ per min., $SD = .69$) than they did in the first one ($M = 1.44$ per min., $SD = .33$), $F(1, 24) = 13.66$, $p = .001$. The effect of working memory index w was not reliable, $F(1, 14.21) = 3.31$, $p = .090$.

5 Discussion

As we have shown above, the rate of expression evaluations explored has a potential of telling the difference between a non-adaptive and an adaptive version of a system. When working with the adaptive version of cWADEIn, subjects were able to explore more expressions. Other studies have also demonstrated that adaptive systems could cause a significant increase of the volume of learning content explored by students [19]. Looked at in another way, the adaptive version has a potential of allowing for a material exposition comparable with a non-adaptive version, but in a shorter amount of time.

However, we did not find the two versions of the system different with respect to the gain score. If we treat a performance on a task to be positively correlated with the amount of work done towards that task we can see that those two results provide some evidence for the existence of the ceiling effect in our study. If the learning sessions were shorter, the adaptive version of the system could have allowed subjects to explore material beyond what could be explored in the non-adaptive version.

Because of that, we were unable to check whether subjects' more efficient work resulted in gaining broader or stronger knowledge. Resolving this problem will guide our future work.

6 Conclusions

We presented an evaluation of the adaptation features of the cWADEIn system that supports students in learning about expression evaluation in the C programming language. We did so by comparing it to another version of the system, deprived of the adaptive capabilities. We have found the two versions indistinguishable with respect to the pretest-posttest difference. We argue that this may be an artifact of a ceiling effect.

We have found that the adaptive version of the system allowed subjects to explore expressions significantly faster. That shows that adaptation has the potential of improving material exposition. It can also provide time savings for students by allowing them to explore the domain of interest in shorter time.

Our immediate future plans related to this project include the analysis of the gaze protocol and a more in-depth analysis of the interaction logs.

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References

1. Baecker, R.: Two Systems which Produce Animated Representation of the Execution of Computer Programs. ACM SIGCSE Bulletin 7(1), 158–167 (1975)
2. Barr, A., Beard, M., Atkinson, R.C.: The Computer as Tutorial Laboratory: The Stanford BIP Project. International Journal on the Man-Machine Studies 8(5), 567–596 (1976)
3. Brusilovsky, P.: Intelligent Tutor, Environment and Manual for Introductory Programming. Educational and Training Technology International 29(1), 26–34 (1992)
4. Brusilovsky, P.: Explanatory Visualization in an Educational Programming Environment: Connecting Examples with General Knowledge. In: Blumenthal, B., Gornostaev, J., Unger, C. (eds.) EWHCI 1994. LNCS, vol. 876, pp. 202–212. Springer, Heidelberg (1994)
5. Brusilovsky, P., Su, H.-D.: Adaptive Visualization Component of a Distributed Web-based Adaptive Educational System. In: Cerri, S.A., Gouardéres, G., Paraguaçu, F. (eds.) ITS 2002. LNCS, vol. 2363, pp. 229–238. Springer, Heidelberg (2002)
6. Brusilovsky, P., Loboda, T.D.: WADEIn II: A Case for Adaptive Explanatory Visualization. In: 11th Annual Conference on Innovation Technology in Computer Science Education (ITiCSE), Bologna, Italy, pp. 48–52 (2006)
7. Daily, L.Z., Lovett, M.C., Reder, L.M.: Modeling Individual Differences in Working Memory Performance: A Source Activation Account. Cognitive Science: A Multidisciplinary Journal 25(3), 315–353 (2001)
8. Kenward, M.G., Roger, J.H.: Small Sample Inference for Fixed Effects from Restricted Maximum Likelihood. Biometrics 53, 983–997 (1997)
9. Koffman, E.B., Blount, S.E.: Artificial Intelligence and Automatic Programming in CAI. Artificial Intelligence 6, 215–234 (1975)
10. Kumar, A.: Generation of Problems, Answers, Grade and Feedback – Case Study of a Fully Automated Tutor. ACM Journal on Educational Resources n Computing 5(3), Article No. 3 (2005)
11. Littell, R.C., Milliken, G.A., Stroup, W.W., Wolfinger, R.D., Schabenberger, O.: SAS for Mixed Models, 2nd edn. SAS Publishing (2006)
12. Peylo, C., Thelen, T., Rollinger, C., Gust, H.: A Web-based intelligent educational system for PROLOG. In: Workshop on Adaptive and Intelligent Web-based Education Systems at 5th International Conference on Intelligent Tutoring Systems (ITS), Montreal, Canada (2001)
13. Reiser, B.J., Ranney, M., Lovett, M.C., Kimberg, D.Y.: Facilitating student's reasoning with causal explanations and visual representations. In: 4th International Conference on Artificial Intelligence and Education (AIED), pp. 228–235 (1989)
14. SAS Institute Inc. SAS 9.1.3 Help and Documentation (2007)
15. Shapiro, S.C., Witmer, D.P.: Interactive Visual Simulation for Beginning Programming Students. ACM SIGCSE Bulletin 6(1), 11–14 (1974)
16. Tobii, http://www.tobii.com

17. Vanneste, P., Olive, H.: Towards an intelligent environment to learn programming (in Pascal). In: CALISCE 1991, Lausanne, pp. 401–408 (1991)
18. Venables, W.N., Ripley, B.D.: Modern Applied Statistics with S. Springer, Heidelberg (2002)
19. Weber, G., Brusilovsky, P.: ELM-ART: An adaptive versatile system for Web-based instruction. International Journal of Artificial Intelligence in Education 12(4), 351–384 (2001)

Interaction Analysis Supporting Participants' Self-regulation in a Generic CSCL System

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Abstract. Interaction analysis can provide information directly to learners and teachers in order to assess and self-regulate their ongoing activity. Omega+ is a generic CSCL system that uses explicit models as parameters for flexibly supporting different kinds of collaborative applications. This paper describes Omega+ model-based generic approach for supporting participants' self-regulation through interaction analysis. Some quantitative and qualitative results obtained with the proposed approach are discussed.

Keywords: collaborative learning, CSCL, interaction analysis, coaching, self-regulation, generic system, model-based approach.

1 Introduction

Computer Supported Collaborative Learning (CSCL) emphasizes the importance of social processes as an essential ingredient of learning. CSCL has been recognized as a possible way for preparing people to the knowledge society, for achieving deeper learning than traditional methods and for better meeting the expectations of the net generation [1]. During its first decade, CSCL researchers have produced a large number of *ad-hoc systems* focusing at a microscopic level on *particular situations and contexts*, and aiming at triggering *specific learning processes*. It is the case of all early specialized synchronous tools for structured discussion (e.g., [2]), collaborative design (e.g., [3]), knowledge construction (e.g., [4]), modeling (e.g., [5]) and writing (e.g., [6]). Many researchers claim that this first generation of ad-hoc, specialized, and closed tools should be replaced by systems "*richer and appropriate for various collaborative settings, conditions and contexts*" [7], "*reconfigurable*", "*adaptive*", "*offering collections of affordances*" and "*flexible forms of guidance*" [8], "*very flexible and tailorable*" [9]. A promising approach for meeting these expectations is to use an *explicit model* which *parameterizes a generic kernel* for flexibly supporting different kinds of collaborative applications [10]. By providing ad hoc models, teachers can tailor the kernel to their specific needs (*definitional malleability*). Moreover, the behavior of the customized system depends on that, continuously queried, model and can dynamically evolve when the model is modified (*operational malleability*). This technological orientation, implemented in the *Omega+ project*, raises many important conceptual and technological issues.

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There exist two complementary approaches for supporting collaborative learning. The first one *structures* the situation in which the collaboration takes place, for instance through process models and interaction models. The second one involves regulating the collaboration itself through *coaching* and *self-regulation* [11]. In this paper we focus on *interaction analysis* that provides information directly to learners and teachers in order to *assess and self-regulate* their ongoing activity. In the specific case of a generic system, such as Omega+, interaction analysis itself has to be generic, i.e., *model-based*. A specific sub-model, called the 'Effect Model', specifies how to measure the effects of collaborative learning. More precisely, it describes the *properties and rules of the interaction analysis and visualization process* for the learning situation defined by the other (process, interaction, and artifact) sub-models which together parameterize the generic kernel.

The remainder of the paper is organized as follows. Section 2 depicts Omega+ overall approach for modeling synchronous collaborative learning activities, i.e., the context of the work. Section 3 discusses the main characteristics of interaction analysis aiming at coaching and self-regulating participants. Section 4 presents Omega+ model-based implementation. Finally, the last section gives some quantitative and qualitative results obtained from a first evaluation study of the current implementation.

2 Modeling Collaborative Learning Activities - Omega+ Approach

The *combination of communication with shared work artifacts* is an important characteristic of synchronous (same-time/same-place or same-time/different-places) CSCL systems [12]. Most of them follow the *dual interaction spaces paradigm* [13], by providing two distinct spaces of interaction. The task space (shared workspace) allows for the collaborative construction and manipulation of shared artifacts that are relevant to the task at hand. The communication space is the place where dialogue-based interaction, mostly textual, takes place. Several recent systems provide multiple tools in the task space for manipulating simultaneously complementary artifacts or multiple views of the same artifact (e.g., [14]).

In a non-trivial CSCL application, the learning task is structured into a *process* including a sequence of collaborative phases. Within each phase participants can play different *roles* which constraint how they can act (in the task space) and how they can talk (in the communication space). In Omega+, a process is a sequence of phases, taking place into rooms: 'simple phases', where all participants collaborate on the same task in the same room, and 'split phases', where participants are divided into parallel sub groups performing different tasks in different rooms. A process model (machine-interpretable script) is a plan which does not prescribe the execution of phases exactly in the specified order. Participants playing the predefined 'Room Operator' role have two buttons for selecting the next phase to execute, either by following the plan (Next) or by selecting any other existing phase (Jump). Each phase type is mainly characterized by a set of role types, a set of tool types and a *floor-control policy* (FCP) at the environment level [15]. In Omega+, application-specific *interaction protocols* are defined by a set of application-related roles, a set of typed messages (speech acts), and a set of adjacency pairs [16] specifying how messages types are related (e.g., question-answer) and which role can speak first. *Application-specific*

FCPs can use application protocols (see the 'based_on' relationship in Figure 1) for controlling the floor either in the communication space only or in both the communication space and the task space (see the 'impact' relationship between FCPs and tools in Figure 1). Figure 1 summarizes Omega+ overall conceptual model.

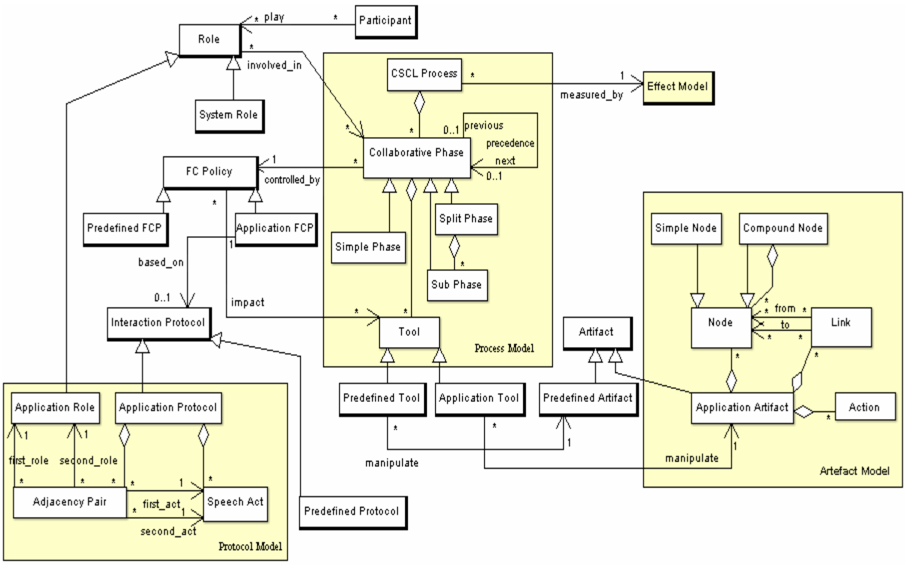

Fig. 1. Omega+ conceptual model

It is worth noting that all important concept types (roles, tools, protocols, FCPs) are specialized into *predefined* and *application-specific* sub types. This reflects the fact that Omega+ provides both hard-coded mechanisms and model-based features which are customizable and evolvable by its users. Three sub-models are highlighted in Figure 1, corresponding to the *process dimension*, the *interaction dimension* and the *artifact dimension* of collaborative learning activities. A fourth one, specifying how individual and group performance can be characterized corresponds to the entity called 'Effect Model'. This sub-model will be studied in greater details in the following sections. Concretely, these four sub-models serve as four *parameters* for the generic Omega+ kernel. This approach makes possible to build the activity representation in different ways, adapted to the skills and needs of different categories of users (researchers, technologists, early adopters, regular teachers): just reusing existing combinations of models, building new combinations of existing sub-models (i.e., following a very high level configuration process), defining or customizing sub-models through high-level visual languages, or through low-level specification languages (including programming languages).

Figure 2 shows Omega+ system customized for supporting a collaborative process of object-oriented design. The communication space on the right includes a protocol model driven chat and an information panel. As Jack plays the Room Operator role the Next and Jump buttons are available to him. The task space on the left may contain up to three tools as requested by the process model definition. Tools are either predefined editors (shared text editor, shared whiteboard) or shared graphical editors customized by artifact (meta-) models. In Figure 2 the task space includes a read-only text viewer (its colored background shows that interaction is not possible) displaying use cases created during a previous collaborative phase and two instances of Omega+ generic visual editor customized with UML collaboration and class diagram meta-models. The model-driven 'Circular Work' protocol controls the floor in both spaces in a round robin fashion. A participant can explicitly pass the floor to the next user with a 'Pass' message (see the combo box on the bottom of the talk panel). Omega+ also provides several dedicated mechanisms for supporting learners at the cognitive and meta cognitive level, such as sticky elements ('sticky annotated snapshots', 'sticky notes' and persistent pointers) for *referencing purposes* [17] and a tool for *collaboratively replaying* any episode of the ongoing knowledge building process (the 'collaborative history browser').

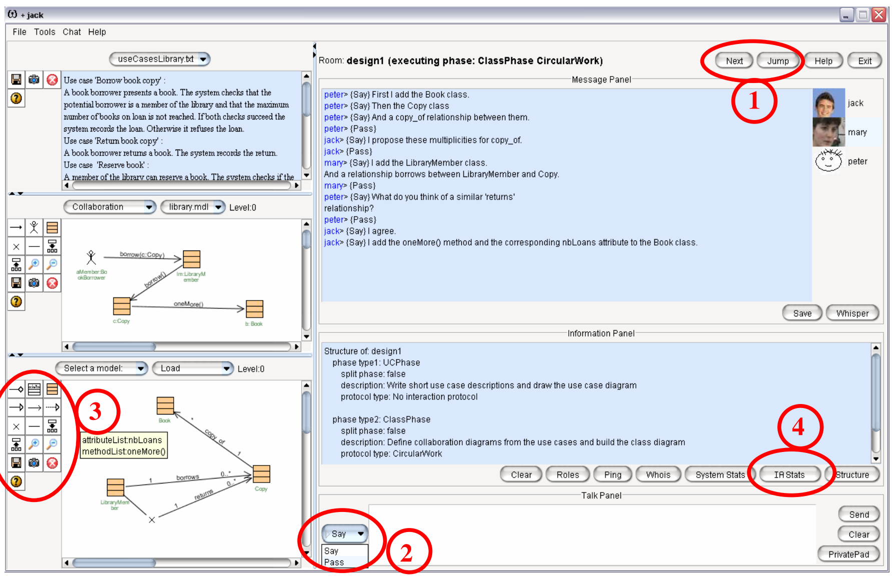

Fig. 2. Omega+ client reflecting process (1), protocol (2), artifact (3) and effect (4) sub-models

3 Interaction Analysis Supporting Participants' Self-regulation

The previous section has illustrated learners' support by structuring the collaborative learning process, its artifacts and interaction protocols. The remainder of the paper focuses on the second approach which involves structuring the collaboration itself through *coaching and self-regulation* [11]. It requires storing continuously the stream of actions and messages, counting them in a predefined set of low level variables, *computing on demand* from these low level variables a set of interaction indicators for supporting the coaching process, and *displaying periodically* a set of synthetic visual representations supporting learners' self-regulation. Indicators for the coaching process are freely configurable in the ‘Effect model’ (see section 4.3). For the self-regulation process, indicators well fitted to the dual interaction spaces paradigm and reflecting the diversity of indicators proposed in the CSCL field [18] have been selected. Some of them are task-dependent and their precise definition is specified in the ‘Effect Model’.

3.1 Interaction Indicators for Participants’ Self-regulation

In a system following the dual interaction spaces paradigm, learners can interact in two ways. They can communicate directly, by using the chat tool, or indirectly, by building the shared artifacts. The *balance between conversation events and action events* is interesting for measuring a correct usage of both modalities by learners. Pure action without dialogue and pure dialogue without any action are not likely to occur. *Participation indicators*, such as the number of produced messages and the number of tool actions, are important because collaboration cannot occur within a group unless there is roughly equal participation among its participants [19]. If some participants do the main part of the work while others barely contribute, then the group is not truly collaborating. Indicators about the *communication style* can also be helpful. It is the case of *the average size of produced messages*, because it is important that learners make efforts for externalizing their ideas and thoughts [20] in an elaborated form. For chat interaction, it is important *to distinguish between on-task and off-task messages*. This indicator is obviously task-dependent. Off-task messages are useful for specific purposes, such as socialization, but should be restricted in quantity for keeping the learners focused on the constructive task at hand. Interaction requires that group members *actively respond to one another, react and change their minds as the interaction progresses* [19]. The most straightforward approach for measuring interaction is to track *event patterns* which reflect specific ‘interaction episodes’: for instance, two learners who successively modify the same element (or directly linked elements) of a graph-based artifact. A second possible approach is to *track explicit referencing mechanisms usage* such as participants’ names referencing, chat line referencing, sticky elements creation and referencing, and so on. A third approach is to track *event patterns* showing an individual activity aiming at *facilitating collaboration* (‘facilitation episode’). For instance, when the same learner changes something on a shared artifact and immediately after or before sends a task-related message with the chat tool, hopefully containing some explanation. Pattern definitions should be customizable for each specific task.

3.2 Interaction Indicators Presentation

For coaching purposes, teachers should be able to access *on demand* to *a detailed representation* of the selected indicators. In particular, *stacked bar charts* are important for contrasting the values for the different learners (for the current phase or for the whole learning process) and *time series* are important for showing the temporal evolution of the values (with a customizable time interval). For self-regulation, learners should receive *periodically* a more *synthetic view*. This view can encompass a *visual evaluation of each criterion*, a kind of *global score* for motivating the participants and *guidance* on what they must do for improving their performance.

4 Omega+ Generic Implementation

The first two subsections discuss message classification and pattern recognition which are complex issues in a generic context. Coaching indicators definition and the monitoring window generation are then discussed.

4.1 Message Classification

For classifying messages into on-task and off-task categories we use a *Naive Bayes Classifier (NBC)* [21]. NBC approach is one of the most effective probabilistic approaches currently known for text categorization. The method is considered naive due to its assumption that every word in the document is conditionally independent from the position of the other words given the category of the document. The classifier learns a set of probabilities from the training data during the learning phase. It then uses these probabilities and the Bayes theorem to classify any new documents. First, an estimate of the probability of the new document belonging to each class given its vector representation is calculated. Then, the class with the highest probability is chosen as a predicted categorization. Omega+ NBC *learns the task vocabulary* by analyzing several sources. First, when the server starts, one (or several) file(s), explicitly referenced into the 'Effect Model' are processed. These files can contain for instance a textual description of a given diagram type (e.g., <OnTaskFile file = "usecase.txt" />) or a summary of the instructions given to the learners. The classifier also analyzes all the files loaded into the text board (containing for instance the problem description submitted to the learners), all the meta-model files which serve as parameters for the generic diagram editor (giving in particular the names of all the concepts), and all the models created with the customized diagram editors (giving in particular the names of all nodes and links created by the learners). Omega+ NBC also includes a 'stemming' phase and a 'stopwords' removal phase. Stemming is the process by which words are reduced to their root forms [22]. For example, suffixes are removed, such as "-ing" and "-s", such that "digging" and "dig" become the same word. Stopwords are words that occur frequently in the language, such as "a", "and" and "the" (http://www.snowball.tartarus.org/algorithms/english/ stop.txt). Because of their frequent occurrence, they may not add any additional information to aid classification, assuming a uniform distribution over all classes. English and French languages are supported.

4.2 Patterns Recognition

In this first implementation, a very simple language is provided for specifying interaction patterns: <InteractionPattern actors ="aaa" tooltype1 ="xxx" tooltype2 = "yyy" tools = "zzz" condition ="ccc" maxtime ="mmm" />, where: actors = same | different; toolType1 = chat | diagrammer | whiteboard | text board; toolType2 = chat | diagrammer | whiteboard | text board; tools = same | different; condition = none | <a_condition_name>; maxtime = n | any.

The proposed language is *extensible* as it is possible to create a condition for a particular task by writing a dedicated method having the same name than the condition in the 'InteractionAnalysis' class of Omega+ server. For instance, <InteractionPattern

actors="different" tooltype1="Diagrammer" tooltype2= "Diagrammer" tools="same" condition="sameobject" maxtime="60000" /> defines a pattern specifying that two different learners modify during the same minute the same object in the same diagram. <InteractionPattern actors="same" tooltype1= "Diagrammer" tooltype2="Chat" tools="different" condition="ontask" maxtime= "30000" /> defines a pattern specifying that the same learner acts on a diagram and sends an on-task message during the next 30 seconds.

Omega+ server stores the message/action history and checks all the patterns *each time an element is inserted* by testing all elements belonging to the time interval. The synthetic view ('monitoring window') is generated for each participant with a frequency also specified in the Effect Model as a multiple of the time series delta (<MonitoringDelta nbTimeSeriesDelta="4" />).

Suthers [23] emphasizes that interpreting actions in a shared workspace in terms of their domain-specific semantics is difficult and illustrates the danger of taking a superficial approach when mapping domain level actions to intentions. It is hypothesised that our simple pattern definition language *is sufficient for roughly estimating the amount of collaborative episodes*. It is not intended to provide a precise quantification but to *trigger guidance* in the case of a very low amount of interaction.

4.3 Coaching Indicators Specification

The 'Effect Model' defines some general parameters, such as the time interval between measures for time series (<TimeSeriesDelta ms ="30000" />). It also defines the characteristics of graphical representations used for coaching purposes: name, informal description, type (bar chart, time series), value labels, and expressions defining how values are computed from the predefined set of low-level variables. For instance, <Diagram name ="MeanMessLengthSeries" descry ="Time series of the mean length of chat messages" type ="TimeSeries" labels ="length" exprs ="ratio: sizeMess nbMess"/>, <Diagram name ="MessVSInteractionChart" descry ="Bar chart of the number of chat messages vs. other interactions" type ="BarChart" labels ="chat messages, other interactions" exprs ="nbMess, sum: nbWhite nbTextb nbDiag" />.

4.4 Monitoring Window Generation

A guidance message is generated when the ratio between the value of an actor and the average value is under a given threshold. A set of rules in the 'Effect model' specify these thresholds and messages that must be generated. For instance, the rule associated to the discourse focus indicator is <Rule name = "DiscourseFocus" threshold ="0.35" message ="Your discourse should be more focussed on the task!" />. A negative value indicates that the indicator is deactivated. Figure 3 shows the monitoring window generated for Peter. In this example, all indicators are activated. Some interaction parameters are well rated (two green squares) while others are weak (four red squares). Peter has the lower global score and receives guidance about his discourse style because this indicator has the worse score ('Write more explicit messages!').

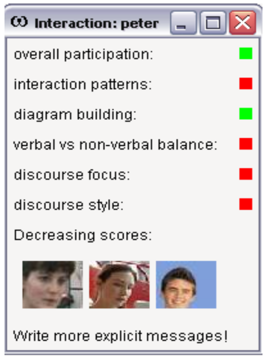

Fig. 3. Omega+ monitoring window

5 A First Evaluation Study

The goal of the evaluation study was twofold: first, analyze the efficiency of the more complex indicators (Bayesian classification and patterns recognition), and secondly carry out interviews to know how learners evaluate the approach. The study has been performed with 24 French students enrolled in a second-year university course in computer science. Small groups of three students, randomly assigned to the groups, received small case descriptions and were asked to build UML use case diagrams or UML Class Diagrams during 30 to 45 minutes length collaborative sessions with Omega+. Students were collocated (in the same classroom) but were not allowed to speak. Omega+ client was configured with a read-only text-board for the case description, a customized shared diagram editor and a chat tool. Students had free access to the communication space and to the task space and no specific process was enforced. Specific control information was written in the log file: the classification of each message by the Bayesian classifier, each recognized pattern associated to its triggering event, and all monitoring values periodically computed for each learner.

5.1 Message Classification

Table 1 gives the results obtained by the Bayesian classifier after a learning phase using a less than one page text file describing the UML formalism. The decision of the classifier ('Classified' column) is compared with the decision of a researcher who has analyzed the messages in the log file after the session ('Analyzed' column). The automatic classification into on-task and off-task messages has an accuracy of 82%. It is sufficient for characterizing students who are not focussed on their task. Errors have multiple causes which are difficult to eliminate. Here are some examples of false off-task messages and false on-task message (translated from French):

- *Improper word usage*: in the message "I place the two functions I have said", the word 'function' is used instead of 'use case' or 'case' for a component in a use case diagram and the message is not recognized as being on-task,
- *Non explicit reference*: the message "I put them" is not recognized as being on-task because no distinctive word is found,

- *Word improperly recognized*: in the message “I am pretty happy of my reorganisation”, “reorganisation” is stemmed into “organisation” which is part of the actor concept definition in a use case diagram “an actor is a person, an organisation or a system (…)”; the message is incorrectly classified as an on-task message.

Misspellings, compounding, abbreviations and initialisms (“answ” for answer), reduplications (“heeellllooo”), and frivolous spellings of interjections (“okey”) are other well known difficulties [24]. Students were asked to avoid ‘chatspeak’ and to spell and punctuate correctly.

Table 1. Classification evaluation

Category	Classified	Analyzed	%
a	On task	On task	37
b	On task	Off task	8
c	Off task	On task	10
d	Off task	Off task	45

Evaluation

accuracy = (a + d) / (a + b + c + d) = 82%

error = (b + c) / (a + b + c + d) = 18 %

5.2 Patterns Recognition

As expected, pattern-based indicators only provide rough evaluations. For example, in the log file excerpt of Figure 4 the same rule (defined by <InteractionPattern actors="different" tooltype1="Diagrammer" tooltype2= "Diagrammer" tools="same" condition="sameobject" max time="60000" />) fires twice in the last two lines. In the first case, the learner with the pseudo name ‘titi’ has created a node at the first line (action numbered 52) and has given to this node the name 'acessoir' which includes a typo (it should be 'accessoire' in French, action 54). This typo has been corrected by ‘tata’ (action 64) 28 seconds after. This is a reasonable example of collaboration with a student who analyzes and reacts to the action of another student. In the second case,

```
févr. 06 15:10:39 in ex1 titi performs a diagram action: Diagrammer0 52:addVertex:Classe:titi5:
févr. 06 15:10:47 in ex1 toto performs a diagram action: Diagrammer0 53:newProperties: numPermis
        Conduire||:toto2:|:
févr. 06 15:10:49 in ex1 titi performs a diagram action: Diagrammer0 54:newName:accessoir:titi5:|:
févr. 06 15:10:54 in ex1 toto performs a diagram action: Diagrammer0 55:newName:Numéro:titi3:|:
févr. 06 15:10:56 in ex1 titi performs a diagram action: Diagrammer0 56:move:336:258:titi5:
févr. 06 15:10:56 in ex1 titi performs a diagram action: Diagrammer0 57:move:195:52:toto0:
févr. 06 15:10:57 in ex1 titi performs a diagram action: Diagrammer0 58:move:196:72:toto0:
févr. 06 15:11:01 in ex1 titi performs a diagram action: Diagrammer0 59:move:190:240:titi3:
févr. 06 15:11:02 in ex1 titi performs a diagram action: Diagrammer0 60:move:302:245:titi5:
févr. 06 15:11:07 in ex1 tata performs a diagram action: Diagrammer0 61:addVertex:Classe:tata0:
févr. 06 15:11:10 in ex1 tata performs a diagram action: Diagrammer0 62:newName:camion:tata0:|:
févr. 06 15:11:13 in ex1 tata performs a diagram action: Diagrammer0 63:move:379:306:tata0:
févr. 06 15:11:18 in ex1 tata has triggered rule 2 in the following action
févr. 06 15:11:18 in ex1 tata performs a diagram action: Diagrammer0 64:newName:accessoire:titi5:|:
févr. 06 15:11:27 in ex1 toto has triggered rule 2 in the following action
févr. 06 15:11:27 in ex1 toto performs a diagram action: Diagrammer0 65:newProperties: code,nom,
        nbArtistes,durée||:titi3:|:
```

Fig. 4. Excerpt of a log file with rule triggering

'toto' has added several properties to the node 'titi3'. The rule was triggered only because 'titi' has moved the same node 26 seconds before when he/she was reorganizing several elements in the graph (actions numbered 56-60). In this case, there is *no real semantic relationship between the two episodes*. A possible improvement could be to test in the method associated to the 'sameobject' condition a Boolean matrix specifying for all couples of actions of the diagram editor if they should be considered or not for triggering the rule (it would be true for 'addVertex' and 'newName' actions and false for 'move' and 'newProperties' actions).

5.3 Other Indicators

The other indicators, mainly based on the number of messages and actions, are easy to implement. The results show that some deeper analysis could be envisioned. For example, in the session summarized in Table 2, different 'profiles' would be easy to detect with student1 mainly talking, student2 mainly constructing the shared artifact and student3 mainly improving the graph layout by moving nodes and edges.

Table 2. Participation analysis

Action	Student 1	Student 2	Student 3	Total
Node creation	3	**7**	3	13
Link creation	3	**13**	3	19
Node or link movement	39	53	**137**	229
Chat contribution	**20**	15	15	50
Total	65	88	158	311
Action/minute	2,8	3,8	6,9	4,5

5.4 Evaluation of the Approach

From the students' point of view, *personalized advices generation* appears to be the most effective way of pushing information to them periodically. Most students recognize that they do not take the time for analyzing in detail the analytic part of the monitoring window. The overall ranking is perceived as a kind of 'high score' that can increase their motivation to actively participate.

After the presentation of the system, the regulation approach generates much more debate and *controversy* than the structuring approach. Constraints at the process, protocol or artifact level are well accepted as pedagogical constraints, while monitoring rules are strongly rejected by a majority of students and we noticed many attempts to fight against the rules, for instance with students sending non-sense messages for impacting the on-task/off-task indicator:

févr. 06 15:20:38 in ex1 tata says: is the weather good in Madrid? (il fait beau à Madrid ?)
févr. 06 15:20:46 in ex1 titi says: lol

6 Conclusion

Omega+ is one of the few fully generic system that support synchronous collaborative learning activities. A survey of the state of the art was already given in [10].

This paper focuses on interaction analysis that provides information directly to students and teachers in order to assess and self-regulate the ongoing activity, and describes the generic model-based approach proposed in Omega+. A specific model, called the 'Effect Model', specifies *how interaction analysis is customized for the specific learning situation* defined by the other models that parameterize the generic system. Interaction analysis mostly relies on a *generic* machine learning algorithm (NBC) and *ad-hoc patterns specification* and *recognition*. Efficiency and acceptance results presented in the previous section are encouraging, even if several aspects require further investigation and improvement such as the pattern definition language, heuristics for generating guidance messages, participation analysis, etc.

It is also sometimes objected that most indicators are about *collaboration* and not about *learning*. It is well established now that collaboration is not sufficient *per se* for producing learning outcomes. Specific kinds of knowledge-productive interactions such as *asking each other questions, explaining and justifying opinions and reasoning, reflecting upon knowledge* are necessary to foster learning. It is the reason why some of the proposed indicators measure *customizable ingredients that are required by these productive interactions* such as on-task messages, actions with accompanying textual utterances, and 'uptaken acts' [23].

References

1. Resta, P., Laferrière, T.: Technology in Support of Collaborative Learning. Educational Psychology Review 19, 65–83 (2007)
2. Baker, M.J., Quignard, M., Lund, K., Séjourné, A.: Computer-supported collaborative learning in the space of debate. In: Proceedings of International Conference on Computer Supported Collaborative Learning (CSCL), Bergen, Norway, pp. 11–20 (2003)
3. Soller, A., Linton, F., Goodman, B., Lesgold, A.: Toward intelligent analysis and support of collaborative learning interaction. In: Proceedings of the Int. Conf. on Artificial Intelligence in Education, pp. 75–82. IOS Press, Amsterdam (1999)
4. Suthers, D., Jones, D.: An architecture for intelligent collaborative educational systems. In: Proceedings of Int. Conf. on artificial intelligence in education, pp. 55–62. IOS Press, Amsterdam (1997)
5. Baker, M.J., Lund, K.: Flexibly structuring the interaction in a CSCL environment. In: Proceedings of Euro AIED, Lisbon, Portugal. Edições Colibri, pp. 401–407 (1996)
6. Jaspers, J., Erkens, G., Kanselaar, G.: COSAR: Collaborative writing of argumentative texts. In: Proceedings of the Int. Conf. on Advanced Learning Technologies, pp. 269–272. IEEE Press, Piscataway (2001)
7. Dimitracopoulou, A.: Designing Collaborative Learning Systems: Current Trends & Future Research Agenda. In: Proceedings of the International Conference on Computer Supported Collaborative Learning (CSCL), Taipei, Taiwan, pp. 115–124 (2005)
8. Suthers, D.: Technology Affordances for Intersubjective Learning: A Thematic Agenda for CSCL. In: Proceedings of the International Conference on Computer Supported Collaborative Learning (CSCL), Taipei, Taiwan, pp. 662–671 (2005)
9. Lipponen, L.: Exploring foundations for computer-supported collaborative learning. In: Proceedings of the International Conference on Computer Supported Collaborative Learning (CSCL), Boulder, Colorado, pp. 72–81 (2002)

10. Lonchamp, J.: Supporting synchronous collaborative learning: A generic, multi-dimensional model. International Journal of CSCL 1(2), 247–276 (2006)
11. Jermann, P.: Computer Support for Interaction Regulation in Collaborative Problem-Solving. Doctoral Dissertation, University of Geneva (2004)
12. Suthers, D., Xu, J., Kukakuka, J.: An Online Environment for Artifact-Centered Discourse. In: Proceedings of 11th WWW Conference, pp. 472–480 (2002)
13. Dillenbourg, P., Traum, D.: Sharing solutions: persistence and grounding in multi-modal collaborative problem solving. Journal of the Learning Sciences 15(1), 121–151 (2006)
14. De Chiara, R., Di Matteo, A., Manno, I., Scarano, V.: CoFFEE: Cooperative Face2Face Educational Environment. In: Proceedings of the 3rd International Conference on Collaborative Computing: Networking, Applications and Worksharing (CollaborateCom 2007), New York, USA (2007)
15. Lonchamp, J.: Floor Control in Complex Synchronous CSCL Systems. In: Proceedings of the International Conference on Web Information Systems and Technology (WebIST), Barcelona, Spain (2007)
16. Clark, H., Schaefer, E.: Contributing to Discourse. Cognitive Science 13, 259–294 (1989)
17. Lonchamp, J.: Linking Conversation and Task Objects in Complex Synchronous CSCL environments. In: Proceedings of the International Conference on Web Information Systems and Technology (WebIST), Barcelona, Spain (2007)
18. Dimitracopoulou, A., et al.: State of the Art on Interaction Analysis: Interaction Analysis Indicators. ICALTS Project Deliverable: D.26.1 (2004), http://telearn.noe-kaleidoscope.org
19. Ingram, A.L., Hathorn, L.G.: Methods for Analyzing Collaboration in Online Communications. In: Roberts, T.S. (ed.) Online collaborative learning: theory and practice, pp. 215–241. Idea Group Inc., Hershey (2004)
20. Nonaka, I., Takeushi, H.: The knowledge-creating company: How Japanese companies create the dynamics of innovation, pp. 61–85. Oxford University Press, New York (1995)
21. Mitchell, T.: Machine Learning. McGraw-Hill, New York (1997)
22. Lovins, J.B.: Development of a stemming algorithm. Mechanical Translation and Computational Linguistics 11, 22–31 (1968)
23. Suthers, D.: Implications of Shared Representations for Computational Modeling. In: Proceeding of the 2nd International Workshop on Designing Computational Models of Collaborative Learning Interaction, Maceió, Brazil, pp. 42–52 (2004)
24. Anjewierden, A., Kollöffel, B., Hulshof, C.: Towards educational data mining: Using data mining methods for automated chat analysis to understand and support inquiry learning processes. In: International Workshop on Applying Data Mining in e-Learning, Crete, pp. 27–36 (2007)

WHURLE 2.0: Adaptive Learning Meets Web 2.0

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Abstract. The adoption of Adaptive Educational Hypermedia Systems into 'real world' teaching has been poor so far. One of the reasons behind this is believed to be due to their architectural design failing to answer the overall needs of Web-enhanced learning. On the other hand, *Web 2.0* emerging technologies are transforming the whole field of e-Learning into one known as "e-Learning 2.0". In this new generation, the learning process becomes a social and collaborative activity. Modern Learning Management Systems (LMS) provide the tools and the environment to enable this social learning. WHURLE 2.0 [1] was proposed as an adaptive LMS framework that allows adaptation functionality to be integrated with a modern LMS, by transforming its overall architecture into a distributed Web service. This paper takes the conceptual framework further by stressing its links with some of the Web 2.0 tools and showing this through an implementation that combines the Web 2.0 social aspects from Moodle as an LMS with the adaptation functionality.

Keywords: Moodle, Adaptive Educational Hypermedia Systems, Learning Management Systems, Web 2.0, e-Learning 2.0, Web Services.

1 Introduction

Adaptive Educational Hypermedia Systems (AEHS)[2], adapt to different models to provide a personalised learning experience to different users. A number of studies demonstrate its value in online learning [3]. However, AEHS poor presence in the online learning market encouraged researchers to investigate its own limitations [4]. This showed that the majority of AEHS are currently prototypic and experimental systems with basic GUI. They are not designed, for the modern e-Learning context which prompts services and reusability of learning content [5]. In terms of easy user-level content authoring and course administration, they are usually limited and require in depth technical knowledge [6]. Since the authoring for such systems remains expensive; reusability of this content became a must. However, the majority of early AEHS were built as monolithic systems, they have to be used as a whole [5]. Research on this issue could be divided into standarised and non-standarised approaches [7]. One of the key issues with AEHS is that they often have (if any) very limited

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social and collaborative learning activities, which are considered a critical issue since learning is known to be a social activity. Providing a one purpose adaptive system that isolates the learners could have very little hope in overtaking LMS. Modern LMS [8] helped in promoting online learning because of their simplicity and their easy-to-use features. One of the advantages that LMS have over AHES is their tools for social and collaborative learning such as blogs, chat, wikis, forums and so forth. Therefore, the major drawback of AEHS appear to be their architectures, implementations and delivery rather than their actual adaptation performance [9]. Hence the focus became on how to improve those architectures to deliver adaptation through a reliable, flexible, and collaborative learning environment, which has been widely adopted in the e-leaning community? LMS appeared as a potential delivery system in which AEH could be presented, since they provide a single login system for a number of learning activities. This paper provides a brief overview of the current status of e-learning and its links to the Web 2.0 revolution (section 2), reports work that integrates Moodle with AEH to provide an adaptive, social and collaborative learning environment in WHURLE 2.0 (section 3) that extends *WHURLE* [10]. Finally, a discussion and conclusions in section 4.

2 Web 2.0 and e-Learning 2.0

In Web 2.0, the focus shifts from the software and infrastructure of the Web to people and services. This influenced Hypermedia Educational Systems to transform into learning environments. The online learning process is transformed from one that provides a passive learning experience, where the students only receive information from the system without being able to interact or contribute, into one where they learn by doing, interacting and socialising [11]. This new generation of e-Learning is known as *"e-Learning 2.0"* [12]. Modern LMS provide the tools and environment where this social collaboration can take place within a learning context [13]. E-Learning 2.0 moves us from traditional standalone learning applications with static predefined learning content to an open learning environment of interoperable, open source platforms and tools that support social networks [14]. With Web 2.0, the importance of personalisation is recognised; users increasingly expect their behaviour to be monitored in order to adapt to the changes in interest or context. Moreover, the importance of community wisdom promoted by Web 2.0 has motivated research such as social browsing and social search [15], and social tagging [16] in the context of adaptive e-Learning. The *Moodle* LMS is one example of an LMS that is developing rapidly and contains the affordances necessary for e-Learning 2.0 [17] In this paper we argue that instead of trying to gain a critical mass of support for a new adaptive system that satisfies e-Learning 2.0 requirements, adaptation should be presented through an already in use LMS that covers the social aspects of online learning. However, we stress here that our implemented approach does not yet adapt to social aspects of the LMS. It brings adaptation where those social activities take place.

3 WHURLE 2.0

The WHURLE 2.0 framework as implemented consists of five services and Moodle. These services are the Aggregation Service (AGS), User Modelling Service (UMS), Lesson Plan Service (LPS), Adaptation Filter Service (AFS) and Chunk Management Service (CMS). They were developed with the ability to communicate with each other by adhering to web service protocols such as SOAP and WSDL. They all share characteristics of independency, interoperability and flexibility. The implementation of this framework was achieved using PHP and XML with XSLT. The learning content is saved in conceptually discrete units called chunks which are XML files that contain text or references to other media types. Figure 1 provides a conceptual description that explains how the system works:

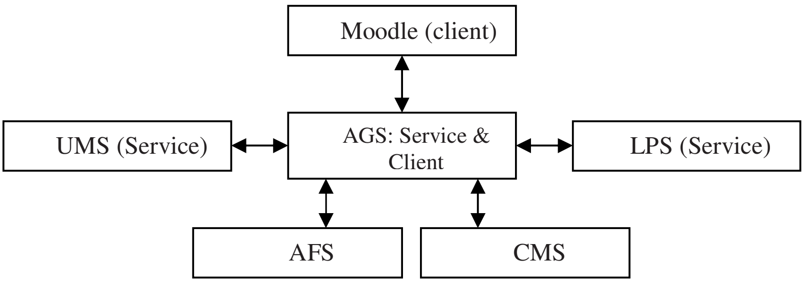

Fig. 1. WHURLE 2.0 conceptual design

The Aggregator Service (AGS) is the heart of WHURLE 2.0 and is both a client and a service. Invoked by Moodle as a service, AGS will then act as a client that invokes four main services before returning the results to Moodle. In addition, it has some other functionality, for example mediating between the UMS and LMS for register the student and updating the user profiles. The User Modelling Service (UMS) has been implemented as a simple, knowledge-based stereotype user model, while designing the system, so that it can be easily extended or replaced. The service has an XML database which stores the users' profiles and that is queried using XSLT to match users with their level of knowledge – this is returned to the AGS. The Lesson Plan Service (LPS) has an XML database, where all the lesson plans' (LP) names and locations are stored. The AGS passes the lesson's name to the LPS, which returns the lesson plan for that lesson. Once the AGS has those two significant arguments (user's level and lesson's plan) it passes them to a third service, the Adaptation Filter Service (AFS). The AFS then applies a special XSLT filter to the lesson plan using the level parameter to apply the required adaptation. It filters the lesson plan according to its rules and produces a list of the required chunks. This XML list of required chunks is then passed to the Chunk Management Service (CMS). The CMS consists of an XML database which contains all the requisite information about the chunks (name, location, type, author, etc) including the meta-data provided for semantic exchange and interoperability. Some of the chunks which are classified as "internal" are stored in the CMS, which also serves as a repository for them. The list produced by the AFS is used by the CMS to select those chunks and pass them to the AGS, which will return them to Moodle. A client in Moodle is responsible for populating its tables of a given learning activity such as the *Lesson* activity with this learning content. Figure 2 illustrates an adaptive lesson presented in WHURLE 2.0's portal (Lesson activity), while figure 3 provides a snapshot of the overall learning environment:

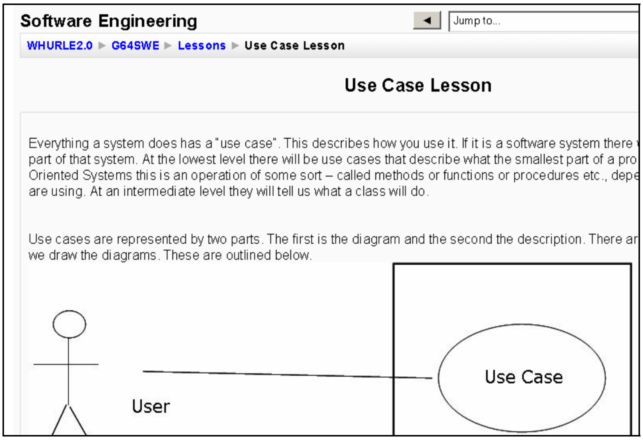

Fig. 2. An Adaptive lesson in Moodle's Lesson activity. A student clicks on a lesson; a client is activated calling AGS. The AGS acts as a client that makes calls the rest of services before returning the results to the calling client in Moodle.

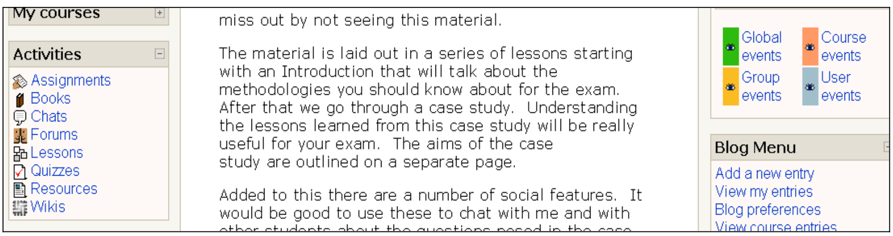

Fig. 3. WHURLE 2.0 Learning environment where adaptive learning content (in Lesson module) is combined with social and collaborative learning tools (activities, blog) from Moodle (LMS)

WHURLE 2.0 has been evaluated by testing its adaptation and collaborative functionalities with students, and testing services' interoperability with another LMS; ATutor [18]. Due to limited space, results will be presented in future publications.

4 Related Work, Discussion and Conclusions

A similar work integrates adaptation, but according to learning styles, with Moodle is described in [19]. The main difference between this work and ours is the use of Web services. A Web service is a self-contained, self-descriptive and modular unit that provides a simple and platform-neutral way of communication between applications. This feature makes it critical for resolving interoperability issues. Therefore, our approach should be more generic and interoperable. Moreover, the integration process requires little integration with Moodle's codebase, whereas in the other work, extensions were made to different parts of the LMS's tools and the adaptation is hard-wired into the system, thus becoming LMS-specific. WHURLE 2.0 was designed to extend the interesting conceptual ideas of the chunks as was presented to the previous WHURLE, yet overcomes its implementation problem. The immigration from the standalone to the service oriented architecture did not have any noticeable negative affect on the system's adaptation behavior. There was no delay in serving the content, nor did the user trials report any complaints regarding the systems' run-time speed. On the contrary, moving from the standalone to SOA served the following purposes: 1) address a number of issues that were affecting WHURLE alongside the majority of AEHS, which is them being prototypic systems with experimental interfaces that have limited social or collaborative learning tools seen as a "must" in the Web2.0 generation. 2) It unlocks the systems allowing for reusability of content and interoperability of system's components. 3) Easy integration and maintenance of each individual service. 4) Easy integration with an external independently developed off-the-shelf popular LMS. The Moodle LMS becomes the delivery platform for the adaptation effect in addition to providing its tried and trusted tools for social learning.

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References

1. Meccawy, M.: An Adaptive Web Service e-Learning Environment for the Web. In: Saudi Innovation Conference. Newcastle upon Tyne, UK (2007) ISBN: 978-0-1955104-92-3
2. Brusilovsky, P.: Adaptive Educational Hypermedia. In: PEG conference, Tampere, Finland (2001)
3. Eklund, J., Brusilovsky, P.: The Value of Adaptivity in Hypermedia Learning Environments: A Short Review of Empirical Evidence. In: 2nd Workshop on Adaptive Hypertext and Hypermedia at Hypertext 1998. ACM, Pittsburgh (1998)
4. Brusilovsky, P.: KnowledgeTree: A distributed architecture for adaptive E-Learning. In: WWW 2004. ACM Press, New York (2004)
5. Brusilovsky, P., Wade, V., Conlan, O.: From Learning Objects to Adaptive Content Services for E-Learning Architecture Solutions for E-Learning Systems. In: Pahl, P. (ed.). Idea Group Inc., Hershey (2007)
6. Meccawy, M., Stewart, C., Ashman, H.: Adaptive Educational Hypermedia Content Creation: A Web Service based Architecture. In: Ah 2006 Workshop on Authoring for AH, Dublin, Ireland (2006)
7. Rey López, M., Meccawy, M., Brusilovsky, P., Díaz Redondo, R., Fernández Vilas, A., Ashman, H.: Resolving the Problem of Intelligent Learning Content in Learning Management Systems. Internationl Journal on E-Learning 73 (2007)
8. Wikiopedia. Learning Management System [cited Novermber 22, 2007](2007), `http://en.wikipedia.org/wiki/Learning_Management_System`
9. Brusilovsky, P.: Adaptive Hypermedia: From Generation to Generation. In: Information & Communication Technologies in Education. Athens (2004)
10. Brailsford, T.J., Stewart, C.D., Zakaria, M.R., Moore, A.: Autonavigation, Links and Narrative in an Adaptive Web-Based Integrated Learning Environment. In: WWW 2002, Honolulu, Hawaii, USA (2002)

11. Alexander, B.: Web 2.0: A New Wave of Innovation for Teaching and Learning? EDUCAUSE Review 412, 32–44 (2006)
12. Downes, S.: "E-learning 2.0". eLearn Magazine. ACM, New York (2005)
13. Weller, M.: VLE 2.0 and future directions in the learning environments. In: First LAMS Conference, Sydney (2006)
14. Fumero, A.: EDUWEB 2.0 - iCamp & N-Gen Educational Web. In: Proceedings of WEBIST conference, Setúbal, Portugal (2006)
15. Freyne, J., Farzan, R., Brusilovsky, P., Smyth, B., Coyle, M.: Collecting community wisdom: Integrating social search & social navigation. In: IUI 2007. ACM Press, Honolulu (2007)
16. Bateman, S., Brooks, C., McCalla, G., Brusilovsky, P.: Applying Collaborative Tagging to E-Learning. In: Workshop on Tagging and Metadata at WWW 2007, Banff, Canada (2007)
17. Corcoles, C., Casado, C., Huertas, M.A., Mor, E., Guerrero-Roldan, A.: Learning 2.0: concepts and experiences with social netwoks software. In: e-Learn 2007, Quebec City, Canada (2007)
18. ATutor. ATutor [cited 2008 28-1], `http://www.atutor.ca/`
19. Graf, S.: Providing Adaptive Courses in Learning Management Systems with Respect to Learning Styles. In: e-Learn 2007, Quebec City, Canada (2007)

Towards Accessing Disparate Educational Data in a Single, Unified Manner

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Abstract. Educational researchers need to exchange and compare their learner-interaction data in order to benefit the learning science community as a whole. In order to support this, we propose accessing data in different repositories via a *mediator component* that maps generic queries to the specific format of a target repository. This approach is supported by a common ontology, and we illustrate the beginnings of such an ontology. We are in the early stages of developing this concept but show its promise by discussing how it can be applied to repositories of disparate educational data, such as collaborative learning interactions and cognitive tutor data.

1 Introduction

A key problem for educational researchers today is sharing and exchanging their learner-interaction data. In order to compare results across studies and across educational systems, it is important to have share data across the studies and systems. We investigated how we can access educational data from different repositories that rely on a variety of perspectives and scenarios, including technology-enhanced learning in lab and classroom experiments, inquiry learning, collaborative learning, classroom learning, and one-on-one tutoring.

Achieving a common access to log data from different learning environments holds several potential advantages for educational researchers and educational technologists. First, it would allow researchers to share and exchange data freely between their systems in theoretically neutral fashion, enabling more direct comparison between approaches and methodologies. Second, it would help to develop community-wide standards and a common format for educational data. This development of standards builds upon previous efforts of the EU Kaleidoscope community [1]. Third, a natural outgrowth of joint access could be the development of shared analysis tools, such as learning curve and social network analyses.

What are the problems to overcome? A key issue is determining how to connect educational data from different perspectives and at different levels of granularity, taking a cue from principled 'knowledge analyses' that have been done by prominent researchers in cognitive science and artificial intelligence [2, 3]. For instance, an intelligent tutor collects data at the cognitive level, while a collaborative learning system collects data at the social interaction level and each has different requirements for data

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storage, format, and analysis. Moreover, although our main interest focuses on student actions, other information must be logged, standardized, and correlated in particular, contextual information. Contextual information includes data about how the educational software responds to student actions and data that are obtained during system use, such as from questionnaires.

There are two principled ways to achieve this goal: (1) coalesce or translate data from different educational data repositories into a single common repository or (2) access the data in different repositories via a mediator that maps generic queries to the specific format of the target repository. The second approach has the advantage of (1) allowing data sources to remain in their original form, avoiding constant translating and copying of data to a central store, and (2) accessing data through a web service.

Necessary steps to support this approach include a formalization and implementation of the ontologies of the different repositories and the development of a common 'umbrella' ontology into which the separate ontologies can be mapped. We are in the early stages of developing this concept but demonstrate its promise by showing how it can be applied to repositories of disparate educational data, such as collaborative learning interactions and cognitive tutor data.

2 Access to Distributed Log Data Repositories

Our mediator approach is based on past work reported in [4]. The mediator architecture allows an application to retrieve objects or data from heterogeneous repositories. A "mediator component" accepts queries formulated in a uniform query language, translates them into repository-specific queries, and passes them to the corresponding repository (see Fig. 1). A 'wrapper' is used with each repository, containing the specification of the ontology of the repositories knowledge (as an OWL definition) and the mapping to the terms of a common ontology. The wrapper translates queries from the common language/ontology into the language of the repository using the mapping. For the translation of queries, we use an ontology-based query-rewriting method. It queries a repository according to the specific commands of the repository; it transfers the query results of the repositories (e.g., URIs) to the application it serves.

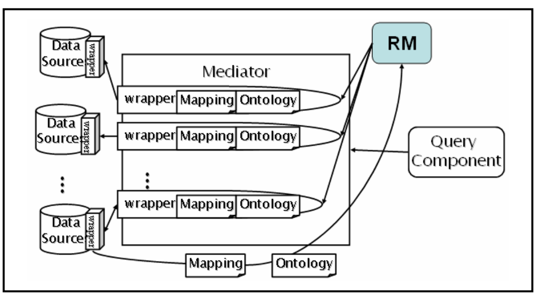

Fig. 1. The mediator architecture

The mediator approach leaves us with the questions "How do we use the mediator technique to query user log data?" and "How do we translate the log data ontologies?" In this paper, we concentrate on the second question, because it must be answered before the implementation of the mediator. The steps towards the translation include (1) a formalization of the ontologies of the repositories, (2) the development of a common ontology, and (3) the development of the mappings.

The transformations that the mediator requires to work with log data ontologies involves a complex ontology which needs to describe not only learning objects but also the UserLogActions and Events. It also requires that we rewrite all the mapping instructions in the XML-based ontology mapping language.

3 Ontologies for the Different Log Data Repositories

We built ontologies for five repositories/tools by analysing the tools' logged data and, when provided by the log data/system owner, some schema specifications for this data (DTD, XSD, databases, etc.). We used OWL (Web Ontology Language) language for the representation of ontologies. OWL is designed for use by computational applications but at the same time is human readable. It was developed to augment the facilities for expressing semantics provided by XML, RDF, and RDF-S. Since OWL is based on XML, it can be easily exchanged between different types of computers using different operating systems and application languages. We modelled the ontologies with the help of Protégé[1] [7]. The Protégé-Frames editor enables users to build and populate ontologies that are frame-based, in accordance with the Open Knowledge Base Connectivity protocol (OKBC). In this model, an ontology consists of a set of classes organized into a subsumption hierarchy to represent a domain's salient concepts, a set of slots associated with classes to describe their properties and relationships, and a set of instances of those classes – individual exemplars of the concepts that hold specific values for their properties.

The systems/formats for which we built the log data ontologies span the gamut from collaborative learning technologies to inquiry learning systems to intelligent tutoring systems. The specific systems we evaluated and created ontologies for are: Digalo[2], ActiveMath [8], the PSLC DataShop [5], GSIC Valladolid [6], and a Demonstrator from Grenoble [7]. After analysing the schemas and log file samples provided by the owners of these various systems, we built an ontology for each data format with Protégé (The ontologies can be downloaded from http://www.noe-kaleidoscope.org/group/datarep/links_page.html). Our next step was to analyse the requirements of the five ontologies and map them to a single, common ontology.

4 Common Ontology

When we refer to the *common* ontology we mean common for the group of repositories whose data/ontology could (somehow) map onto the shared ontology. The goal of the common ontology is to support the construction of queries that can be forwarded to the five log data repositories (or more that could be added) via a mediator and to interpret their responses. The components of the ontologies that cannot be mapped to the common ontology are system-specific concepts that have no representation in the common ontology. These unmatched elements will be analysed in the future.

In Fig. 2 the top-level structure of the common ontology is depicted. For instance, the Action class is connected with the Session class through the relation

[1] http://protege.stanford.edu/

[2] http://dito.ais.fraunhofer.de/digalo/webstart/index.html

action_in_session (represented here by an arrow between the two classes). These classes and relation have mappings to four of our five separate ontologies (only Digalo does not have an equivalent). Likewise, the other concepts and relationships in the common ontology have been mapped to our five ontologies, where possible. Our next step is to experiment with how our mediator allows us to access the data of the separate repositories through common queries.

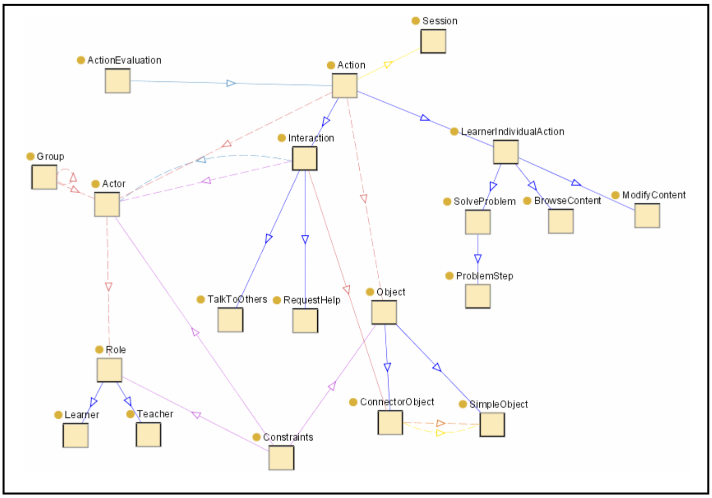

Fig. 2. The high-level structure of the common ontology

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References

[1] Kaleidoscope. Kaleidoscope Project Report D31.2, Project "Interaction Analysis (IA)," Library of Interaction analysis methods (2005)
[2] Anderson, J.R.: Spanning Seven Orders of Magnitude: A Challenge for Cognitive Modelling. Cognitive Science 26(1), 85–112 (2002)
[3] Newell, A.: Unified Theories of Cognition. Harvard Univ. Press, Cambridge (1990)
[4] Kärger, P., Ullrich, C., Melis, E.: Integrating Learning Object Repositories Using a Mediator Architecture. In: Innovative Approaches for Learning and Knowledge Sharing, 1st European Conference on Technology Enhanced Learning, pp. 185–197 (2006)
[5] VanLehn, K., Koedinger, K.R., Skogsholm, A., Nwaigwe, A., Hausmann, R.G.M., Weinstein, A., Billings, B.: What's in a Step? Toward General, Abstract Representations of Tutoring System Log Data. In: Conati, C., McCoy, K., Paliouras, G. (eds.) UM 2007. LNCS (LNAI), vol. 4511, pp. 455–459. Springer, Heidelberg (2007)
[6] Martínez, A., de la Fuente, P., Dimitriadis, Y.: Towards an XML-based Representation of Collaborative Interaction. International Conference on Computer Support for Collaborative Learning, pp. 379-384 (2003)
[7] Adam, J.-M.: Demonstrator of an Infrastructure for Collection and Exchange of Experimental Traces, Kaleidoscope Initiative report D7.8.1 (2006)
[8] Melis, E., Goguadse, G., Homik, M., Libbrecht, P., Ullrich, C., Winterstein, S.: Semantic-Aware Components and Services in Activemath. British Journal of Educational Technology. Special Issue: Semantic Web for E-learning 37(3), 405–423 (2006)

Bridging the Gap between Practitioners and E-Learning Standards: A Domain-Specific Modeling Approach

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Abstract. Developing a learning design using IMS Learning Design (LD) is difficult for average practitioners because a high overhead of pedagogical knowledge and technical knowledge is required. Through using peer assessment as an exemplary pedagogy, this paper presents a domain-specific modeling (DSM) approach to a new generation of LD authoring tools, for enabling practitioners to create learning designs. Adopting a DSM approach, on the one hand, pedagogic experts develop a pedagogy-specific modeling language, in which notations are directly chosen from the concepts and rules used to describe pedagogic approaches. On the other hand, technical experts develop transformation algorithms, which will map the models represented in the pedagogy-specific modeling language into machine-interpretable code represented in LD. This technical approach to a new generation of LD authoring tools has been illustrated through presenting the whole procedure of the development of a peer assessment authoring tool.

Keywords: domain-specific modeling, IMS LD, IMS QTI, peer assessment.

1 Introduction

IMS Learning Design specification (LD) [3] is a pedagogy-neutral and machine-interpretable educational modeling language. It can be used to describe a wide range of pedagogies as units of learning (UoL). However, developing a UoL using LD constructors (e.g., roles, learning activities, properties, and conditions) is not an easy task because the required level of pedagogical knowledge and technical knowledge is significant. Although several LD authoring tools have been developed, they assume a keen knowledge of the technical specification and thus are developed for experts, who can deal with pedagogic issues and handle technical complexity at the same time. Finding out how to empower practitioners, who cannot sustain a high overhead of pedagogical and technical knowledge, is crucial for the wide application of LD in practice. In this paper, we present a domain-specific modeling (DSM) approach to a new generation of LD authoring tools and show how it can help practitioners develop complicated learning designs without handling technical complexities of the open e-learning standards. Throughout the paper, we will use peer assessment as an exemplary pedagogy, although the DSM approach is in no way restricted to such an application.

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2 Modeling Peer Assessment in IMS LD

Peer assessment is a process consisting of various cognitive activities such as reviewing, summarizing, clarifying, providing feedback, diagnosing errors, and identifying missing knowledge or deviations [10]. In the literature many peer assessment models have been described [4, 7, and 11]. Note that various peer assessment models are available in practice and there is no “one-size-fits-all”. The variables of the peer assessment could include levels of time on task, engagement, and practice, coupled with a greater sense of accountability and responsibility. Topping [8] developed a typology, which consists of a survey of variables found in the reported systems of peer assessment. These pedagogic issues have to be taken into account systematically for designing an effective and efficient peer assessment model.

A technical approach to script a peer assessment through a combined use of LD and IMS Question and Test Interoperability (QTI) [6] has been proposed in [5]. Various activities (e.g. designing assignment, writing report, reviewing, providing feedback, and identifying missing knowledge) performed by different learners (including the tutor) have to be modeled in sequence and/or in parallel as control-flow. Various information units (e.g., analysis reports and feedback, modeled as properties in LD) produced by using various services (e.g., text editor, QTI authoring tool and QTI player) and transferred between activities/peers have to be modeled as information flows. As indicated in [5], if the number of participants is large and the information exchange patterns are sophisticated, specifying a peer assessment model in terms of LD and QTI will be very complex and time-consuming.

3 Domain-Specific Modeling

Domain-specific Modeling (DSM) or Domain-specific Modeling Language (DSML) is a new method in software development. It has been applied in many application domains. In comparison with the Unified Modeling Language (UML), DSM is more expressive and therefore tackles complexity better, making modeling easier [2]. In addition, DSM allows automatic, full code generation, similar to the way today's compilers generate Assembler from a programming language like JAVA [1].

DSM raises the level of abstraction beyond programming by specifying the solution in terms of concepts and associated rules extracted from the very domain of the problem being solved. The final software products are generated from this high-level abstraction [1]. Notations in a domain-specific model are a whole level of abstraction higher than those in UML. As shown in Figure 1, normally software developers will implement the final product by mapping the domain concepts to assembler, code, or UML model. By adopting the DSM, a meta-model of the problem domain will be constructed as a modeling language by domain experts. Domain-specific code generators and executable components will be developed by experienced technical experts. Hence, less experienced developers and even practitioners can understand, validate, and develop DSML programs through employing the concepts and rules familiar to them, whereas developing equivalent solutions in a general-purpose language such as UML or JAVA is often too daunting a task for people typically not trained as software engineers. In addition it is often possible to validate and optimize at the level of the domain rather than at the level of general-purpose languages where detail may obfuscate important features [9].

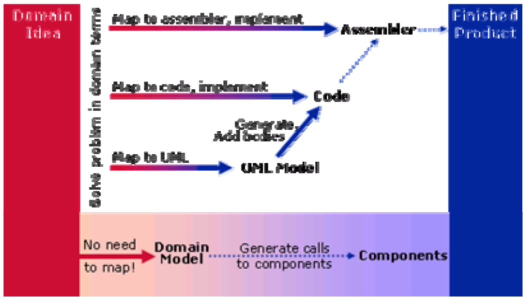

Fig. 1. DSM and other software development approaches (taken from [1])

4 A Peer Assessment Modeling Language

The definition of a peer assessment modeling language should start with choosing the vocabularies used in the domain of peer assessment. Such vocabularies provide natural concepts that describe peer assessment in ways that practitioners already understand. They do not need to think of solutions in coding terms (e.g., classes, fields, and methods) or/and generic concepts (e.g., activities, action objects and decision points).

Based on the peer assessment models and the typology mentioned in the last section, we developed a peer assessment meta-model by deriving many of the modeling concepts and the constraints. As shown in Figure 2, a peer assessment process normally consists of four stages: *assessment design, evidence collection, giving feedback,* and *reacting to feedback*. In the assessment design stage, one or more various activities such as *constructing assessment form, designing assignment,* and *setting time* may take place. A *designer* can perform one or more activities and one activity can be done by one or more designers. Performing design activities may produce *assignment description* and/or *assessment forms*. Note that the assessment design stage may or may not be included in a peer assessment, because sometimes the assignment description and the assessment form have been pre-defined before the peer assessment starts. No matter whether the assessment design stage is included, a peer assessment actually starts from the evidence collection stage, in which one or more *candidates* do assignments such as *responding to questions* or *performing tasks* according to the assignment description. Then the *assignment outcomes* will be produced and distributed to the activities in a subsequent giving feedback stage, in which one or more *reviewers* will *comment on, rate,* and *grade* the allocated assignment outcomes using the assessment form, and finally provide feedback in forms of *comments, rates,* and *grades*. In summative peer assessments, the process may terminate here. In the formative peer assessment, typically a reacting to feedback stage will follow, in which the candidate may *view* or *review feedback*. Sometimes, candidates further *improve* assignment outcomes and even *require elaborate feedback*. In the later case, the reviewer may *provide elaborate* or *additional feedback*. In some extreme situations, reacting to feedback stages and giving feedback can be repeated several times.

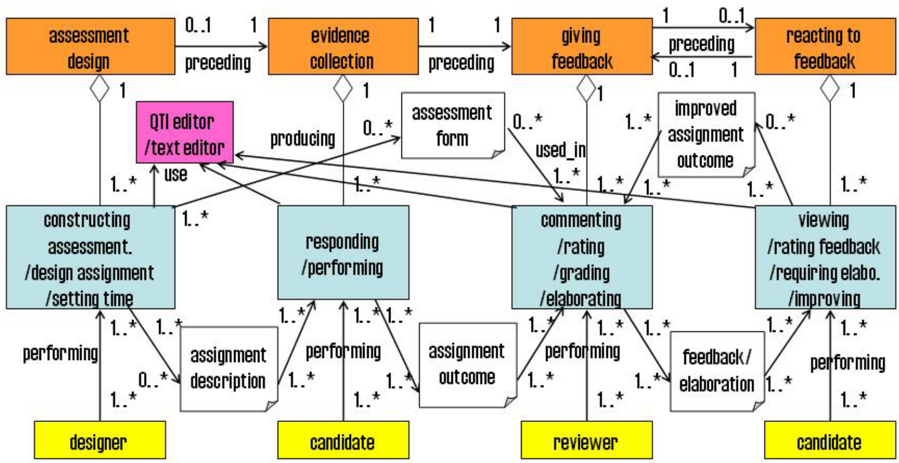

Fig. 2. The meta-model of peer assessment

The peer assessment meta-model as just discussed is formally defined in XML schemas, which can be regarded as a high-level process modeling language to specify various peer assessment models. Note that the diagram of Figure 2 just illustrates the most important concepts of the meta-model and primary relationships between them. Many details of the modeling language are actually represented as alternatives, constraints, and rules, which have not been drawn in the diagram. When specifying a peer assessment model, one has to represent the design decisions in terms of the modeling language.

5 A Peer Assessment Authoring Tool

For experienced users, the peer assessment modeling language can be used to specific a peer assessment model directly in the form of XML. In order to support practitioners to develop online peer assessments, an authoring tool for modeling with the peer assessment modeling language should be provided.

Guidelines for design decisions. The peer assessment modeling language can be used to specify a peer assessment model directly. However, it would be nice if practitioners could be guided to make a series of design decisions. Figure 3 illustrates the design guidelines for developing a peer assessment model step by step. All design decisions will be captured, and then will be available for subsequent design and refinement in the process of modeling. In order to help practitioners make design decisions, the peer assessment modeling language defines default values for certain design variables. For example, it is assumed that only two persons are involved in the process and both are *candidates* and *reviewers*. If the default values are not appropriate, practitioners can assign the variable values and thus customize the design. For example, it can be changed as five persons are engaged in the customized process and each reviews three of the others' assignment outcomes. Moreover, certain design decisions are related so that if one design decision has been made then another decision will be made accordingly. For example, if the purpose of the peer assessment to be modeled is a summative assessment, then the activity *improving assignment outcome* in the *reacting to feedback* stage and the activity *elaborating feedback* in the *giving feedback* stage will be excluded; there is no need then to specify them.

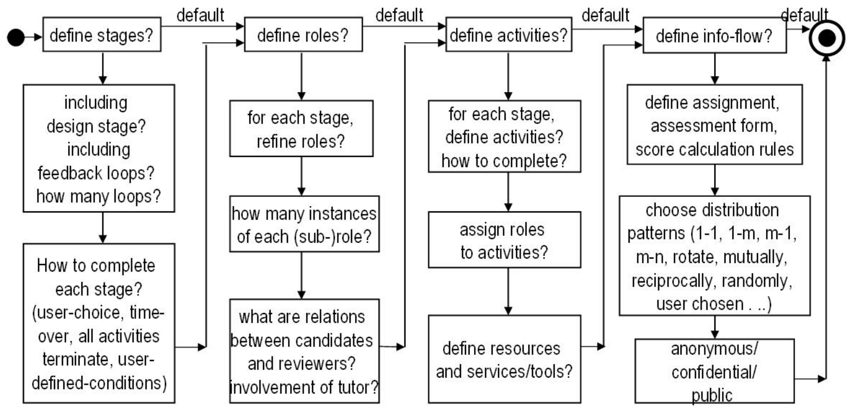

Fig. 3. Design guidelines

User interface of the authoring tool. Based on the design guidelines described above, a 'wizard' is developed to guide the practitioner through a sequenced set of pages. The wizard page defines the controls that are used for making design decisions. It responds to events in its decision-making areas. After the practitioner has made choices or/and has provided input on the current page, he can go ahead by clicking the "Next" button. When required inputs from the practitioner on all relevant pages have been received, the wizard will complete and all decisions (including the default values selected) will be captured by the wizard and represented internally in the peer assessment modeling language.

Transforming algorithm. After a peer assessment model has been specified using the wizard, the authoring tool will transform the model, represented in the peer assessment modeling language, into an executable model, represented in LD and QTI. The basic idea of the transformation algorithm is to create a set of instances of domain-generic concepts for each instance of a domain-specific concept and to maintain their relationships. For example, the notation *commenting* in the peer assessment modeling language will be translated into a *support-activity* element of LD with an associated *environment* element that will be generated together with the *support-activity* element.

6 Conclusions

In this paper, we outlined an approach to apply the DSM paradigm to the development of a pedagogy-specific modeling language. Through developing a peer assessment authoring tool, we demonstrated that a DSM approach can be used to develop a new generation of LD authoring tools, for supporting practitioners to develop learning designs. Using such a pedagogy-specific modeling tool, practitioners can benefit from open technical e-learning standards without having to deal with their technical complexity. Moreover, the quality of the resulting models is higher on both pedagogical and technical aspects because experienced pedagogical and technical experts developed the domain-specific modeling language and the code generator. We will conduct experiments with the target user group after the tool is completely developed and tested. It is also expected that more pedagogy-specific modeling languages with different abstraction levels as a hierarchic structure and a corresponding authoring toolset will be designed and implemented in the future for practitioners to develop and combine various learning designs.

References

1. DSM forum, `http://www.dsmforum.org/`
2. Bruce, D.: What makes a good domain-specific language? APOSTLE, and its approach to parallel discrete event simulation. In: Kamin, S. (ed.) DSL 1997 – First ACM SIGPLAN Workshop on Domain-Specific Languages, in Association with POPL 1997, Paris, France, January 1997, pp. 17–35. University of Illinois Computer Science Report (1997)
3. LD: IMS Learning Design Specification (2003), `http://www.imsglobal.org/learningdesign/index.html`
4. Liu, Z., Lin, S., Yuan, S.: Experiencing NetPeas: Another way of learning. In: Zhong, N., Yao, Y., Ohsuga, S., Liu, J. (eds.) WI 2001. LNCS (LNAI), vol. 2198, pp. 584–588. Springer, Heidelberg (2001)
5. Miao, Y., Koper, R.: An Efficient and Flexible Technical Approach to Develop and Deliver Online Peer Assessment. In: Proceedings of CSCL 2007 conference, New Jersey, USA, July 16-21, 2007, pp. 502–511 (2007)
6. QTI: IMS Question and Test Interoperability Specification (2006), `http://www.imsglobal.org/question/index.html`
7. Sitthiworachart, J., Joy, M.: Web-based Peer Assessment in Learning Computer Programming. In: Proc. of the 3rd IEEE ICAL 2003, Athens, Greece, July 9-11, 2003, pp. 180–184 (2003)
8. Topping, K.J.: Peer assessment between students in colleges and universities. Review of Educational Research 68, 249–276 (1998)
9. van Deursen, P.K.A., Visser, J.: Domain-specific languages: An annotated bibliography. ACM SIGPLAN Notices 35(6), 26–36 (2000)
10. van Lehn, K.A., Chi, M.T.H., Baggett, W., Murray, R.C.: Progress report: Towards a theory of learning during tutoring. Pittsburgh, PA: Learning Research and Development Center, University of Pittsburgh (1995)
11. Volder, M.D., Rutjens, M., Slootmaker, A., Kurvers, H., Bitter, M., Kappe, R., Roossink, H., Goeijen, J., Reitzema, H.: Espace: A New Web-Tool for Peer Assessment with In-Built Feedback Quality System. In: Proceedings of ABR & TLC Conference 2007, Hawaii, USA (2007)

Supporting Learners' Organization in Collective Challenges

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Abstract. This article presents research that aims to construct a computer-based system that (1) supports learners in organizing themselves in the context of a mediated pedagogic collective challenge and (2) supports human tutors in monitoring the learners' process, and supporting it. We present the result of an exploratory experiment that helps in understanding the organizational dimensions of this type of learning situation, a theoretical background originating from CSCW, a prototype designed according to this theoretical background and preliminary results.

Keywords: CSCL; Pedagogic Collective Challenge; Organizational Issues.

1 Introduction

Collaborative learning emerges from knowledge-generative interactions such as conflict resolution, explanation or mutual regulation [1]. In order to enhance the probability that such interactions occur, CSCL scripts define precise sequences of activities, creating roles and constraining the mode of interaction among peers [2]. *Pedagogic collective challenges* correspond to another strategy, based on learners' motivation: the scenario is less detailed and, rather, emphasis is on introducing a challenge to enhance learners' motivation for involving themselves and solving the problem.

Scripts and challenges correspond to particular cases of collective *work situation*, learners being mutually dependent in their work [3]. This requires the overhead activity of articulating their respective activities [4,5]. When learners only communicate via a computer-based system, taking these organizational dimensions into account is a core issue [3,6] as they (1) impact the overall process and (2) conduct learners to be involved in knowledge-generative interactions such as building a common ground, planning, conflict resolution or mutual regulation.

Our research aims at constructing a computer-based system that (1) supports learners in organizing themselves in the context of a mediated pedagogic collective challenge and (2) supports human tutors in monitoring and supporting the learners' process, it. In section 2 we introduce the notion of pedagogic collective challenge. In section 3 we summarize some findings related to an exploratory experiment. In section 4 we present how we use theoretical works by Bardram [4] to model organization. In Section 5 we

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present the prototype we have designed to support learners, and some usability results. Finally, Section 6 presents the results of a preliminary experiment, and Section 7 draws general conclusions and perspectives.

2 Pedagogic Collective Challenges

We define a pedagogic collective[1] challenge as a learning situation where: (1) the problem is designed to make learners practice some target domain-related and/or meta-cognitive competencies; (2) a group of learners is involved, as a team, in the solving of the problem; (3) the solving of the problem requires the learners to join their forces; (4) the problem and the setting are designed to create a positive tension that motivates learners.

Such learning situations present different interesting features [7]: they allow addressing domains (e.g., mathematics) from new perspectives, which can raise the interest of some learners; their playful nature enhances learners' motivation; the fact that they are based on different work modalities (individual, group, class) allow all learners to involve themselves and participate in different ways; the status of « error » is different from usual exercises. Pedagogic challenges present different properties that have been identified as positively impacting students' motivation such as promoting situational interest, students' self determination, working in the presence of others or self regulation [8,9].

Van Eck & al. [10] highlight that a challenge should be difficult enough to create some uncertainty about obtaining a result whilst not going to an extent where learners may doubt they will succeed. Retroaction is also identified as an important issue for learners' motivation. Attention should be paid to the fact that, when experts tend to spend time in planning their work, novices tend to jump in a too straightforward way to problem-solving basic actions [11]. Finally, collective problem-solving is not to be understood as a set of individual (sub)problem-solving and sharing of sub-problems' inputs and outputs [12]. Individual problem-solving strategies can act as resources for proposing what tasks are to be addressed; collective problem-solving however also requires the additional task of the collaboration management.

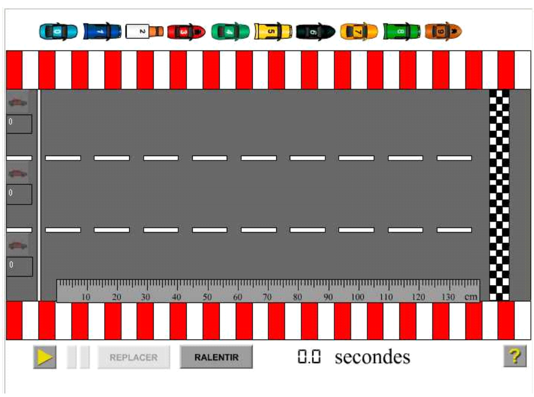

Fig. 1. The simulation (the track)

[1] As we believe the "cooperative" / "collaborative" distinction is often a question of level of granularity, point of view and/or matter of concern, we will use "collective" as a wide concept, however using "cooperative" / "collaborative" when well suited or when quoting other authors.

We use the problem (and the Flash simulation) “the race with no winner” created by a community of practice dedicated to the use of simulations in mathematics and physics [13] as a field study. The simulation embeds 10 cars that can be put on a track (cf. Fig 1). The cars have different behaviours: they have different speeds, and when on the track some of them stop for a time (different one from another) and start again. The challenge is as follows: the tutor selects one car and puts it somewhere on the track (not necessarily on the departure line); he then indicates two other cars to the learners; the learners have to calculate where to put each of these two other cars on the track for all three cars to arrive simultaneously at the final line. The pedagogical situation has thus 3 phases: (1) preparing the data: learners must achieve a mathematical analysis of the 10 cars’ behaviours and collect the data necessary to establish a relation between the departure position of every single car and its arrival at the final line, which involves calculus and competencies related to position, time and speed (variation rate, table of values, cartesian plan and equation, etc.); (2) the launch of the challenge: the tutor puts a car (out of the 10) on the track, designates two others, and the learners have a limited amount of time to calculate where to put these two cars, on the basis of their behaviours as calculated at the previous step; (3) the simulation is played to check if it is a success or a failure. This can of course be followed by a debriefing phase with the tutor.

Such a simulation / challenge can be used to target different pedagogical objectives, e.g., to discover some principles of physics (relation speed/distance) by inquiry learning, practice the involved calculus techniques or practice how to formalize a problem. In the context of our study, the simulation is used in the context of a mathematical course with 11th Grade students (16-17 year-olds), targeting competencies related to planning and regulation as a means to be able to react to various situations [14,15]: different studies (e.g., [14]) have demonstrated the interest of situations where students are confronted with concrete cases where they have to make different strategies explicit, select one, apply it, and evaluate its effectiveness. Such situations also contribute to active learning by making learners reflect on what they do and by involving them in an evaluation of their process and results. The rationale for using a collective activity is (1) it stimulates making problem-solving strategies explicit and (2) it generates peers’ interactions related to the problem-solving strategies and their evaluation (some evaluation thus takes place before and differently from the final simulation). Finally, a minor pedagogical objective is to make learners practice the elaboration and implementation of a mathematical model. With respect to these objectives, the challenge is interesting by the fact that, after the tutor has put his car on the track, the learners only have a limited amount of time to place theirs (in our experiment we gave them 20 minutes). Therefore, in the first phase, they must not only prepare all the useful data (i.e., calculate the different cars’ behaviours), but also organize themselves for the second phase: identify what the different tasks to be achieved during phase 2 are (acquire x, measure y, calculate z), and decide how to organize themselves (who will achieve each subtask, etc.). As we observed in our exploratory experiment, the learners realize they have enough mathematical knowledge to solve the problem, but also that solving the problem in limited time can be carried out only by sharing the work and adopting an effective strategy. They have to adopt a strategy (out of the different ones they individually proposed) and set up a form of monitoring and regulation of the process.

3 Organizational Dimensions of a Pedagogic Collective Challenge

3.1 Definition

A collective learning situation such as a pedagogic collective challenge is made of two overlapping systems of activities: the collective problem-solving and the organization of this collective problem-solving. A pedagogic collective challenge corresponds to a particular case of collective *work situation*, i.e., a situation where the learners are mutually dependant in their work. Works in CSCW highlight that actors engaged in such interdependent processes must address an overhead activity, that of articulating (dividing, allocating, coordinating, scheduling, meshing, interrelating) their respective activities [4,5]. This is a meta-level overhead activity that is not focused on producing the targeted output, but on setting the conditions of the production of this output by maintaining a more-or-less stable pattern of cooperative arrangement between people.

With respect to organization in the context of CSCL scripts, [3] introduces the notion of *learners' self-organization*, which is defined as "the meta-level activity that a group of learners engaged in a CSCL script may engage in so as to maintain, within the reference frame that is externally defined by the script, a more-or-less stable pattern of collective arrangement". In this definition, "self" is meant to highlight that, in such a context, part of the organization is set by the script, and part is related to emergent features of learners' enactment of the script at run-time. We use the same notion to analyze pedagogic collective challenges. There is no "obvious" strategy to solve the problem (indeed, there are several good strategies and also bad –ineffective– ones). Learners have some latitude and, in particular, can self-organize themselves (elaborate and consider different strategies). Given the pedagogical objectives, the fact they address this explicitly is of core importance.

3.2 Exploratory Experiment

An exploratory experiment was conducted with two groups of three and four learners in a classroom. Each group had a computer with the simulation. The objective of this experiment was to acquire some general input in respect to if and how, in a face-to-face setting, learners engage naturally in an organization activity, as a first step to inform the system design. We summarize here below the major findings as they came out from the interactions with the learners, the analysis of the video and of the groups' products.

Learners appear to be very involved in the challenge. They understand what is necessary to cope with. The structure of the challenge (limited duration, mass of data to be collected, crucial precision of measurements, risk of errors and number of calculations to be carried out) does create a situation where learners have to and do interact about the organization to be adopted. In the two groups, the learners naturally came to discuss the strategy and to distribute tasks and roles. We were lucky to observe two different strategies. One of the groups spent quite some time in the planning phase before starting to collect the data. They adopted an organization which could be described as collaborative: the learners remained very close to each other and interacted all along the activity, e.g., two learners measuring a distance to be sure of the value, and the third one checking the coherence and structuring the data. The other group adopted a more cooperative division of work, i.e., divided and distributed the tasks and worked in a more autonomous way. No conclusion can be drawn from this, but it can be noted that the first group succeeded when the second failed.

With respect to organizational dimensions, the characteristics of the learners' self-organization that appeared to be positive and important to be transposed for the mediated situation are as follows: spending time to reflect on the strategy; using a common language to describe the data and the actions to achieve; collectively acknowledging the adopted strategy; continuously checking the process with respect to the strategy, and adapting the strategy if needed; easy communication, feeling of proximity and possible mutual assistance. Negative features to be taken into account are as follows. First, the simulation structure may implicitly conduct learners to a simplistic (and rather inefficient) cooperative organization (i.e., dividing the number of cars by the number of students and acting separately). Such a strategy should be allowed, but not implicitly suggested by the setting. Second, not calling the strategy into question during the process is more than risky, in particular given the fact that in case of failure, time is missing to redefine the strategy during the final phase of the challenge. We observed a phenomenon already related in literature: in case of difficulty, if the strategic dimension has always been or has become implicit, the interrelation between learners' actions distends but however does not necessarily conduct them to question their organization. Finally, learners may encounter classical difficulties in collaborating, due to lack of experience. For instance, some learners don't communicate to concentrate better, or for fear of creating a disturbance. At this level, absence of coordination and of information-sharing conducts to persistence of bad strategies, each learner believing he is the only one not knowing what to do or how to do it. From a content-domain point of view (mathematics), two points can be noted: it is important that learners do use a common mathematical language to describe the data in order to understand each other, and they need means to edit the data.

3.3 Brief Analysis and Conclusions with Respect to Design

From a general point of view, these findings are in line with general state-of-the-art knowledge in CSCL. Different key-dimensions, in relation to organization, can however be specifically noticed and identified as general specifications for the design of the computational environment.

First, just allowing means to make the strategy explicit is not enough. The system must force learners to create an explicitly shared strategy whose different aspects must be agreed by all members. The system must make the adopted strategy salient during its elaboration and its enactment. It must suggest that each learner has the means and the legitimacy to participate in the elaboration of the strategy, to ask for its reconsideration at any time during enactment, and to participate in its modification. This is in line with findings in CSCW related to the role of plans as being to be thought of as resources (and not constraints) adaptable in context (cf. Bardram's work on the non-contradiction between planning seen from this perspective and Suchman's situated-action views [16]).

Second, the environment must induce learners to use a common vocabulary to reflect both on organizational issues (e.g., subtasks) and domain-related issues (e.g., data to be acquired). This can be related to the classical notion of common ground [1].

Third, the environment must allow the tutor to detect some aspects of the organization that could lead to breakdowns, and propose means to achieve regulation actions. At the current state of analysis, these aspects are, in particular: the fact that a plan is adopted and collectively acknowledged; the way in which each student participates in the elaboration of the plan; how students share the subtasks; how students achieve their subtasks (e.g., quality of the calculus or the fact that a student does not seem to work any more); deviation in the implementation of the plan (which is not necessarily a problem, but is an interesting point for the tutor); individual or collective demand of a modification of the plan. Identifying these features allow tutor's actions such as: questioning the fairness of the plan; questioning the effectiveness of the plan; supporting the collective planning; supporting a given student for a given task; etc.

Other specifications are: the integration of organizational dimensions, communication dimensions and the simulation; the communication and awareness means.

4 A Dynamic Model of the Organizational Dimensions of a Pedagogic Collective Challenge

In line with our conceptualization of pedagogic collective challenges as particular cases of collective work situations [4,5], we adopt an Activity Theory point of view [17]. More precisely, we propose to consider the learners' organizational actions of a pedagogic collective challenge as an activity, and to model it following Bardram's model [4]. This model focuses on collective work dynamics, and stresses the fact that perceiving breakdowns appearing during collaboration is an important dimension of the understanding of the collaboration dynamics.

Bardram proposes a three level structure to denote the transformations that may appear in a collective activity: co-ordination, co-operation and co-construction (cf. Fig 2). He highlights the importance of supporting the dynamic transitions that may occur from one level to another during the activity (these levels corresponding to analytic distinctions: an activity takes place simultaneously at all levels.). At the co-ordination level, actors concentrate on the task they have been assigned. Their work is related to a common goal, but their individual actions are only externally related to each other. They realize the global task from the point of view of their individual activity. Co-operation is an intermediate level where actors are active in considering the shared objective. This enables them to relate to each other and make corrective adjustments to their own and others' actions according to the overall collective objective. Co-construction is the level where actors focus on re-conceptualizing their own organization and interaction in relation to

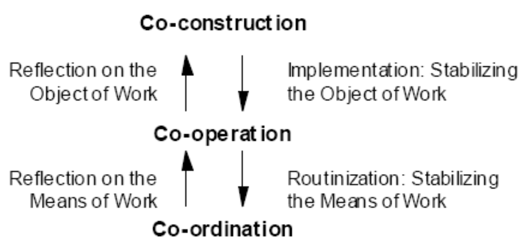

Fig. 2. Bardram's 3-levels model [4]

their shared objects. Bottom-up transitions are related to an analysis of the object or the means of the work, which can occur in relation to a breakdown or an explicit shift of focus. Top-down transitions are related to the solving of problems and contradictions, and lead to a stabilization of the object and of the means of the work.

In our case, the co-construction level is the level where learners elaborate their strategy. It must correspond to a phase/place allowing the elaboration (and, in case of difficulty or breakdown, revision) of a common view and vocabulary (grounding), and of the general scheduling of subtasks. As said in the introduction, the purpose of such a collective learning situation is to create conditions that enhance the probability that learners will engage in knowledge-generative interactions. Here, drawing learners' attention to this phase, proposing means such as adapted communication tools, and allowing/facilitating tutors' monitoring and regulation, aims at enhancing the chances that students involve in communication, argumentation, analysis or reflection related to both (1) the problem-solving strategy and division of labor and (2) the domain-level issues (mathematical issues). The co-operation level is the level related to how to achieve what has been planned: the role of each member (task attribution, task decomposition if necessary), the means to achieve the tasks (e.g., a tool to help in editing and structuring the data), the sequencing, etc. Organization must be made visible and presented in a way that allows learners and tutors to understand its details. Finally, the co-ordination level is the level where each learner is confronted with his tasks: measuring distance or time, calculating speed, applying mathematical procedures, etc. Tasks, rules or roles have been fixed at the preceding level (and learners can come back to this upper-level by a bottom-up transition). At this level, each learner's work is separated (but coordinated) with that of other learners.

Transitions from one level to another can originate from two sources. First, as suggested by Bardram, learners can spontaneously go from one level to another in relation to a difficulty they encounter, or by a voluntary shift of focus. Such transitions correspond to self-organization dimensions as defined previously. Differently from Bardram's work, in our case another origin for transition appears. We are in a pedagogic context, and the learners' process is monitored by the tutor. He can launch regulation actions, e.g., drawing learners' attention to the fact they should shift from one level to another (i.e., interact about a feature of another level than the current one) in relation to a problem encountered by a learner or by the group, an anticipation of a breakdown, or a pedagogical opportunity.

5 Prototype and Usability Experiment

We present here at the same time the prototype and the usability experiment. This experiment was conducted by first testing the individual phase in a classroom, each student working individually on a computer, and the experimenter observing the setting. Then, the collective phases were conducted on-line, two students connecting from home to the server and the experimenter playing the role of the third student online, thus being involved, as an observer, "in" the activity. A second experiment was conducted with three students connected to their individual computer and addressing the overall challenge (all individual and collective phases), which confirmed the results described here after. The prototype is implemented using Flash, PHP, XML and network technologies. We focus here on the preparation phases rather than the challenge itself.

The prototype first presents an introduction to the simulation and the challenge. Students then skip to a first individual phase. The system provides each student with the simulation and an array to be filled in individually (cf. Fig 3). This array suggests that students define the data they will need to solve the problem. The first column introduces the basic objects. We have decided to support students by introducing the following notions: “all cars”, “cars that stop” and “cars that do not stop”. This pedagogic decision implements (on the basis of the lessons learned from the preliminary experiment) the principle “create some uncertainty about obtaining a result whilst not going to an extent where learners may doubt they will succeed” [10]. The second column suggests defining the name of the data to be examined, for instance “car number” or “race duration”, and the third column allows a textual description of the data. The last column suggests defining the type of actions related to this data. We support students by providing a predefined list: “read”, “measure” or “calculate”. Students can add as many lines as they wish.

Fig. 3. Defining the data (individual phase)

With respect to the pedagogic analysis and to the theoretical model, this first phase aims at making students familiar with the challenge and the setting. It implements the fact that individual problem-solving strategies can act as resources for proposing which tasks are to be addressed, as an insufficient but preliminary step to the collective solving and, more precisely, the co-construction phase. As expected given the lessons learned from the exploratory experiment, all students first test the simulation and attempt to solve the problem intuitively, by successive trials. At this grade, they however quickly understand that a more analytical approach is requested. Then comes a phase of conceptualization, and in particular the understanding that the requested data and actions should be defined. Following the theoretical background and the lessons learned from the exploratory experiment, the interface supports/suggests this by providing the array to be filled in (at this level different pedagogic options are open: suggesting types of cars and types of actions is but an option). The objective here is to make students appropriate the problem and setting to themselves, and to develop a first individual analysis that will serve as a boot-strap for the building of a common ground and the co-construction phase. Although the focus is on the data to be defined, this data is to be associated with an action (measure, etc.): in fact, each line introduces a subtask. This phase lasted for approximately half an hour. Students then appeared to be willing to discuss the problem collectively, i.e., to skip to phase 2.

The next level proposes a shared interface: the simulation, students' individual productions from the first phase (individual arrays), an empty collective similar array, and communication tools: a chat and voting tools to add or suppress a line of the array. The different lines (and their items) must here be collectively defined. Again, types of cars and types of actions are to be selected in a predefined list. The data names and descriptions are to be edited through the shared editor (directly in the array, just by clicking on the cell) and collectively acknowledged by the voting tool: all three students must accept every line, and any of them can come back at any time to what has been defined previously.

With respect to the model, this part of the system corresponds to the co-construction phase: students define a common view and vocabulary (grounding) and the general plan (sequence of subtasks). From the point of view of the experimenter, it appears that the interface (the structured array) does indeed provide students with what is both a support and a constraint. Due to the similarity with phase 1 interface, students handled this second editor very easily. This is an important point as it was our objective that the collective phases should be as little technically surprising as possible for the students. We were surprised that, although they had a specific chat, they used some of the unused cells of the array to discuss synchronously, each of them using a different cell for typing his/her text. Technically, the chat was much more convenient, in particular because the array only allows 2 lines. This suggests, here again, the relevance of integrated tools. Another organizational pattern appeared: as this phase may become very long, it appeared that students proposed to define a limited time, and to consider that if two students were agreeing on a line, the third should be considered as agreeing if not saying explicitly that he is not after some time. This suggests that overruling functionalities should be available.

The students are then presented with a shared interface for the next two steps (top-down transitions). The interface (cf. Figure 4) is generated from the collective result of the preceding phase. For every couple data/action (e.g., "all cars" / "define race duration") a line is generated with 3 columns for each car (e.g., "car#0" column "A", "car#0" column "B", "car#0" column "C"), "A", "B" and "C" being the names of the students.

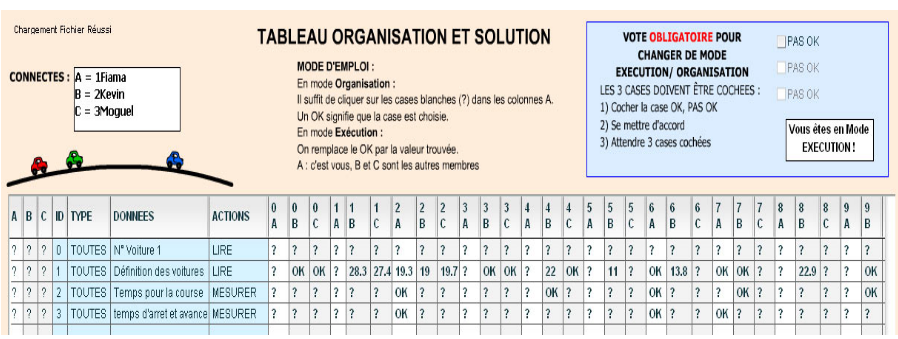

Fig. 4. Defining the organization and enacting the plan

First, it is suggested that students declare who will achieve each action. All cells are initialized with "?". If "A" clicks on a cell he declares he will achieve this task; the "?" is replaced by an "OK" in the "A" column; "B" and "C" are immediately aware as this appears synchronously in the shared array. As each couple car/action is associated with a column by student, the students can decide to delegate each action to just one student, two or three of them. They can come back on their declaration at any time. A chat allows synchronous interaction, and the students have to vote on the result to skip to next phase. During the experiment we could observe propositions such as "important tasks must be done by all (…) and others as measures by only one [student]", counter-propositions, decisions and votes. With respect to the model, we are here at both the co-construction and co-operation levels. The array denotes the (emerging) adopted organization. In the first stage, students were selecting one cell or another more or less randomly (or, more precisely, in a way that was not understandable). After a while, the students' declarations became inter-related. This inter-relation denotes another interesting dimension of what we have defined as students' self-organization. This suggests that the interface fulfills the double objective of (1) supporting students and (2) providing the tutor with means to analyze, understand and possibly support the students' organization. How the evolution of the way the array is filled may denote some students' self-organizational dimensions, and how to help the tutor to interpret this, will be two issues at the core of our future investigations.

Second, students arrive at the execution level where they are supposed to enact their plan, i.e., achieve their individual subtasks ("read x", "calculate y", etc.). This idea of "enacting the plan" (to be understood as defined here before) is implemented by providing them with almost the same interface as when defining the tasks (cf. Fig 4). Now, the cells marked as "OK" for a student become editable, i.e., he can edit the value (e.g., "A" measured car#2 needed 19.3 seconds to complete the race). With respect to the model, we are here at the co-ordination level (top-down transition): students are individually measuring, calculating, etc. As highlighted in Bardram's model, actors concentrate on the task they have been assigned, their work being related to a common goal, but their individual actions being only externally related to each other. The interface is however common, allowing every one to know what he is supposed to do and what the others are doing. The evolution of the solving is denoted by the fact the "OK" are gradually replaced by effective values. Fig 4 denotes the ongoing solving after 30 minutes.

Here again, the coherence organization level / execution level appeared to make the interface easily understandable and usable by the students. Interestingly, and in coherence with the theoretical background, some students did request, during the plan execution (i.e., in context), to skip back to the organization interface and slightly modify the plan. As an example, one of the students discovered some discrepancies in the measures for one of the cars (columns 2A, 2B, 2C) in Fig 4. He used the chat to suggest there was a problem (extracts from the chat, translated: student A "there is a problem … I think we are not all measuring from the same position … I'm not measuring from the line but from the start"; student B "I'm measuring from the line … what do we do?"; observer C "We should all do the same thing"; student B "do we start from the start or from the line"; etc.).

The interface is designed to allow this bottom-up transition: it requires the transition to be an explicit move (because of our pedagogic objectives), but makes it very simple. Our concern here is that, as emphasized in the Activity Theory line of thinking, tensions and breakdowns are core phenomena to be studied. Making the bottom-up transition explicit makes it perceivable by the students themselves, and by the tutor. In our setting, such tensions and breakdowns may be linked to an ineffective plan, a student that downloads his work, recurrent calculus errors, etc. Tensions and breakdowns in the flow of students' activity might however also originate from inadequate technology and interfaces. This is why we have adopted an iterative design in order to limit this risk, in particular on this very core issue of the connection "defining the subtasks" / "achieving the subtasks". At this level, the important points are: the organization/execution interfaces are similar; if something is modified in the organization the execution interface is automatically adapted; importantly, only the items that have been changed in the organization are modified in the execution interface: modifying the organization does not mean re-starting from scratch or changing everything. Fig 4 also highlights that students can enact partial organizations. As said previously, the different levels are analytic and, in fact, intertwined.

6 Preliminary Experiment

In order to prepare an analysis of the impact of the prototype on the way students organize themselves and, in particular, elaborate a definitive analysis grid, we have analyzed (using a first version of such a grid) two groups: group G1 using the prototype and group G2 just using the shared simulation and a basic chat (but no shared array). We focused the analysis on the organizational issues and not the result (as a matter of fact, both groups failed in the final challenge, for different reasons however). We based our analysis on the three distinct aspects of coordination (the degree of mutuality in interaction, the extent to which there was a joint focus of attention and the level of shared task alignment) and the markers proposed in [6]. The results are summarized in Table 1.

Although this is only a very preliminary experiment, we noticed for G1 that the tool inventory data and development of a common language allowed the students to develop a mutual comprehension of the problem, and a general problem solving strategy. The organization tool allowed students to develop a collaborative orientation and a joint problem solving. The challenge itself (final calculations) appeared to be a failure because the group, involved in a very collaborative process, had a (collective) doubt with respect to a given value and spent too much time in discussions to solve it. At the time of the final simulation, they felt as if having correctly managed the preparation phases but having made a punctual mistake, and acknowledging their solution was probably incorrect (which was the case). This confirms that, from a pedagogical point of view, the objective of making students work together and practice the targeted mathematical and organizational competences must not be confused with that of succeeding with the final challenge, and that this must be managed (although teachers may consider the preparation work rather than the result, students are of course very concerned by the final challenge). In G2, each student worked separately, with some communications about the problem comprehension, but little organization. In the final phase the students had three different solutions they had not confronted before the challenge, and no criteria or common understanding to choose one of them. Although

Table 1. Preliminary experiment analysis

Criteria	Group using the prototype	Group not using the prototype
Duration	3h 41	2h50
Challenge success	Failed but near to success.	Completely failed.
Elaborated solution	One solution for the group.	Three different solutions.
Cause of the failure	Too much discussion (cf. "mutuality" item).	Conflicts.
Common view of the problem	Yes	No
Making the organization explicit	Yes (during 20 minutes and 32 messages).	Very low
Type of organization	Collective, collaborative.	Individual, separated.
Shared Task Alignment (establishment of a collaborative orientation toward problem solving)	High (co-construction of solutions and reference to others' ideas: collective work from the beginning to the end).	Low (independent solution paths and reference to own ideas: each member working separately on his own solving).
Joint Attention (degree to which attention is jointly focused during solution-critical moments)	High (prototype as the centre of coordination: each member knew exactly the state of progress of the resolution; joint monitoring of solution: double check of each result, etc).	Very low (individual monitoring) until the final phase (the simulation).
Mutuality (reciprocity with potential for all members to meaningfully contribute)	High (participation of each member in the elaboration of the solution, data or explanations; transactional responses and turn-taking norms respected; resulted in a common solution, but a punctual mistake and time/energy to solve it caused the final failure.	Very low (conflicting solutions; no means to solve the discrepancies).

still chatting and willing to solve the problem, they faced a conflict they were not able to solve. At the time of the final simulation they felt as if they were facing a complete failure, and acknowledged their overall strategy was not relevant.

7 Conclusions and Future Works

The usability experiments show that the principles we have proposed are relevant for fulfilling the two objectives of (1) supporting students' problem-solving in a way that makes them work out the domain-related and meta-cognitive issues we target and (2) providing tutors with some means to monitor the process. Various ergonomic details of the interfaces were identified and will be improved. However, the overall approach and the design decisions underlying the interfaces appear to be adequate in conducting students to work out in an explicit way their organization. The design of the prototype succeeds in making the organizational issues salient (common ground, subtasks, division of labor, top-down and bottom-up transitions) in a way that does not appear too artificial or counter-productive for students while preparing the challenge (on the contrary, it was judged as very helpful). Let us recall that we see this planning and division of work as a resource for both the students and the tutor, and not as a rigid structure (cf. the transition means).

The perspectives include studying the impact of the model/prototype on the students' organization, the relation between the elaborated strategy and winning the challenge, and studying to what extent the elaborated common ground is effectively shared. In particular, we plan to study how the evolution of the way the array is filled in denotes some students' self-organizational dimensions (strategy patterns, tensions and breakdowns, etc.), and how to help the tutor to interpret this and act on the basis of the different types of regulation actions suggested by Bardram's model (suggesting a reflection on the goal of the work or its means in relation to bottom-up transitions, top-down transitions; etc).

References

[1] Dillenbourg, P.: What do you mean by collaborative learning? In: Dillenbourg, P. (ed.) Collaborative-learning: Cognitive and Computational Approaches, 1999, pp. 1–19. Elsevier, Oxford (1999)

[2] Dillenbourg, P., Tchounikine, P.: Flexibility in macro-scripts for CSCL. Journal of Computer Assisted Learning 23(1), 1–13 (2007)

[3] Tchounikine, P.: Conceptualizing CSCL Macro-Scripts Operationalization and Technological Settings. International Journal of Computer-Supported Collaborative Learning 3(2), 193–233 (2008)

[4] Bardram, J.: Designing for the Dynamics of Cooperative Work Activities. In: Poltrock, S., Grudin, J. (eds.) CSCW conference, Seattle, pp. 89–98 (1998)

[5] Schmidt, K., Bannon, L.: Taking CSCW Seriously: Supporting Articulation Work. CSCW 1(1-2), 7–40 (1992)

[6] Barron, B.: Achieving coordination in collaborative problem-solving groups. The Journal of the Learning Sciences 9(4), 403–436 (2000)

[7] De Vries, E.: Les logiciels d'apprentissage: panoplie ou éventail? Revue Française de Pédagogie 137, 105–116 (2001)

[8] Hidi, S., Harackiewicz, J.M.: Motivating the academically unmotivated: A critical issue for the 21st century. Review of Educational Research 70(2), 151–179 (2000)

[9] Malone, T.W.: Toward a theory of intrinsically motivating instruction. Cognitive Science 4, 333–370 (1981)

[10] Van Eck, R., Dempsey, J.: The effect of competition and contextualized advisement on the transfer of mathematics skills in a computer-based instructional simulation game. Educational Technology Research and Development 50(3) (2002)

[11] Larkin, J.H., Reif, F.: Understanding and teaching problem solving in physics. European Journal of Science Education 1, 191–203 (1979)

[12] Baker, M.J., Hansen, T., Joiner, R., Traum, D.: The role of grounding in collaborative learning tasks. In: Dillenbourg, P. (ed.) Collaborative Learning: Cognitive and Computational Approaches, pp. 31–63. Pergamon / Elsevier Science, Amsterdam (1999)

[13] http://www.patrickmoisan.net/copains/course_sans_gagnant.html

[14] Poissant, H., Poellhuber, B., Falardeau, M.: Résolution de problèmes, autorégulation et apprentissage. Canadian Journal of Education 19(1), 30–44 (1994)

[15] Flavell, J.H.: Metacognition and cognitive monitoring. American Psychologist 34(10), 906–911 (1979)

[16] Bardram, J.: Plans as situated action: an activity theory approach to workflow systems. In: European Conference on CSCW, Lancaster, UK, pp. 17–32 (1997)

[17] Engeström, Y.: Learning by expanding. An activity-theoretical approach to developmental research. Orienta-Konsultit, Helsinki (1987)

When Co-learners Work on Complementary Texts: Effects on Outcome Convergence

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Abstract. In this paper, we examined the effect of knowledge interdependence among co-learners on knowledge convergence outcomes. Prior to collaboration, two partners read the same text in the independent condition while each of them read one of two complementary texts in the interdependent condition. In the remote collaboration phase, partners were asked to build a collaborative concept map. While interacting, they were provided with visualizations (concept maps) of both their own- and their partner's knowledge. No effect of interdependence could be found with respect to both outcome knowledge equivalence and shared outcome knowledge. In the independence condition, convergence was mainly due to the fact that partners received the same text before collaboration. In the interdependence condition, shared knowledge did not occur as a result of social interaction. It seems that participants were able to individually link what they learnt from text to complementary information provided by their partner's map.

Keywords: Computer-supported collaborative learning, jigsaw scripts, knowledge interdependence, outcome knowledge equivalence, shared outcome knowledge.

1 Introduction and Objectives

In a Computer-Supported Collaborative Learning (CSCL) setting, one potential way to reinforce co-learners in their effort of building a shared understanding is to increase their level of mutual interdependence. In the present study, a macro-collaborative script (i.e., a sub-class of jigsaw scripts; see [1]) was used to produce knowledge interdependence among learners. The principle of this script was to provide each collaboration partner with different but complementary information about the learning topic (the neuron).

1.1 Knowledge Interdependence in Collaborative Learning

Two alternative hypotheses regarding the effects of knowledge interdependence in collaborative learning are usually stated. One assumes that participants would benefit from working on identical information (independence) [2]. The other assumes that

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working on complementary information (interdependence) would lead participants to improve their outcome knowledge [3; 4; 5]. The main benefit of knowledge independence is that it allows co-learners to confront their understanding of the same information. This could lead to socio-cognitive conflict which is widely recognized as beneficial to learning [2]. One drawback of working on identical information is that it can reinforce the tendency for individuals to evaluate themselves in comparison with others [6]. The social comparison can be detrimental for collaborative learning [3; 4; 5]. Co-learners might be focused more on comparing their own knowledge to their partner's knowledge (who gives the correct information?) and less on processing together the learning content. Moreover, in order to appear competent, they might be tempted to quickly accept their partner's contribution (even if they are not convinced of their validity). They might also hesitate to ask for clarification and explanation [7]. One way to reduce the competence threat is to increase the partner's dependence, e.g., by sharing resources between partners [3; 4; 5]. Knowledge interdependence also has the benefit of stimulating co-learners into reasoning on their partner's understanding and promoting helping behavior. It allows them more easily to express their difficulties of understanding or to provide feedback with respect to the quality of their partner's explanations. Although working on complementary information can produce more positive interactions, this might be not sufficient to overcome the disadvantage of learners who access information only via their partner's explanations [3; 4]. One way to prevent this problem is to enhance and facilitate information exchange, e.g., by using learning materials with a level of difficulty adapted to learners' prior knowledge or by providing learners with tools (e.g., note-taking, external representations) to help them to explain what they read to their partner.

To our best knowledge, few empirical studies (see [3; 4]) were carried out in order to test the effects of knowledge in(ter)dependence in collaborative learning. In the studies of [3; 4], students worked in face-to-face dyads on two social psychology texts and were asked to discuss their shared understanding. In the "same information" (SI) condition, both students read both texts while each partner read only one of the 2 texts in the "complementary information" (CI) condition. In addition, in both conditions, one of the students – within the dyad – was asked to play the summarizer role (for the text he/she was assigned in the CI condition, or for one of the 2 texts he/she read in the SI condition) while the other student played the listener. Roles have been reversed for the second text. Results showed that when difficult texts were used, participants who worked on identical information performed better on an immediate learning test than participants who worked on complementary information. The disadvantage was observed mainly for listeners of the CI condition who accessed information only via their partner. When easier texts were used, no difference in immediate performance occurred between the two conditions whereas delayed performance was higher in the CI condition than in the SI condition. These results suggest a clear benefit of sharing complementary resources when the quality of information transmission is improved.

As in the studies of [3; 4], participants of our experiment worked in (remote) dyads either on identical or complementary information. The present study consisted of two main phases, an individual reading and a collaborative concept mapping. During the individual reading phase, peers were asked to read either the same text (SI condition) or different but complementary texts on the neuron (CI condition). Immediately after reading, they had to graphically summarize what they learnt from the text in the form of an individual concept map. During the collaborative concept mapping, peers were provided with the availability of both their own- and their partner's individual maps. The access to visualizations of collaborating partners' knowledge during interaction is assumed to facilitate communication and foster collaboration [8]. We believe that it could improve the quality of information transmission, especially in the CI condition.

1.2 Knowledge Interdependence and Knowledge Convergence

The main research question of the present paper can be stated as the following: To what extent does knowledge interdependence between collaboration partners affect knowledge convergence outcomes? [3; 4] suggested that working on complementary information may enhance the level and quality of interaction between partners. Thus, we hypothesized a beneficial effect of knowledge interdependence on convergence.

In CSLC research field, we need to deepen our knowledge of the process by which representations of co-learners become similar after collaboration [9; 10]. Knowledge convergence is viewed as a crucial outcome of collaborative interactions [11]. In a long-term work team, similarities in team members' representations are predictive of team coordination and performance [12]. [9] has described two types of knowledge convergence outcomes, namely (1) *outcome knowledge equivalence* and (2) *shared outcome knowledge*. One the one hand, partners may become similar regarding their level of expertise, i.e., the amount of knowledge they individually acquired subsequent to learning together (knowledge equivalence). On the other hand, partners may mutually influence each other in such a way that they possess more common knowledge after collaborative learning (shared knowledge).

[10] stressed the necessity for researchers to be aware that an increase in common knowledge is not always attributable to collaboration. For [10], two sources of knowledge convergence must be taken into account. First, convergence may arise because collaboration partners were provided with the same learning material and/or were exposed to the same learning environment (knowledge convergence considered as a "by-product of learning"; see [10], p. 292). Second, convergence may occur as an effect of joint interaction. One way to identify relative contributions of each source of convergence is to use (*post hoc*) nominal groups as control groups. In our experiment, nominal dyads were constructed *post hoc*, by pairing participants who were assigned to the same conditions but who had not worked together. Real and nominal dyads were then statistically compared with respect to knowledge convergence outcomes.

2 Method

2.1 Participants

Sixty 1st year students from EPFL (Ecole Polytechnique Fédérale de Lausanne, Switzerland) participated in this study. They were randomly grouped into 30 dyads. Participants did not know each other before the experiment. We also made sure that all participants were novices in the learning domain (the functioning of the neuron). At the very beginning of the experiment, their background on the neuron was tested through an open question in order to detect potential experts.

2.2 Material and Procedure

The two partners were distributed into two different rooms. They were installed in front of two computer setups running a learning interface developed especially for the experiment. As displayed in Table 1, the procedure consisted of four phases.

Table 1. Phases of the Experimental Session

Phase	Mode	Duration	Description	Software
1	Individual	10 mn	Reading a text about the functioning of the neuron	
2	Individual	12 mn	Building a concept map to graphically represent their own understanding	CmapTools
3	Collaborative	20 mn	Discussing and building a joint map to represent their shared understanding	TeamSpeak CmapTools
4	Individual	15 mn	Completing a knowledge post-test	

Text. In the reading phase, both partners read the same text (original version) in the "same information" (SI) condition, while each of them was assigned to the reading of one of two complementary texts (electric version and ionic version) in the "complementary information" (CI) condition. The three versions (original, electric and ionic) included three parts. Each part dealt with one of the three main phenomena occurring during the neural communication: (1) the resting membrane potential, (2) the initiation of the action potential, and (3) the action potential propagation and its synaptic transmission. For each of these three phenomena, the original version provided a description of the interplay between the electric and chemical processes. The original version was divided into two (shorter) versions for the CI condition, that is, the electric and ionic versions. The electric version provided information only about the electric processes in neurons (the flow of electric charges) while the ionic version provided information only about the chemical processes (the flow of chemical ions). The electric and ionic versions were also equivalent in terms of number of information elements provided.

Collaborative Learning Environment. Figure 1 shows the screen layout during the collaboration phase. Peers had to construct a joint concept map using the CmapTools software (http://cmap.ihmc.us/). They were also able to speak with each other thanks to a microphone-headset and the TeamSpeak software. During collaborative concept-mapping, peers could see both their own- and their partner's individual concept maps. The aim of providing partners with visualizations of their respective knowledge was mainly to improve the quality of information transmission during collaboration.

Post-Test. The knowledge test was designed to assess the knowledge participants acquired with respect to both the electric and chemical processes involved in neurons. This test was composed of 18 questions (6 multiple-choice questions and 12 inference verification questions), 6 questions (3 electric and 3 ionic) per phenomenon (resting membrane potential, action potential, transmission). The multiple-choice questions included 4 possibilities with 1 or more possible correct answers. The minimum score for these items was 0 and the maximum 4. Regarding the inference verification questions, participants had to judge whether these statements were true or false. The score was 0 for incorrect answers and 1 for correct answers. The maximum score that could be attained for the knowledge test was 36. As for the texts, all questions were validated by experts (a neurobiology researcher and a biology teacher) of the domain. Their variability was also tested in a pilot study. Questions with extremely low or high performance were eliminated; all the items used in this questionnaire were thus medium difficulty (minimum mean scores were 0.28 and 0.87; maximum mean scores were 0.55 and 2.55 for inference and multiple-choice questions, respectively). The 18 items were presented to all participants in a random order.

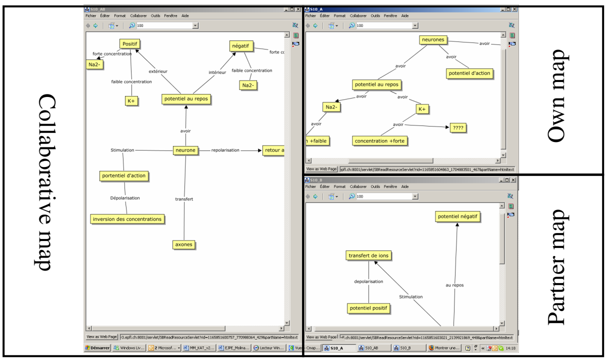

Fig. 1. Screen layout during collaborative concept-mapping

2.3 Design and Dependent Variables

The 'Knowledge In(ter)dependence' factor ("same information" or SI condition versus "complementary information" or CI condition) was between-subjects. Dyads were randomly assigned to one of the two conditions: 16 pairs in the SI condition and 14 pairs in the CI condition.

Three dependent variables (all determined by the knowledge post-test) were used in this paper: (1) learning post-test scores, (2) outcome knowledge equivalence and (3) shared outcome knowledge. Both outcome convergence measures were calculated following the method suggested by [9]. The assessment of outcome knowledge equivalence involved two main steps. First, standard deviations of learning post-test scores of learners within one dyad are calculated and then aggregated. Second, the aggregated standard deviations are divided by the dyad mean to obtain a *coefficient of variation*. The lower this coefficient is, the more collaboration partners are similar to each other with respect to their level of outcome knowledge. We also calculated the amount of *correct* common knowledge after collaboration. In order to assess shared outcome knowledge, the two partners of each dyad were compared with respect to the adequacy of their answers to the 18 items of the knowledge post-test. For an inference verification question, the value for shared outcome knowledge could be either 1 when both partners gave the correct answer to this question or 0 in the other cases. For multiple-choice questions (remember that all of them had 4 alternatives), the value for shared outcome knowledge ranged from 0 to 4. The maximum overall score that could be attained for common knowledge was 36.

As outcome convergence variables are group measures, the dyad was used as the unit of analysis. We performed *post hoc* comparisons between real dyads and nominal dyads. Nominal dyads were constructed by pairing participants who were assigned to the same learning condition but who had collaborated with another participant. For example, in the CI condition, the Sally (who read the electric text) – Pierre (ionic text) dyad and the Alice (electric text) – Patrick (ionic text) dyad corresponded to real dyads. The Sally (electric text) – Patrick (ionic text) and Alice (electric text) – Pierre (ionic text) dyads corresponded to nominal dyads.

3 Results

3.1 Effect of Knowledge Interdependence on Learning Performance

There was no significant difference in learning post-test scores between dyads in the SI condition (M = 16.19, SD = 3.16) and dyads in the CI condition (M = 15.07, SD = 4.15), $F(1, 28) = 0.67$, *n.s.* It is noteworthy that standard deviations were relatively large indicating considerable variation among students. Standard deviations were also higher in the CI condition than in the SI condition.

3.2 Effect of Knowledge Interdependence on Outcome Convergence

No effect of knowledge interdependence with the partner could be found with respect to outcome knowledge equivalence (see Table 1), $F(1, 28) = 0.60$, *n.s.* In addition, we observed that similarity between partners in terms of outcome knowledge level could not be attributed to collaborative interaction. Indeed, there was no difference between real and nominal dyads with respect to outcome knowledge equivalence, in both the SI condition ($F(1, 30) = 0.23$, *n.s.*) and the CI condition ($F(1, 26) = 0.08$, *n.s.*).

Regarding shared outcome knowledge, 22% of (correct) knowledge was shared by members of real dyads. There was no difference in the amount of common outcome knowledge between: (1) the SI and CI conditions ($F(1, 28) = 0.68$, *n.s.*); (2) real and

Table 2. Knowledge convergence outcomes for real and nominal dyads in the two conditions (SI: same information; CI: complementary information)

		Real dyads SI condition	Real dyads CI condition	Nominal dyads SI condition	Nominal dyads CI condition
Knowledge equivalence*	M	0.61	0.68	0.64	0.65
	SD	0.22	0.27	0.23	0.22
Shared (correct) knowledge#	M	8.56	7.36	8.81	6.93
	SD	3.65	4.34	3.41	3.54

* Lower values indicate knowledge equivalence.

Higher values indicate more shared knowledge.

nominal dyads in the SI condition ($F(1, 30) = 0.04$, *n.s.*) as well as in the CI condition ($F(1, 26) = 0.08$, *n.s.*) (see Table 1). Thus, these results did not provide evidence that knowledge interdependence and collaboration within (real) dyads facilitate outcome convergence.

4 Discussion and Conclusions

First, results show no difference in performance between the conditions. Students who worked on complementary information seem to perform as well as those who worked on identical information. However, given large standard deviations, it is not possible to conclude that knowledge independence and interdependence have similar effects on learning. This rather shows a large variation among students; this variation seems also to be larger in the CI condition than in the SI condition. One reason would be that the texts used in this study could influence the level of variability in students' scores. This variation could correspond to a variation in how well students learnt from these texts. One limit of our study is the use of an immediate learning test that assesses the content of learners' working memory and not a change in their knowledge structure.

Second, no evidence was found to support our hypothesis of a beneficial effect of knowledge interdependence on outcome convergence. In both conditions, the portion of (correct) common knowledge was relatively small (22%). Moreover, no difference occurred (in both conditions) between real and nominal dyads as regards the amount of common knowledge. This suggests that the obtained convergence was more a "by-product of learning" and less a result of collaborative interaction [10]. For participants of the independence condition, it is quite acceptable to conclude that convergence is mainly due to the fact that they received the same learning texts before collaboration. In contrast, for participants of the interdependence condition, it is not possible to consider the shared learning resources as the main source of convergence since they did not read the same text before interacting together. Two potential explanations of this surprising result can be given. First, based on what they learnt from the electric (or ionic) text, participants of the CI condition could be able to individually infer ionic information since the electric and chemical aspects of the functioning of the neuron are intrinsically interwoven. Participants of the CI condition could be also able to link what they read to complementary information provided by their partner's individual map without need of their partner's explanations. Even though all participants of our study were novices in the domain of the neuron, we might expect that they were able to use their basic scientific background (all these students were enrolled in scientific courses) to perform these (linking) inferences.

Since the present results are not quite conclusive, additional analyses are required. It would be helpful to analyze the impact of knowledge interdependence on student interactions (on their level of interaction at both the verbal level and the concept map level). Our aim will be also to examine the relationships between student interactions and knowledge convergence.

References

1. Dillenbourg, P., Jerman, P.: Designing integrative scripts. In: Fischer, F., Mandl, H., Haake, J., Kollar, I. (eds.) Scripting Computer-Supported Collaborative Learning – Cognitive, Computational, and Educational Perspectives. Computer-Supported Collaborative Learning Series. Springer, New York (2007)
2. Doise, W., Mugny, G.: The social development of the intellect. Pergamon Press, Oxford (1984)
3. Buchs, C., Butera, F.: Complementarity of information and quality of relationship in cooperative learning. Social Psychology of Education 4, 335–357 (2001)
4. Buchs, C., Butera, F., Mugny, G.: Resource interdependence, student interactions and performance in cooperative learning. Educational Psychology 24(3), 291–314 (2004)
5. Darnon, C., Buchs, C., Butera, F.: Epistemic and relational conflicts in sharing identical vs. complementary information during cooperative learning. Swiss Journal of Psychology 61(3), 139–151 (2002)
6. Festinger
7. Lambiotte, J., Dansereau, D., O'Donnell, A., Young, M., Skaggs, L., Hall, R.: Effects of cooperative script manipulations on initial learning and transfer. Cognition and Instruction 5, 103–121 (1988)
8. Engelmann, T., Tergan, S.-O.: An innovative approach for fostering computer-supported collaboration. In: Chinn, C., Erkens, G., Puntambekar, S. (eds.) Proceedings of the 7th Computer Supported Collaborative Learning Conference, pp. 187–189. International Society of the Learning Sciences, Inc., New Brunswick (2007)
9. Weinberger, A., Stegmann, K., Fischer, F.: Knowledge convergence in collaborative learning: concepts and assessment. Learning and Instruction 17, 416–426 (2007)
10. Jeong, H., Chi, M.T.H.: Knowledge convergence and collaborative learning. Instructional Science 35, 287–315 (2007)
11. Roschelle, J.: Learning by collaborating: Convergent conceptual change. In: Koschmann, T. (ed.) CSCL: Theory and practice of an emerging paradigm, pp. 209–248. Lawrence Erlbaum, Mahwah (1996)
12. Lim, B.C., Klein, K.J.: Team mental models and team performance: A field study of the effects of team mental model similarity and accuracy. Journal of Organizational Behavior 27, 403–418 (2006)

Using LEGO Mindstorms as an Instructional Aid in Technical and Vocational Secondary Education: Experiences from an Empirical Case Study

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Abstract. This paper reports on an empirical study concerning the use of LEGO Mindstorms Robotics kit as an instructional tool in technical and vocational secondary education. In particular, a robot car was developed and programmed in order to be utilized in teaching classes in the field of Mechanical Engineering. The paper describes the rationale for that construction and the robot car itself and proposes a lesson plan exploiting this technology. The pilot study that was conducted aimed at measuring the effectiveness of this approach in terms of learning outcomes as well as students' satisfaction, enjoyment and perceived usefulness. The results of the study are encouraging towards the adoption of robotics in technical education although raising some issues that need to be further explored.

Keywords: LEGO Mindstorms; educational robotics; evaluation; technical education; mechanical engineering.

1 Introduction

Robotics, apart from being a subject by itself, can also be used as an instructional tool in a wide range of subjects: from Engineering (e.g. [1]) and Computer Programming [2], to Artificial Intelligence [3] and Psychology [4]. In the last twenty years or so, a lot of research energy has been put in investigating the role that robotics can play when integrated in the course work at all levels of education. The literature regarding research on that area indicates that robotics are used in education with several aims, such as teaching various scientific, design and mathematic principles through experimentation [5], developing students' ability to solve mathematical and logical problems [6], enhancing their critical thinking skills [7], motivating them to pursue careers in science and technology and increasing their technological literacy [8], engaging them [9] and promoting their collaboration spirit and skills [10]. Moreover, robotics may be effective for at-risk or under-served student populations ([9]; [5]; [11]).

The idea of using robotics in education is based on earlier research work of the MIT mathematician and Piaget's pupil, Seymour Papert, the creator of the LOGO programming language [12]. Papert believed that learning is more effective when

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students are experiencing and discovering things for themselves and that the computer is a perfect medium for discovery learning. LOGO was based upon these two ideas and was designed to let young students solve design problems using an on-screen small robot called the "Logo Turtle".

Papert's work with LOGO served as the basis for research partnerships between the MIT Media Lab and LEGO Corporation [13]. In 1998, the LEGO Company released a new product called the LEGO Mindstorms Robotic Invention System (RIS) kit that became an instant commercial success. In 2006 a major upgrade was released called LEGO Mindstorms NXT kit and won the 2006 Innovation Toy Award in the "Technology" category. The kit consists of 577 pieces including LEGO bricks, motors, gears, different sensors (touch, light, sound, ultrasonic), and an intelligent "NXT Brick" with an embedded microprocessor. Also, the set includes the Mindstorms NXT software. By programming the NXT brick -using a PC- one can create an autonomous robot made out of LEGO bricks. The Mindstorms NXT software is an icon-based programming language, loosely based on LOGO. It allows users to drag and drop in certain order graphical blocks of code representing commands such as left and right turns, reverse direction, motor speed, motor power, etc. and thus define the behaviour of the robotic construction.

This paper reports on our attempt to explore the potential of LEGO Mindstorms as an instructional tool in technical/vocational education. In particular, a robot car was developed and programmed in order to aid instruction in the field of Mechanical Engineering. The rationale of that development and the robot car itself are described in the subsequent section of the paper. The section that follows proposes a lesson plan utilizing this technology and describes a study that was conducted in a Greek Technical high school to evaluate this approach. Finally, in the last section of the paper some conclusions are drawn and discussed.

2 Development of an Educational Robot Car

2.1 Fulfilling the Need for Bridging Theory to Practice

The development of an "intelligent" robot car and its utilization in the classroom may support an interdisciplinary instructional approach in the field of Mechanical Engineering. A car is a complex system consisting of many subsystems whose role and functioning are usually described in a course that in Greek technical education is called "Automotive Systems". Students however, in order to understand these concepts, frequently need to trace back fundamental concepts that they have been taught in several other subject areas: physics, chemistry, biology, mechanics, mathematics, computer architecture and programming, electronics, etc. This need to look back and combine concepts from various subject areas introduces a high degree of difficulty in the courses taught in technical/vocational high schools, especially if we consider the cognitive gaps that many students may have from their previous school years. An approach aiming at directly addressing these gaps is impossible mainly due to time limitations. It is more realistic and appropriate to let students discover and address their gaps through trial and experimentation. Students are usually willing to try to assimilate concepts and procedures that they consider useful for their future profession and related to their vocational experiences so far, i.e. the mental models that they have built based on their observations on the operations of machines.

The traditional approach in technical education suggests that students should be attending a hands-on lab lesson only after they have been taught the corresponding theory. On the contrary, the constructivist approach and especially discovery learning theory [14] argues that students are more likely to understand and remember concepts they had discovered in the course of their own exploration. The LEGO Mindstorms constructions can be extremely helpful in that direction. For example, though a student may not know the theory that predicts a cantilever's bending moment, s/he may find out -while trying to build a machine- that a long axle will bend more than a short axle of the same cross section when a force of the same magnitude is exerted on their ends. In that way, we can assume that robotics construction kits like LEGO Mindstorms may help students not only to deeply understand concepts they already know but also to discover concepts that they have not been taught yet.

Furthermore, working with robotic constructions offers students an authentic problem solving experience since the procedures they should follow emulate those needed in real-life situations. Providing such experiences to students is probably a way of preventing what Brown et al. in [15] called inert knowledge (i.e. skills that students have learned but do not know how to transfer later to problems that require them) which results from learning skills in isolation from each other and from real-life application.

2.2 The Robot Car

The car that was constructed is illustrated in Fig. 1 (left). It is a front wheel drive car with a classic chassis type, powered by an electronically controlled electric motor (Lego NXT), and a 3-speed gear box. The car can drive straight forward or reverse. In order for the car to interact with its environment, three sensors are connected to the NXT brick: a sound sensor, an ultrasonic sensor and a touch sensor. The sound sensor is used for remotely controlling the car with a clap sequence: one clap starts or stops the car and two claps drive the car backwards. The ultrasonic sensor (front part) is

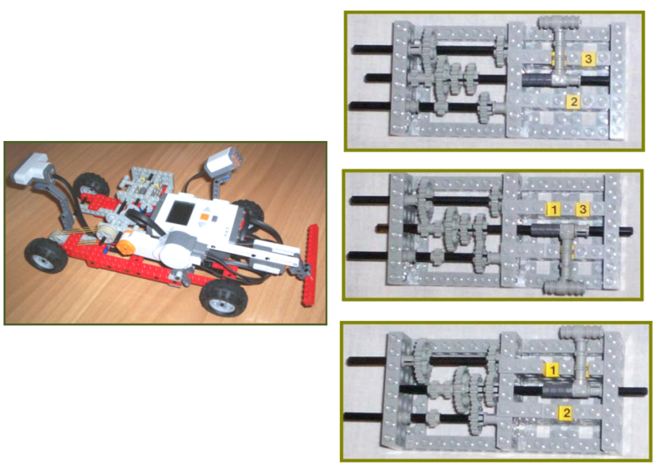

Fig. 1. Left: The robot car. Right: Top view of the gear box with 1st, 2nd, 3rd gear selected.

used for reversing the motion when an obstacle is detected within a given distance (e.g. 30cm). The touch sensor (rear part) is used for reversing the motion when the rear bumper hits an obstacle.

The gear box is a variation of the mechanical sliding gears type. First, second, and third gear give a gearing down ratio of 9:1, 3:1 and 1:1 respectively. The primary axle is connected directly to the rotor of the electric motor. The secondary axle is connected to the car's front axle via a triple elastic belt with a transmission ratio of 1:1. Electric motor's power can be adjusted from 0% to 100% in 5% increments. Fig. 1 (right) illustrates three top views of the gear box with 1st, 2nd and 3rd gear selected. The transmission ratios are formed with 8, 16, and 24 teeth gears.

The car functions only if the proper executable file is loaded into the NXT brick's memory. The workflow algorithm (program) is written in the provided graphical user interface of the NXT software by selecting the proper icons where each icon represents a specific action for the robot (i.e. motor movement, sensor reading, etc). Then the executable is automatically generated from the NXT software and transmitted to the brick via USB cable or wireless Bluetooth connection. The program consists of the main routine and many subroutines (MyBlocks and WebBlocks). The main routine and one of the subroutines (right NXT button control for power increase) are shown in Figures 2 and 3 respectively.

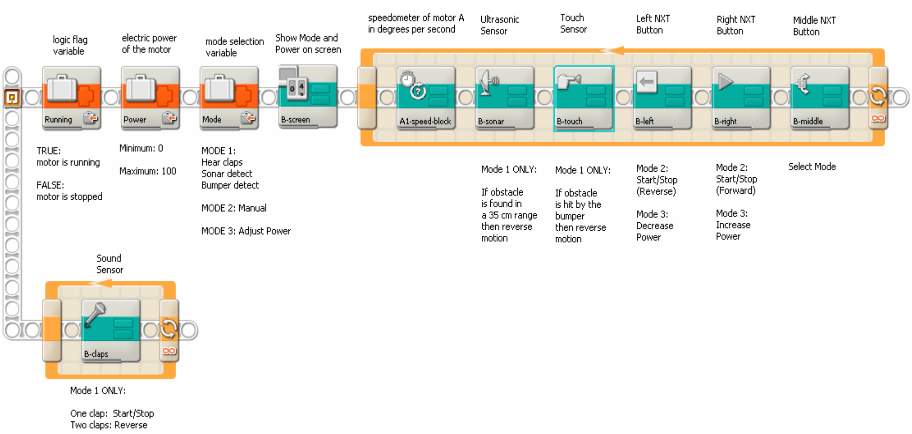

Fig. 2. The main program

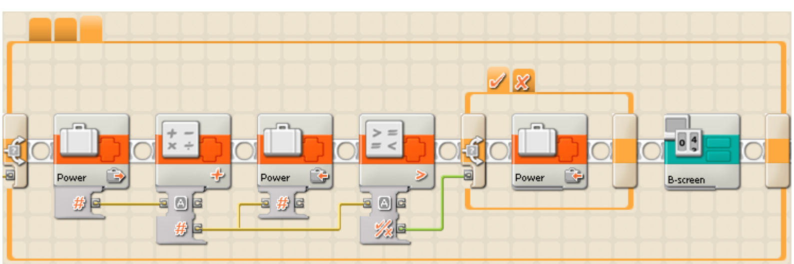

Fig. 3. MyBlock: B-right subroutine

3 The Robot Car in the Classroom

3.1 Lesson Plan

After the development of the robot car, a lesson plan was designed in order to be used in the pilot study that would follow. The objectives of the proposed lesson are the following: (i) students should understand the concepts of speed, torque and power of a rotating axle, (ii) they should be able to describe the direct or inverse proportion ratio of speed and torque of two axles coupled with gears, (iii) they should become familiar with the programming environment of a microcontroller, (iv) they should realize the necessity of a flowchart in order to create a correct control algorithm.

Teaching with the robot car includes a number of phases/activities. In the first phase, the instructor presents the LEGO Mindstorms kit: the bricks, the gears, the NXT brick, the sensors, the motors, etc. and makes clear to students that the software is necessary for the operation of the car since its motors and sensors are controlled by the NXT brick and they are not operating autonomously. Following that, the instructor describes briefly the car's capabilities: electronic control of the electric power, mechanical control of the torque via the gear box, sound controlled via clap sequences, front and rear obstacle avoidance mechanism.

In the next phase, students are separated in groups and they are asked to study and write down the transmission ratios of 1st, 2nd, and 3rd gear of the gear box. In case that a group does not know how to proceed, the instructor offers help explaining them that they have to count the number of teeth of every gear. To facilitate their work, the instructor may give them a real copy of the car's gear box so that they can turn both primary and secondary axle by hand and observe the resulting transmission ratios.

In the third activity the car's wheels are running without touching the ground and students are asked to empirically notice the torque output change according to the selected transmission ratio and try to find an empirical formula that connects these two quantities. Students can feel the magnitude of the secondary axle torque by applying on it an opposite braking torque with their fingers. Additionally the output torque for every gear can be observed by the ability or not of the car to run on a gradually increasing ground slope.

After the students will have discovered by themselves the formulae that link the ratio of gear circumferences with the ratio of axle speeds and torque, the instructor may present them these concepts in their theoretical form.

During the last activity, students in pairs are encouraged to experiment with programming the robot car, either by altering the initial algorithm that controls the car's operation, or by making from scratch their own small programs to control the vehicle. Each pair of students modifies the program or creates a new one and the rest of the class is watching their actions.

Finally, students are asked to fill in a test in order to assess their knowledge and understanding in the corresponding concepts. Obviously, a traditional paper-and-pencil test is not the most appropriate way to measure the overall learning gains obtained from working with LEGO Mindstorms. However, the limited time that was available for completing the whole pilot lesson precluded any other -more appropriate- kind of assessment.

3.2 The Study

The above mentioned two-hours lesson plan was implemented at a Technical and Vocational School in Greece (4^{th} T.E.E. of Sivitanidios School) in a class of the Mechanical Sector, attending the second year of the three years course of study for "Car Machinery and Systems" field of specialization. The class that participated in the study consisted of 14 students aging between 16 and 18. The concepts that are involved in the lesson plan had already been taught to those students in previous years of their studies in the context of the lessons entitled «Machine Design» and «Automotive Systems I». The reason for choosing this class instead of a class that had not been taught those concepts yet was twofold: there was a serious time limitation (the study could not exceed two hours) that would not allow the teaching of completely new concepts and also, it would be interesting to see whether the robotics approach could manage to correct students' possible misconceptions and address their cognitive gaps.

Before the beginning of the lesson, the instructor initiated an informal discussion with the students on the concepts involved in the lesson to follow, in order to diagnose their current knowledge and misconceptions. Students' responses in the discussion revealed that their knowledge on the subject was average and some of them were rather confused.

Then, the lesson began following the aforementioned phases. During the last part of the lesson at which students attempted to modify the existing program controlling the robot car or build a new one, the instructor was closely observing students' discussions, activities and reactions and kept notes on all that. These notes were one more source of information to be used in the evaluation of this approach.

Table 1. Assessment quiz

Questions, possible answers (the right one appears here in bold face) and percentage of correct responses to each question (appears in brackets)
1. By knowing the transmission ratio between two gears we can find
A. The speed ratio of the axles
B. The torque ratio of the axles
C. Both A and B ***[100%]***
2. In a working pair of gears their speed ratio is a direct proportion of their circumference ratio.
A. True   **B. False** ***[0%]***
3. In a working pair of gears their torque ratio is a direct proportion of their circumference ratio.
A. True ***[50%]***   B. False
4. Shifting down during driving can help
A. Reduce car speed
B. Increase car speed
C. Both A and B depending on the way the accelerator pedal is used ***[100%]***
5. Some cars cannot reach top speed with the longest (5^{th}) gear selected. This is:
A. True. Near top speed, 5^{th} gear may prove very weak to provide the needed torque for acceleration towards top speed. ***[57%]***
B. Just a myth. The longest gear always moves the car faster or it wouldn't exist since it adds more cost and complexity to the gear box.
6. Changing the memory contents of an Electronic Control Unit (ECU) can
A. Either improve or worsen the car's performance ***[93%]***
B. Only benefit the car
7. Car's sensors (e.g. exhaust gases temperature sensor) collect information which is processed by the ECU depending on the program that is loaded in its memory.
A. True ***[93%]***   B. False

Table 2. Questionnaire regarding the LEGO Mindstorms experience

Questions and possible answers
1. What is your previous experience with LEGO: A. LEGO DUPLO B. LEGO Bionicles, City, StarWars etc. C. LEGO Racers D. LEGO Technics E. LEGO Robotics
2. What are the teaching tools that you have used in the past in order to understand the theory of today's lesson? A. Real engines B. Educational engine models C. Other (please describe)______________ D. None
3. How would you rate LEGO in comparison with the other tools used? A. Much more effective. B. About the same effective. C. Less effective. Besides, it is just a game.
4. Would you like to gain experience in building LEGO machines and robots? A. Yes, although it will not be helpful in my profession B. Yes, it will also be helpful in my profession C. No. Job and school are so much time consuming that I would prefer to learn something more directly useful.
5. My current professional status is: ____

After the completion of the lesson students were requested to answer along with the assessment quiz, a questionnaire regarding their experience with the robot car. The assessment quiz and the questionnaire are presented in Tables 1 and 2 respectively.

3.3 Results of the Study

Students' answers to the assessment quiz (see Table 1), especially if compared to their responses in the discussion preceding the lesson, show that in general, the robotics approach was useful in helping them understand the principles that underlie the transmission of rotational motion with gears. In particular, all of the students answered correctly questions 1 and 4, all but one also answered correctly questions 6 and 7 and 57% answered correctly the quite difficult 5th question.

However, all of the class gave the wrong answer to question 2 and half of them also to question 3. Since these two questions are related to each other, we believe that students who answered erroneously to both these questions (50% of the class) have understood better the corresponding concept, than those who answered correctly the 3rd question, because the first group of students has probably understood that torque and speed of an axle are inversely proportionate quantities. The reason for giving wrong answers to these two questions is possibly the "mathematical" language that was used for their statement. If this is indeed the case, then it can be assumed that these students were not able to answer the questions correctly due to the deeper cognitive gaps that they have. This finding was not surprising considering the group of students that participated in the study: students that attend Technical and Vocational Schools in Greece are mainly students with strong technical skills but rather weak in traditional math and science classes. These students who are not usually willing to work in a more formal way, could be extremely benefited by approaches like the one described here which are based on the “learning by doing” paradigm [16] and look more like a game than like a learning aid.

As for the students’ responses to the questionnaire, these were recorded as follows:

- To almost all students this technology was completely unknown. Half of them were familiar with LEGO Technics or Racers and only one with LEGO Robotics. 5 students out of 14 had no idea what any kind of LEGO is. This finding implies that in order for these technologies to be welcomed in the classroom, students should get hands-on training and given plenty of time to practice on them before using them in the context of a specific lesson.
- Concerning the tools that were used so far in their teaching, not surprisingly, most of the students stated that these were either real engines or educational engine models. Indeed, this finding confirms the general picture that the approach of educational robotics has not reached yet the mainstream of education, albeit it has gained a lot of attention and most of the studies on them have yielded positive results. Possibly, the reason for this delay is the fact that teachers have not been trained -at least not in a wide scale- in the use of these technologies.
- Compared to the above mentioned instructional aids, LEGO was judged by 40% of the students as more effective. 30% of the students believed that LEGO is less effective and the rest 30% could not tell the difference. Taking into account that the group of students participating in the study were experiencing this technology for the first time and they have not even had enough time to explore its full potential, the fact that 70% of them perceived the robot car as being equally or more effective than the traditional instructional tools is considered definitely a very encouraging finding towards the use of LEGO Mindstorms as a teaching/learning aid.
- All but one of the students expressed their desire to learn more about developing LEGO machines and robots and an impressive 30% of them felt that such knowledge would be needed in their future workplace. This is also a very positive finding, not only because this technology seems to have gained students’ interest but also because their experience helped them realize that in order to be competitive in their profession they should be well informed and trained in the use of the emerging technologies.

As it has been already mentioned, while students were modifying the existing program or building one of their own, the instructor was observing them and kept notes on every point he considered interesting. Overall, according to those observations, students seemed to be satisfied with their experience with LEGO Mindstorms. In particular, the LEGO construction encouraged students to be actively involved and hence awakened their interest in the lesson. Moreover, students seemed to enjoy watching the car interacting with the environment through its sensors (obstacle avoidance and sound control) and they were impressed by the capability of using the menu to adjust according to their will the power of the car as well as its mode of function. Furthermore, they were impressed by the ability of the car to climb on a very steep slope with 1^{st} gear due to its massive torque as well as by the quite high top speed reached with the 3^{rd} gear.

4 Concluding Discussion

This paper reported on the first of a series of studies we plan to conduct regarding the use of LEGO Mindstorms as an instructional aid in technical and vocational secondary education. For the purposes of the study, a robot car was developed and used in a two-hour lesson with a class of the Mechanical Sector in a Greek technical school. The prime motivation for the study was to gather some initial evidence about students' attitudes and feelings towards the use of robotics technology in the classroom. In addition, the study attempted to measure the effectiveness of this approach in terms of short-term learning outcomes. Indeed, the results of the study were positive and thus provide the impulse for further and in-depth research in the field.

In particular, students' scores to the assessment quiz were rather high, showing that in general, the robotics approach was useful in helping them understand the underlying concepts, correct possible misconceptions they previously had and address their cognitive gaps. Hence, the objectives of the designed lesson seem to have been met. However, the fact that the majority of students failed in two of the questions which were stated more formally, on one hand confirms the need for practical, hands-on learning experiences for those students, but on the other hand raises questions that need further investigation: how can these students see more positively math and science in their theoretical form? And can educational robotics -through their motivational quality- help in that direction too? In the study described here, students were exposed to this technology for a very short period of time thus not allowing to draw any conclusion about what would happen in the long run.

Another finding of the study -rather common knowledge- was that currently this kind of technology is not being used in school classrooms. The research on the field is ongoing and the results so far are in their majority positive but what we believe is missing is large-scale and long-term experiments to prove the effectiveness of that approach. If such experiments manage to confirm that educational robotics is indeed effective, the next step will be to design a framework for their integration in the school curricula and properly train the teachers that will be using them.

Students participating in the study were satisfied with the robot car, enjoyed working with it, expressed their desire to learn more on this technology and the majority of them judged it as being equally or more effective than the tools that were normally used for their instruction. These findings are definitely positive, but the short duration of the experiment poses some considerations: Would the students' feelings and attitudes be the same if they were been using that technology over longer time? Becoming more familiar with that would replace the initial enthusiasm with boredom or with greater acceptance? Answering these questions is a matter of further research that we plan to conduct in the near future.

As a matter of fact, it is within our future plans to examine the long-term effects of using robotic constructions in technical education. In this examination we will investigate how the increase of students' motivation may be connected to long-term effects in their performance and also whether students' attitude will remain positive if they are using this technology on a regular basis. Furthermore, we intend to run more experiments following this approach involving students from other Technical education's sectors and fields of specialization as well, and from various age groups. In that way, we will have the opportunity to evaluate the effect of robotics along the two dimensions of the domain taught and the age of students.

References

1. Ringwood, J.V., Monaghan, K., Maloco, J.: Teaching engineering design through Lego® Mindstorms™. European Journal of Engineering Education 30(1), 91–104 (2005)
2. Lawhead, P.B., Duncan, M.E., Bland, C.G., Goldweber, M., Schep, M., Barnes, D.J., Hollingsworth, R.G.: A road map for teaching introductory programming using LEGO© mindstorms robots. ACM SIGCSE Bulletin 35(2), 191–201 (2003)
3. Parsons, S., Sklar, E.: Teaching AI using LEGO Mindstorms. In: Greenwald, L., Dodds, Z., Howard, A., Tejada, S., Weinberg, J. (eds.) Accessible Hands-on AI and Robotics Education: Papers from the 2004 Spring Symposium, pp. 8-13. Technical Report SS-04-01. Menlo Park, California: American Association for Artificial Intelligence (2004)
4. Miglino, O., Lund, H., Cardaci, M.: Robotics as an Educational Tool. Journal of Interactive Learning Research 10(1), 25–47 (1999)
5. Rogers, C., Portsmore, M.: Bringing engineering to elementary school. Journal of STEM Education 5(3&4), 17–28 (2004)
6. Lindh, J., Holgersson, T.: Does lego training stimulate pupils ability to solve logical problems? Computers & Education 49(4), 1097–1111 (2007)
7. Ricca, B., Lulis, E., Bade, D.: Lego Mindstorms and the Growth of Critical Thinking. In: Intelligent Tutoring Systems Workshop on Teaching with Robots, Agents, and NLP (2006)
8. Ruiz-del-Solar, J., Avilés, R.: Robotics courses for children as a motivation tool: the Chilean experience. IEEE Transactions on Education 47(4), 474–480 (2004)
9. Robinson, M.: Robotics-driven activities: Can they improve middle school science learning? Bulletin of Science, Technology & Society 25(1), 73–84 (2005)
10. Chambers, J., Carbonaro, M., Rex, M.: Scaffolding Knowledge Construction through Robotic Technology: A Middle School Case Study. Electronic Journal for the Integration of Technology in Education 6, 55–70 (2007)
11. Miller, G., Church, R., Trexler, M.: Teaching diverse learners using robotics. In: Druin, A., Hendler, J. (eds.) Robots for kids: Exploring new technologies for learning, pp. 165–192. Morgan Kaufmann, San Francisco (2000)
12. Papert, S.: Mindstorms: Children, computers and powerful ideas. Basic Books, New York (1980)
13. Martin, F.G., Mikhak, B., Resnick, M., Silverman, B., Berg, R.: To Mindstorms and beyond: Evolution of a construction kit for magical machines. In: Druin, A., Hendler, J. (eds.) Robots for kids: Exploring new technologies for learning, pp. 10–33. Morgan Kaufmann, San Francisco (2000)
14. Bruner, J.: The relevance of education. W.W. Norton & Company, New York (1973)
15. Brown, J.S., Collins, A., Duguid, P.: Situated cognition and the culture of learning. Educational Researcher 18(1), 32–41 (1989)
16. Alimisis, D., Karatrantou, A., Tachos, N.: Technical school students design and develop robotic gear-based constructions for the transmission of motion. In: Proceedings of Eurologo 2005 Conference, pp. 76–86 (2005)

Measuring Learning Object Reuse

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Abstract. This paper presents a quantitative analysis of the reuse of learning objects in real world settings. The data for this analysis was obtained from three sources: Connexions' modules, University courses and Presentation components. They represent the reuse of learning objects at different granularity levels. Data from other types of reusable components, such as software libraries, Wikipedia images and Web APIs, were used for comparison purposes. Finally, the paper discusses the implications of the findings in the field of Learning Object research.

Keywords: Learning Object, reuse, granularity.

1 Introduction

The reuse of learning resources is the *raison d'être* of Learning Object technologies. Reusing learning objects is believed to generate economical and pedagogical advantages over the construction of learning objects from scratch [1]. Creation of high quality learning objects is a time and resource consuming task [2]. Reusing them in many contexts helps to compensate for those creation costs. Also, learners could have access to learning materials of good quality even if those objects were produced for other contexts.

Due to the importance of reuse in the context of learning objects, it has been one of the most visited topics in Learning Object literature. Some papers concentrate on the theoretical issues that are thought to intervene in the reuse of learning material [3] [4]. Simple questions, such as what percentage of learning objects would be reused in a given collection, however, have no answers yet. Moreover, assertions, such as the inverse relation between granularity and probability of reuse [5] , are taken for granted, but have never been contrasted with real-world data. In recent times the landscape of learning object publishing has changed thanks to initiatives like Creative Commons (CC) [6]. This openness finally enables the study of reuse mechanisms. This paper uses this newly available information to perform a quantitative analysis of the reuse of learning objects of different granularities in different contexts. In order to provide a useful comparison framework, the same analysis is also applied to other forms of component reuse, such as images in encyclopedia articles, libraries in software projects and web services in web mashups.

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2 Data Sources

To perform a quantitative analysis of the reuse of learning objects, this paper uses empirical data collected from three different openly available sources. The sources were chosen to represent different reuse contexts and different object granularities.

Small Granularity: Slide Presentation Components. A group of 825 slide presentations obtained from the ARIADNE repository were decomposed and checked for reuse using the ALOCOM framework [8]. From the decomposition, 47,377 unique components were obtained.

Medium Granularity: Learning Modules. The 5,255 learning objects available at Connexions [7], when the data was collected. Some of these objects belong to collections, a grouping of a similar granularity as a course. 317 collections are available at Connexions.

Large Granularity: Courses. The 19 engineering curricula offered by ESPOL, a technical University at Ecuador, reuse basic and intermediate courses. When a new curriculum is created, existing courses, such as Calculus and Physics, are reused. 463 different courses were obtained.

In order to offer a reference for comparison, data from other reusable components was also obtained from openly available sites on the web. The sources were chosen to be as similar as possible in granularity to their learning object counterparts.

Small Granularity: Images in Encyclopedia Articles. A dump of the English version of the Wikipedia database was used to obtain the identifier of the images used in different articles. 1,237,105 unique images were obtained.

Medium Granularity: Software Libraries. The information posted at Freshmeat under the category "Software Libraries" was used to obtain a list of 2,643 software projects whose purpose is to be used in other programs. Each project in Freshmeat can declare which libraries it depends on. That information was used to measure the reuse of each one of the posted libraries.

Large Granularity: Web Services. Programmable Web compiles one of the most comprehensive lists of Mashups and Web Services available on the Web. Given that a the code of the Mashup is small compared with the code of the Web Services, the Web Service could be considered as coarse-grained in the context of the Mashup. 670 Web Services were listed in Programmable Web.

3 Quantitative Analysis

We measure the percentage of objects that has being reused within a collection. To measure this percentage, the number of objects that have been reused was obtained for each set. This number was then compared with the total number of objects in the set. Table 1 presents the results of this measurement for each data set.

Table 1. Percentage of reuse in the different data sets

Data Set	Objects	Reused	% of Reuse
Small Granularity			
Components in Slides (ALOCOM)	47,377	5,426	11.5%
Images (Wikipedia)	1,237,105	304,445	24.6%
Medium Granularity			
Modules in Courses (Connexions)	5,255	1,189	22.6%
Soft. Libraries (Freshmeat)	2,643	538	20.4%
Large Granularity			
Courses in Curricula (ESPOL)	463	92	19.9%
Web APIs (P.Web)	670	216	32.2%

The most interesting result from this analysis is that, in almost all the data sets, the percentage of reuse is close to 20%. This percentage is the same for learning object related sets and sets used for comparison. It is also maintained at different levels of granularity. However, two sets deviate from this value. The reuse of slide components has a percentage of reuse significantly lower (11.5%). On the other hand, the reuse of Web APIs is significantly higher (32.2%). A possible interpretation for this factor is presented in section 4.

The quantitative analysis seems to indicate that in common settings, the amount of learning objects reused is around 20%. While relatively low, this result is very encouraging for Learning Object supporters. It indicates that even without support or the proper facilities, users do reuse a significant amount of learning materials.

The quantitative analysis suggests that the percentage of learning object reuse in a given collection or repository is similar to the percentage of reuse of other types of reusable components, such as images, software libraries and Web APIs. This answer implies that learning objects are not intrinsically easier or harder to reuse than other types of components.

The theory of Learning Objects affirms that higher granularity leads to lower reusability. A naïve interpretation of the results contradicts this affirmation. The percentage of object reuse was similar regardless of the granularity of the object. Courses were even reused more often than slide components. Merging the theory with the empirical finding leads to a new interpretation of the role of granularity in the reuse of learning objects. This new interpretation involves also the granularity of the context of reuse as the determining factor. Objects that have a granularity immediately lower than the object being built are easier to reuse than objects with a much lower or higher granularity. For example, when building a course, it is easier to reuse whole lessons than reusing complete courses or individual images. Also, when building a curriculum, it is easier to reuse complete courses than to reuse another complete curriculum or individual lessons. Empirical support for this new interpretation can be found in [9]. It was found that when building a slide presentation, the most reused component type was by far individual slides. The reuse of text fragments and individual images represent just 26% of the total reuse.

4 Conclusion

This paper offers a quantitative analysis of the reuse of learning objects in real-world scenarios. Long-held ideas and beliefs about learning object reuse are tested against empirical data. The results obtained in the analysis should force us to rethink some of those ideas. However, the analysis also shows that the theoretical and empirical developments made in other types of component reuse can be "reused" in our context to accelerate the understanding of the mechanisms behind learning object reuse.

Arguably, the most important conclusion of this work is that the reuse of learning objects is a process taking place in the real world, even without encouragement or the support of an adequate technological framework. However, it also can be concluded that the efforts made in Learning Object technologies to improve the reuse process through facilitating the different steps during the process can lead to increases in the amount of reuse.

References

1. Campbell, L.: Engaging with the learning object economy. In: Reusing Online Resources: A Sustainable Approach to E-Learning, pp. 35–45. Kogan Page Ltd (2003)
2. Wilhelm, P., Wilde, R.: Developing a university course for online delivery based on learning objects: from ideals to compromises. Open Learning: The Journal of Open and Distance Learning 20(1), 65–81 (2005)
3. Littlejohn, A.: Issues in reusing online resources. In: Reusing Online Resources: A Sustainable Approach to E-Learning, pp. 1–7. Kogan Page Ltd (2003)
4. Collis, B., Strijker, A.: Technology and human issues in reusing learning objects. Journal of Interactive Media in Education 4 (1) (2004)
5. Duncan, C.: Granularisation. In: Reusing Online Resources: A Sustainable Approach to eLearning, pp. 12–19. Kogan Page Ltd (2003)
6. Creative Commons: Creative commons licenses, http://www.creativecommons.org
7. Baraniuk, R.G.: Challenges and Opportunities for the Open Education Movement: A Connexions Case Study. In: Opening Up Education – The Collective Advancement of Education through Open Technology, Open Content, and Open Knowledge. MIT Press, Cambridge (2007)
8. Verbert, K., Duval, E., Meire, M., Jovanovic, J., Gasevic, D.: Ontology-based learning content repurposing: The ALOCOM framework. International Journal on E-Learning 5(1), 67–74 (2006)
9. Verbert, K., Duval, E.: Evaluating the ALOCOM Approach for Scalable Content Repurposing. In: Duval, E., Klamma, R., Wolpers, M. (eds.) EC-TEL 2007. LNCS, vol. 4753, pp. 364–377. Springer, Heidelberg (2007)

Issues in the Design of an Environment to Support the Learning of Mathematical Generalisation*

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Abstract. Expressing generality, recognising and analysing patterns and articulating structure is a complex task and one that is invariably problematic for students. Nonetheless, very few systems exist that support learners explicitly in the process of mathematical generalisation. We have addressed this by developing a novel environment that supports users in their reasoning and problem-solving of generalisation tasks. We have followed a stakeholder-centred design process, integrating feedback and reflections from twenty-four children, five teachers and a variety of other stakeholders. This paper focuses on several inter-related design issues that have been informed by this iterative process and demonstrates how the system can be used for a typical generalisation task to foster an appreciation of generality and indeed algebra.

1 Introduction

In the traditional mathematical curriculum, algebra is a means of expressing generality. However, generalisation is so implicit in algebra that experts no longer notice the strategies they have integrated into their thinking [1]. This causes problems for students who perceive algebra as an *endpoint* rather than a tool for problem solving [2].

Several learning environments have been developed and integrated in classroom contexts over the last few years that attempt to help students in algebra and problem solving. However, the vast majority of these environments (e.g. [3,4,5]) are aimed at students who already have at least a basic understanding of algebra and attempt to develop students' understanding of various representations such as tables and graphs. These learning environments therefore do not deal explicitly with the generalisation difficulties that students face before they are comfortable with algebra. A different approach could focus on helping students derive generalisations from patterns. For example, in Mathsticks [6] students use a subset of LOGO commands to work on patterns and regularities constructed out of matchsticks. This allows them to explore how the variables within the task relate to each other. Despite some successes, difficulties remain, and these tend to coalesce around the need for significant pedagogic support from the teacher to provide a bridge to algebraic symbolism and generalisation.

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This paper presents a mockup mathematical microworld — ShapeBuilder — that attempts to address these issues by supporting users in their reasoning and solving of generalisation problems. As the user constructs their model of the problem, they implicitly use the power of algebra and, as such, student experiences of the system serve to provide a smooth transition to the teaching of algebra and an intuitive justification as to why algebra is such a useful and powerful tool.

Throughout the development of ShapeBuilder, we have followed a stakeholder-centred design process,[1] interleaving software development phases with small-scale pilot studies with groups of children of our target age (11–14 years old). We have also integrated feedback from various other stakeholders such as teachers and teacher educators. This co-design with teachers is critical since former studies have shown that the use of educational tools in the education of mathematics must be carefully integrated within the classroom context [6]. In addition, studies about the adoption of educational software highlight that teachers would like the opportunity to be more involved in the entire design process of computer-based environments for their students [7,8].

The remainder of the paper is structured as follows. Section 2 discusses the theoretical background of mathematical generalisation and the difficulties of developing this kind of thinking in young learners. Section 3 then briefly describes the key functionality of ShapeBuilder. This is followed by detailed discussions of various inter-related design issues in Section 4. Section 5 presents a concrete task we have used extensively for exploring generalisation, discussing its typical classroom deployment and how ShapeBuilder can be useful in its exploration. Section 6 draws together the various issues described in the paper and discusses future work.

2 Theoretical Background

The difficulty that algebraic thinking poses to children has been thoroughly studied in the field of mathematics education [9,10]. One of the significant issues is that generalisation problems are frequently presented to students in confusing ways and this is compounded by strict constraints on the teaching approaches used [11]. These difficulties have to be investigated in the context of the curriculum, the nature of the tasks posed and the tools available for their solution [2]. The general tension in schools is towards pattern spotting. As mentioned by many authors [2,12], most instructions emphasise the numeric aspect of patterning. These unfortunately lead to the variables becoming obscured and limit students' ability to conceptualise relationships between variables, justify the rules and use them in a meaningful way [11]. In addition, teachers tend to teach "the abstracted techniques isolated from all context" or alternatively "the technique as a set of rules to be followed in specific contexts" [13] to help their students find the rule. This could result in students' own powers atrophying due to lack of use [14].

Another difficulty secondary school students face is their inexperience with the use of letters. They struggle to grasp the idea of letters representing any value (e.g. [15]) and lack some of the mathematical vocabulary needed to express generality at this age. Even though it is a reasonable idea to introduce algebra early, there is still the issue

[1] This term is intended to encompass user-centred design and learner-centred design since our design process has integrated feedback from stakeholders other than users/learners.

of how to introduce it so that students can make the transition from simple arithmetic to algebra smoothly. Other researchers [16] describe that students' written responses lacked precision which supports the view of primary school students' inexperience with the mathematical language. Even if students succeed in expressing generality, they do so in natural language. The right design of tasks though has the potential to encourage students to write expressions in a general form rather than give a description in words. This articulation process needs to be addressed so that students can learn to express their thinking using algebraic notation. Deployed appropriately, ICT can help students understand different representations — the symbolic, the iconic and the numeric — and reinforce connections between them once they realise the relationships and the equivalence of different representations.

Students are required to learn techniques to pass exams and use examples as ways to learn different techniques, whereas working on different examples should help them realise "how the calculations are done, with an eye to seeing if they generalise" [14]. The idea of 'seeing the general through the particular' is a powerful way to introduce students to generalisation [14]. It is important, though, to introduce different approaches to students and allow them to explore. In this way, students are more likely to "strengthen their own powers, and at the same time, because of the pleasure experienced in exploiting their own powers, actually find mathematics enjoyable, creative and involving" [14]. This can be further enhanced by having students construct their own mathematical models [2]. This modelling approach seeks not only to foster seeing the general in the particular by construction and exploration, but also a sense of ownership of the abstraction process, which as claimed above is of great value to the students.

Learning is an active process and learners construct mental models and theories of the world as they understand it. This latter idea is characterised as constructivism. Papert ([17]), though, introduced another notion inspired by constructivism, which is characterised as constructionism. This supports "the idea that learners build knowledge structures particularly well in situations where they are engaged in constructing public entities" [12, p.61]. Such a constructionist pedagogical approach allows students to explore and construct their own models and can be usefully adopted when building systems. In contrast to much of the content of modern school mathematics textbooks, tasks within such systems can aim at generating understanding rather than inducing repetitive behaviour.

3 ShapeBuilder

ShapeBuilder[2] is an environment which aims to encourage structured algebraic reasoning of 11–14-year-old students. It allows the learner to create constants, variables and arbitrarily-complex compound expressions involving basic algebraic operations. These expressions can then be used to define various different shapes. Once a shape is defined, the user can move it, attach it to other shapes and alter its defining expressions as desired. The actual numerical values of expressions can be found by dragging them into the evaluator.

[2] Please see the project web-site (http://www.migen.org/) to download this and other project-related software.

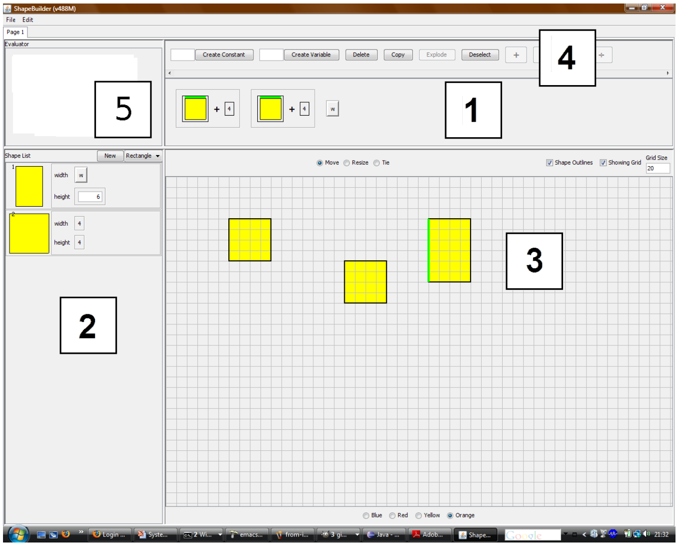


Fig. 1. Screenshot of ShapeBuilder, showing the main areas: Expression Palette (1), Shape List (2), main interaction area (3), Expression Toolbar (4), Evaluator (5)

A critical feature of the software allows users to *define expressions using shapes*. Specifically, by double-clicking on an edge of a shape, the user is able to obtain an *icon-variable* [18] which, at all times, evaluates to the current value of that dimension of the shape. These icon-variables are *bona fide* expressions and, as such, can be combined with other expressions in the usual way.

Figure 1 shows the layout of the ShapeBuilder. The following section explains the design issues behind its crucial functionalities, and their evolution through our stakeholder-centred iterative design process.

4 Design Issues

Due to the nature of the tasks that the system is able to address, and the developmental level of the students, there is a pragmatic requirement to design the user interface in an optimal way: not only should it be intuitive for all students to use but it should also support their cognitive processes and reduce their memory load in relation to how the software works. As explained in Section 1, one of the aims of our project is to develop tools that provide assistance to learners and advice to teachers based on analyses of individual students and the activities of the group overall. This requires striking a balance between the need to design parts of the system with intelligent support in mind, and the need to take into account pedagogical and HCI considerations.

Several pilot studies have been conducted so far, involving 26 sessions with children in our age range (11–14 years old). They are helping to raise implications for the design of the system's intelligent support. However, due to the constructionist principles behind our approach, the expressive power of the system and the freedom for students to interact with it in an exploratory manner are not compromised by the need for intelligent pedagogic support.

4.1 Direct Manipulation

In initial iterations of the software, creating a new rectangle required the user to select two expressions and click on the 'Make Rectangle' button (Figure 2a).[3] This creates a new shape on the canvas at a default location and adds its details as an entry in the Shape List (Figure 2b).

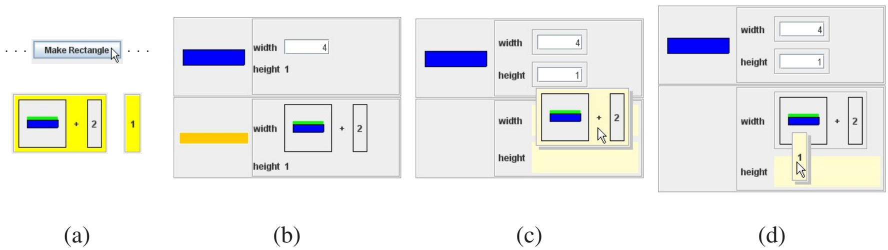


Fig. 2. Using direct manipulation. (a) The user selects two expressions and clicks on 'Make Rectangle'; (b) This creates the appropriate entry in the ShapeList. (c) The user drags an expression for the width; (d) and for the height.

As part of our reflections through contact with users and other stakeholders, it became clear that this interface was far from intuitive. Primarily, this was due to the fact that the user's action of clicking on the 'Make Rectangle' button was dislocated from the system responses of creating an entry in the Shape List and a shape in the interaction area. We addressed this issue through allowing the user to drag expressions to slots within the Shape List as shown in Figures 2c-d. Once all appropriate expressions are specified, the shape is created at a default location.

This refinement relates to the notion of 'distance' in direct manipulation interfaces [19] as it reduces 'the effort required to bridge the gulf between the user's goals and the way they must be specified to the system' [20]: if the user wants an expression to be used as the width for a shape, they simply drag it to the appropriate location; there is no need to understand that they must first select two expressions and then click on a specific button to create a shape.

Other aspects of the interface also relate to issues of directness. For example, recent iterations introduced the facility for cloning shapes through dragging their thumbnail from the Shape List to the interaction area. This is even required for creation of the initial shape rather than it being created at a default location. In future work, the creation of values and icon-variables will both adopt direct manipulation interface metaphors. In general, such interface design considerations are important for a constructionist environment since it has the potential to increase the clarity of the construction and make the process more intuitive.

[3] The expression selected first was used as the width and the second as the height.

4.2 Variables, Constants and Values

Initially the software allowed the user to create variables whose value could change and constants whose values were fixed. These were displayed differently on the screen. However, during user trials it was often the case that constraining the user to choose between these two types *at creation time* led to unnecessary and confusing interaction. Consider for example the situation where a user decides they want the side of an already-created shape to be a variable rather than a constant. With this constraint in place, they would have to create a new variable and put it in place of the original constant. This situation becomes more complex if the constant that they want to change is buried deep within another expression. Not only is this sequence of steps an issue in terms of usability but, as part of a system that will feature intelligent support, detecting that such an episode of interaction solely achieves the transformation of a constant into a variable introduces an unwanted element of complexity.

In view of this, we experimented with another user interface which allowed the user to convert variables to constants and vice versa at any time. This was achieved through the use of a 'Toggle Lock' tool. Using this new tool on a variable would 'convert' it to a constant and, similarly, using this tool on a constant would 'convert' it to a variable.

Through various discussions with teachers and teacher educators, it later became clear that the use of the terms 'variable' and 'constant' were problematic in themselves since, in terms of the National Curriculum, a variable is an entity with a name such as x which varies in some way. Since the representation of variables within ShapeBuilder was purely in terms of its current value and not in terms of a name, this could be a potential source of confusion for users of the system. As a result of these considerations, the most recent iteration of the software development disengages entirely from this false dichotomy of constant and variable and provides a tool that creates a new *value*. The user can switch between locked values ('constants') and unlocked values ('variables') using the Toggle Lock tool as before. An important aspect of this final configuration is that values are always created *locked*. In this way, it is clear to the user and the system (for the purposes of intelligent support) whether they want the values to be able to change or not.

4.3 Building with 'n'

When expressing generality, one of the main difficulties is the use of variables for expressing universal concepts (e.g. n representing the number of people in *any* room). This basic foundation of algebra is a difficult skill for children to acquire. Previous research has shown that children start viewing variables as static objects with no general meaning and then pass through a series of steps. These steps include viewing variables as concrete numbers then generalised numbers and, finally, as general entities [9].

When designing our system, one of our main concerns was to give the learner the facility to 'build with n'. We were conscious that using letters to denote variables was likely to prove difficult for learners so we addressed this problem by using 'icon-variables' [18]. Icon-variables are iconic representations of an attribute of an object (such as the height of a rectangle). They are defined from objects and can be used to construct expressions that, in turn, define other objects.

Icon-variables are a pictorial representation of a concept and provide a way to identify a general concept that is easier for young learners to comprehend. They can be used in exactly the same way as other expressions: copied, deleted, used in operations (e.g. addition), used to define other objects, etc. In this way, they are an intermediate step that scaffold the use of variables.

This design feature holds significant potential to lead to generalised thinking. For example, a constant and an icon-variable can be added to express relationships such as "the width of shape B is the width of shape A plus 2", or "shape A is twice as high as shape B". These expressions can be built on screen and used as a resource for reasoning by the user.

4.4 Evaluating Expressions

As explained in Section 2, a typical problem with the deployment of generalisation tasks is the premature engagement with specific numbers. Avoiding this problem was therefore an important requirement of the software.

Initially, this was achieved through providing tooltips on expressions. When the user hovered with the mouse cursor over an expression, a tooltip would appear showing the result of evaluating the expression. This is a standard interface metaphor wherein waiting over various screen areas for a moment leads to more information. It was precisely this status of 'additional information' that satisfied the design requirement of number as secondary.

Although during the student trials, users had minimal difficulty in using this software feature, we still concluded that its use was nonetheless problematic. This was due to the fact that the use of the tooltip was *ambiguous*; when a user displays a tooltip, it is not clear whether it is deliberate or whether they are attending to it appropriately. For the user, this means that the tooltip is potentially distracting if it is displayed when unwanted. For the system — in which intelligent support is an important design consideration — unambiguous interaction is essential as recognised by a large body of work since the early 1990s [21]. The use of a tooltip for evaluating expressions therefore can increase the noise in the system.

In view of these considerations, we included a specific screen area within the interface — the 'Evaluator'. It is *only* through this component that a user can evaluate expressions explicitly.[4] To demonstrate the behaviour of this component, consider the case where the user has created a rectangle (of, say, width 4 and height 3) and wants to evaluate expressions for both its area and its perimeter. They place these in the Evaluator and it displays their initial values as shown in Figure 3a. If the width of the rectangle is now changed to 5, the value of both these expressions then changes as a result since they both depend on the width of the rectangle. Given this dependency, the Evaluator obscures the evaluation component with question marks (Figure 3b). In order to see the new values of these expressions, the user must now click on these question marks (in any order they choose). In this way, an expression within the evaluator requires *explicit* action from the user to view values as they change, which not only directs their attention

[4] Currently, all expressions can be evaluated by the user manually in that they could carry out the operations on the expressions themselves. The incentive to use the Evaluator therefore is to save calculation time and ensure calculation accuracy.

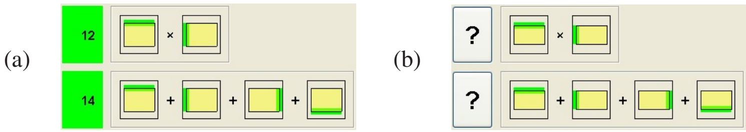


Fig. 3. The behaviour of the Evaluator. (a) Two expressions first evaluated; (b) Both expressions have changed.

and therefore reduces their cognitive load but also provides information to the system increasing the amount and quality of the input (also referred to as 'bandwidth' [22]) for intelligent components of the system.

5 Pond Tiling: A Concrete Task for Exploring Generalisation

As a first exploration of using ShapeBuilder, we focused on one particular generalisation problem: pond tiling, which is typical in the British algebra curriculum for children in our target age group. The simplest version of this task can be described as follows: "given a rectangular pond with an actual integer length and breadth, how many 1×1 tiles are needed to surround it?". We have focused on the pond-tiling activity both because of its appropriateness for presentation on a computer and the fact that it naturally lends itself to a variety of different representations. The task encourages students to find expressions for the number of tiles needed based on the length and the breadth of the pond. Four different ways students could visualise the pond and its surrounding tiles are shown in Figure 4. Given these different arrangements, students can be asked to have interesting discussions about the equivalence of the expressions derived from each viewpoint. There is then an incentive to develop some of the basic rules of algebra intuitively such as commutativity and associativity.

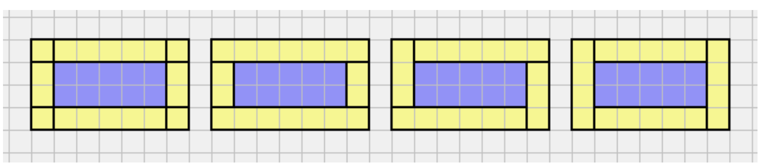


Fig. 4. Tilings corresponding to the general algebraic equations: $2l + 2b + 4$, $2l + 2(b + 2)$, $2(l + 1) + 2(b + 1)$, and $2(l + 2) + 2b$ (l is the length of the pond; b the breadth)

The following sections illustrate how this problem is usually approached in the classroom and how the introduction of ShapeBuilder affords a different approach, in line with the constructionist principles discussed in Section 2.

5.1 Pond Tiling in the Classroom

In order to tackle pond tiling and similar generalisation problems in the classroom context, students are often advised to try different values for the length (l) of the pond and arrange them in a table such as the one shown in Table 1. The numbers in the table are then used to determine the relationship between l and the number of tiles. This of course enables students to generate a relationship using pattern spotting based on the numbers in the table. However, this is far from ideal since this relationship is independent of the structure of the initial problem.

Table 1. A table of differences, typically used to find general rules

Length	**Number of tiles**	**Difference**
1	8	+2
2	10	+2
3	12	+2
...	...	+2
50	?	

Another disadvantage of this approach is that it is limited to problems involving one variable. In cases where more than one variable is involved, the approach becomes cumbersome. A further — and more crucial — issue is that this representation is usually given to students without any justification. As a result, students learn to become perfect executors of 'tricks' without being prompted to think of *why*, but rather only *how* similar problems were solved by the teacher. Lastly, since there is no sense of ownership in the abstraction process, it becomes less meaningful.

5.2 Pond Tiling in ShapeBuilder

As presented in Section 4, students can use ShapeBuilder to construct their own models, play with these creations and put them to the test. Users can either build specific constructions using explicit values or use icon-variables (as discussed in Section 4.3) so that their constructions are general. Figure 5 illustrates the construction of a general tiling using icon-variables.

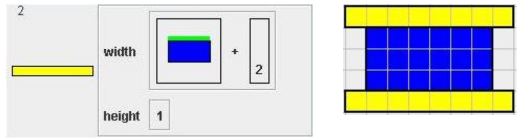
During the pilot studies, one typical yet erroneous approach that students take is to construct their solution for a *specific* pond. After the solution has been constructed, the given values of the problem (e.g. width and height of the pond) can be changed 'surprising' the student who has to figure out what was wrong with the construction. In the dynamic geometry literature, this operation is referred to as 'messing up' [23]. An example of this is shown in Figure 6a where the width of the rectangle is defined by the constant 5. This looks correct for a pond of width 3 (Figure 6b). However, if the width of the pond is changed by the teacher (or indeed another student or, in the future, the system itself), the construction is no longer valid (Figure 6c).

The challenge for students, therefore, is to construct a solution that is impervious to 'messing up' in this way. This 'incentive to generalise' [1] provides students with the opportunity to realise that there is an advantage in using icon-variables and promotes thinking in terms of abstract characteristics of the task rather than specific numbers, thus leading to a type of mathematical generalisation.

The next step for students is to name their expressions. They typically produce phrases such as 'width of the swimming pool' or 'number of tiles'. This initiates an articulation process. Students could be further prompted to use words instead of phrases

Step 1. The user creates two independent variables, clicks on ‘New Shape’ and then drags these expressions to define the width and height of their pond (rectangle).

Step 2. The user creates an iconic expression for the pond width and add 2 to it. They then use this to define the width of the horizontal tile. They copy it (by dragging) to create two instances.



Step 3. They then create an iconic expression for the height of the pond and use this to define the height of the vertical tile. Once again, they copy this through dragging.

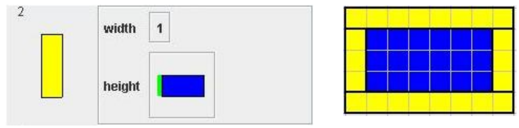


Fig. 5. Using ShapeBuilder for the pond tiling task. Each step shows the latest entry in the shape list and the current state of the canvas.

(a) 

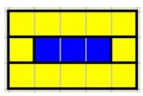
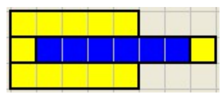
(b) 
(c) 

Fig. 6. ‘Messing up’. (a) The definition of the long rectangle; (b) the tiling for pond width 3; (c) and 6.

and, later on, letters instead of words. As discussed in the background, this process should help them make a smooth transition to the use of letters in the traditional algebraic symbolism. Depending on the task, there are opportunities for students to see the point in the use of letters since, for instance, naming their objects or expressions will enable them to refer to them in a laconic way when they collaborate with fellow students. Furthermore, in line with the constructionist approach, the process of constructing objects or expressions and then naming them as they wish engages students and deviates in a positive way from the traditional teaching method of algebra.

6 Conclusions and Future Work

The need to recognise, express and justify generality is at the core of mathematical thinking and scientific enquiry. However, it has been consistently shown to be complex and problematic for students. Several systems have been developed to help students in algebra but assisting the development of mathematical generalisation still presents important challenges. Although it may seem that it is the students’ responsibility to actively construct mathematics for themselves, it is unreasonable to expect they will do it on their own. This is particularly true in the case of mathematics because it is not observable: unlike the physical world, mathematics only exists within people’s minds.

This paper presents a system that could act as a mediator between the learner and mathematics and therefore assist students visually in their mathematical knowledge and development of generalisation.

The tool follows a constructionist approach, allowing students to create shapes and expressions and see the relationships between them. The paper has presented the design of the system, describing and discussing several design issues: the need for direct manipulation; the importance of how values are presented in the system; the need for building with ‘n’ using icon-variables; and the issue of evaluating expressions.

Our aim is to foster the idea of seeing the general through the particular by construction and exploration, but also to promote a sense of ownership of the abstraction process. However, we recognise that this also depends on the activities undertaken and the educational settings in general. The paper presented how the tool has been applied to a well-known generalisation problem and discussed the added value compared to the traditional classroom-based approach. Future work will formally evaluate its effectiveness. In addition, the iterative design and development of the system and the suggested activities will continue to co-evolve. It is important to find the right balance between the degree of structure and degree of flexibility built into the learning process. While we recognise the importance of giving clear guidance and support to students to achieve the learning objectives, we also need to give them freedom to explore, experiment, enjoy, interact and arrive at their own generalisations.

Next steps in our research include exploring collaboration among learners within a classroom context and integrating intelligent support within the system to assist students and teachers in the teaching and learning of mathematical generalisation.

References

1. Mason, J., Graham, A., Johnston-Wilder, S.: Developing Thinking in Algebra. Paul Chapman Publishing, Boca Raton (2005)
2. Noss, R., Healy, L., Hoyles, C.: The construction of mathematical meanings: Connecting the visual with the symbolic. Educational Studies in Mathematics 33(2), 203–233 (1997)
3. Tall, D., Thomas, M.: Encouraging versatile thinking in algebra using the computer. Educational Studies in Mathematics 22(2), 125–147 (1991)
4. Roschelle, J., Kaput, J.: SimCalc MathWorlds: Composable components for calculus learning. Communications of the ACM 39, 97–99 (1996)
5. Kieran, C., Yerushalmy, M.: Research on the role of technological environments in algebra learning and teaching. In: Stacey, K., Shick, H.H., Kendal, M. (eds.) The Future of the Teaching and Learning of Algebra. The 12th ICMI Study. New ICMI Study Series, vol. 8, pp. 99–152. Kluwer Academic Publishers, Dordrecht (2004)
6. Hoyles, C., Healy, L.: Visual and symbolic reasoning in mathematics: Making connections with computers. Mathematical Thinking and Learning 1(1), 59–84 (1999)
7. Underwood, J., Cavendish, S., Dowling, S., Fogelman, K., Lawson, T.: Are integrated learning systems effective learning support tools? Computers and Education 26, 33–40 (1996)
8. Pelgrum, W.: Obstacles to the integration of ICT in education: results from a world-wide educational assessment. Computers and Education 37, 163–178 (2001)
9. Küchemann, D., Hoyles, C.: Investigating factors that influence students’ mathematical reasoning. PME XXV 3, 257–264 (2001)
10. Healy, L., Hoyles, C.: A study of proof conceptions in algebra. Journal for Research in Mathematics Education 31(4), 396–428 (2000)

11. Moss, J., Beatty, R.: Knowledge building in mathematics: Supporting collaborative learning in pattern problems. International Journal of Computer-Supported Collaborative Learning 1, 441–465 (2006)
12. Noss, R., Hoyles, C.: Windows on mathematical meanings: Learning cultures and computers. Kluwer, Dordrecht (1996)
13. Sutherland, R., Mason, J.: Key aspects of teaching algebra in schools. QCA, London (2005)
14. Mason, J.: Generalisation and algebra: Exploiting children's powers. In: Haggarty, L. (ed.) Aspects of Teaching Secondary Mathematics: Perspectives on Practice, pp. 105–120. Routledge Falmer and the Open University (2002)
15. Duke, R., Graham, A.: Inside the letter. Mathematics Teaching Incorporating Micromath 200, 42–45 (2007)
16. Warren, E., Cooper, T.: Generalising the pattern rule for visual growth patterns: Actions that support 8 year olds' thinking. Educational Studies in Mathematics 67, 171–185 (2008)
17. Papert, S.: Mindstorms: Children, Computers, and Powerful Ideas. Perseus Books, U.S (1993)
18. Gutiérrez, S., Mavrikis, M., Pearce, D.: A learning environment for promoting structured algebraic thinking in children. In: Int. Conf. in Advanced Learning Technologies (ICALT 2008). IEEE Computer Society Press, Los Alamitos (2008)
19. Schneiderman, I.E.: Direct manipulation: A step beyond programming languages. IEEE Computer 16, 57–69 (1983)
20. Hutchins, E.L., Hollan, J.D., Norman, D.A.: Direct manipulation interfaces. Human-Computer Interaction 1, 311–338 (1985)
21. Orey, M., Nelson, W.: Development principles for intelligent tutoring systems: Integrating cognitive theory into the development of computer-based instruction. Educational Technology Research and Development 41(1), 59–72 (1993)
22. VanLehn, K.: Student modeling. In: Polson, M., Richardson, J. (eds.) Foundations of Intelligent Tutoring Systems, pp. 55–78. Erlbaum, Hillsdale (1988)
23. Healy, L., Heltz, R., Hoyles, C., Noss, R.: Messing up. Micromath 10, 14–17 (1994)

ISiS: An Intention-Oriented Model to Help Teachers in Learning Scenarios Design

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Abstract. This paper presents ISiS model (Intentions, Strategies, interactional Situations), a conceptual framework elaborated to structure the design of learning scenarios by teachers-designers and to favour sharing and reuse practices. The framework is based on an intention-oriented approach and proposes to identify intentional, strategic, tactical and operational dimensions in a learning scenario. This paper gives an overview of research context, presents the model and how it has been elaborated in collaboration with teachers.

Keywords: technology enhanced learning, learning scenarios, goal-oriented approach, requirements engineering, authoring approach.

1 Introduction and Use Cases

Currently, a set of researches concerns Educational Modelling Languages which provide interoperable descriptions of learning activities. As noticed by IMS-LD authors [1], an EML is not intended to be directly manipulated by teachers or engineers: specific authoring systems [2, 3, 4] must be provided to allow designers to design scenarios. In this paper, we focus on the case where the teacher is the designer. In this case, it becomes necessary to provide teachers with authoring tools allowing to express their requirements by using their own vocabularies or concepts. This research is realized in collaboration between Laboratoire Informatique de Grenoble and Institut National de Recherche Pedagogique within the CAUSA project. This project closely associates teachers in charge to co-elaborate and experiment specific models and tools dedicated to assist them in scenario design by favouring share and reuse approaches.

In order to illustrate our research problem, we describe below three use cases where Paul, Judith and Simon represent teachers in French Secondary School. Use cases represent fictional situations based on the use of the models and tools we develop. In the use cases, we distinguish our conceptual framework ISiS (Intentions, Strategies, interactional Situations) from ScenEdit, the authoring environment we propose to manipulate ISiS model. ISiS and Scenedit are presented further in this paper.

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Use case 1. Paul, teacher in Physics, frequently consults a database gathering scenarios provided by colleagues, centralized and labeled by the ministry of Education. Usually, Paul finds descriptions he cannot effectively exploit: a narrative scenario describes, often in a very contextualized way, the linear progress of activities in classroom context. Even if he can isolate some relevant information, Paul finds very uneasy to understand the designer's goals and to reuse a scenario in another context. Now, Paul finds in the database a scenario described with ISiS, a formalism organizing a scenario in terms of intentions, strategies and situation patterns. This graphical formalism allows to easily understand the progress of the scenario and the underlying pedagogical choices made by the designer. Paul decides to pick up the selected scenario, to instantiate and operationalize it on Moodle LCMS. Then, Paul recommends to his colleagues Judith and Simon to consult a specific database where all scenarios are described according to ISiS formalism.

Use case 2. Judith interrogates ISiS database by detailing a set of criteria: she wants to find a scenario adopting a defined pedagogical approach (scientific investigation approach) in her domain (Physics). She doesn't obtain the wanted result, but finds a scenario in another domain (foreign languages), using the requested approach. She decides to reuse it by adapting some elements of the scenario. If she keeps the general organization of the scenario, she has to redefine her didactical intentions (related to the program in electricity) and the situation patterns which do not match with the constraints of her specific audience. For example, she replaces a situation named "moderated debate in the classroom" by another "moderated debate with a forum" because she wants to exploit the period between two lessons in classroom. She replaces also the situation "discover the subject by looking at a movie" by "discover the problem by manipulating a simulation").

Use case 3. Simon is a young innovative teacher and wants to use a recent simulation software in his classroom. Simon, who has a weak experience in teaching, uses Scenedit environment in order to create its own scenario. The environment asks him to explicit his intentions, his strategies and the situations he wants to propose to his pupils. For each level, some assistance is provided by the means of patterns he can adapt. This assistance allows Simon to check relevance of the scenario. At the end, Simon sends its scenario to Paul and Judith for validation. Paul and Judith lightly modify the scenario which will be commonly used by the three teachers.

2 Research Presentation

The previous use cases illustrate the questions we address: we aim to provide teachers with formalisms and tools satisfying the three following criteria of understandability, adaptability and appropriability.

Scenarios must be *understandable* by teachers, non specialists in learning design or in computer science. This concerns, not only the progress "step by step" of a learning unit, but also the intentions which structure the scenario. More precisely, the teacher must be able to isolate the general organization of the scenario from implementation details depending on elements of contextualization.

Scenarios must be *adaptable and instantiable*. After having understood an existing scenario, a teacher must relatively easily be able to adapt it to his own needs. The adaptations may concern either the general structure of the scenario (for example by choosing an alternative learning strategy, by substituting a situation pattern by another, etc.), or contextualisation details (for example, by selecting such or such tool or document, by defining the precise number of groups, etc.).

Finally the scenario design model must be *appropriable* in order to promote an effective authoring approach. The manipulated concepts must be adequate with the professional culture of users and assist them efficiently in design process.

In order to propose adapted formalisms and tools, CAUSA Project (2006-2008) has been organized in four phases, described in this paper. After a preliminary phase where we defined precisely the targeted audience, the first phase consisted in analyzing current uses of share and reuse of scenarios. The obtained results allowed, in a second phase, to co-elaborate with teachers an intention-oriented model: ISiS which structures the design of a scenario. In a third phase we have experimented ISiS model with a pilot group of teachers by the means of textual forms and graphical representations. After evaluation of this experiment, we currently develop a graphical tool which will be next experimented in classrooms.

Preliminary phase: definition of targeted audience

CAUSA Project is focused on teachers who are called to integrate digital technologies in the French secondary educational system. We state that these teachers gather a set of characteristics which influences models we propose. Our *teacher-designers* have a good knowledge of the knowledge domain to be taught and can be considered in a certain way as domain-specialists. They have followed a specific training to master didactical competencies (how insure appropriation of domain-specific knowledge for targeted audiences?) and pedagogical competencies (how to organize or regulate efficient learning situations?). They do not benefit of a deep training in computer science; however, they are supposed to master a certain range of basic competencies defined by a national certification. They are generally not assisted by technical specialists in charge of implementation. They have to use existing models, methods or tools in order to develop effective learning solutions, generally in a short time compatible with his job. They may belong to a teachers' community of practice, whose emergence is made easier by Internet, and which allows new possibilities of sharing and reuse between practitioners.

From these characteristics, we have constituted a pilot group of five teachers, implied in the integration of digital technologies in a set of various domains (history, economical sciences, German, English, technology). This group has been closely associated to the phases 1 and 2 described below.

Phase 1: Analyzing current uses of database

In this phase, we asked [5] the pilot group to find and analyse web resources that can be qualified as "learning scenarios". Their goal was to be able to reuse and integrate them in their own domains. The first given task was to analyse search strategies provided by various scenarios databases and to evaluate the relevance of obtained results. The second task was to make a synthesis and a set of suggestions which could improve design process. A set of common findings and proposals have been formulated whereas it is possible to observe some differences by domain.

First, there is a strong heterogeneity of terminology concerning scenarios between disciplines and even within a discipline. The terms (scenario, phase, activity, session, play, act, competence, know-how, theme, etc.) are rarely clearly defined and often complexify appropriation of scenarios developed by others or in other domains. This finding underlines the importance to dispose of a corpus of better defined concepts to generalize real practices of mutualization.

Secondly, some scenario descriptions do not refer to domain concepts such as studied knowledge or programs. This lack makes it difficult to find relevant scenarios in a specific subject matter, and to identify the designer's intentions which aim most frequently to solve issues related to learn some particular knowledge or acquire some particular competence or know-how.

Then, for a given scenario, the pedagogical strategy is not often clarified (for example, the choice between an expositive approach and a more participative approach like problem solving). This lack of elicitation requires a very precise analysis of the scenario to stand out the strategy or approach which could be an important criterion of choice.

Finally, asked teachers suggest that design task could be facilitated by providing libraries of typical strategies, scenarios, or situations of various granularities. Each of these components could be illustrated by concrete reproducible examples.

Moreover, these proposals put forward the need to assist the teacher-designer by providing him assistance mechanisms during the elaboration of scenarios.

Phase 2: Co-elaboration of an intention-oriented model

From those results, we elaborate during brainstorming sessions with teachers a proposition of conceptual model. ISiS model (Intentions, Strategies, interactional Situations) is the result of this phase and can be linked to recent researches about Goal Oriented Approach [6]. It is based on four complementary principles: understanding, design, adaptation and exchange of learning scenarios must be facilitated by:

1. Elicitation of context, particularly by distinguishing the knowledge context from the situational context of a learning unit;
2. Elicitation of intentional, strategic, tactical and operational dimensions;
3. Use of intermediary objects, interactional situations or situation patterns, that allows a more efficient articulation between intentional and operational levels;
4. Reuse of existing scenarios, components or design patterns which allows teachers to design more efficiently his scenarios.

According to ISiS model [7], organization and progress of a learning unit can be described with a high-level scenario, called structuring scenario. This scenario organizes a set of interactional situations or "situation patterns" that can themselves be described by more low-level scenarios: an interactional scenario defines the precise organization of situations in terms of activities, interactions, roles, tools, services, provided or produced resources, etc. The interactional scenarios are the level typically illustrated with EML examples of implementation.

The structuring scenario, which reflects designer's intentional and strategic dimensions, organizes the scenario in phases or cases. An item (strategy, phase or case) can be linked to an interactional situation selected for its ability to handle different constraints inherent to knowledge or situational contexts.

Phase 3: First experimentation of the model

The first tools based on ISiS model have been experimented in secondary school by a "community of practice" of five others teachers in technological disciplines. Each teacher had one month to model a learning sequence that he must implement during the school year, by using a set of provided forms and graphical representations. All teachers accomplished the required task in prescribed time, and the different produced sequences had a duration varying between two and six hours. Moreover, one teacher has covered the complete process by describing its scenario with paper forms, encoding the designed scenario with LAMS editor, implementing the result automatically towards Moodle, a learning management system and testing the scenario with its pupils. After these first experimentations, the teachers were questioned about their design activity. The following points can be raised:

- At the beginning, it is considered as uneasy to describe intentions and strategies associated to a learning sequence. In the business context, this type of task is currently very implicit and the elicitation represents a real effort;
- However, after several tries and interactions within the group, each teacher has been able to model the sequence he wanted to implement;
- At the end of experimentation, elicitation of intentions and strategies has been positively appreciated. Particularly, this elicitation allowed underlining some incoherencies in current practices of teachers: several regularly proposed activities have been judged as useless or non-essential;
- Elicitation of intentions and strategies allows a teacher-designer to better understand a scenario created by a peer;
- The need to define a scenario in terms of "situation patterns" also questioned about current practices. That has led some teachers to design innovative situations, using for example mobile devices within the classroom. According to teachers, those situations could not be imagined without ISiS framework;
- Teachers expressed the need to provide reusable components allowing to decrease significantly the design duration and to explore solutions, proposed by peers, able to suggest a renewal of practices;
- The complete implementation on a LMS done by one of the teacher has been considered easier by the use of ISiS model;
- Provided tools (paper forms and mind mapping tool) have been considered as too costly to be integrated in a regular professional use.

These first results show the abilities of ISiS model to encourage an efficient authoring approach. The main restriction formulated by users consists in providing adapted graphical tools.

Phase 4: Development of a dedicated authoring tool

To solve this limitation, we currently develop a specific graphical authoring environment, named ScenEdit, which proposes different workspaces to edit a structuring scenario. The principle of this environment is to provide the designer with workspaces where he can specify components (intentions, strategies, situations patterns) in order to organize them in a central one representing the structuring scenario, according a spatial metaphor. The environment may allow also to feed databases by exporting components and fragments of the created scenario, in order to reuse them further in close or in different contexts.

3 Conclusion

In this paper, we have presented an overview of ISiS Model, an "intention-oriented model" which assists teachers in the design of learning scenarios and favours share and reuse. The model, co-elaborated with panel of users, seems to be efficient, according to first experimentations which have shown the benefits of the model (a) to illustrate the importance of elicitation of intentions and strategies by users, (b) to better understand the scenarios created by others and (c) to simplify the design process by reducing distance between users requirements and implemented systems.

The first version of ScenEdit, the dedicated authoring environment we developed from our conceptual model is under experimentation. This experimentation essentially aims to validate the visual representation of a scenario we propose and to enrich the system with patterns or components allowing effective practices of sharing and reuse.

References

1. Koper, R., Tattersall, C.: Learning Design: A Handbook on Modelling and Delivering Networked Education and Training. Springer, Heidelberg (2005)
2. Koper, R.: Current Research in Learning Design. Educational Technology & Society 9(1), 13–22 (2006)
3. Botturi, L., Cantoni, L., Lepori, B., Tardini, S.: Fast Prototyping as a Communication Catalyst for E-Learning Design: Making the Transition to E-Learning: Strategies and Issues. In: Hershey, M.B., Janes, D. (eds.) (2006)
4. Murray, T., Blessing, S.: Authoring Tools for Advanced Technology Learning Environment, Toward Cost-Effective Adaptive, Interactive and Intelligent Educational Software. In: Ainsworth, S. (ed.), p. 571. Kluwer Academic Publishers, Dordrecht (2003)
5. Emin, V., Pernin, J.-P., Prieur, M., Sanchez, E.: Stratégies d'élaboration, de réutilisation et d'indexation de scénarios. In: actes du colloque SCENARIO 2007, Montréal, pp. 25–32 (2007)
6. Rolland, C.: Capturing System Intentionality with Maps, Conceptual Modelling in Information Systems Engineering, pp. 141–158. Springer, Berlin (2007)
7. Pernin, J.P., Emin, V., Guéraud, V.: Intégration de la dimension utilisateur dans la conception, l'exploitation et l'adaptation de systèmes pour l'apprentissage, Actes atelier PeCUSI. In: INFORSID conference, 2008, Fontainebleau, pp. 15–27 (2008)

Open Educational Resources: Inquiring into Author Reuse Behaviors

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Abstract. For teachers and learners, the proliferation of open educational resources (OER) in combination with advances in information technologies has meant centralized access to materials and the possibility of creating, using, and reusing OER globally, collaboratively, and across multiple disciplines. Through an examination of a community of author users of the OER portal Connexions, this article explores OER reuse behaviors and factors contributing to and hindering those behaviors. As such, the article sheds light on how OER can be sustained and continuously improved, with an emphasis on the reuse of dynamic, relevant, and high quality materials over time.

Keywords: open educational resources, OER, reuse, Connexions, log file analysis.

1 Introduction

Open educational resources (OER) have gained increased attention for their potential to obviate demographic, economic, and geographic educational boundaries—in short, for their ability to serve as an equitable and accessible alternative to the rising costs and increased commercialization and privatization of education (Ishii & Lutterbeck, 2001). Pushed along by early initiatives such as the Massachusetts Institute of Technology's open courseware collection and by advocacy for other institutions and organizations to follow suit, the Internet now is home to numerous repositories and aggregators, all offering freely available open educational resources. For educators and students, the proliferation of OER has meant centralized access to materials that meet unique teaching and learning needs, and the possibility of collaborating with peers to create, use and reuse OER globally and across multiple disciplines.

But the question remains as to how much and in what ways the promise and potential of OER is being realized. As evidenced by the open source software movement, the sustainability of open, peer-driven models is contingent upon continuous user contribution, collaboration, open exchange, and ongoing modification of content (Benkler, 2005). However, recent research into the use of OER has indicated that while educators and learners are accessing OER materials (Massachusetts Institute of Technology, 2006; Harley et al., 2005; Hylén, 2006), the sharing of one's own OER

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and the reuse or modification of those materials less expansive (Collis & Strijker, 2003; Harley et al., 2006; Petrides et al., 2008). Few of these studies, however, have empirically addressed author use and reuse, and therefore, our understanding of the extent to which it occurs and the incentives and factors supporting it are limited.

In an effort to build on existing studies and address issues of OER reuse, this paper examines how and to what extent OER are adapted, augmented, and "remixed" by a community of OER users. Specifically, through an examination of those who have created open education materials within the repository called Connexions (www.cnx.org), this study explores the extent and nature of reuse practices, or those practices that involve remixing or adaptation of OER for new and/or local purposes. In doing so, the study seeks to shed light on how OER collections and repositories can create a user-driven infrastructure that supports the continuous addition and modification of content and which in turn can help in the effort to create ongoing advancements in the creation of materials that are freely available.

2 Literature

Open educational resources (OER) are defined as web-based materials that are free and open for use and reuse in teaching, learning and research (UNESCO, 2006). Examples of OER include course materials such as syllabi, lecture notes, and educational games; primary and secondary research materials such as historical documents and reports; and pedagogical tools for creating lesson plans, worksheets and exercises. With roots in the open source software movement, where users continuously review, critique and develop openly available source code, OER serves to facilitate—through accessible technology and alternative licensing—a community of users who collaborate, discuss, critique, use, reuse and improve educational content. Thus, for educators and students, OER translates into centralized access to materials to supplement their local teaching and learning needs, as well as the possibility of sharing materials, collaborating to improve upon existing materials, and creating new OER globally and across disciplines (Petrides & Jimes, 2006).

Recent research into OER use and reuse has provided evidence that some of this promise and potential is in fact being realized. In a survey of 452 college instructors, Petrides et al. (2008)[1] found that 92 percent had searched for course-related materials on the Internet. Reasons cited by the participants included their desire to integrate new materials into their courses, to improve their teaching methods and knowledge, and to connect with colleagues who have similar teaching interests. Likewise, MIT's recent evaluation report of its OpenCourseWare (OCW) collection revealed that educators are accessing OER to support their course planning and preparation and to enhance their personal knowledge (Massachusetts Institute of Technology, 2006). Ninety-six percent of these educators indicated that MIT's OCW collection has improved or will help to improve their courses.

Additional research has indicated that while educators are accessing and using OER materials, the reuse of others' is less expansive (Collis & Strijker, 2003; Harley et al.,

[1] This study is titled "An Instructor Perspective on Online Teaching and Learning in Developmental Education," and is pending review.

2006; Petrides et al., 2008). A key concern around the reuse of other's OER materials appears to be the viability of OER as related to issues of contextualization. Specifically, it has been noted that highly de-contextualized OER are reusable in the greatest number of learning situations, but this means that they can be the most expensive and difficult to reuse, localize, and personalize. This is because such resources, by nature of their high level of granularity, are devoid of the context that may be needed to make them comprehensible on their own (Wiley, 1999; Calverley & Shephard, 2003). For example, a visual representation of a particular social science theory created in English with accompanying labels and text may be reusable for instructors in English classrooms, but may not be for those who instruct, e.g., within purely Russian-language classrooms. Removing the contextual labels and accompanying text allows the visual to be reused by multiple instructors who wish to add foreign language labels and context; however, it may also render the visual representation incomprehensible. Given that ease of incorporation into instructional activities has been identified as a central facilitator of reuse (Recker, Dorward, & Nelson, 2004), the ability to contextualize OER across various teaching and learning situations becomes central.

Perhaps a more challenging barrier to reuse cited within the literature, however, stems from the proprietary, hierarchical nature of educational content. That is, given the educational context, wherein individual proprietary knowledge is incorporated into classroom instruction (Collis & Strijker, 2004), and where the roles of professors, teachers, administrators, and students are distinct and embedded, users may lack the confidence, capacity, or willingness to contribute changes to OER. In short, such an environment, in serving as the backdrop to OER creation, brings with it assumptions and structures that can hinder OER reuse.

Despite the emergence of literature that has begun to address central obstacles and issues of OER reuse, several gaps remain. That is, while studies reveal how OER content is being used, we still know little about how users are reusing, adapting, remixing and modifying content, and what potentially motivates those behaviors. Given the emergence of OER repositories and aggregators that support the re-contextualization of OER, the time is ripe to further address issues of author reuse, the focal point of this paper.

3 Methodology and Source of Data

This paper is part of a larger study that sought to explore use, reuse and collaborative authorship of OER. As part of the selection process for the larger study, over one dozen open education collections and repositories were examined—from subject-specific university collections to cross-disciplinary open content repositories. Selection criteria included the amount and type of content that comprised the collection or repository, the user groups that it targeted (instructors, students, and self-learners), and the features and functions it offered. As the focus of the larger study was on use, reuse, and collaborative content creation, the criteria for selection were that the source be a robust collection or repository that emphasized instructor use and that it enabled users to create, augment and remix content individually and in groups within an online environment. Another central criterion was whether the collection or repository tracked user behaviors and actions by way of log files[2]—as this would facilitate an analysis of use practices over time.

The collection/repository that best met the selection criteria was Connexions (CNX). The reason for choosing the CNX repository, which includes a range of both small and large chunks of scholarly content spanning multiple subjects in K-12, higher education, self-learner and professional needs alike, was the following: First, in operating as a multi-functional OER repository platform, it encompassed a wide range of possible user activities from searching and viewing content, to creating, augmenting and publishing OER.

Additionally, and perhaps most importantly for the paper at hand and its focus on reuse behaviors, CNX was chosen because it actively tracks and archives user behaviors through log files, and its management was willing to share these files for the purpose of the study. These files included several types of data, such as if a piece of content had been augmented or published, the date that this occurred, and whether or not a piece of content originated from a pre-existing item within the system. The log files also provided reuse data by way of an open-ended field within the CNX system in which users could report how and why they had augmented, remixed, or otherwise changed a piece of existing content, as well as their perceptions of and experiences with the technical functions that facilitated their reuse activities.

The study of OER reuse within the CNX environment occurred by way of the log file analysis, as well as interviews with a selection of CNX users. CNX log file data were analyzed from the period of April 2000 to July 2005[3]. Examination of these data—in the form of frequencies and qualitative analyses—allowed for the quantification and qualification of OER reuse behaviors and provided insight into the factors that support and hinder OER reuse. Also, because CNX allows users to enter comments about why they augmented and published OER content, these data allowed for the analysis of the reasons for modifying content, and user perceptions of that process.

Because the focus of this study is to better understand aspects of behaviors that center around content modification and reuse, the analysis was confined to CNX users who have created, augmented and contributed OER content to CNX. These users are referred to in this study as “author users.” Thus, users who simply search, access, view and download content were not included in the study.

After the log file analysis was completed, eleven follow-up phone interviews were conducted in order to contextualize the findings from the log file analysis from the perspective of specific CNX author users. For this paper, the interviews were analyzed through the lens of understanding obstacles to and incentives for content reuse. The interviewees were originally selected based upon the frequency and type of CNX activities that they participated in—the objective being to have a diverse mix of participants with varying levels of use and types of activities. The questions posed to the eleven participants centered on why they chose to use CNX, their typical activities within CNX, and their prior experiences with creating and using OER. Thus, while the quantitative data

[2] In general, log files can be used to record and study user behaviors, including how users navigate through a site, what they click on, and what specific actions they take.

[3] This date range represents the month and year of CNX inception (April 2000) to the month and year that the data collection was completed (July 2005).

provided insight into reuse practices, the interviews conducted with the selection of CNX author users added depth to these findings by delving into the why and how behind reuse practices, as well as into the discontinuation of reuse behaviors by some users.

The findings below are categorized as follows: 1) the extent to which OER is being modified, or reused, within the CNX system, 2) the nature of reuse, and 3) incentives and disincentives to reuse. It is important to note that this study does not attempt to provide a comprehensive assessment of OER reuse; instead it aims to explore some of the ways a particular community of OER authors—i.e., 247 authors participating in the CNX community from April 2000 to July 2005—create, work with, and collaborate around open educational resources.

4 Findings

4.1 Amount of Reuse

CNX author users create content individually and in groups. When creating content individually, author users work within their online private work areas, and the content created and augmented in these areas is only visible to others when published at the author's discretion. To work on content collaboratively, author users can create an online shared workgroup around content and invite other author users to join, or conversely, they can become a member of a pre-existing workgroup through invitation by that workgroup's members.

All content within CNX is organized into modules, and multiple modules can be grouped to form courses. All modules potentially undergo a series of iterations as users edit and modify them, which creates versions. Table 1 shows the number of new modules created each year and the corresponding quantity of versions.[4] As can be seen, the collection grew from 199 modules in 2000 to 2,514 modules in 2005. Concomitantly, the number of versions grew from 199 in 2000 to a total of 12,993 in 2005. Expressed as average yearly growth, the modules grew at a compounded annual rate of 76 percent, and the versions at an annual rate of 153 percent.[5] The figures thus reveal growth in both the creation of original modules or content that is remixed or broken down into new modules, and in the reuse and augmentation of those modules by way of versions.

A calculation of the ratio of versions to modules shows that on average, authors created four versions per module. However, some author users were more active reusers than others: the maximum number of versions published by a single author user was 94 and the minimum was one.[6] The discussion below turns to the types of reuse

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[4] Upon the creation of an original module, the CNX system assigns the module two numerical IDs: a module identification number and a version identification number. As users create versions of the original module, additional version ids are assigned. Table 2 was created from the counts of total module and version ids within the CNX system. This explains why in 2000 there were 199 modules and also 199 versions—for author users during this first year did not create additional versions of their original modules.

[5] Content growth calculations were based upon the entire period of analysis, from April 2000 to July 2005, in order to incorporate the version and module totals.

[6] The maximum number of versions published excludes 14 extreme cases, which were defined as cases where a single author user published more than 94 versions or modules.

Table 1. Number of modules and versions created by year

Year	Modules	Versions
2000 (from 4/2000)	199	199
2001	292	2,937
2002	389	3,050
2003	692	3,107
2004	692	2,502
2005 (to 7/14/05)	250	1,198
Total	2,514	12,993

behaviors that surfaced through the analysis, and subsequently to the factors contributing to the presence of those behaviors.

4.2 Author Reuse Behaviors

As part of CNX's version and module submission process, authors were asked to provide an open-ended reason (or reasons) for why they were publishing the content.[7] There were a total of 14,429 reasons[8] provided by the author users. For the analysis that follows, 3,174 reasons that were related to new versions were not included, that is, first time publishing activities or reasons related to the testing of the CNX publishing function. The remaining 11,255 reasons were related to reuse activities—that is, activities that involve the remixing or adaptation of content for new and/or local purposes. From these data, we examined the nature of reuse activities and the extent to which they occurred. After addressing the categories of reuse behaviors that surfaced from the analysis of the reasons, we conclude with a discussion of the extent to which the behaviors were conducted by authors who reused others' content.

4.3 Types of Author Reuse

In examining the reasons that authors provided for changing content, the analysis revealed seven main categories of author reuse: 1) visual and technical changes, 2) general editing, 3) collaboration-related changes, 4) metadata changes, 5) modularization, 6) language translations, and 7) other miscellaneous reuse behaviors. Table 2 below provides an overview of the extent to which these behaviors occurred.

As displayed in the table, the creation of new versions through visual and technical changes to content surfaced as the most prevalent author reuse behavior. This category of reuse encompassed 51 percent of the reasons for augmenting or changing versions. It included uploading visual files (graphics, figures, tables, etc.) and changing and improving content layout and display. The latter of these entailed fixing bugs and editing or writing display code in cases where users were technically proficient enough to do so.

[7] This was not a required field.

[8] Some versions had more than one reason attached, which is why the number of reasons (14,429) is greater than the total number of versions (12,993). Author users did not provide reasons for 295 of the new versions created.

Table 2. Type and quantification of reuse behaviors

Type of Reuse	Number of Reuse Reasons (%)
Visual and technical changes	5,694 (51%)
General editing	2,657 (24%)
Collaboration-related changes	1,201 (11%)
Metadata changes	880 (8%)
Modularization	100 (1%)
Language translations	91 (1%)
Miscellaneous reuse behaviors	632 (6%)
Total	11,255 (100%)

A second category of author reuse behaviors was general editing of content, which accounted for 24 percent of the reasons for augmenting or changing versions. It included correcting typos, spelling, punctuation, and grammar, refining and rewriting text, and revising versions from the bottom up. It also included updating out-of-date portions of content, and adding or removing content sections.[9]

Furthermore, 11 percent of the reasons for version changes were attributed to workgroup collaboration activities. Examples of this category of reuse include making changes requested by a group member or the primary author, accepting edits from a group member, and modifying a group member's role.

Eight percent of the reasons for version changes were attributed to metadata changes. Metadata changes included cases where author users added, deleted or modified the version title, abstract, and/or keywords. Metadata changes also occurred when author users corrected typos in author names or in other metadata components.

Modularization encompassed activities in which author users separated modules into smaller units or combined or remixed various sub-units to form entirely new modules. Although only 1 percent (100) of the reasons fell into this category of reuse by author users[10], it is noted here due to the fact that it diverges from the other behaviors. The analysis revealed that breaking existing modules into smaller units to create several new modules was a prevalent type of modularization (69 of the 100 reasons in this category). To a lesser degree, modularization encompassed activities wherein author users combined pre-existing modules to form larger modules or courses (27 of the reasons) or where authors redistributed and passed content from one pre-existing module to another (4 of the reasons).

A final category of reuse behavior was language translation, which was cited for only 1 percent of the reasons for version changes. Language translations occurred in the form of author users posting, for example, a Spanish version of an existing module or changing a module title to include Japanese fonts.

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[9] The interviews with a selection of author users allowed for additional insight into the reasons behind general editing activities. Several of the instructors were said to use CNX as a distribution tool for their offline courses—i.e., as tool to help distribute information to their students, including course schedules, syllabi, and course content. As the courses progressed throughout the term, these instructors made changes to their materials held in the CNX repository.

[10] While authors create new derivative modules based on previously existing modules, they do not have to formally attribute the original content to the original author. This prevents a complete understanding of the extent to which modularization occurred.

Additional, miscellaneous author behaviors surfaced in the analysis that included changes to personal contact information (email addresses) and cases where author users indicated fixes or changes they would like to make in the future. This category of author behaviors combined accounted for 6 percent of the reasons for version changes.

4.4 Reuse of Others' Content

Due to the ability to create "derived" modules without attributing the original author, we were able to identify only 80 modules with their original authors. An analysis of these 80 derived modules revealed that 88 percent (70) of them involved author users manipulating their own content. The remaining 12 percent (10) of the derived modules were published by authors who were not the original authors. This suggests a hesitancy to reuse others' content, especially with regard to modularization activities.

For versions, however, reuse of other's content was more likely. The log files contained authorship documentation on 7,016 versions, of which 3,578 (57 percent) were published by individuals who were not the original author (nor were they part of the original author's workgroup).

4.5 Incentives and Disincentives for Reuse

Beyond providing an indication of how and why authors augmented content, the reasons analysis provided an indication of author users' perceptions about the process of publishing versions and modules. Specifically, 149 author users submitted comments about the user-friendliness of the CNX publishing process or about the structure and role assignation process of the shared workspaces. Examining these comments facilitated, to some degree, an understanding of the incentives and disincentives to reuse.

First, the interviews with a selection of users revealed technical barriers that prevented members' ability to augment content. The technical barriers were said to stem from coding and markup errors or to the lack of technical skills on behalf of the author users. Some of the less technically skilled members emphasized technical barriers as an overall disincentive to OER reuse, as the CNX site represented a "steep learning curve" and was said to be too time consuming.

Conversely, other users cited—within the interviews—their technological know-how and prior experience publishing online content as facilitators of their continued reuse. Examination of the author comments in the reasons analysis included examples of successfully expedited edits and technical changes, and revealed exclamations such as "Done!" and "Eureka! I got one of the equations to work!" Occasionally, author users expressed excitement and provided a brief explanation of how to execute a particular action—for example, "Yay! .png will look fine if you double the resolution instead of changing height/width".

Another incentive mentioned by author users was that it enhanced their professional lives, which helped to create a continuous need for re-using content. That is, consistent users explained that as teaching professionals they had a heightened need for timely content for their students and colleagues. Interestingly, however, other users—some of whom were also teachers—identified the lack of relevant content on CNX as a disincentive to reuse.

5 Discussion and Conclusions

Through the coalescence of technology, organizational capital, goodwill, and individual drive, the burgeoning open educational content movement has the potential to bring about a paradigm shift in content creation by way of expanding access to and active participation in the development of educational resources for teachers across the globe and in hard-to-reach locations. However, realizing this shift necessitates an understanding of how we can move beyond existing challenges—for while new developments in OER have surfaced, more research and discussion must be enacted to address use and reuse sustainability.

In extrapolating the CNX findings to the wider OER context, this study reveals that the creation and reuse of OER, while still a nascent phenomenon, has developed and grown. This study reveals that users are creating and reusing an increasing amount of content, as the data showed that modules and versions grew at an annual percentage rate of 76 percent and 153 percent, respectively. Interestingly, as the growth of versions has been faster than that of modules, author users are reusing existing content to a greater extent than they are creating new content.

In examining reuse behaviors, the data provides an indication that reuse of content involving, e.g., general editing and visual changes is more likely to occur than more the expansive reuse activities such as remixing and new module creation. However, the mere presence of modularization as an author user behavior suggests that flexibility, adaptability, and interchangeability of content are in fact promising facilitators of new OER creation. That is, users are breaking apart, combining, and redistributing portions of existing content to form entirely new OER when given the tools, capability, and technological know how to do so. The next potential step is to inspire more of this behavior, and to facilitate the process of modularizing content outside of their own author groups.

Therefore, while this study shows that OER reuse is present and growing, there is still a limited understanding of how to move beyond some of the encumbrances—specifically with regard to reusing others' content as well as more complex reuse behaviors that lead to new configurations of existing content. Additionally, future research might explore the characteristics of resources that make them conducive to reuse—i.e., what is it about a given resource that invites users to edit, augment, and remix it?

Understandings such as these are necessary in order to create the critical mass of content that is needed to support the vision of equitable education, and to inspire a culture of continuous improvement in OER so that we can in turn truly move toward improved teaching and learning. Importantly, however, such research will require widespread access to OER user data, so that more generalizable conclusions can be made. Specifically, understanding OER author use and reuse requires looking at detailed and comprehensive data for many more collections and repositories—and log files are one important and fruitful means of obtaining such data. Additionally, log files and in-depth interview data around author users' reasons for augmenting and changing content could serve to inform meaningful categories of author reuse. However, in attempting to provide data, repository owners and collections may consider finding ways to encourage users to document their activities and the reasons for them more concretely. Thus, beyond facilitating group authorship, cross-disciplinary collaboration, and enhanced support for new, non-vanguard users, this study calls for the creators of OER repositories and aggregators to collect such data, and in the name of openness and OER sustainability on a global level, to share them.

References

1. Benkler, Y.: Common Wisdom: Peer Production of Educational Materials. COSL Press, Utah State University, Utah (2005), http://www.benkler.org/Common_Wisdom.pdf
2. Calverley, G., Shephard, K.: Assisting the Uptake of On-line Resources: Why Good Learning Resources Are Not Enough. Computers & Education 41, 205–224 (2003)
3. Collis, B., Strijker, A.: Technology and Human Issues in Reusing Learning Objects. Journal of Interactive Media in Education 4 (2004), http://www-jime.open.ac.uk/2004/4/collis-2004-4.pdf
4. Nasatir, D., Henke, J., Lawrence, S., Miller, I., Perciali, I., Nasatir, D.: Use and Users of Digital Resources: A Focus on Undergraduate Education in the Humanities and Social Sciences. Center for Studies in Higher Education, UC Berkeley, Berkeley (2006), http://cshe.berkeley.edu/research/digitalresourcestudy/report/digitalresourcestudy_final_report_text.pdf
5. Hylén, Jan: Open Educational Resources: Opportunities and Challenges. OECD's Centre for Educational Research and Innovation, Paris, France (2006), http://www.oecd.org/dataoecd/5/47/37351085.pdf
6. Ishii, K. and Lutterbeck, B.: Unexploited Resources of Online Education for Democracy – Why the Future Should Belong to OpenCourseWare. First Monday 6(11) (2001), http://www.firstmonday.org/issues/issue6_11/ishii/
7. Massachusetts Institute of Technology 2005 Program Evaluation Findings Report (2006), http://ocw.mit.edu/ans7870/global/05_Prog_Eval_Report_Final.pdf
8. Petrides, L., Jimes, C.: Open Educational Resources: Toward a New Educational Paradigm. Journal Insight into Student Services (14) (October 2006), http://www.ijournal.us/issue_14/ij_14_04_articleframe_Petrides_Jimes.html
9. Petrides, L., Karaglani, A., Jimes, C., and Mindnich, J.: An Instructor Perspective on Online Teaching and Learning in Developmental Education (2008, review pending)
10. Recker, M., Dorward, J., Nelson, L.M.: Discovery and Use of Online Learning Resources: Case Study Findings. Educational Technology & Society 7(2), 93–104 (2004)
11. Wiley, D.A.: Learning Objects and the New CAI: So What Do I Do With a Learning Object? (1999), http://wiley.ed.usu.edu/docs/instruct-arch.pdf
12. UNESCO: Open Educational Resources: Deliberations of a Community of Interest. ICDE SCOP, Lillehammer, Norway, June 11-13 (2006)

No Guru, No Method, No Teacher: Self-classification and Self-modelling of E-Learning Communities

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Abstract. Learning processes are an infinite chain of knowledge transformation initiated by human collaboration. Our intention is to analyze E-Learning commu-nities. The current drawback of communities is a lack of common vocabularies that can be used for an E-Learning community description, design, evolution, and comparison. We examine structural and semantic parameters of E-Learning communities gathered in MediaBase of the PROLEARN Network of Excellence for professional learning. Using the parameters and the community-of-practice theory we define more standard description for a particular community or a set of communities and to identify factors that are essential for identifying overlappings between communities.

1 Introduction

While the institutional context for formal learning is still dominant and supported by the European Community, e.g. in the Bologna process, the importance of self-regulated and life-long learning is becoming more and more important for a growing number of knowl-edge workers and people with continuing training needs. Different educational roadmaps like the PROLEARN Roadmap for Technology Enhanced Professional Learning [22] or the Open Educational Practices and Resources (OLCOS 2012) Roadmap [17]. The latter is supported by national programs like the German "New Media in continuing education" [16] and "Web 2.0 in continuing education" [1]. The roadmaps identify the needs of those working in demanding professional businesses where the half-life of knowledge is very short. In the future we have to learn during work time, we have to do it on-line, we have to choose our learning materials and our learning partners by ourselves and we have to re-mix them, thus becoming not only learners but also learning content authors and even teachers. We will need new competences and meta-competences for life-long learning and we will acquire it under constant external market pressures and the forces of globalization. Does not sound like a happy future for learners! On the contrary, today, we have the unique opportunity to choose learning materials from an almost unrestricted pool of resources and to choose learning partners from the many people available on the net. Learning visionaries like John Seely Brown and Richard P. Adler [6] have already transferred the concept of the long tail [2] to the realm of technology enhanced learning to make this point. We are not bound anymore to formal learning contexts like schools and universities but can

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expand our human skills in any direction at any age. While both views, the life-long learning pressure and the bright future of unlimited learning have their own truth, we think the right way is somewhere in the middle.

Even in the long tail with its millions of learning opportunities the success of learning will not only depend on the intellectual capital of learners but also on their social capital [5,8]. Social capital can be defined as the "stock of active connections among people: the trust, mutual understanding, and shared values and behavior that bind the members of human networks and communities and make cooperative action possible. (...) Its char- acteristic elements and indicators include high levels of trust, robust personal networks and vibrant communities, shared understandings, and a sense of equitable participation in a joint enterprise - all things that draw individuals together into a group" [8, 4].

In this paper we will undertake a journey into the long tail of learning, investigate how learning communities are structured and what they are trying to learn. Our approach is analytical, as we study data sets collected from different sources in the PROLEARN Academy MediaBase (www.prolearn-academy.org). We combine different analysis methods in a new structural-semantic way. One fine day, we want those methods in the hands of the learning communities. Our approach is constructive. We create tools for learning communities. Our approach is reflective. We want the learning communities to make their needs, their mutual dependencies, their cooperative action more explicit by modelling them on a strategic level. In the end, there are millions of learning com- munities out there in the long tail, every community is unique in all the components described. But our research goal is not only to allow communities a better understand- ing what they are actual doing in their learning niches but also to enable them to find similar communities to exchange ideas, methods and knowledge. Imagine two up to now disconnected communities about poetry from England in the Middle Ages, one in Scandinavia one in Latin America. Can they find each other? And was does it mean for them? For professional communities there will be still the need to match learning goals and acquired competences with profiles of their current or future employees. A lengthy discussion in the media about unwanted traces left in social networking sites affecting future employability of people can be turned into the systematic care of one's portfolio for better employability.

The rest of the paper is organized as follows. In the next section we introduce the basic concepts of our approach. In Sections 3 and 4 we demonstrate the technical means for self-observing and self-modelling E-Learning communities. In Section 5 we give first results from the application of our approach while a discussion and an outlook is concluding our paper.

2 Modelling E-Learning Communities as Communities of Practice

E-Learning communities can be examined as a Community of Practice (CoP) [37], a community of interest (CoI) or both. The most significant difference of a community representation is that for a CoP learning is proceeding from one domain instead of a CoI that defines learning as a process within different domains. Empirical experiences from [13] show how risky it is to study and to manage learning communities modeled by a simple CoI.

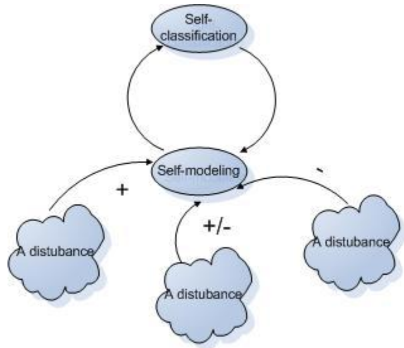

Fig. 1. The lifelong loop

"Communities of practice are groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly" [37].The understanding of communities from a dynamic perspective is essential, because the perspective facilitates reasoning about real objects such as complex dynamic systems that evolve over time. We consider the process of communities evolvement in a lifelong loop that includes three components: self-modelling, self-classification and disturbances as presented in Figure 1. Communities are influenced by various external factors called disturbances. The self-classification of the community is divided into two parts: the measurement and the analysis phase. The first defines a set of properties that characterizes community structures and semantics and that includes cross-media analysis. The output of the measurement phase is used in the second, the analysis phase, to build hierarchies or clusters of communities and to identify patterns. The patterns are generally repeatable solutions to commonly-occurring problems, i.e. disturbances [24]. In the self-modelling component of the loop the previously described calculations and conclusions are used so that modells can be created. As a matter of course the disturbances coming from outside change the community inside. That is the reason to re-classify and re-model communities in the lifelong loop in order to get the correct actual information about the communities. A CoP is characterized by three dimensions introduced by Wenger [37]:

- **Mutual engagement**
  Community members are engaged in interaction within a community. Nevertheless, a membership in a community is not just a belonging to one organization; a CoP is not only a set of members having personal contacts with other members.
- **Joint enterprises**
  Members of a CoP should negotiate communally and the CoP mediate those negoti- ations. These communally negotiations result in the intention that the members have. The intention is supported by different technologies, policies and rules explored by the CoP.
- **Shared repertoire**
  The repertoire consists of words, tools, ways of doing things, actions and concepts that a CoP has produced.

For applying CoP concepts to E-Learning communities we need a theory that tries to explain social order through relations between human agents, technologies and objects. The applicable theory should model the co-working of different dimensions of a CoP, i.e. mutual engagement(ME), joint enterprises(JE) and shared repertoire(SR) that are presented not only by humans but also by non-humans actors. The actor-network-theory (ANT) [28] doesn't distinguish between human and non-human actors and examines the networks formed by humans in collaboration with media [9]. Such an non-differenciation between people and technologies intertwines actions, influences, or results of actions. Any social action performed using technologies is influenced by these. The type of media we are using for any task affects our behavior and our position in a society.

We choosed the i* framework for notating E-Learning modells. The framework stands out for opportunities to describe relations between actors in frames of a particular social system in a clear way. An i* model focuses on motives, interests, and options of an actor that plays a role in the examined system. Such modelling is appropriate for a community representation because it reflects social characteristics of system construction [38]. The framework gives an opportunity to visualize dependencies (described as ME for a CoP) and goals (JE in the CoP). Further with the help of the model we are going to follow the intentions within the communities in order to identify the users with particular behaviors, i.e. experts, novices, etc.

Our view of an E-learning community system is a system with three CoP dimensions in Figure 2:

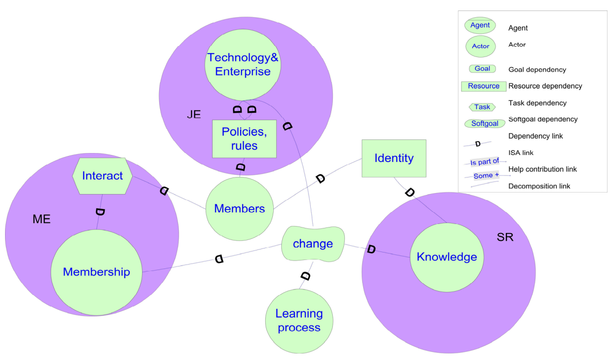

Fig. 2. i* E-learning community model

– Everything about members and their interactions is *mutual engagement (ME)* dimension. The ME is presented by an agent called "Membership". The meaning of an agent is described by agent's dependencies and responsibilities available in i* Modelling.

  - **Dependee** is an agent that influences the performance of other agents. The "Members" agent is dependent on the "Membership" agent. The dependence between agents is presented as the **task** called "Interact". If some members of a community are not interacting, their dependency between the "Membership" and the "Members" agent is not working thus they have no impact in the community.

- The “Learning process” agent is an unavoidable part of a learning community. A change that happens in the “Membership” agent (ME changes) affects the “Learning process” agent. The dependency between the “Learning process” and the “Membership” is presented by **dependum** called **softgoal**. Generally, the softgoal is used when the goal is unable to be described clearly, though a dependency exists and has an influence.

– *Joint enterprises* (JE) reverberate in communities as its technologies and enterprises. Especially, they are important for E-Learning communities because the communities are strongly based on technologies, i.e. Web 2.0. Surely, the agents create a set of policies, rules or regulations within a particular community. Only members which know the community regulations are inside the community. Otherwise they are outside. **Resource** “Policies & rules” is the dependum between ”Technology & Enterprise” and ”Members” agents. The JE agent, i.e “Technology & Enterprise”, has its impact on the ”Learning Process” agent.

– *Shared repertoire* (SR) is the knowledge of a community. The “Knowledge” agent is the context identity of the community. The “Members” agent should possess the context identity that correlates with the community identity. The dependum between the “Members” and the “Knowledge” agents called the ”Identity” resource dependum. The influence of the “Knowledge” agent on the “Learning process” is identified as the softgoal.

With the help of the i* Framework, CoP concept and the analysis we introduce different types of communities within the long tail of E-learning: 1) a question-answer community; 2) an innovation community; 3) a disputative community. The details about those models are presented in the self-classification part of the paper, i.e. Section 5. In the following section it is explained how the data was processed and metadata extracted.

3 The Self-monitoring of the Repository of E-Learning Resources

The data set we used in our experiment was created in the scope of the PROLEARN Network of Excellence supported by the IST (Information Society Technology) Program of the European Union. A part of PROLEARN is the PROLEARN Academy with ist MediaBase. Its data set collects different media in professional learning, e.g. mailing lists, newsletters, feeds, websites. The data collection was organized according to the architecture of the MediaWatchers in [33] for communities in the cultural sciences and the BlogWatcher in [23].

Here we focus on mailing lists and the MailinglistWatcher. First of all a mailing list is a CoP as it possesses three necessary characteristics, i.e. interactions between members, same number of rules and regulations and the same lexicon. Moreover the mailing list is a medium with a number of threads. A thread has one or more mails (posts). Threads are identified through IDs of mails that start new discussions. The mails are called root mails. If a mail has a reference to a root mail - it is automatically in a thread of the root mail, instead if a mail has no reference, it is a root mail of a new thread. The presented approach of identifying threads based on a mail header *reply_to* field is not always successful. The header can include none *reply_to* value, a *reply_to* value that points not to the root mail, but to the general mail of the mailing list or to the other author in the thread, etc. In order to refine thread structure we examined a *subject* field as well.

Before analyzing the content of mailing list communities we tested its consistency.

The thread content should include the text that senders wrote and posted for the others to read. It is always the case that a mail can include technical stuff (e.g. HTML, CGI, etc.) that disturbs mail content analysis. Moreover when a sender replies, her reply may include the mail to which she replies consequently the mail body. As there is no applicable standard, it is possible that a mail appears before a reply mail or after the reply mail. A thread structure is complex: a root mail can have several answers within a thread; the answers may have replies, the replies may have replies, etc. The thread is not structurally consistent while it is full of technical stuff, duplicates, a symbol or a set of symbols that has no functions for thread semantics.

We avoided HTML tags and leave only text data. Other sequences of repeated characters that have no sense were successfully deleted by using regular expressions. Finally, the data refinement script uses complex algorithm that utilize the Levenshtein distance [17] and results in the complete structure of mailing lists threads.

We analyzed E-Learning communities as social networks [3], that give an opportunity to focus rather on relationships between community members than on members attributes [18]. We consider a member of a community as a node of a graph G and a relation of the member to the other one as an edge of the graph. The important concepts of social networks are as follows [23]: connections between members are channels for transfer or flow of either material or nonmaterial resources. We performed semantic analysis of E-Learning communities as well. It is based on text examination. Linguistics is able to analyse and characterize the gist of text items. We used the currently prevailing approach in computer linguistics, i.e. statistical natural language processing (NLP). The metadata got after applying described analysis is differentiated according to the CoP dimensions.

Mutual engagement includes the measures that attend the interactions of members.

Connectiveness, biconnectiveness. A pair of graph nodes a and b is strongly connected if it is a directed path from a to b. The connectiveness property counts the number of closely connected structures of the graph G. Biconnected components are 2 nodes in the graph G where each of the node has connection the other[5]. The connectiveness properties indicate how dense the connections are within a community graph, i.e. how diverse a community is and what are the relations within items of the community.

Hubs, authorities and scale free network. A scale free network possesses a lot of nodes with a minor number of edges and several nodes with a large amount of edges. The latter type of the node is called a "hub" in the network [2]. The distribution function of scale free networks obeys the power law [1]. If a network is not scale-free, all nodes are more or less the same at all scales and it is complicated to differentiate between the nodes [21]. The ”authorities” are the nodes that are pointed from many others, i.e. hubs. The nodes in a network possess *hubness or authoritativeness* properties [14].

Degree centrality, closeness centrality, and betweenness centrality. The study of in- and out- edges of a node defines centrality properties. The higher the degree centrality of a node is, the more visible the node is in a network. Closeness centrality shows how close a node is to the others [4,8,10]. Betweenness centrality identifies how many paths are going through members, how many times they are bridges of information.

Emotions. The other important aspect of ME is an emotion as it is an unavoidable part of negotiations between members of communities. It reflects the full complexity of doing things together [24]. Information about moods can be classified as aggressive, supportive, with an interest, etc. [11,19]. Emotion frequency counts how many phrases from the manually constructed list of emotional phrases are present in a mail content. The list from LIWC project (http://www.liwc.net/index.php) is used for emotions extraction. The list includes 32 word categories tapping psychological constructs (e.g., affect, cognition, biological processes), 7 personal concern categories (e.g., work, home, leisure activities), 3 paralinguistic dimensions (assents, fillers, and nonfluencies) and others, together about 4500 different words and its stems.

Joint enterprises gather the measures that are caring of the awareness of technologies and goals in a community.

Affordance puts constraints on the type of processes that a community member may perform within a given medium [9]. Such conditions are shaped outside the control of members as a result of long historical developments. Nevertheless, the further success of media environment depends on perceptions of affording actions [20] of the members. The members participate in the JE evolving in the community.

Awareness is the boolean property that makes members of the network to be aware or not aware about network changes [6]. This property plays a central role because users feel themselves concerned or unconcerned by what they do and what is happening around them.

Media centric theory of learning was born combining social learning processes and knowledge creation and is based on media operations [7,12,13].

Shared repertoire analyses mails content with different measures where the topic/term identification is the most significant.

Sentence model purposes to find the sequence of words that denotes the logical sentence. The model applied in the experiment is based on sentence boundary indexes (stop lists, impossible penultimates and impossible sentence starts).

The Part-Of-Speech (POS) tagging of the texts can simplify the Gist extraction [15] as it is incredibly useful for overlapping text topics that have the same sense but are named with different words. The approach of our tagger is based on Hidden Markov Models (HMM) and its implementation is done with the help of the Viterbi algorithm [22]. As a result each item of the input text is labeled with POS.

4 Metadata Extraction

The exploration of ME measures based on the SNA approach reveals the following characteristics for threads and members of mailing lists.

- **One-mail-threads** are threads with one mail only. These can include cases when administrators send some informative emails (posts) which don't initiate a discussion. The other possibility are threads that introduce some unknown, uninteresting topics to a community. If more than a half of community threads are one-mail threads, such a community is ineffective and non-interactive. Surely, one-mail-threads can be spam threads, though some of the examined mailing lists are observed by administrators that avoid spam posts.

- **Threads with monologues** are varieties of the one-mail-threads. A thread where its initiator posts more than one mail and gets no answer in the thread is called a monologue-thread. For instance, with the help of the monologue thread the sender is trying to explain a topic. Nevertheless, the monologue thread has no impact on community interactions.
- **Threads without monologues** positively characterize a community. In a combination with a nearly absence of one-mail-threads it can be inferred that at least ME dimensions are partly supported for the community. There are a number of different structures that can be defined with the non-monologues threads: dyads, triads, mul- tiple dialogues, sequent conversations, balanced communications, communicative communications, etc.
- **Unluckily initiators** are users that initiate one-mail-threads and monologue threads. It depends on the network which thresholds to use to define the unluckily initiators though it can be found that the initiators receive answers in other threads, i.e. they are not so unluckily.
- **Reply senders** or **answering persons** are senders who reply on posts from other senders. Depending on thresholds a group of users that send replies can be defined . However belonging to the group doesn't mean that its members are experts. They can be spammers, trolls as well as newbies in a discussion topic.
- **Reply receivers** are users that initiate threads and receive answers. A number of answers shows the importance of a discussion topic for community users.
- **Communicators** are reply senders and reply receivers. One can put the threshold for the number of replies the communicators send as well as the threshold for the number of replies communicators receive. As well it is useful to mention if the examined user is in the group of unluckily initiators.
- **Cross-monospeakers** , **cross-reply receivers** , **cross-reply senders** , **cross-communicators** are users that appear as monospeakers, reply receivers, etc. in more than one mailing list community.

Using linguistics methods we analyze the refined content of the examined E-Learning communities. We calculate the frequencies of LIWC categories of words that appear in the threads of the mailing lists. The frequencies are stored in the database.

5 Self-classification

A community possesses a set of parameters. It consists of structural parameters presented in a previous section and semantic parameters. Some categories of words with examples that were used as a locus for semantic parameters are presented in Table 1. The communities are presented as vectors where variables are their parameters. Following our purpose to find similar communities we applied hierarchical clustering (HC) and factor analysis (FA) to our data set. We utilized those two methods to find communities corresponding to the E-Learning models. With the help of the HC we found the vectors which correlate significantly. The vectors form a cluster. In its term, the FA defines a factor, i.e. the consistent group of vectors. Clusters and factors reveal similar communities. As it was earlier noticed we differentiate between question-answer, innovative and disputative communities.

Table 1. Community semantic parameters

Word category	Words number	Included symbols or words
FRIENDS	36	companion, friend, mate, roomier, etc.
ANGER	364	danger, defense, enemy, rude, victim, etc.
INSIGHT (understanding)	193	become, believe, feel, inform, seem, think, etc.
FILLER	8	yakno, ohwell, etc.
POSEMO	405	agree, casual, improve, support, sweet, etc.
NEGEMO	495	broke, fury, panic, temper, etc.
DISCREP (discrepancy)	75	hopeful, must, ideal, prefer, problem, etc.
HOME	92	bad, garage, mailbox, rug, vacuum, etc.
HUMANS	60	adult, boy, citizen, individual, person, etc.
NONFLU (nonfluency)	7	hmm, um, etc.
CERTAIN	82	clear, correct, forever, indeed, total, truly, etc.
PERCEPT (observation)	371	black, circle, sand, skin, etc.

One of the extracted clusters is similar to the question-answer E-Learning community. The number of dyadic and sequent communications is very high within the cluster. It infers that there are a lot of threads where one member asks and the other answers. Also there are some threads where two members discuss something and send each other several mails. The number of questions signs within the cluster and "insight" and "discrep" parameters of the cluster are significant thus these indicate the query- explanation nature of the texts within the cluster.

The other cluster looks like a very interactive system with a lot of users characterized as the "reply sender" . The semantic parameters, e.g. explanations, disagreements and quarrels, infer presence of discussions in the cluster. We assume that the cluster is a realization of the disputative E-learning community.

Considering groups of communities defined by FA, one of the group has two options: the disputative community or the question-answer community. The identity of the question-answer community are "dyadic" communications that are not the case for the group, although it has a lot of semantic parameters which fit to the question-answer community. For the disputative community high weights of "reply sender" and "reply receiver" parameters within the group are important, though the "reply sender" parameter is only significant for the group. The communities in the group might be a kind of mixture between two options. The discussions appear not only between two members and are performed using words that denote doubts and disagreements .

The other group we defined with the help of the FA is positioned between the *disputative* and the *innovation* communities. There are "*communicator*" (refers to innovation community), "*reply receiver*" and "*reply sender*" (two last refer to disputative community) parameters presented.

After comparing the results of the HC and the FA approaches we concluded that the HC focuses on the whole set of variables that represents a community. The FA concentrates on the variables that even after normalization are bigger than the others. For our data set the difference of the approaches means that the HC pays more attention to structural parameters and organizes communities according to them while the FA focuses on the semantic parameters.

6 Conclusion and Outlook

The focus of the paper was the E-Learning community, its structures and content. The theory that we used to study the community notion is CoP [24]. According to CoP dimensions, a community is a CoP if there are interactions of members within the community (ME); the community possesses technologies, rules and policies (JE); the community members are aware of community knowledge (SR). The model of CoP for E-Learning communities was illustrated with the help of the i* modelling. Each actor of a community is presented with the same prototype and is completed by adding a set of parameters that identifies the actor. Using the ANT [16] model it makes the definition of relations between actors easier and consequently the classification of them easier.

Before applying the analysis we refined the data. The result of the refinement is a 10% decrease in the number of threads of mailing lists and consistency of the mailing lists content.

The paper demonstrates how E-Learning communities can observe themselves and basing on the observations how they can model themselves. The work we have done opens several issues that can possibly improve the results we achieved and defines new topics.

- It is useful to analyze E-learning communities according to processes that can be performed within media and how these processes influence the learning process?
- Can the i* models of E-learning communities can be effectively extended by consid- ering semantic parameters?
- Is the application of linguistic techniques important and will it open many possibilities for the semantic analysis of E-learning communities?
- Which analysis is appropriate for determining all components of CoP and consistent groups of communities?

There will be even more transitions between informal and formal learning phases in future. Learners will spend some of their lifetime still in institutions offering formal edu- cation, training and qualification. However, life-long learning and continuing education create also the need for more informal learning situations like learning in communities which share a common practice. In the roadmaps created by major European research intitiatives theses needs are clearly expressed. However, the long tail of learning puts complex decision processes on the learners. Our research investigates these decision processes by the means of applied game theory. We will find models to help learning communities finding optimal strategies in selecting learning materials and the right ratio between experts and novices in the communities.

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References

1. Albrecht, D., Arnold, R., Bauerfeld, W., Bode, A., Bruch, E.-M., Cress, U., Haake, J., Keil, R., Kuper, J., Nejdl, W., Reinmann, G., Rensing, C., Schaper, J., Zimmermann, V.: Web 2.0: Strategievorschläge zur Stärkung von Bildung und Innovation in Deutschland. Technical report, Bundesministerium für Bildung und Forschung (BMBF) (2007)
2. Anderson, C.: The Long Tail: Why the Future of Business is Selling Less of More. Hyperion, New York (2006)
3. Barabási, A.-L.: The Physics of the Web. Physics World 14, 33–38 (2001)
4. Barabási, A.-L.: Linked: The New Science of Networks. J. Artificial Societies and Social Simulation 6(2) (2003)
5. Baron, S., Field, J., Schuller, T.: Social Captial - Critical Perspectives. Oxford University Press, Oxford (2000)
6. Seely Brown, J., Adler, R.P.: Minds on Fire: Open Education, the Long Tail, and Learning 2.0. EDUCAUSE Review 43(1), 16–32 (2008)
7. Christensen, K., Levinson, D., Jarrett, R., Judd, D.R., Metcalf, W., Moudry, R., Oldenburg, R., Salamon, S., Sander, T., Shuman, M., Wellman, B., Zuckerman, M.: Encyclopedia of Community: From the Village to the Virtual World, p. xxxi. Sage, New York (2003)
8. Cohen, D., Prusak, L.: In Good Company - How Social Capital Makes Organizations Work. Harvard Business School Press, Boston (2001)
9. Couldry, N.: Cultures of Connectivity. In: Hepp, A., et al. (eds.) Actor Network Theory and Media: Do They Connect and On What Terms?, pp. 1–14. School of Economics and Political Science, London (2004)
10. Degenne, A., Forsé, M.: Introducing Social Networks. SAGE Publications, London (1999)
11. Diestel, R.: Graph Theory, 2nd edn. Graduate Texts in Mathematics, vol. 173. Springer, New York (2000)
12. Dourish, P., Bellotti, V.: Awareness and Coordination in Shared Workspaces. In: CSCW 1992: Proceedings of the 1992 ACM Conference on Computer-Supported Cooperative Work, pp. 107–114. ACM Press, New York (1992)
13. Fischer, G., Rohde, M., Wulf, V.: Community-based Learning: The Core Competency of Residential, Research-based Universities. International Journal of Computer-Supported Collaborative Learning 2(1), 9–40 (2007)
14. Fohrmann, J., Schüttpelz, E.: Die Kommunikation der Medien. Niemeyer, Tübingen (2004)
15. Freeman, L.: Centrality in Social Networks. Conceptual Clarification. Social Networks 1, 215–239 (1979)
16. Bundesministerium für Bildung und Forschung. Neue Medien in der Beruflichen Bildung. Technical report, Bundesministerium für Bildung und Forschung (BMBF) (2007)
17. Geser, G.: Open Educational Practices and Resources - the OLCOS Roadmap 2012. Technical report, Salzburg Research (2007)
18. Gibson, J.J.: The Ecological Approach to Visual Perception. Laurence Erlbaum Associates, Inc., Hillsdale (1979)
19. Hanneman, R.A.: Introduction to Social Network Methods. University of California, Online text book (last access on 12.03.07) (2001), `http://www.faculty.ucr.edu/hanneman/nettext/`

20. Haythornthwaite, C., Gruzd, A.: A Noun Phrase Analysis Tool for Mining Online Community. In: Proceedings C & T 2007, Michigan, USA, pp. 67–86 (2007)
21. Jäger, L., Stanitzek, G. (eds.): Transkribieren - Medien/Lektüre. Wilhelm Fink Verlag, Munich (2002)
22. Kamtsiou, V., Naeve, A., Kravcik, M., Burgos, D., Zimmermann, V., Klamma, R., Chatti, M.A., Lefrere, P., Dang, J., Koskinen, T.: A Roadmap for Technology Enhanced Learning (TEPL). Technical report, PROLEARN Network of Excellence (2008)
23. Klamma, R., Cao, Y., Spaniol, M.: Watching the Blogosphere: Knowledge Sharing in the Web 2.0. In: Nicolov, N., Glance, N., Adar, E., Hurst, M., Liberman, M., Martin, J.H., Salvetti, F. (eds.) International Conference on Weblogs and Social Media, Boulder, Colorado, USA, March 26-28, pp. 105–112 (2007)
24. Klamma, R., Spaniol, M., Cao, Y., Jarke, M.: Pattern-Based Cross Media Social Network Analysis for Technology Enhanced Learning in Europe. In: Nejdl, W., Tochtermann, K. (eds.) EC-TEL 2006. LNCS, vol. 4227, pp. 242–256. Springer, Heidelberg (2006)
25. Klamma, R., Spaniol, M., Jarke, M.: Do You Know a Similar Project I Can Learn From?Self-Monitoring of Communities of Practice in the Cultural Sciences. In: ICITA 2005: Proceedings of the Third International Conference on Information Technology and Applications (ICITA 2005), vol. 2, pp. 608–613. IEEE Computer Society Press, Washington (2005)
26. Kleinberg, J.: Authoritative Sources in a Hyperlinked Environment. J. ACM 49, 604–632 (1999)
27. Lakoff, G., Johnson, M.: Metaphors We Live By. University of Chicago Press, Chicago (1980)
28. Law, J.: Notes in the Theory of the Actor Network: Ordering, Strategy and Heterogeneity. System Practice 5, 379–393 (1992)
29. Levenshtein, V.I.: Binary codes capable of correcting deletions, insertions, and reversals. In: Soviet Physics Doklady 10, pp. 707–710 (1966)
30. Mika, P.: Social Networks and the Semantic Web. Springer Science + Business Media, LLC (2007) ISBN-13: 978-0-387-71000-6
31. G. Mishne and N. Glance. Leave a Reply: An Analysis of Weblog Comments. WWW 2006, 3rd Annual Workshop on the Weblogging Ecosystem: Aggregation,Analysis and Dynamics, Edinburgh (May 23-26, 2006) (Retrieved from 25.06.07), `http://staff.science.uva.nl/~gilad/pubs/www2006-blogcomments.pdf`
32. Mynatt, E.D., O'Day, V.L., Adler, A., Ito, M.: Network Communities: Something Old, Something New, Something Borrowed. Computer Supported Cooperative Work: The Journal of Collaborative Computing 7, 123–156 (1997)
33. Spaniol, M., Klamma, R., Jarke, M., der Evidenz, D.L.: Sozialen Netzwerkanalyse kulturwissenschaftlicher Communities. In: Selbstbeobachtungswerkzeuge zur cross-medialen, DuMont, Köln, pp. 239–254 (2006)
34. Vega-Redondo, F.: Complex Social Networks. Cambridge University Press, Cambridge (2007)
35. Viterbi, A.J.: Error Bounds for Convolutional Codes and an Asymptotically Optimum Decoding Algorithm. IEEE Transactions on Information Theory 13(2), 260–269 (1967); The Viterbi decoding algorithm is described in section IV
36. Wasserman, S., Faust, K.: Social Network Analysis. Cambridge University Press, Cambridge (1994)
37. Wenger, E.: Communities of Practice. Learning, Meaning and Identity, chapter Communities, pp. 72–85. Cambridge University Press, Cambridge (1998)
38. Yu, E., Mylopoulos, J.: Towards Modelling Strategic Actor Relationships for Information Systems Development – With Examples from Business Process Reengineering. In: Proceedings of the 4th Workshop on Information Technologies and Systems (1994)

Extraction of Socio-semantic Data from Chat Conversations in Collaborative Learning Communities

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Abstract. Online collaboration among communities of practice using text-based tools, such as instant messaging, forums and web logs (blogs), has become very popular in the last years, but it is difficult to automatically analyze all their content due to the problems of natural language understanding software. However, useful socio-semantic data can be retrieved from a chat conversation using ontology-based text mining techniques. In this paper, a novel approach for detecting several kinds of semantic data from a chat conversation is presented. This method uses a combination of a dialogistic, socio-cultural perspective and of classical knowledge-based text processing methods. Lexical and domain ontologies are used. A tool has been developed for the discovery of the most important topics and of the contribution of each participant in the conversation. The system also discovers new, implicit references among the utterances of the chat in order to offer a multi-voiced representation of the conversation. The application offers a panel for visualizing the threading of the subjects in the chat and the contributions function. The system was experimented on chat sessions of small groups of students participating in courses on Human-Computer Interaction and Natural Language Processing in "Politehnica" University of Bucharest, Romania.

Keywords: Computer-Supported Collaborative Learning, Dialogism, Chat Visualization, Natural Language Processing, Ontologies.

1 Introduction

Collaborative technologies have changed traditional learning scenarios towards Computer Supported Collaborative Learning (CSCL). The widely used discussion forums and instant messaging (chat conversation) offer natural and well-suited tools for such an approach. However, these tools lack abstraction and analysis facilities, which could help the assessment of the contribution of each participant to the collaborative learning process. This paper is proposing both a theoretical background and an implemented system for the analysis of knowledge building in communities that learn collaboratively through chat conversations.

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Learning paradigms that consider the computer support have changed in last decades from Computer-Assisted Instruction and Intelligent Tutoring Systems to Computer-Supported Collaborative Learning [1,2], which is specific for the socially-based, Web2.0. The way learning is considered has implications on the nature of the computer tools designed to support it. As a consequence, learning is conceived in CSCL as discourse building, as Sfard remarked: “rather than speaking about ‘acquisition of knowledge,’ many people prefer to view learning as becoming a participant in a certain discourse” [3]. Following this idea, in this paper we propose a series of tools that offer the possibility of visualising the discourse in chat conversations of students learning collaboratively. The discourse is analysed starting from Bakhtin’s dialogistic theory [4,5], which may be seen as extending Vygotsky’s socio-cultural ideas [6].

There are chat environments for CSCL containing facilities like whiteboards and explicit referencing. Such an environment is ConcertChat [7], used in the experiments presented in this paper. There are also approaches that use natural language processing for abstracting (e.g. speech acts identification [8] and summarization [9]) or knowledge extraction from chats and forums. However, these facilities are limited, and one assumption of the research whose results are presented here is that the limitations are due to the neglecting of the socio-cultural paradigm, and in special of dialogism.

The experiments for testing and validating the developed application were performed with students involved in courses of Human-Computer Interaction and Natural Language Processing. The students were divided in small groups of 4-5 persons that had to debate on a given subject using ConcertChat. The debate could be either collaborative, like finding the best tools that can be used to support team work for a project, or competitive. For example, each student had to choose a text classification technique (for NLP) or a web-collaboration platform (for HCI) and prove its advantages over the ones that were chosen by the other participants. The application described in this paper was used to facilitate the discovery of several semantic and social data from the chat: the topics that were covered by the students (and maybe, more important, to determine the topics that were very poorly covered), the main subjects of the discussion, an evaluation of the competence of each participant, a graphical view of the chat that can be useful to evaluate the implication of each participant and the degree of debate and other data that will be presented in the following chapters.

The paper continues with a section introducing the socio-cultural and Bakhtin’s dialogism paradigms. The third section discusses the knowledge-based ideas used in the present approach. The next section contains the description of the visualisation tools. The paper ends with conclusions and references.

2 Bakhtin’s Polyphonic Theory

In forums and chat conversations, knowledge is socially built through discourse and is preserved in linguistic artefacts whose meaning is co-constructed within group processes [10]. These socio-cultural ideas are based on the work of Russian psychologist Lev Vygotsky, who emphasized the role of socially established artefacts in communication and learning [6].

Mikhail Mikhailovici Bakhtin has extended the ideas of Vygotsky, emphasizing the role of speech and dialog in analyzing social life. He remarks that in each dialog and even in written texts there are communities of voices: "The intersection, consonance, or interference of speeches in the overt dialog with the speeches in the heroes' interior dialogs are everywhere present. The specific totality of ideas, thoughts and words is everywhere passed through several unmerged voices, taking on a different sound in each" [4]. This dual nature of community and individuality of voices is expressed by Bakhtin also by the concept of *polyphony*, that he considers the invention and one of the main merits of Dostoevsky novels [4]. The relation of discourse and communities to music was remarked also by Tannen: "Dialogue combine with repetition to create rhythm. Dialogue is liminal between repetitions and images: like repetition is strongly sonorous" [11].

Bakhtin makes dialogism a fundamental philosophical category: "… Any true understanding is dialogic in nature." [12]. Moreover, Lotman considers text as a „thinking device" [13], determining that: "The semantic structure of an internally persuasive discourse is not finite, it is open; in each of the new contexts that dialogize it, this discourse is able to reveal ever new ways to mean" [5].

In chat conversations, different voices are obvious recognized. However, starting from Bakhtin's ideas, in our approach the concept of voices is not only limited to the physical vocal characteristics of participants in the chat. A voice is, from our perspective, something said by a participant in a given moment and it may be reflected in many subsequent utterances. Also, each utterance may contain an unlimited number of voices.

3 Ontology-Based Text Processing

Ontologies are very successful inheritors of knowledge representation research in artificial intelligence. They are semantic networks or frame structures built starting from human experience and, in fact, they are ways of sharing classification data in communities. Any collaboration using natural language, any discourse needs to start from a common vocabulary, a shared ontology. WordNet (http://wordnet.princeton.edu) or FrameNet (http://framenet.icsi.berkeley.edu) are examples of ontologies built as extended vocabularies, offering also linguistic data like related words, or case grammars.

The word "ontology" is used in philosophy to denote the theory about what is considered to exist. Any system in philosophy starts from an ontology, that means from the identification of the concepts and relations considered as fundamental. Ontologies capture fundamental categories, concepts, their properties and relations. One very important relation among concepts is the taxonomic one, from a more general to a more specific concept. This relation may be used as a way of "inheriting" properties from the more general concepts ("hypernyms"). Other important relations are "part-whole" ("meronym"), "synonym", "antonym".

Ontologies are very important in text mining. For these kind of applications they offer the substrate for semantic analysis and, very important, the possibility of defining a measure of semantic closeness, based on the graph with concepts from ontologies as nodes and their relations as arcs. This semantic closeness is very important in text analysis for example in the retrieval of texts that do not contain a given word, but they contain a synonym or a semantically related word.

4 Socio-semantic Data Extraction Tool

The approach presented here integrates Bakhtin's socio-cultural ideas with knowledge-based natural language processing for the visualisation of the contributions of each learner. The ideas are the identification of the topics discussed in the chat, to separate the contributions of each participant to a topic (the voices) and, eventually, to measure and visualize these contributions.

4.1 Identification of the Chat Topics

The chat topics are identified as a list of concepts (words) that appeared most frequently in the conversation, by using statistical natural language processing methods. Accordingly, the importance of a subject is considered related to its frequency in the chat. The first step in finding the chat subjects is to strip the text of irrelevant words (stop-words), text emoticons (e.g. ":)", ":D", and ":P"), special abbreviations used while chatting (e.g. "brb", "np", and "thx") and other words considered of no use at this stage.

Then, the resulted chat is tokenized and each different word is considered a candidate concept in the analysis. For each of these candidates, WordNet is used for finding synonyms. If a concept is not found on WordNet, mistypes are searched using a web service. If successful, the synonyms of the suggested word will be retrieved. If no suggestions are found, the word is considered as being specific to the analyzed chat and the user is asked for details. In this way, the user can tag the part of speech for each word and can add synonyms. All this information is saved into a cache, so the user will not be prompted twice for the same word. The prompt user for unknown words feature can be disabled, if so desired.

The last stage for identifying the chat subjects consists of unifying the candidate concepts discovered in the chat. This is done by using the synonym list for every concept: if a concept in the chat appears in the list of synonyms of another concept, then the two concepts' synonym lists are joined. At this point, the frequency of the resulting concept is the added frequencies of the two unified concepts. This process continues until there are no more concepts to be unified. At this point, we shall acknowledge the subjects of the chat conversation as the list of resulting concepts, ordered by their frequency.

In addition to the above method, used for determining the chat topics, there is a possibility to infer them by using a surface analysis technique of the conversation. Observing that new topics are generally introduced into a conversation using some standard expressions such as "let's talk about email" or "what about wikis", we can construct a simple and efficient method for deducing the topics in a conversation by searching for the moment when they are first mentioned.

We have manually defined a list of patterns for determining the moment a new topic is introduced in the conversation. These patterns are applied to each utterance in the chat and if an utterance matches any one of the patterns, then it means that the utterance introduces a new topic. A pattern consists of a number of words that must be identified in the utterance and a key word that is associated to the new topic of the conversation (e.g. "let's talk about <topic>" or "what about <topic>"). The process of identifying a pattern in an utterance is done using the synset for each word that has already been extracted from WordNet.

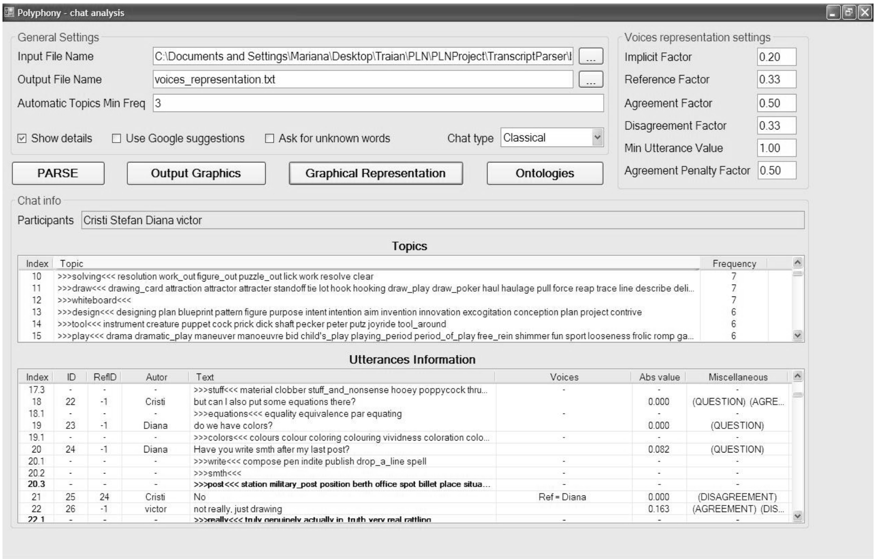

Fig. 1. Topic identification panel

This technique can be improved in the future by using machine-learning methods for detecting the patterns specific to the introduction of new topics. The idea is to annotate the utterances that introduce new topics within a corpus of chats, the application automatically discovering the new rules used in topic introduction. Another option is to consider the extension of the simple patterns described above to more complicated parsing rules.

The topics of the chat may be also detected as the connected components in the chat graph described in the next section.

4.2 The Graphical Representation of the Conversation

The graphical representation of the chat was designed to permit the best visualization of the conversation, to facilitate an analysis based on the polyphony theory of Bakhtin, and to maximize the straightforwardness of following the chat elements. For each participant in the chat, there is a separate horizontal line in the representation and each utterance is placed in the line corresponding to the issuer of that utterance, taking into account its positioning in the original chat file – using the timeline as an horizontal axis. Each utterance is represented as a rectangle aligned according to the issuer on the vertical axis and having a horizontal axis length that is proportional with the dimension of the utterance. The distance between two different utterances is proportional with the time passed between the utterances. Of course, there is a minimum and a maximum dimension for each measure in order to restrict anomalies that could appear in the graphical representation due to extreme cases or chat logging errors.

The relationships between utterances are represented using coloured lines that connect these utterances. The explicit references that are known due to the use of the ConcertChat software are depicted using blue connecting lines, while the implicit references that are deduced using the method described in this paper are represented using red lines. The utterances that introduce a new topic in the conversation are represented with a red margin.

The graphical representation of the chat has a scaling factor that permits an attentive observation of the details in a conversation, as well as an overview of the chat. The different visual elements determined by our application – such as utterances in the same topic, topic introducing utterances and relationships between topics – can be turned on and off in the graphical representation by use of checkboxes.

At the top of the graphical representation of the conversation, there is a special area that represents the importance of each utterance, considered as a chat voice, in the conversation. How this importance is determined is presented further in this paper. Moreover, all the details of an utterance in the chat – the content of the utterance, the implicit and explicit references and other details – can be visualized by clicking the rectangle representing the utterance.

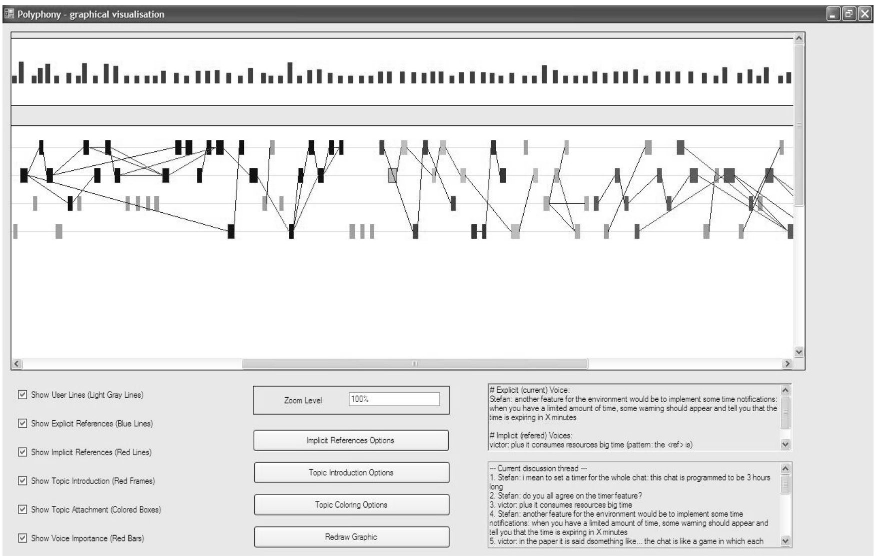

Fig. 2. The threads of references in the chat

4.3 The Conversation Graph

Starting from existing references within the analyzed conversations, both those explicit, offered by the used chat environment, as well as those implicit determined by the program using the methodology presented in the next chapter, one could assemble a conversation graph. Within this graph, each utterance from the chat is a vertex, while the references between utterances (either explicit or implicit) represent the edges. The output is a directed graph specific to the conversation.

As there can be no references to future utterances, only to previous ones, the consequence is that the graph of the conversation will be an acyclic oriented graph. Based on the utterances and on the references between utterances, we have constructed the graph of the conversation, to be used both for determining the strength value of each utterance in the chat considered as a separate voice, as well as for emphasizing certain subjects (lines) of the conversation.

One of the essential properties of the acyclic oriented graph is that it accepts a topological sorting, in other words it allows an ordering of its vertexes. In the case of chats, the utterances (vertexes) are sorted topologically according to the moment when they were "uttered".

Determining the Strength Value of an utterance

The importance of an utterance in a conversation can be calculated through its length and by the correct selection of the words in the utterance – they should contain as many possible key (important) words. This approach could prove useful in chat summarization. Nevertheless, in a *social context*, another approach is also possible: an utterance is important if it influences the subsequent evolution of the conversation. Using this definition as a starting point, we may infer that an important utterance will be that utterance which is a reference for as many possible subsequent utterances.

Even if this approach could be extended to include the types of subsequent references (implicit or explicit, agreements or disagreements), in the present case we have preferred a more simplistic approach, without making allowances for the types of references to the utterance.

Consequently, the importance of an utterance can be considered as a strength value of an utterance, where an utterance is strong if it influences the future of the conversation (such as breaking news in the field of news). When determining the strength of an utterance, the strength of the utterances which refer to it is used. Thus, if an utterance is referenced by other utterances which are considered important, obviously that utterance also becomes important.

As a result, for the calculation of the importance of every utterance, the graph is run through in the opposite direction of the edges, as a matter of fact in the reverse order of the moment the utterance was typed. Utterances which do not have references to themselves (the last utterance of the chat will certainly be one of them) receive a default importance – taken as the unit.

Then, running through the graph in the reverse order of references, each utterance receives an importance equal to that of the default plus a quota (subunit) from the sum of the importance of the utterances referring to the current utterance. Another modality to calculate could be 1 plus the number of utterances which refer to the present utterance, but this choice seemed less suitable. However, perhaps a better way to do it might have been 1 + quota1 * number of referrers + quota2 * sum of the importance of the referrers.

By using this method of calculating the importance of an utterance, the *utterances* which have started an important conversation within the chat, as well as those *utterances* which begin new topics or mark the passage between topics, are more easily emphasized. If the explicit relationships were always used and the implicit ones could be correctly determined in as high a number as possible, then this method of calculating the importance of a voice would be successful.

Segmenting the conversation in discussion topics, starting from the graph

Using an algorithm for determining the connected components from the conversation graph, we were able to find the *utterances* connected through at least one relationship, implicit or explicit. It is normal to assume that all these *utterances* are part of a single discussion topic.

This method can be used for successfully finding the conversational threads only if the explicit references have been used correctly and the implicit relationships were determined as precisely as possible. We have considered that the important topics are those consisting of at least four *utterances*. This minimum number of *utterances* in a topic should be parameterized according to the length of the chat, but 4 *utterances* is considered to be a minimum. For each determined topic, we have highlighted the most frequent concepts (as a synset list) in that topic. This way, each topic is described by the most relevant concepts found in the *utterances* present in that topic.

An interesting observation to be made is that this method to determine the topics of the conversation produces some remarkable results. Thus, the discussion can have more than one topic at a moment in time – the participants being involved in different topics at the same time. Inter-crossings between different topics can be easily observed on the chat graphics as well as topics started and finished whereas other more important topics are abandoned for a while and then continued.

4.4 Discovering the Implicit Voices

Considering each chat utterance as a chat voice that has a certain importance in the conversation, it is obvious that each utterance generally contains more than a single voice, as it includes the current voice and probably at least one referring voice. As we are working with ConcertChat transcript files, we acknowledge the voices that are explicitly pointed out by the chat participants during the conversation, using the software's referencing tool. Nevertheless, because users are seldom in a hurry or simply not attentive enough, part of the utterances do not have any explicit references. Thus, it is necessary to find a method for discovering the implicit references in an utterance; in this way, we shall identify more relationships between the utterances in the chat.

The method proposed here is similar to the one presented above for determining the introduction of new chat topics. We are using another list of patterns that consists from a set of words (expressions) and a local subject called the referred word. If we identify that an utterance matches one of the patterns, we firstly determine what word in the utterance is the referred word (e.g. "I don't agree with your assessment"). Then, we search for this word in the predetermined number of the most recent previous utterances. If we are able to find this word in one of these utterances, we have discovered an implicit relationship between the two lines, the current utterance referring to the identified utterance.

We have also implemented two empirical methods, which provide very good results when utilizing any chat software. The first one is based on the fact that, if an utterance contains a short agreement or disagreement – containing at most a word after stripping the utterance of irrelevant words – and this utterance has no explicit reference attached to it, then it is a big probability that this utterance refers implicitly to the most recent previous utterance. This is based on the fact that a short utterance can be typed very quickly. In the example presented below, the implicit relationship between the utterances is obvious:

A – I think wikis are the best
B – I disagree

The second empirical method is based on the following fact: if between three utterances there are two explicit relationships from the first to the second and from the second to the third and the second utterance is a short agreement or disagreement, then between the first and the third utterance there exists an implicit relationship. For example, consider the following example, where there are explicit references between A and B, respectively B and C, it is clearly we have an implicit relationship between A and C. In the last utterance, we have influences from both A and B:

A – I think wikis are the best
(…)
B – I disagree *REF A*
(…)
C – Maybe we should talk about them anyway *REF B*

The process of automatically discovering the implicit relations between chat utterances can be characterized by two important factors: the quantity of the relations that were found and the quality of these relations. The current approach tries to determine as many implicit relations as possible, without decreasing the average quality of a relation. The quality of an implicit relation is a measure that is difficult to define properly – one way of defining it is to consider the chat being manually analyzed by a number of persons, thus highlighting the relations between the utterances of the chat. The quality of a reference would then be dependent of the percentage of the people who have highlighted it. We have observed that references to previous utterances in the chat conversations are likely to appear as part of a well known pattern or expression (like "*using a <ref>*", "*did <ref> it*", "*to allow <ref>*", etc). Moreover, these patterns produce an important number of implicit references that are of high quality. Using the synset lists increases the power of these expressions as we are also looking for slight variations in the written expression.

The greatest disadvantage of this method is that the list of patterns is defined manually and there may be a great number of patterns used for expressing implicit relations to previous utterances that might be omitted. Using an automatic process for discovering these patterns increases the quantity of the implicit relations being discovered. We have not achieved the full automation of this process, but implemented a semi-automatic procedure that discovers the utterances containing at least one word in common with one of the previous utterances. By omitting the stop words and using synsets from Wordnet, a great number of utterances are discovered and these become candidates for containing references to previous utterances. Still, the process of selecting implicit references and of discovering patterns must be manually performed by the user. The advantage of this method is the filtering of candidate patterns by a human mind, thus ensuring a good quality of the implicit relations. In the future, we propose to improve the rules used for defining the patterns employed by casting the referenced words into specific roles (e.g. noun, verb, adjective) and by not using the synsets for certain words.

Assessing the competencies of the learners in the conversation

In order to determine the competences of the chat users, we first searched the most important topics in the analysed chat conversation.

The generated graphics evaluate the competences of each user starting from the list of subjects determined as explained above and using other criteria such as questions, agreement, disagreement or explicit and implicit referencing. The graphics are generated using a series of parameters like: implicit and explicit reference factors, bonuses for agreement, penalties for disagreement, minimum value for a chat utterance, penalty factors for *utterances* that agree or disagree with other *utterances* as these *utterances* have less originality than the first ones.

During the first step of the graphics generation, the value of each utterance is computed by reporting it to an abstract utterance that is built from the most important concepts in the conversation determined as described above. When constructing this utterance, we take into account only the concepts whose frequency of appearance is above a given threshold. Then all the *utterances* in the chat are scaled in the interval 0 – 100, by comparing each utterance with the abstract utterance. The comparison is done using the synsets of each word contained in the utterance. Thus, this process uses only the horizontal relations from WordNet. An utterance with a score of 0 contains no words from the concepts in the abstract utterance and an utterance with a score of 100 contains all the concepts from the abstract utterance.

On the Ox axis the graphics hold all the *utterances* in the chat and on the Oy axis the value attributed to each participant in the conversation, representing each user's competence. Accordingly, for each utterance, at least the value of a user competence is modified – the value for the user that issued that utterance.

For each utterance in the chat, the values of the users' competences are modified using the following rules:

1. The user that issued the current utterance receives the score of the utterance, eventually downgraded if that utterance is an agreement or disagreement in relation to a previous utterance (in order to encourage originality);
2. All the users that are literally present in the current utterance are rewarded with a percentage of the utterance value, considering that they have some merit in the value of this utterance, as being mentioned in the text of the utterance encourages us to think so;
3. The issuer of the utterance explicitly referred to by the current utterance is rewarded if this utterance is an agreement and is penalized if the utterance is a disagreement;
4. The issuer of the utterance explicitly referred to by the current utterance that is not an agreement or a disagreement, will be rewarded with a fraction of the value of this utterance;
5. If the current utterance has a score of 0, the issuer will receive a minimum score in order to differentiate between the users that actually participate in the chat and those who do not.

All the percentages and all the other factors used for computing the competence of each user are used as parameters of the process and can be easily modified in the application interface. The process described above builds competence function graphics for each participant in the chat.

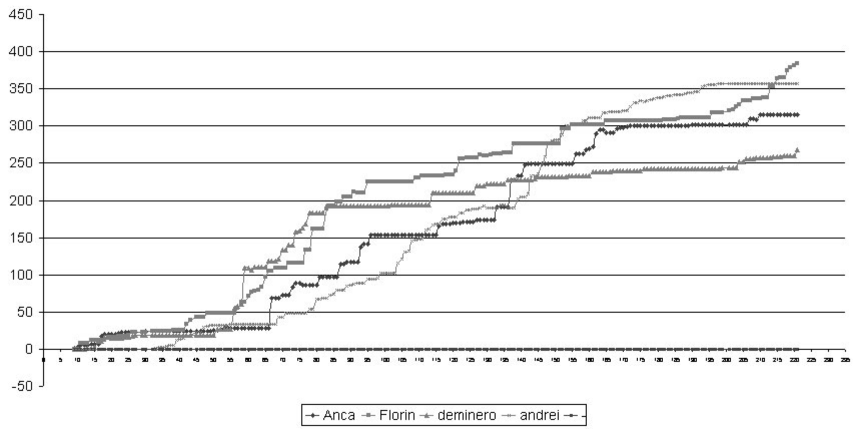

Fig. 3. The evolution of the competence degree

5 Conclusions

The paper presents an application that visualizes the voices of the participants on forums or chat conversations, similarly to music scores (following Bakhtin's ideas). In addition, some other diagrammatic representations are used for viewing the influence of a given speaker's voice.

The application may be used for inspecting what is going on and in what degree learners are implied in a forum discussion or a chat conversation. Moreover, the competence of each participant may be measured, that means that learners may be assessed in collaborative learning on the web.

The application uses the WordNet ontology and can construct specific domain ontologies and/or folksonomies starting from the main topics discovered in the conversation. Knowledge acquisition for concepts that are not present in this ontology is provided through dialogs with the user of the analysis system and by caching the results. Natural language technology is used for the identification of discussion topics, for segmentation and for identifying implicit references.

Further work will consider more complex semantic distances (than only synonymy). Machine learning techniques will be used for the identification of discourse patterns. Moreover, a completely automated version for discovering new rules for the implicit relations is in progress.

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References

1. Koshmann, T.: Toward a Dialogic Theory of Learning: Bahtin's Contribution to Understanding Learning in Settings of Collaboration. In: Hoadley, C., Roschelle, J. (eds.) Proceedings of the Computer Support for Collaborative Learning 1999 Conference, Stanford. Laurence.Erlbaum Associates, Mahwah (1999)
2. Stahl, G.: Group Cognition: Computer Support for Building Collaborative Knowledge. MIT Press, Cambridge (2006)
3. Sfard, A.: On reform movement and the limits of mathematical discourse. Mathematical Thinking and Learning 2(3), 157–189 (2000)
4. Bakhtin, M.M.: Problems of Dostoevsky's Poetics, Ardis (1973)
5. Bakhtin, M.M.: The Dialogic Imagination: Four Essays. University of Texas Press (1981)
6. Vygotsky, L.: Mind in society. Harvard University Press, Cambridge (1978)
7. Holmer, T., Kienle, A., Wessner, M.: Explicit Referencing in Learning Chats: Needs and Acceptance. In: Nejdl, W., Tochtermann, K. (eds.) EC-TEL 2006. LNCS, vol. 4227, pp. 170–184. Springer, Heidelberg (2006)
8. Trausan-Matu, S., Chiru, C., Bogdan, R.: Identificarea actelor de vorbire în dialogurile purtate pe chat. In: Trausan-Matu, S., Pribeanu, C. (eds.) Interactiune Om-Calculator, Editura Printech, Bucuresti, pp. 206–214 (2004)
9. Trausan-Matu, S., Stahl, G., Sarmiento, J.: Polyphonic Support for Collaborative Learning. In: Dimitriadis, Y.A., et al. (eds.) CRIWG 2006. LNCS, vol. 4154, pp. 132–139. Springer, Heidelberg (2006)
10. Schegloff, E.: Discourse As An Interactional Achievement: Some Uses Of 'Uh huh' And Other Things That Come Between Sentences. In: Tannen, D. (ed.) Georgetown University Roundtable on Languages and Linguistics 1981; Analyzing Discourse: Text and Talk. Georgetown University Press, Washington (1981)
11. Tannen, D.: Talking Voices: Repetition, Dialogue, and Imagery in Conversational Discourse. Cambridge University Press, Cambridge (1989)
12. Voloshinov, Marxism and the Philosophy of Language. Seminar Press, New York (1973)
13. Wertsch, J.V.: Voices of the Mind. Harvard University Press (1991)

Knowledge Processing and Contextualisation by Automatical Metadata Extraction and Semantic Analysis

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Abstract. The third project of the MoKEx project series focused on organisational issues that arise in the context of blended learning scenarios and knowledge management. We developed MetaXsA (Metadata Extraction and semantic Analysis) - a module that analyses given knowledge assets and returns a metadata file, which is stored in a global metadata database. This paper gives an introduction to MetaXsA and the surrounding Single Point of Information architecture.

Keywords: knowledge management, information retrieval, metadata, contextualisation, semantic analysis.

1 Scope of the Project

MoKEx (Mobile Knowledge Experience) is an international project series of universities and industrial partners from Germany and Switzerland (cf. [3]) and it is also linked with the EU IP-project MATURE[1]. The third project started in April 2007 and ended in March 2008. It focused on organisational and technical issues of blended learning and knowledge management. Our concept of a single point of information (SPI) [2] and contextualised information retrieval requires the enfolding use of multi-layered metadata in each step of the knowledge processing. The main objective in this project was to design and develop a module for (semi-)automatical generation of such metadata of various knowledge assets and learning objects and to embed this module in a flexible service oriented architecture.

The following sections describe our vision of a single point of information, the module for automatic metadata extraction and semantic analysis (MetaXsA) and an overall architecture that makes use of the benefits from MetaXsA. Concluding in section 5 we describe the overvalues of our approach and give an outlook on further developments.

[1] See `http://mature-ip.eu` for further information.

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2 Single Point of Information

Considering the increasing number of enterprise applications and communication methods it becomes obvious that both productivity and efficiency of the employees are decreasing because the right information cannot be accessed in the right time [4,1]. One would wish to have one single access point to the IT infrastructure where information objects can be created, stored and any information from any information basis can be found (cf. [2]). Figure 1 shows a common process in the organisational creation of learning objects. While author 1 and author 2 use the corporate information basis and the internet for information retrieval for some specific information, author 3 does the same without regarding the results gathered by his colleagues. Assuming the availability of a corporate single point of information a search request containing the terms used by author 3 would yield the documents from author 1 and author 2 first because they are in the same organisational unit and they work on similar topics.

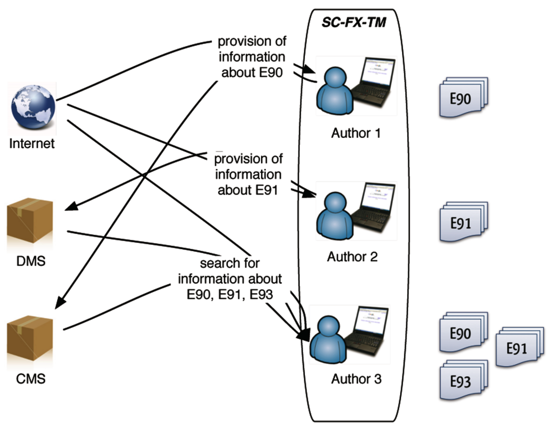

Fig. 1. Typical scenario during the creation of learning content

The idea of such a SPI strongly depends on intelligent strategies for information storage and retrieval. Intelligent information retrieval techniques can only be achieved by a connection of data objects with content related metadata. In the context of e-learning scenarios metadata mining is the key requirement to the (semi-)automatical creation of new learning objects and the connection of learning objects and knowledge assets.

3 MetaXsA

This chapter describes MetaXsA, a software which meets the demands of automatic metadata generation in a SPI architecture. It analyses input documents and returns an extended LOM XML-document containing the extracted metadata. MetaXsA consists of two components, metadata extraction and semantic analysis. The metadata extraction uses several extractors to extract metadata information included in the file. The semantic analysis comprises semantic modules which investigate the parsed document with respect to semantically relevant metadata.

The **automatic metadata extraction** implements the first step in the analysing process. Concerning the choice of tools, a set of project-specific requirements such as licensing conditions, costs, quality of the results and the possibility of embedding the external tools into a software environment have been criteria of major importance. Based on an evaluation of existing metadata extraction tools a combination of the three tools Libextractor[2], Hachoir-Metadata[3] and Exiftool[4] represents the most adequate solution of extracting administrative metadata from files by referencing external libraries. After an extraction process is finished the results are passed on to a closer examination.

As each extractor uses a specific key/value representation, there is a necessity of *parsing* the three results in order to facilitate a further interpretation. As the LOM [5] standard is applied to the result of the analysis there are some value spaces, a fix vocabulary and datatypes that have to be used for LOM conformity. Thus, parsing functionalities to ensure LOM compliance are implemented as well.

An *interpretation and comparison* of the three result sets requires a common basis which is provided by the elements of the LOM standard. The proprietary designators of the extraction tools are mapped to the LOM elements. Thus, the previously parsed (possibly different) result values can be compared via case differentiations. Additionally, a mechanism of computing a quality attribute for each LOM attribute is implemented.

The second MetaXsA component is the metadata generation by **semantic analysis**. The semantic analysis builds metadata sets by using techniques of information extraction. This functionality is embedded into a framework which organizes modular information processing resources. The **framework for semantic analysis** consists of an initialisation and an extraction phase to extract data from input files interacting with different connected modules. Since the *GATE API*[5] offers different services for information extraction, it is implemented as a general architecture. During an initialisation phase the connected modules are detected and their specifications are read out. Depending on these specifications, the MetaXsA webserver is extended by module specific webservices. In the extraction phase a preprocessing parses the content and identifies text tokens followed by an extraction pipeline comprising the connected information extraction modules (cf. figure 2) analyses the document content, extracts results and computes the result quality. Finally, the module results with particular quality following from pipeline processing are collected and included into the output file.

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[2] http://gnunet.org/libextractor/index.php?xlang=German

[3] http://hachoir.org

[4] http://www.sno.phy.queensu.ca/~phil/exiftool

[5] http://www-odp.tamu.edu/isg/appsdev/docs/gate.pdf

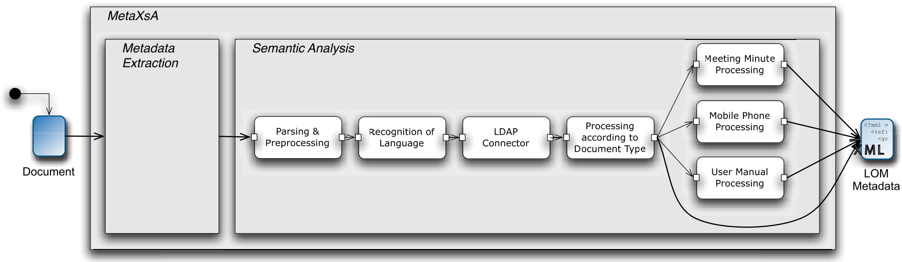

Fig. 2. MetaXsA-Pipeline

In the first module a word sample, taken from the document, is analyzed in order to determine the document's **language** and later on to perform a **part-of-speech recognition** for six different languages. The part-of-speech annotations can both be used by other modules and also as a filter to accelerate query processes. The keyword module extracts a selection of high-value keywords belonging to a document. On the one hand a user can administer lists of keywords and regular expressions which are of special interest. Every occurence of these words is included in the keyword data-set with high priority indication. On the other hand we use a heuristic approach based on the part-of-speech annotations. The nouns included in the document are analysed, clustered and get a priority note, depending on the noun frequency in the document. Both approaches of keyword generation result in weighted keyword sets describing the relevance of keywords. The LDAP connector uses a LDAP system to read out organisational units and related staff mentioned in the document. The document is analysed with respect to organisational units and staff data. This results in a company specific contextualisation of the document. As the LOM file includes the name of the document's author, staff networks can be deduced enabling the identification of groups working together. A document's relevancy can be considered in terms of persons related to the document.

The metadata sets resulting from the currently observed data have a high quality although some intuitive approaches are followed up. Widespread extensions are possible due to the modular approach of MetaXsA. The system can be extended for more source types like blogs or wikis.

4 The KnowledgeManager

MetaXsA is integrated into a full service oriented architecture in order to evaluate its functionality and performance (c.f figure 3).

We are using a Document Management System for keeping our documents and an IBM DB2 for storing and querying the metadata. Furthermore, we integrate an User Directory to get the necessary information for contextualization. A central module called KnowledgeManager handles the coordination and communication within the server system. On the client-side the user interactes with the system by using the prototype client DyOgeneS which only communicates with the KnowledgeManager.

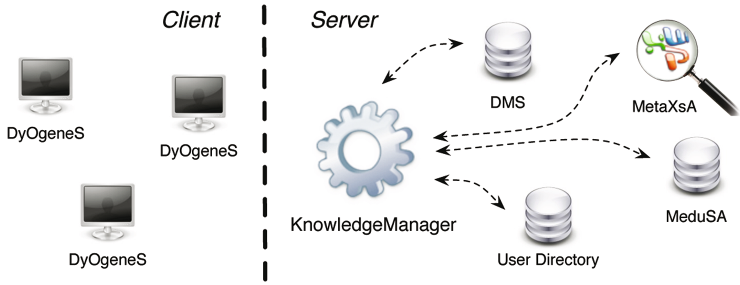

Fig. 3. The overall architecture with MetaXsA and the KnowledgeManager

5 Conclusion and Outlook

With MetaXsA we developed a module for the semi-automatic[6] metadata extraction and the semantic analysis of typical office documents in order to support the authoring process of knowledge objects with metadata of high quality. To provide these metadata all documents traverse a process of automatical metadata extraction and semantic analysis. Our module for metadata extraction combines several open source extractors that have been selected regarding various criteria. Due to the availability of multiple extractor results, we are able to provide the user with graphical assistance on how secure a specific date was extracted. The module for the automatical metadata extraction is built modularly. Thus, further extractors can be added easily. The module for the semantic analysis of documents works with partly naive approaches, which nevertheless yield good results that are sufficent for the needs of the content analysis.. The semantic analysis can be adapted easily to a specific organisational context by servicing the specific keyword and regular expression lists. Each organisation can characterise its own document types and define specific processing steps for further contextualisation. Due to its consequently modular design the extension of the semantic analysis module is easy to handle.

With the KnowledgeManager as an implementation of the single point of information and MetaXsA as a component for the deployment of high quality metadata we provide a feasible approach of intelligent knowledge management. The authoring process of structured learning objects profits from the consideration of contributing organisational units. Authors of learning objects can refer to documents with a full set of technical and semantic metadata that are on a professional level that dispenses from manual revising. The specific semantic processing according to the found document type provides deep semantic analyses and therefore a very specific contextual information, which can easily be accessed by authors of learning materials.

The presented prototype underwent several performance and stress tests with thousands of real-world documents provided by our partners. During the first testing phase of the MetaXsA component its speed was very impressive. The

[6] There still is the possibility of a final edition process done by the author.

average round trip time for the automatic metadata extraction and semantic analysis from providing a document to the complete LOM metadata set only took about 6 seconds. In the meantime the project group finished up the work and the prototype undergoes the further evaluation and testing phase with our partners. Even if the outcomes so far are fully satisfying we are currently working on the further development of our approach. The contextualisation of knowledge objects can be heavily expanded, if taking the business processes into account in which the are integrated. The semantic analysis of knowledge objects can be improved by means of implementing approaches of machine learning and the support of ontologies. The relation of documents to persons within an organisation opens the possibility to visualise on-topic social networks. With the integration of further knowledge intense systems like wikis, weblogs and e-mails, our architecture will be enabled to aggregate formal and informal learning considering the knowledge anchored in the employees heads to foster personal and organisational learning processes.

References

1. Barreau, D., Nardi, B.A.: Finding and reminding: file organization from the desktop. SIGCHI Bull. 27(3), 39–43 (1995)
2. Hinkelmann, K., Magenheim, J., Reinhardt, W., Nelkner, T., Holzweißig, K., Mlynarski, M.: KnowledgeBus - An Architecture to Support Intelligent and Flexible Knowledge Management. In: Duval, E., Klamma, R., Wolpers, M. (eds.) EC-TEL 2007. LNCS, vol. 4753, pp. 487–492. Springer, Heidelberg (2007)
3. Hinkelmann, K., Holzweißig, K., Magenheim, J., Probst, F., Reinhardt, W.: Linking Communities of Practice with Learning Communities in Computer Science Education. In: Education for the 21st Century — Impact of ICT and Digital Resources, IFIP Computer Science, pp. 83–92. Springer, Berlin (2006)
4. Kwasnik, B.H.: The importance of factors that are not document attributes in the organisation of personal documents. Journal of Documentation 47(4), 389–398 (1991)
5. Learning Technology Standards Committee Learning Standards Committee of the IEEE. Draft standard for learning object metadata (2002) (last viewed on 2008-01-11), http://ltsc.ieee.org/wg12/files/LOM_1484_12_1_v1_Final_Draft.pdf

Knowing What the Peer Knows: The Differential Effect of Knowledge Awareness on Collaborative Learning Performance of Asymmetric Pairs

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Abstract. In an empirical study, we provided (or not) pairs of students working in a remote collaborative learning situation with a knowledge awareness tool that provided learner A with learner B's level of knowledge measured through a pre-test. We analyzed the effect of the knowledge awareness tool on asymmetric pairs with regards to the prior-knowledge. Post-hoc analysis on the pairs' knowledge level showed that the knowledge awareness tool mainly affects the learning performances of asymmetric pairs. Further analysis on the learners' level showed that the knowledge awareness tool mainly affects the collaborative learning gain of the more-knowledgeable peers of asymmetric pairs. The results are discussed in light of socio-cognitive processes such as audience design and perspective taking.

Keywords: CSCL, Knowledge Awareness, prior-knowledge asymmetry, audience design.

1 Introduction

In an empirical study [1], we provided learners in a remote peer-to-peer collaboration setting with cues about their partner's prior knowledge through a technical support we refer to as a Knowledge Awareness Tool (KAT hereafter). In the present paper, we ask whether the KAT has a differential effect on pairs that are of the same level of prior-knowledge compared to asymmetric pairs in terms of prior-knowledge. A large body of research reported on a robust bias called "the false consensus effect" which stipulates that people are biased in the direction of their own knowledge when they have to rely mainly on subjective cues to make inferences about others' knowledge ([2]; [3] among others). The higher the knowledge discrepancy, the more the estimation of more-knowledgeable peers is biased. In the present paper, we argue that providing co-learners with objective cues about their peer's knowledge should reduce the negative effect of the so called "false consensus" effect and enhance learning performances of asymmetric pairs, more specifically the learning performances of more-knowledgeable peers of asymmetric pairs. Post-hoc analyses are reported and discussed.

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1.1 Asymmetry of Knowledge in Peer-to-Peer Collaboration

The added value of peer-to-peer collaboration is currently widely acknowledged. Theoretical approaches to collaborative learning emphasize the role of social interaction among peers during collaborative activities, in the process of shared knowledge construction. In the research tradition inspired by the socio-historical approach to learning ([4]; [5]; [6]), cognitive development is guided by more-knowledgeable social partners (e.g. parents, teachers, tutors) who mediate and scaffold the acquisition of new competencies [5]. Accordingly, more knowledgeable peers help less knowledgeable learners by providing guidance and monitoring their understanding. On the other hand, the socio-constructivist perspective (see for instance [7]) relies on the work of Piaget and emphasizes the importance of notions such as cognitive conflict and coordination of viewpoints during symmetric interaction between learners of approximately the same level of knowledge [8]. However, as stressed by Verba [9], a large body of research shows that the effective collaborative knowledge construction can emerge through variety of socio-cognitive processes involving either asymmetrical or symmetrical interaction.

Dillenbourg [10] identified the symmetry of interaction as a main characteristic of peer to peer collaborative situation. The author proposed three different dimensions of symmetry: the symmetry of action describes the proportion of actions accessible to each peer; the symmetry of status corresponds to the differences in terms of status with regards to the community; finally, the symmetry of knowledge refers to discrepancies in the level of knowledge and expertise among peers. It is noteworthy that symmetry of knowledge should not be confused with heterogeneity of knowledge. Peers of approximatively the same level of knowledge can however have different understandings. Furthermore, a complete symmetry of knowledge is difficult to obtain, even in peer-to-peer collaboration. The chance of two peers having exactly the same knowledge is rather small and the symmetry of knowledge is subject to change during the course of collaboration. Researchers agree that a slight knowledge asymmetry among peers is suitable for learning and can lead to effective interaction such as elaboration of points of view, argumentation and conflict resolution [8]. As argued by King [11], all collaborative situations do not involve a more expert and a more novice participant. For instance, collaborative situations involving same level peers can be more egalitarian where the “cognition is distributed more evenly” ([11], p. 59). In these settings, peer partners engage in some mutual scaffolding and mediation processes characterized by reciprocity of interaction and activity.

Peer-to-peer collaborative learning presents some obvious advantages. The intrinsically status-free interaction guarantees a certain symmetry in roles and participation which is generally beneficial to the collaborative learning process. Furthermore, the rather low discrepancies among same level peers (e.g. class-mates) usually grant an optimal zone of “proximal development” (see [4]). On the other hand, as mentioned before, even in peers of supposedly the same level, slight differences usually still persist. In these cases of slight level of knowledge asymmetry, an implicit illusion of knowledge symmetry can occur, misleading learners to expect a higher level of shared understanding than what is actually the case; as shown in the next section, this ‘illusion of mutuality’ could, in turn, strain the collaborative learning process.

1.2 Awareness of Peer Knowledge

In order to build a shared understanding of the task, co-learners must build a certain representation of their partners' knowledge. Knowing what the peer knows and needs to know is a prerequisite for effective communication ([12]; [3]; [2]). Krauss and Fussell [2] suggested that speakers may rely on two different sources of information: the prior knowledge and the current feedback. These sources are dynamically related and feed each other. The authors argue that this process of "audience design" and "perspective taking" is necessarily based on probabilistic inferences and consequently suffers from certain biases.

For instance, a now established bias is the "false consensus effect". Studies showed that people are usually biased in the direction of their own knowledge when assessing others' knowledge ([3]; [13]). More-knowledgeable (e.g. experts) people are more likely to overestimate their peers' knowledge whereas less-knowledgeable people (e.g. novices) have the propensity to underestimate it [13]. Investigations in the domain of expert-layperson communication (e.g. [14]) showed that the experts' biased estimation of novices' knowledge when they provide explanations is detrimental to the novices' understanding. Chi et al. [15] found that tutors have the propensity to systematically overestimate the students understanding. This overestimation is expected to lead to explanations that do not optimally fit the novices' needs.

Nückles and colleagues ([16][17][13]) conducted a series of experiments in expert-layperson asynchronous dialogue setting to assess the effect of a "knowledge assessment tool." Nückles and Stürz [16] showed that providing experts with knowledge assessment cues helped experts to more efficiently plan and communicate their answers to a layperson's inquiry. On the layperson's side, the assessment tool substantially reduced the frequency of comprehension questions and declarative knowledge acquisition. In a follow-up study, Nückles, Wittwer and Renkl [17] focused more specifically on the cognitive processes used by the experts to plan and communicate efficient solutions to the layperson's inquiries. They further explored two alternative explanations of the cognitive effect of the assessment tool. On one hand, the assessment tool's effect could be that it sensitizes the experts to the layperson status of the audience, prompting them to carefully adjust their explanations to the typical knowledge characteristics of the community of laypersons. On the other hand, by presenting experts with individuating information about the layperson's knowledge level, the assessment tool may have enabled the experts to more quickly and accurately adapt their mental model of the layperson's knowledge. The results suggested that rather than a sensitizing effect, the assessment tool seems to have a specific adaptation effect.

These considerations are of a particular importance for the field of computer supported collaborative learning (CSCL). In remote collaborative learning situations, knowledge estimation biases are even more likely to appear, given that remote interactions are usually poorer than face-to-face communication and that collaborants are less likely to know each other. Consequently, several researchers have proposed technical solutions to enhance the awareness of the partners' knowledge. Ogata and Yano [18] introduced the notion of knowledge awareness and a tool aimed at increasing collaboration opportunities of shared knowledge construction in an open-ended collaborative learning environment. Leinonen and Järvelä [19] showed the positive effects of a knowledge externalization and visualization tool to support awareness of the knowledge of group members. To sum up, the main idea here is that providing co-learners with an external aid may help them to accurately assess their partners' knowledge and enhance collaborative learning efficiency.

It is important to point out that the present study presents some important distinctions compared to the aforementioned studies. We argue that these differences raise some fundamentally different assumptions about the underlying socio-cognitive mechanisms. First, while the previous studies mainly focused on asynchronous communication, the present study reports on a synchronous verbal communication situation. In an asynchronous communication setting, the possibilities of providing feedbacks (e.g. acknowledgements and back-channels) are seriously limited [20]. On the other hand, speakers have more time at their disposal to carefully plan their contributions. Second, the expert-layperson dialogue settings imply asymmetric and unidirectional learning processes whereas the KAT experiment reports on peer-to-peer and bidirectional knowledge acquisition processes. In a status-free situation, some degree of mutual influence is expected among the peers. Therefore, in the context of peer-to-peer collaboration characterized by an asymmetry in knowledge but not in status, we argue that this overestimation may lead to suboptimal grounding processes that may hinder the collaborative performance of asymmetric pairs, and more specifically, the knowledge gain of more-knowledgeable peers. If a slight asymmetry in terms of knowledge exists, more-knowledgeable peers that do not have a relatively accurate model of their partner's knowledge are more likely to be influenced in the wrong direction. Furthermore, providing more-knowledgeable collaborants with knowledge awareness should prompt them to provide their less-knowledgeable peers with more elaborated explanations, a process that is known to enhance the learning performances ([21]; [22]).

1.3 The Present Study and Research Questions

In an experimental study, we investigated the effects on the learning performance of a technical support providing co-learners with cues about their partner's prior knowledge. In a remote dyadic synchronous learning situation, co-learners of the experimental condition were provided with cues about their partner's knowledge in the form of a visualization tool we will refer to as the *Knowledge Awareness Tool* (KAT hereafter). The co-learners of the control condition were not provided with the KAT. The results showed that providing co-learners with cues about their peer's knowledge during the collaboration significantly enhances their learning gain compared to co-learners who were not provided with these cues. This result is detailed and discussed elsewhere [1]. The present contribution focuses on post-hoc analyses of how the KAT differentially affects co-learners presenting asymmetries in terms of prior-knowledge. In light of what has been previously discussed herein, we ask the following research questions:

1. Is the KAT differentially affecting asymmetric pairs with regards to the prior-knowledge compared to symmetric pairs?
2. Within the pairs, does the KAT differentially affect the more-knowledgeable peers compared to the less knowledgeable peers?

2 Method

2.1 Participants and Design

Sixty-four first year university students were remunerated to participate to the study and were randomly assigned to dyads. Half of the dyads were randomly assigned to each of the two experimental conditions: (1) the KAT condition, in which the participants were provided with awareness cues about their peer's prior knowledge; (2) the control condition, where they were not provided with the cues about their peer's prior knowledge.

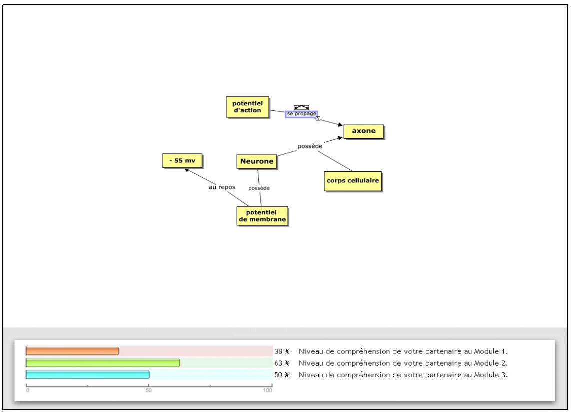

Fig. 1. Screenshot of the KAT condition during the concept-map building phase

2.2 Instructional Material and Technical Setup

Instructional Material. An explanatory text about the neurophysiologic phenomenon of "neural transmission" was developed with the help of domain experts and served as instructional material (see authors [1]). The text was divided into three chapters of approximately the same size: "the resting potential", "the initiation of the action potential" and "the propagation of the action potential".

Technical Setup. We developed an automated experimental setup running on two identical computers distributed in two different rooms, allowing us to automate the learning phases (i.e. individual and collaborative) and measures. During the collaborative phase, participants used an on-line concept-map building software (CmapTools, © IHMC). They were also provided with a microphone-headset during this phase, allowing them to communicate with each other.

2.3 Procedure

Procedure. The experimental session lasted for an overall of approximately 90 minutes and consisted of 6 phases:

1. *Prior-knowledge verification*: the participants' prior knowledge of the instructional material was tested through an open question in order to detect and remove from the analyses potential experts of the domain (4 min).

2. *Individual reading phase*: participants were requested to carefully read the instructional text. They could freely access the three chapters in any order (12 min.).
3. *Pre-test*: The pre-test was administrated individually before the collaborative learning phase. It consisted of 30 items: 6 multiple-choice items and 24 inference verification items. The multiple-choice items included four possibilities with one or more possible correct answers. The inference verification items consisted of true or false assertions. The same number of items was related to the content of each of the three chapters of the instructional material (i.e. two multiple-choice and six inference verifications per chapter). The *pretest's* overall score ranged from 0 to 48 (0 to 16 for each chapter). All items were validated by experts of the domain.
4. *Collaborative concept-mapping phase*: Participants were provided with textual instructions and a short video tutorial on how to use the CmapTools© interface. Then during 20 minutes, they had to produce a collaborative concept-map describing the content of the instructional text. They were able to communicate orally through headsets. The participants of the experimental condition were provided with the *KAT* on the bottom part of the screen (see Fig 1): it presented a graphical representation of the partner's pre-test scores on each chapter. Participants of the control condition were not provided with the *KAT*.
5. *Post-test*: The post-test was administrated individually after the collaborative phase and included the same items than the pre-test presented in a different order.
6. *Estimation of peer's knowledge.* Participants were finally asked to estimate their partner's knowledge at the post-test for each of the three chapters on a 7-point Likert-like survey. Analyses about this measure are not reported in the present paper.

2.4 Dependant Variables

We used *Relative Learning Gain (RLG)* as the learning outcomes measure. On the individual level, The *RLG* with regards to each chapter was computed by taking the difference between the learners' post-test and pretest scores divided by the maximal score minus the pretest score, and multiplied by 100. The total *RLG* consisted of the mean of the *RLGs*. from the three chapters. With regards to the first research question, a pair level RLG (*pair-RLG*) was computed by taking the mean between the *RLGs* of peers of same pairs.

2.5 Hypotheses

With regards to the theoretical considerations and the research questions, the following hypotheses were proposed and tested:

1. On the pair level, we expect the KAT factor to differently affect symmetric and asymmetric pairs. In other words, an interaction between the KAT factor and the pair-level asymmetry post-hoc factor is expected. More specifically, we expect the learning performances (i.e. *pair-RLG*) to be higher for the KAT condition asymmetric pairs than the control condition asymmetric pairs.
2. Within the asymmetric pairs, we expect the KAT factor to differentially affect the learning performances of more-knowledgeable and less-knowledgeable peers of the asymmetric pairs. In other words, we expect the learning gains for more-knowledgeable peers of the KAT condition to be higher than those of the control condition.

3 Results

3.1 Interaction between KAT and Pair Level Prior-Knowledge Asymmetry

We hypothesized a significant interaction between the KAT factor and the prior knowledge asymmetry among peers. To test this hypothesis, a post-hoc factor called *pair-asymmetry* was built by taking the absolute value of learner A's score minus learner B's score on the pretest – A and B being peers of the same pair. Multiple-regressions statistical methods were used to test the interaction (see [23] for further discussion of the statistical methods) with the *pair-RLG* as a criterion. The product of *pair asymmetry* and *KAT* factors was computed and added to the regression equation comprising the centered *KAT* and the centered *pair-asymmetry* factors as predictors.

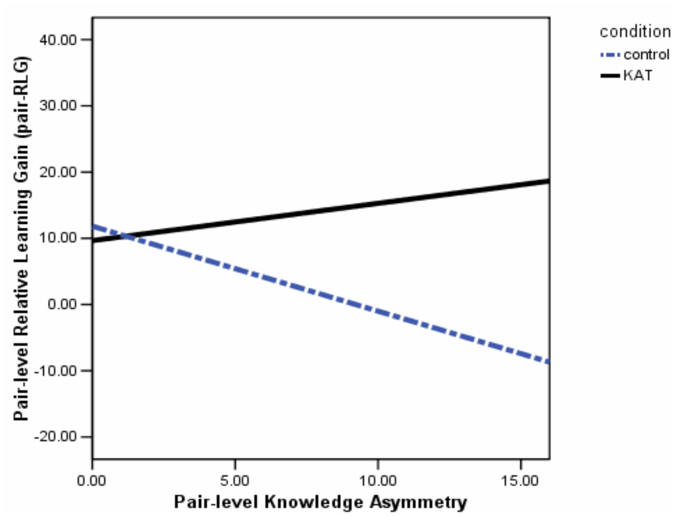

Fig. 2. Pair-level Prior-Knowledge Asymmetry on the individual level plotted against the pair-level relative-learning-gain for the control (dashed line) and KAT (plain line) conditions

The results reported a significant multiple linear regression (F = 4.36, p = .013; R^2_{adj} = .26). The regression analysis reported that the product of the *pair asymmetry* and the *KAT* factor is a significant predictor of the *pair-RLG* while the two factors are controlled (*B* = 1.85; *p* = .039). This indicates a significant interaction between the *pair asymmetry* factor and the *KAT* factor. This result confirms our hypothesis. The KAT factor seems to affect symmetric and asymmetric pairs differently in terms of prior-knowledge. Figure 2 represents the best fits of *pair-RLG* plotted against the *pair asymmetry* with regards to the KAT and the Control conditions. We can see that KAT condition's *pair-RLGs* (plain line) improve with the *pair-asymmetry* whereas the control condition's *pair-RLGs* decrease with the *pair-asymmetry*. Hence, we can conclude that the KAT positively impacts the learning performance of asymmetric pairs, whereas the performance of control condition pairs seems to decrease as their prior-knowledge asymmetry increases.

3.2 The Differential Effect of KAT on Less- and More-Knowledgeable Peers

We hypothesized that the KAT should differentially impact the learning performances of more-knowledgeable peers of asymmetric pairs. In order to test this hypothesis, we built a post-hoc factor called *prior-knowledge-asymmetry* by subtracting B's pretest score from A's pretest score, A and B being members of the same pair. It is noteworthy that, as learner A and B are undistinguishable within the pair, the *prior-knowledge asymmetry* can be considered as an individual and bidirectional estimation of the knowledge asymmetry. Consequently, more-knowledgeable learners are associated with positive values and less-knowledgeable peers are associated with the negative values of the same axis. For instance, if within an asymmetric pair learner A's pretest score is 13 and B's pretest score is 25, the less-knowledgeable A will be associated with a prior-knowledge-asymmetry value of -12 (i.e. 13 – 25) and the more-knowledgeable B will be associated with a corresponding *prior-knowledge-asymmetry* value of 12 (i.e. 25 – 13).

The product of *prior-knowledge-asymmetry* and *KAT* factors was added to the regression equation comprising the centred *KAT* and *prior-knowledge-asymmetry* factors as predictors. The multiple regression reported a significant model ($F = 4.19$, $p < .01$, $R^2_{adj} = .14$). The results reported a significant interaction between the *prior-knowledge asymmetry* and *KAT* factors when predicting the *RLG* ($B = 1.89$; $p = .04$).

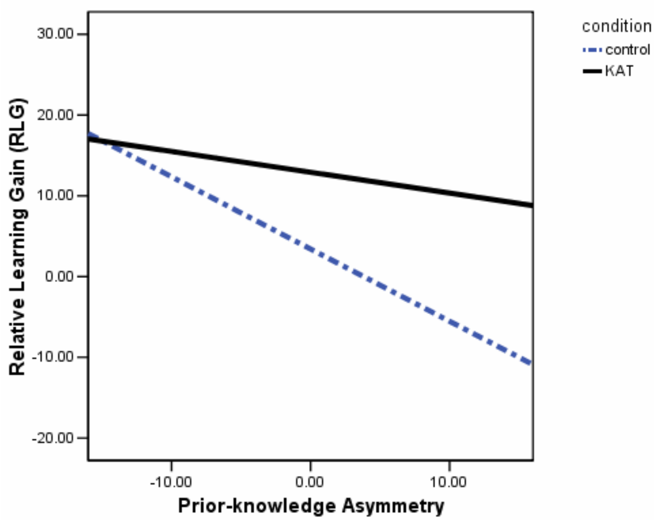

Fig. 3. Prior-Knowledge-Asymmetry on the individual level plotted against the relative-learning-gain for the control and KAT conditions

Figure 3 represents the best fits of *RLG* plotted against the *prior-knowledge asymmetry* with regards to the KAT and the control conditions. The dashed line represents the best fit for the learners of the Control condition. We can see that the RLG of the less-knowledgeable peers (left-side of the abscise axis) is positive whereas the RLG of the more-knowledgeable (right side of the abscise axis) is negative. The dashed line's slope suggests a negative relation between the *prior-knowledge asymmetry* and the *RLG*. More-knowledgeable peers' knowledge within asymmetric pairs of the control condition seems to be impaired. On the other hand, the slope of the KAT condition's best fit line (plain-line) suggests that more- knowledgeable peers have a positive RLG. The KAT condition's more-knowledgeable peers seem to progress almost at the same level than less-knowledgeable peers. Hence our hypothesis is confirmed. More-knowledgeable peers benefit more from having cues about their partner's knowledge than less-knowledgeable peers.

4 Discussion

A large body of literature highlights the importance for co-learners to know what their audience knows and does not know in order to make communication effective ([12]; [2]; [20]; [14]). On the other hand, effective communication is known to positively affect collaboration and support the construction of shared understanding ([10]; [24]). Consequently, researchers in the field of CSCL and CSCW showed a particular interest in developing solution to support and mediate the awareness of peers' knowledge ([18]; [19]). Knowledge awareness is particularly important in remote collaboration settings providing less situational opportunities for co-learners to build an accurate model of their peers' knowledge. Past research has shown that biases can occur when collaborants cannot rely on objective cues to build an accurate model of their partners' prior-knowledge and understanding. The "false-consensus effect" is defined as a bias towards one's own understanding when one estimates others seemingly similar peers' knowledge ([2]; [3]; [13]; [16]; [17]).

Under the light of these considerations, we addressed the question of the interaction between prior-knowledge asymmetry and the availability of objective cues about the peers' prior-knowledge, with regards to the collaborative performances. In the present contribution, we analyzed the differential effect of cues about the peer's prior-knowledge on the collaborative learning gain with regards to the degree of knowledge asymmetric within pairs. The results showed that the Knowledge Awareness Tool differentially affect symmetric and asymmetric pairs. More specifically, asymmetric pairs seem to take a better advantage of having the Knowledge Awareness Tool. This first result is in line with the aforementioned research. Co-learners presenting a certain discrepancies in terms of prior-knowledge seem to take advantages of having cues about each others prior-knowledge. A deeper analysis showed that it is mainly the more-knowledgeable peers of the asymmetric pairs that take advantage of the KAT. Rephrased differently, it seems that more-knowledgeable peers that do not have objective cues about the level of prior-knowledge of their less-knowledgeable peer can only rely on subjective estimations of their partner's knowledge. They may have thus been subject to 'the false consensus' and have overestimated their peer's prior-knowledge. They may have produced suboptimal contributions that may have impaired the construction of shared understanding ([14]; [13]). Expecting the peer to have the same level of knowledge may lead more-knowledgeable peers to make less effort to provide an elaborated explanation – a process that have been proven to be beneficial for collaborative learning gain ([21]; [22]). Furthermore, more-knowledgeable peers are also more likely to learn incorrect information from their less-knowledgeable partners in the case of potential epistemic conflict, when the conflict is solved on the basis of trustfulness or how convicting is the peer when he or she provides contradicting information. Hence in the KAT condition, prior-knowledge cues may have helped co-learners towards the coordination of prior-knowledge and efficient peer-tutoring.

Further analyses should focus on the verbal interaction process within asymmetric pairs of both control and KAT conditions. One may expect more-knowledgeable peers to provide significantly more explanations and elaborations when they are made aware of the knowledge discrepancies among the pair. On the other hand, less-knowledgeable peers may also, for instance, produce more questions and knowledge verifications.

Acknowledgements

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References

1. Sangin, M., Molinari, G., Dillenbourg, P., Nüssli, M.-A.: "I know what you know": how awareness cues about the peer's prior-knowledge affect collaborative learning in dyads. Journal of the Learning Science (submitted)
2. Krauss, R.M., Fussell, S.R.: Perspective-taking in communication: The determination of others' knowledge and referential language use. Social Cognition 9, 2–24 (1991)
3. Nickerson, R.S.: How we know – and sometimes misjudge – what others know: Imputing one's own knowledge to others. Psychological Bulletin 125, 737–759 (1999)
4. Vygotsky, L.: The Role of Play in Development. In: Mind in Society. Harvard University Press, Cambridge (1978)
5. Rogoff, B.: Apprenticeship in thinking. Cognitive development in social context. Oxford University Press, New York (1990)
6. Wertsch, J.V.: Adult-child interaction and the roots of metacognition. The Quarterly Newsletter of the Institute for Comparative Human Development 2(1), 15–18 (1978)
7. Doise, W., Mugny, G.: The social development of the intellect. Pergamon Press, Oxford (1984); Driver, R., Guesne, E., Tiberghien, A.: Children's ideas in science. Open University Press, Buckingham (1985)
8. Dillenbourg, P., Baker, M., Blaye, A., O'Malley, C.: The evolution of research on collaborative learning. In: Spada, E., Reiman, P. (eds.) Learning in Humans and Machine: Towards an interdisciplinary learning science, pp. 189–211. Elsevier, Oxford (1996)
9. Verba, M.: Tutoring interactions between young children: how symmetry can modify asymmetrical interactions. International Journal of Behavioral Development 22(1), 195–216 (1998)
10. Dillenbourg, P.: What do you mean by collaborative learning. In: Dillenbourg, P. (ed.) Collaborative learning: Cognitive and Computational Approaches, pp. 1–19. Elsevier, Oxford (1999)
11. King, A.: Transactive peer tutoring: Distributing cognition and metacognition. Computer-Supported Cooperation Scripts 52. Educational Psychology Rev. 10, 57–74 (1998)

12. Clark, H.H., Marshall, C.R.: Definite reference and mutual knowledge. In: Joshi, A.K., Webber, B.L., Sag, I.A. (eds.) Elements of Discourse Understanding. Cambridge University Press, Cambridge (1981)
13. Wittwer, J., Nückles, M., Renkl, A.: Is underestimation less detrimental than overestimation? The impact of experts' beliefs about a layperson's knowledge on learning and question asking. Instructional Science (2008)
14. Bromme, R., Jucks, R., Runde, A.: Barriers and biases in computer-mediated expert-layperson communication. In: Bromme, R., Hesse, F.W., Spada, H. (eds.) Barriers and biases in computermediated knowledge communication – and how they may be overcome, pp. 89–118. Springer, New York (2005)
15. Chi, M.T.H., Siler, S., Jeong, H.: Can tutors monitor students' understanding accurately? Cognition and Instruction 22, 363–387 (2004)
16. Nückles, M., Stürz, A.: The assessment tool. A method to support asynchronous communication between computer experts and laypersons. Computers in Human Behavior (2006)
17. Nückles, M., Wittwer, J., Renkl, A.: Information about a layperson's knowledge supports experts in giving effective and efficient online advice to laypersons. Journal of Experimental Psychology: Applied 11, 219–236 (2005)
18. Ogata, H., Yano, Y.: Combining Knowledge Awareness and Information Filtering in an Open-ended Collaborative Learning Environment. International Journal of Artificial Intelligence in Education 11, 33–46 (2000)
19. Leinonen, P., Järvelä, S.: Facilitating interpersonal evaluation of knowledge in a context of distributed team collaboration. British Journal of Educational technology 37(6), 897–916 (2006)
20. Clark, H.H., Brennan, S.E.: Grounding in communication. In: Resnick, L.B., Levine, J.M., Teasley, S.D. (eds.) Perspectives on socially shared cognition, pp. 127–149. DC American Psychological Association, Washington (1991)
21. Webb, N.M.: Task-related verbal interaction and mathematics learning in small groups. Journal of Research in Mathematics Education 22, 366–389 (1991)
22. Webb, N.M.: Peer interaction and learning in small groups. International Journal of Educational Research 13, 21–39 (1989)
23. Baron, R.M., Kenny, D.A.: The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. Journal of Personality and Social Psychology 51, 1173–1182 (1986)
24. Roschelle, J., Teasley, S.D.: The construction of shared knowledge in collaborative problem solving. In: O'Malley, C.E. (ed.) Computer-Supported Collaborative Learning, pp. 69–197. Springer, Berlin (1995)

Onto'CoPE: Ontology for Communities of Practice of E-Learning

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Abstract. The purpose of this article is to extend the application of the communities of practice to the e-learning field which handles an interdisciplinary techno-pedagogic knowledge: cognitive, psycho-pedagogic, multi-media, software, etc. We propose a new category of CoPs called CoPE (Communities of Practice of E-learning) which combines two fields: CoPs as basic field, and E-learning as an application domain. To be able to capitalize the knowledge in a CoPE, we propose an ontology entitled "Onto'CoPE" that aims to model the members of the CoPE and their roles, the learning situations, and annotating the CoPE's knowledge resources through activities and possible types of interactions, as well as the environment made up of services, tools and resources. The paper briefly describes our method for building our ontology, its structure, and contents.

Keywords: Ontology, Community of Practice, e-learning, collaborative learning, Onto'CoPE.

1 Introduction

Improving the quality of education through the diversification of methods, innovation, sharing, communication, and best practices are one of the most important strategies for managing the educational system process. E-learning is recognised as a strategically important element for the provision of learning across all areas of society, in particular at government level. However, the use of e-learning faces a number of challenges related to: i) the difficulty in interpretation of domain concepts like the scenario, learning situation, activity, role, etc. ii) the multiplicity of approaches, models, methods, techniques and tools used in the development of the online systems, and iii) the heterogeneity of learning platforms. The need for capitalization is necessary in terms of knowledge and know-how related to the field of e-learning and its tools, the exchange resulting from techno-pedagogic practices, and in terms of collaboration between various e-learning actors. Based on work done on communities of practice and the success they made in collaborative learning [1], we propose to help educators

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in the e-learning field by providing them a space for exchanging and sharing their knowledge and know-how through a community of practice of e-learning (CoPE). In [2] we defined a CoPE as virtual space of exchanging, sharing and resolution of problems encountered by the actors of the e-learning during all phases of an online learning system life cycle. The main objective of this paper is to provide an ontology for a uniform vocabulary for CoPEs which we entitled Onto'CoPE. This ontology aims to model the members of the CoPE and their roles, the learning situations, and annotating the CoPE's knowledge resources through activities and possible types of interactions, as well as the environment made up of services, tools and resources.

In the following, section 2 introduces the background of our research and related work. In section 3, we define the main concepts of the Onto'CoPE ontology. Some results and future work are discussed in section 4.

2 Background and Related Work

The present research is part of the European project "PALETTE[1]" (2006-2009) which aims at facilitating exchanges and learning in CoPs. Four domains are involved and studied in PALETTE: management, engineering, teaching and health. Our work comes under the teaching domain, more specifically the field of e-learning.

We address the problem of conceptual representation of techno-pedagogic knowledge, tacit and explicit in the domain of e-learning. Very often, there is a need to share the meaning of terms in a given domain. Most of the work that has been done in the teaching domain through online CoPs didn't take into consideration a formal modelization of the concepts. For example TeacherBridge [3] proposed a set of online tools to help create a community of teachers using dynamic web pages creation. This project lacks of semantic annotations of knowledge especially the tacit knowledge. There is no mean to retrieve it. Another work by Khan and Maull [4] on "Teaching Boxes" addressed the problem of knowledge capitalization that teachers accumulate during their teaching career by reusing digital resources repositories through a teaching box model. However, their model doesn't differentiate between the roles of the teachers and does not talk about a formalization of the concepts. Dubé et al. [5] proposed a typology of several virtual CoPs (VCoPs). Their findings show that most of the VCoPs had some characteristics in common. However, they didn't try to formalize the VCoPs based on common conceptual ontology. On the other hand, PALETTE's proposed an ontology based on twelve existing CoPs (called O'CoP) [6]. The ontology is dedicated to CoPs in general and is built based on analysis of information sources gathered from the twelve CoPs.

Our approach in the ontology creation is done in a collaborative way. We are working collaboratively within our subgroup to define the main concepts of a CoPE. We are actively participating in some CoPs (e.g. www.cpsquare.org) exchanging ideas and sharing knowledge with fellow researchers. The following section shows the main concepts defined in our ontology.

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[1] PALETTE: *Pedagogically sustained Adaptive Learning through the Exploitation of Tacit and Explicit Knowledge;* http://palette.ercim.org/

3 Onto'CoPE: Ontology for CoPEs

Fig. 1 represents the basic concepts of the CoPE: actors with role and profile, competency, knowledge, activity, internal and external environment, etc.

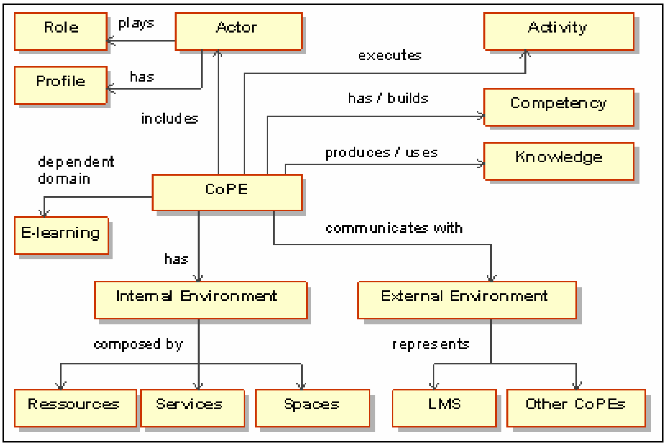

Fig. 1. CoPE's Concepts

Actors and Roles

Many authors illustrated the level of engagement of a member in a CoP such as visitor, beginner, regular, leader, and senior [7-9]. In our approach in the CoPE, we considered the actors coming from the e-learning domain as teachers, pedagogues, tutors, experts, etc. These actors have different levels of skills and knowledge based on their training and level of expertise in the field. Their competencies can be measured by the number of active participations, the specialty, and the seniority in the field or other metrics. For a better management of their work, the actors can organize themselves in groups on the basis of their objectives and concerns. The CoPE has the particularity of assigning some roles immediately from the beginning of the activity while others are negotiated between participants. A member can take a role of senior in a field where he is an expert while he is a simple participant in another field for which his competency is limited. The advice or an opinion would rather be considered from a senior and expert member than from a beginner or less qualified member. We distinguish four roles: 1) *the support members' role*; 2) *the learner members' role*; 3) *the visitor members' role*; and 4) *the guest members' role*. Fig. 2 illustrates the concept model of «C-Role» as defined in our ontology.

Activities

The members of the CoPE carry out joint activities to exchange techno-pedagogical information. These activities can be synchronous or asynchronous, and are often collaborative, and informal. They intervene in the framework of a learning situation. They correspond to the stages of analysis, design, implementation, and utilization phase of the learning life cycle [2]. Consequently, we propose to classify them into four types of activities: *analysis-activity*, *design-activity*, *implementation-activity*, and *utilization-activity*. Every activity is described with data that is either already defined by IMS-LD pedagogical specification or specific to CoPEs. Fig. 3 describes the elements that have been added (Approach, Context, Problem to Solve, Constraints, Result, and Date).

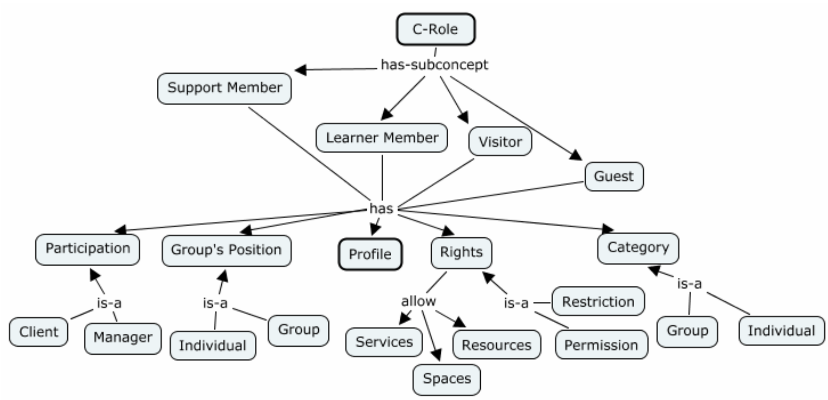

Fig. 2. Concept model of «C-Role»

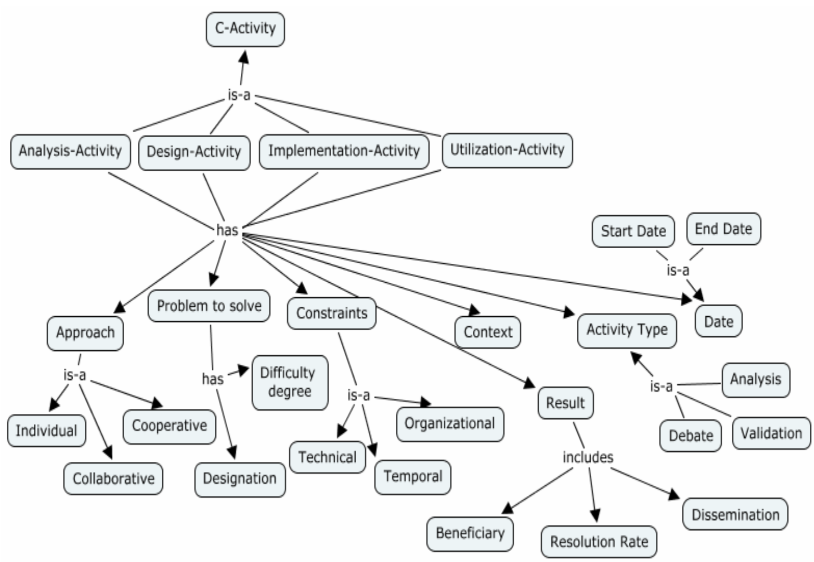

Fig. 3. Concept model of «C-Activity»

Learning Environment

The CoPE actors carry out their activities in a learning environment. A CoPE requires a technical environment which offers a virtual space to its members in order to realize their learning activities. Table 1 presents the three elements which compose the «C-Environment»: *C-Service, C-Resource and C-Space.*

Table 1. C-Environment Concepts

Element	Element Sub-Concept	Description
C-Service		Can be a simple or a group-service.
	Service type	Specifies the nature of the required service: communication, argumentation, validation, edition and research aspects.
	Service profile	Indicates the technical characteristics: the capacity and limitations of a given service, and information about connection and access.
	Sub-service	Gives the possibility to define more specialized services.
C-Resource		Defines the resources used by a CoPE. Classified by activity-type:
	Type	Technical, pedagogical, mediatic, or didactic
	Source	Source of the resource
	Validation	Validation of the resource
	Category	Analysis-resources; Design-resources; Implementation-resources; and Utilization-resources
C-Space		Workspace which helps in organizing and performing activities.
	Analysis-space Design-space Implementation-space Utilization-space	Every space type is composed of three sub-spaces: «Problem solving sub-space», «Decision sub-space», and «Project sub-space». In addition, we foresee another space, «Free-space».

4 Conclusion and Future Work

In the present paper, we proposed an ontology for representing a uniform vocabulary for CoPEs. Some preliminary work using OntoC'oPE within our CoPE framework was done as part of the project of distance education CoseLearn "Cooperation Suisse en matière de eLearning" that was initiated by QualiLearning company (www.coselearn.org) using a learning scenario based on IMS-CLD specification[10].

We envisage extending the ontology to include a modelization of members' interaction and collaboration. We also plan to provide a set of knowledge management services that will support CoPEs' activities; and finally design an architecture of virtual environment to support the CoPE activities.

The main goal of our work is to contribute to the learning process of individuals and organizations especially in the teaching domain, and also to contribute in proposing technology support for the CoPEs and the management of explicit and tacit techno-pedagogic knowledge in the e-learning field.

References

1. Wenger, E.: Communities of Practice in 21st-century Organizations. Foreword to the CEFRIO guidebook (2005)
2. Chikh, A., Berkani, L., Sarirete, A.: Modeling the Communities of Practice of E-learning "CoPEs". In: Proceedings of the Fourth Annual Conference of Learning International Networks Consortium (LINC), Jordan, October 27- 30 (2007)
3. Rosson, M.B., Dunlap, D.R., Isenhour, P.L., Carrol1, J.M.: Teacher Bridge: Creating a Community of Teacher Developers. In: 40th Annual Hawaii International Conference on System Sciences (HICSS 2007) (2007)
4. Khan, H., Maull, K.: Teaching Boxes: Customizable Contextualized Digital Resources. In: Pearson, E., Bohman, P. (eds.) Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2006, pp. 666–671. AACE, Chesapeake (2006)
5. Dubé, L., Bourhis, A., Jacob, R.: Towards a Typology of Virtual Communities of Practice. Interdiscipl. Jounal of Information, Knowl., and Manag. 1, 69–93 (2006)
6. Tifous, A., El Ghali, A., Dieng-Kuntz, R., Giboin, A., Evangelou, C., Vidou, G.: An ontology for supporting communities of practice. In: K-CAP 2007: Proceedings of the 4th international conference on Knowledge capture, Whistler, BC, Canada (2007)
7. Wenger, E.: Communities of Practice: Learning, Meaning, and Identity. Cambridge University Press, New York (1998)
8. Robien, M.: Communauté de pratique et travail collectif à distance en documentation. DEA Communication homme-machine et ingénierie éducative, Technical Report, Université de Maine, France (2003-2004)
9. Kim, A.J.: Community Building on the Web. Peachpit Press, Berkeley (2000)
10. Chikh, A., Berkani, L., Sarirete, A.: IMS-CLD: a new Specification for Learning Scenarios in CoPEs. In: The Proceedings of The Fourth International Conference on Web Information Systems and Technologies, Funchal-Madeira – Portugal, May 4-7 (to appear, 2008)

A Flexible and Tailorable Architecture for Scripts in F2F Collaboration

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Abstract. In this paper we introduce the architecture of the script engine of a collaborative co-located discussion support system, named CoFFEE, and, in particular, we describe its extendibility and flexibility as a macro-script engine for CSCL activities [7].

1 Introduction

Among educational researchers, it is well known how critical is the design of the educational setting since it strongly impacts on learners activities. Their research has proved that fruitful collaboration require careful design and not occur *per-se* [6], and that, otherwise, the partners may not engage in productive collaboration. One of the possible solutions to stimulate productive interactions within the collaborative process are the *scripts for collaborative learning* [17] that are considered useful instruments to facilitate and stimulate equal participation in collaborative learning activities with respect to the unscripted collaborative learning activities.Several examples of scripts date back even before the term was coined such as the well-known Jigsaw [1] but more recent examples are Concept Grid script [5], ArgueGraph script [11] and RSC script [2].

While scripting is generally considered useful and fruitful, the researchers are clearly aware of the dangers of too much structure, called over-scripting [5] where, in general, the scripts become obstacles to learners' own strategies. In [7], the author investigates the trade-off between the structure provided by the script and its *flexibility*, i.e. the possibility that the teacher and the learners can modify some features of the script. In the same paper, the distinction between intrinsic (to the pedagogical design) constraints and extrinsic (i.e. induced by the technology) constraints is made, so that the goal of a script engine can be clarified as to help maintaining the intrinsic constraints and to provide flexibility on the extrinsic constraints.

Following [7], (macro-)scripts can be defined as pedagogical methods that aim at producing desired interactions, and consists of several phases, namely, individual phases, collaborative phases (intensive interactions within small groups) and collective phases (looser interactions with larger groups e.g. classroom discussions).

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Besides flexibility, another characteristic among CSCL systems has been emerging recently: the software should be easily modifiable ([12]) because users (and their needs) evolve over time and the groupware should be able to follow the evolution of users' expectations, as well as adapt itself to different settings and new scenarios [8]. With different terms and slightly different meanings, the characteristics has been also referred to in literature as tailorability [19], malleability [15]) and composability [21].

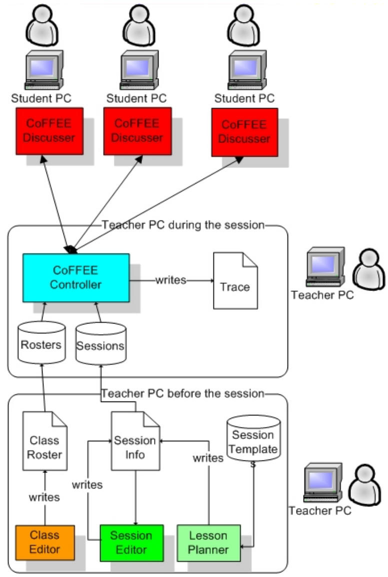
We adopt the following definition of *user-centered tailorability* given in [3] and based on the work on [18,19] with the explicit instantiation of the stakeholders of tailorability's advantages. In this definition, four different types of tailorability are distinguished:

- Tailorability by Customisation. it allows to configure the basic properties to slightly modify the behavior of a functionality. This level is addressed to "ordinary" users (e.g., learners, novice teachers, etc).
- Tailorability by Integration. it allows the user (e.g. experienced teacher or facilitator) to select the desired functionalities (tools) from a predefined set given within the system. It requires predefined communication interfaces between the components.
- Tailorability by Expansion. the user is empowered to widen the set of available functionalities by adding new, compatible tools to the system. In this case, the needs of a more experienced user (such as pedagogical researchers) are addressed.
- Tailorability by Extension. (or Extensibility) it allows the user to add new components from third parties in the groupware without changing the existing components. This requires open standards for interoperability and is of particular interest to developers.

In this paper we present the architecture of a flexible and tailorable script engine that is part of the CoFFEE environment [3,4,16] developed within the EU VI Framework Lead project [13]. The project already delivers a face2face cooperative environment with several tools already available and an environment and support to write new tools to be included in the platform. CoFFEE delivers a script mechanism that allows teachers and researchers to write/edit/modify their "sessions" by using a Session Editor component that offers the flexibility of choosing tools, their configuration, their layout and their interaction within the session.

2 CoFFEE System: An Overview

In order to present the script engine provided by CoFFEE, we need to describe, first, its software architecture.From the purely technological point of view, CoFFEE architecture principles are inspired by the tailorability principles described in the introduction but also, from the pedagogical point of view, by the guidelines [8] that support a *sustainable and reusable* CSCL environment, that allows to "*amplify, transform, and extend their work to new or additional outcomes*".



CoFFEE is a suite of applications: the Class Editor, the Session Editor, the Lesson Planner, the CoFFEE Controller and the CoFFEE Discusser. The CoFFEE Controller (launched by the teacher) and the CoFFEE Discussers are the applications developed to support the face to face collaboration in the classroom. They provides access to a predefined set of collaborative tools. The main tools provided at this moment by CoFFEE are the Threaded Discussion tool and the Graphical Discussion tool. The Threaded Discussion tool allows synchronous messaging between the users, structuring the contribution in threads. As reported in literature the standard chats have limitations at managing the discussion flow and organizing turn taking, making sometimes the whole discussion comprehension difficult [20]. The usage of a threaded discussion aims to address this lack of control over discussion structure. It must be said, that the structure of a threaded chat shows also some limitations due mainly to the lack of awareness about the location of new contribution. We addressed this issue by providing a simple (and configurable) awareness mechanism that highlights the most recently added nodes (or branches) in the threaded view.

The Graphical Discussion tool allows synchronous messaging between the users, representing the contributions as boxes in a graphical space, eventually linked by several kinds of arrows. This tool is designed to support brainstorming processes and conceptual maps creation, but it is enough generic and malleable to satisfy other usage scenarios.

CoFFEE provides also other tools, like a Group Presence tool to provide presence and group membership awareness within the groups, a CoWriter tool to allow cooperative writing with turn taking (just one user writes into the text at a time), a Private Notes tool to provide a personal workspace to write some textual notes and a Positionometer to support voting and giving one's opinion.

2.1 CoFFEE Sessions

The collaboration in classroom via CoFFEE is structured into *sessions* representing the scripts designed to support the collaborative activity. A session is a sequence of *steps*; each step can have one or more *groups* of students; each group has a set of tools chosen from a set of predefined tools. The groups of students can have the same set of tools or even a different set of tools. Moreover, within each group, a tool can be present more than one time with different configurations.

An example of a CoFFEE session with three steps will be used for illustrating the run-time architecture of CoFFEE and is shown in Fig. 1: in the first step

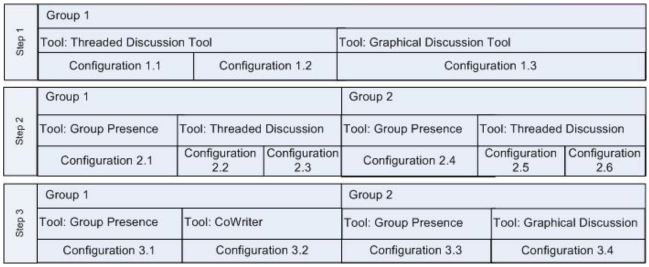


Fig. 1. A CoFFEE session

there is just one group where there are occurrences of the Threaded Discussion Tool with different configurations, and an occurrence of the Graphical Discussion Tool; tipically, the two different configurations for the same tool allow to have a private (personal) version of the tool as well as a a shared collaborative one.In the second step there are two groups: both groups have an occurrence of the Group Presence and two occurrences of the Threaded Discussion Tool. Finally, in the third step there are two groups: both the groups have an occurrence of the Group Presence; moreover the first group has an occurrence of the CoWriter Tool, while the second group has an occurrence of the Graphical Discussion Tool.

We are describing the session here to emphasize the flexibility that is offered by CoFFEE, where the pedagogical rationale is under research and preliminary results can be found in [14]

The teacher organizes the session by using the Lesson Planner, leveraging on a set of pre-assembled template sessions (coming from the experiences and research from the pedagogical partners of the project).The Lesson Planner doesn't allow to modify the structure of the template: it is designed to create a session in a quick and simply way on the basis of the templates. However, the Teacher can design a new session from scratch or can modify the structure of existing sessions by usign the Session Editor.

Then the session is played at run-time by the server (CoFFEE Controller). More details on this mechanism will be provided in the next section.

2.2 CoFFEE Architecture

As previously described, tailorability is a crucial issue for CSCW software architectures. Following this principle, we have designed a component based architecture leveraging on Eclipse Rich Client Platform (RCP) [10]. Eclipse is an open component-based Integrated Development Environment; its architecture allows Eclipse to offer its own core, RCP, to build general purpose applications leveraging on its own component based model.

The Eclipse architecture is based on the concepts of plug-ins, extension-points and lazy activation. Briefly, the plug-ins are the components of the system, the extension-points are the rules of plug-ins composition and lazy activation is the property of activating a plug-in only on demand. This kind of architecture allows to develop a system composable and extensible. Indeed, designing the tools as components to integrate over a core component allows to achieve a model where is possible both choosing the desired tool from a predefined set and expanding that set by adding a new tool.

The network communication between the distributed components (the server side and the client side) is based on the Eclipse Communication Framework [9], a subproject of the Eclipse community that provides a communication framework.

CoFFEE Applications have a component based architecture: we distinguish between the core component (respectively, the CoFFEE Controller Core and the CoFFEE Discusser Core) and the tools components (see Fig. 2). Each tool has a server side extending the CoFFEE Controller and a client side extending the CoFFEE Discusser. The integration of the tools on the cores is managed with the extension-point mechanism: we have defined on the cores an extension point specifying which information and API must be provided by the tools. Any tool wishing to extend CoFFEE has to provide a server component and a client component and both the components have to extend the extension point, providing the required information and API.

The communication between the CoFFEE Controller and Discusser is based on ECF. We use two kinds of communication objects provided by ECF: the containers and the shared objects. The containers provide access to a communication protocol while the shared objects (hosted by a container with a unique ID) manage the messaging. A shared object can send/receive messages only to/from other shared objects with the same ID. We have used an ECF container in the core of the CoFFEE Controller and of the CoFFEE Discusser, while each tool uses the shared objects (see Figure 2). In detail, each tool defines a *Service* as a pair (GUI, SharedObject) where the GUI (Graphical User Interface) provides the tool functionalities to the user while the shared object is in charge of communication. Each Service represents (an instance of) the tool functionalities and, potentially, a tool can have several independent Service instances running at the same moment. This is one of the key architectural points where the flexibility is grounded. The state of the GUI of a Service on a CoFFEE Discusser determines the state of that Service for that student; the graphical interface can be *visible* or *invisible*, *enabled* or *disabled*:

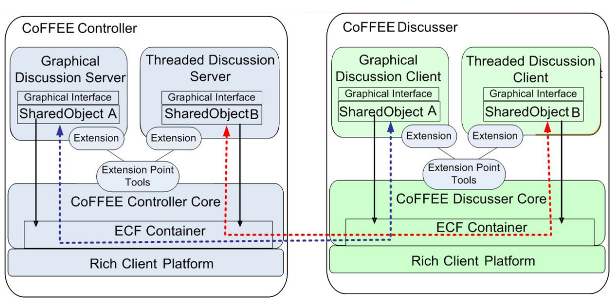


Fig. 2. CoFFEE technical architecture

- The service is *active* for a student if the GUI is visible AND enabled on its CoFFEE Discusser ;
- The service is *frozen* (i.e. it does not allow interactions but can be seen) for a student if the GUI is visible AND disabled on its CoFFEE Discusser; the situation when a service is frozen include previous steps or turn-taking is going on in the classroom (managed by the teacher on the Controller);
- The service is *unavailable* for a learner if the GUI is not visible on its CoFFEE Discusser.

In the following, we describe the system architecture during the execution of the example session represented in Fig. 1, and we show the system state in Fig. 3 on page 407.

In the first step of there is one group which uses two instance of the Threaded Discussion Tool and one instance of the Graphical Discussion Tool. During this step, the CoFFEE Controller activates the Threaded Discussion Tool and the Graphical Discussion Tool. Within the Threaded Discussion Tool it creates two Services (remember that a service consists of the Graphical User Interface and the Shared Object) corresponding to the two instances of the Threaded Discussion Tool required by the session. Within the Graphical Discussion Tool, the CoFFEE Controller creates one Service corresponding to the instance of the tool required by the session. Since during the execution of the first step there is just one group, all the CoFFEE Discussers have the same state of the CoFFEE Controller and all the students have the Services active. The second step of the session defines two groups; each group uses two instances of the Threaded Discussion Tool and one instance of the Group Presence Tool. When the teacher move on to the second step, the CoFFEE Controller freezes the previous step but does not eliminate the Services previously created: simply, it disables the GUI of each Service of the previous step, keeping the GUI visible (even if disabled) and the Shared Object active.

At the beginning of the second step, the Controller creates four Services of the Threaded Discussion Tool, two instances for each group. It creates also two instances (one for each group) of the Group Presence tool. Indeed, the students of one group receive also the Services of the other group, but with the GUI not visible. This allows the flexibility of moving a learner from a group to another simply by making not visible, on its CoFFEE Discusser, the graphical interfaces of the "old" group and making visible the graphical interfaces of the "new" group. Furthermore, at the end of the step, it is possible to show the artifacts of each group to the others by simply making visible on all the CoFFEE Discussers the Graphical User Interface of all the groups.

The third step of the session defines two groups. The first group uses an instance of the CoWriter Tool and an instance of the Group Presence Tool; the second group uses an instance of the Graphical Discussion Tool and an instance of the Group Presence Tool.

As done before, at the beginning of the third step, the Controller freezes the second step but does not eliminate the Services previously created.Then, the CoFFEE Controller creates a Service of the CoWriter Tool and a Service of the

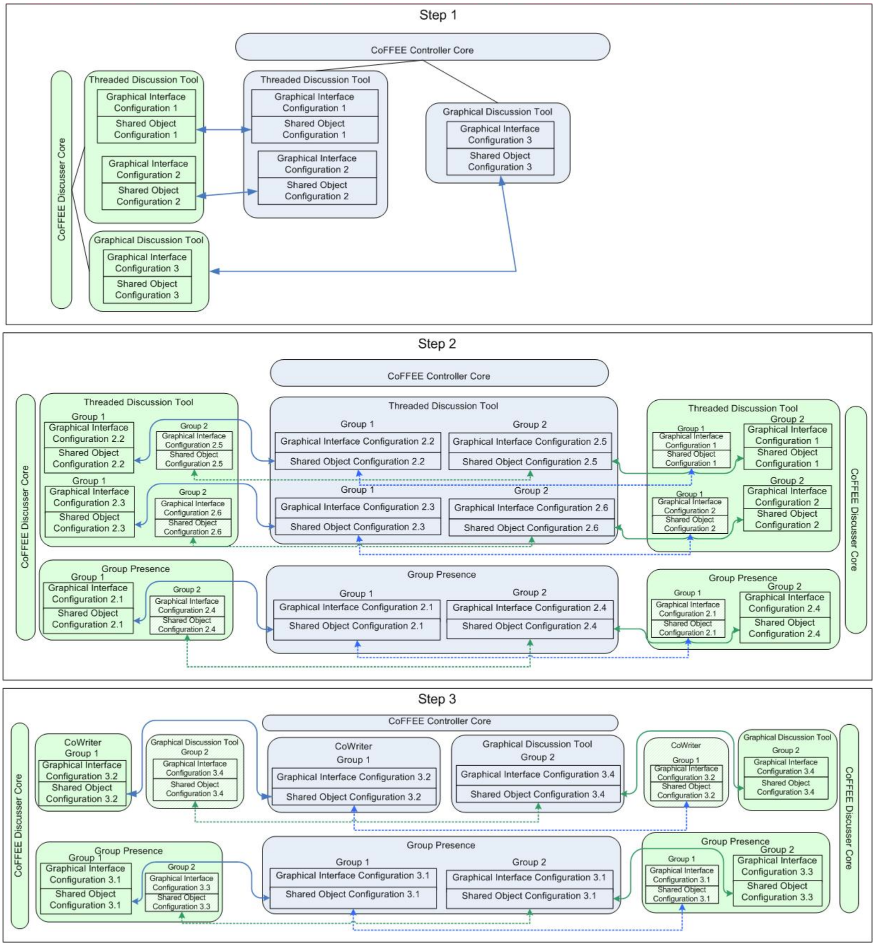


Fig. 3. Session Execution

Group Presence Tool for the first group, a Service of the Graphical Discussion Tool and a Service of the Group Presence Tool for the second group. The students in each group have also the Services of the tools of the other groups, but with the related GUI not visible.

3 Scripting in CoFFEE

Now, we describe the flexibility in scripting that is exhibited by CoFFEE architecture, just described in the previous section. The principle of the architecture is to support flexibility in the script design process at several levels according to user role, user expertise and to the timeline (before or during the script execution).

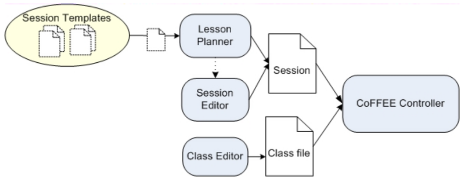


Fig. 4. The roles of each of CoFFEE components with regard to the script design and execution

In fact, scripts in CoFFEE are managed in this order (with different objectives) by the following components: Lesson Planner, Session Editor, Class editor (for the default group composition), Controller (for the flexibility at runtime).

The **Lesson Planner** offers a simple interface, providing access to the user to several templates of scripts from which the user can choose a template on the basis of the desired activities. Then, the teacher can fill in the context-specific contents.

In particular among the parameters that can be instantiated from the template we include: title and subject of the session, the title and task of each step, the number of groups for each step.

Then, the **Session Editor** offers to the experienced users (teachers/researchers) the possibility to fine-tune the script as originated by the Lesson Planner or, alternatively, to create a new script from scratch. The user can define the step sequence, the tools for each step, the groups (that can have same or different configuration) and where to place each tool in the layout. Furthermore, each tool has a number of configuration parameters to adapt its functionalities to the specific needs of the script: the Session Editor delivers the complete control over the tools included into the script.

The group composition at runtime is facilitated by the **Class Editor** that allows to define a default group for each student so that groups can be pre-assembled by the teacher. The teacher can still change the groups composition at any time during the execution.

The **Controller** executes the script created by the Lesson Planner and/or the Session Editor, eventually using a class file created by the Class Editor that contains the class composition and, possibly, the groups initial composition. The Controller is managed by the teacher, while the students run the Discusser. The Controller has a synchronized visualization of all the groups activities, with the same layout as in the Discusser, and can interact with them. The Controller is in charge of decide when to start/end script execution and when to move to next step (steps are synchronized), manage turn/taking, block/unblock/disconnect specific students, turn on/off anonymity, manage groups composition.

In Fig. 4 we show the interactions among the CoFFEE components just described for scripts design and execution.

Main Components of CoFFEE Script Flexibility

According to [7], four main components are needed by a platform that wants to provide flexibility in scripting: a model of the script, a model of the actual interaction patterns, the script intrinsic constraints and the script extrinsic constrains (to take contingent decisions). CoFFEE architecture provides them as follows.

- *A model of the script:* in CoFFEE this is accomplished by the Lesson Planner and the Session Editor applications, that allow an organization of the script in two levels of detail. With the Lesson Planner the teacher has the choice among generalized scripts that implement different pedagogical scenarios with pre-defined models of interaction, and can fill in the specific values for the context, such as strings or number of groups. The Session Editor allows "fine tuning" of the script model by defining a number of tool-specific parameters, adding/removing steps, or even creating a different script from scratch.

  The component based architecture of the system allows to integrate new tools with the Session Editor, so that the set of tools available to define the scripts can grow.
- *A model of the actual interaction patterns:* in CoFFEE the actual interaction is visible by the teacher at any time, as the Controller application shows every group's activity in collaborative tools. This allows the teacher to intervene when he notices some incorrect deviation from the expected behavior, or wants to stimulate the discussion in some way.
- *The script intrinsic constraints* i.e. the design rationale of the script, defined by the script designer, that must be respected in order to maintain the specific mechanisms that underlie the script. In CoFFEE the model of interaction (choice of the tools, organization of the steps, etc.) is defined by the script design facilities (Lesson Planner / Session Editor), and the actual interaction (step timing, group changing at run time) is regulated by the teacher (via Controller), so the intrinsic constraints should be respected due to the constraints imposed by the software application. The management of step sequence-and step-synchronization is a consequence of the general architecture of the system: the collaborative process is driven by CoFFEE Controller on the basis of the Session previously defined. The architecture can ensure Turn Taking handling the Services graphical interfaces.
- *The script extrinsic constraints:* in some cases the actual evolving of the interaction may suggest some changes in strategy. In CoFFEE the teacher can decide to change the groups composition at run-time, to block/unblock the classroom or specific students, to perform turn-taking. Both client management and changing group composition are achieved by handling the visibility and the level of activity of the Services Graphical User Interfaces; among the future planned enhancements of CoFFEE, already fully supported by the current architecture, the teacher will be also able to add a step at run-time, or to move to a previous step.

In Table 1 on page 410, a comparison of the flexibility exposed by CoFFEE and other similar proposal is provided, to support the claim of flexibility of the platform we proposed. Note that, as far as we can argue from their description in the bibliography, CoFFEE can implement most of the features required by the specific scripts referenced in the table (ArgueGraph and ConceptGrid), except

Table 1. A summary of the flexibility provided by CoFFEE and compared to other results. Information about other CSCL system has been taken by their relevant bibliography and, to the best of our knowledge, is correct but may not be totally accurate.

Flexibility		CoFFEE	ArgueGraph	ConceptGrid	RSC
Script modeling	Tool for script Modeling	Yes	Fixed structure	Fixed Structure	Yes
	Tool layout management	Yes	Fixed layout	Fixed Layout	External tools can be used so layout cannot be controlled completely
	Collaborative script modeling	It can be done with a collaborative session followed by a non-collaborative actual script modeling	No	No	Yes
Actual interaction patterns	Run-time visualization of the activity	Yes	? (contains individual phases)	Yes (only for collaborative phases)	No
	Complete activity log	Yes	?	No	No
	Automatic interaction analysis	No	No	No	No
Script intrinsic constraints (managed by the application)	Step-sequence	Yes	Yes	Yes	No
	Step synchronization	Yes	Yes	Yes	No
	Turn taking	Yes	No	No	No
	Control group size	No (group composition can be managed at design- and run-time but no constraints can be put on their sizes)	Yes	Yes	No
Script extrinsic constraints (contingent decisions)	Changing group composition at run-time (during the step)	Yes	No	N.A. (may violate intrinsic constraints)	Yes
	Switching anonymity on/off	Yes	No	No	No
	Modifying script structure at run-time	Possible to add a new step at run-time (planned by Nov. 2008)	No	No	Yes
	Move to a previous step	Planned by Nov. 2008	No	No	Yes
	Latecomer accepted and included into the activities	Yes	No	No	Yes
	Client management (freeze of a client, forced disconnection)	Yes	No	No	No

for the specific module for automatically evaluating answers required by ArgueGraph. Then, our solution is tailorable in three of the four levels of tailorability described in the Introduction: it is *customisable* for the teacher/facilitator, since it allows to tune the script selecting parameters of the tools configuration; it offers *tailorability by integration* since it allows to use predefined templates as starting points and offers freedom in assembling a script from the available tools; finally, it provides *expandability* since the scripting mechanism allows to include new tools into the scripting design, because the Session Editor is designed to be general, dealing with the all the tools that export some known configuration capabilities.

4 Conclusions

We have presented the architecture and the features of the script engine of CoFFEE. Its flexibility is significantly enhanced by the tailorability of the architecture at different levels, since it offers a sustainable, reusable, personalizable environment for F2F CSCL applications.

The CoFFEE version currently available is version 3.0 (codenamed"*Irish*") that can be downloaded at the Lead project web site http://www.lead2learning.org under Technologies. Its scripting facilities include the Session Editor, the Lesson Planner, the Class Editor and the Controller.

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References

1. Aronson, E., Blaney, N., Sikes, J., Stephan, G., Snapp, M.: The Jigsaw Classroom. Sage Publication, Beverly Hills (1978)
2. BetBeder, M.L., Tchounikine, P.: Symba: a framework to support collective activities in an educational context. In: Lee, K., Mitchell, K. (eds.) Proc. of the International Conference on Computers in Education, pp. 188–196. AACE, Hong-Kong (2003)
3. De Chiara, R., Di Matteo, A., Manno, I., Scarano, V.: Coffee: Cooperative face2face educational environment. In: Proceedings of the 3rd International Conference on Collaborative Computing: Networking, Applications and Worksharing (CollaborateCom 2007), New York, USA, November 12-15 (2007)
4. De Chiara, R., Manno, I., Scarano, V.: Design issues for a co-located collaborative learning system. In: EARLI 2007 Book of Abstracts, in the Computer support for face-to-face collaborative problem solving Symposia (in press, 2007)
5. Dillenbourg, P.: Over-scripting CSCL: The risks of blending collaborative learning with instructional design, pp. 61–91 (2002); Kirschner, P.A. (ed.), Open Universiteit Nederland, Heerlen

6. Dillenbourg, P., Baker, M., Blaye, A., O'Malley, C.: The evolution of research on collaborative learning, pp. 189–211. Elsevier/ Pergamon, Oxford (1995)
7. Dillenbourg, P., Tchounikine, P.: Flexibility in macro scripts for computer-supported collaborative learning. Journal of Computer Assisted Learning 23(1), 1–13 (2007)
8. Dimitracopoulou, A.: Designing collaborative learning systems: current trends & future research agenda. In: CSCL 2005: Proceedings of th 2005 conference on Computer support for collaborative learning, pp. 115–124. International Society of the Learning Sciences (2005)
9. Eclipse Communication Framework (ECF), http://www.eclipse.org/ecf/
10. Eclipse, http://www.eclipse.org
11. Jermann, P., Dillenbourg, P.: Elaborating new arguments through a CSCL scenario. In: Andriessen, J., Baker, M., Suthers, D. (eds.) Arguing to learn: Confronting Cognitions in Computer - Supported Collaborative Learning Environments, CSCL, pp. 205–226. Kluwer, Amsterdam (2003)
12. Koch, M., Teege, G.: Support for tailoring cscw systems: adaptation by composition. In: Proceedings of the Seventh Euromicro Workshop on Parallel and Distributed Processing, 1999. PDP 1999, February 3-5, 1999, pp. 146–152 (1999)
13. Lead - technology-enhanced learning and problem-solving discussions: Networked learning environments in the classroom, 6th Framework Programme Priority IST, http://lead2learning.org/
14. Ligorio, M.B., Tateo, L., Manno, I., De Chiara, R., Iannaccone, A.: Coffee: a software to blend face-to-face and written communication in collaborative problem solving-based scenarios. Summer School, Building Knowledge for deep Understanding, at the Institute for Knowledge Innovation and Technology (August 2007)
15. Lonchamp, J.: Supporting synchronous collaborative learning: a generic, multi-dimensional model. International Journal of Computer-Supported Collaborative Learning 1(2), 247–276 (2006)
16. Manno, I., Belgiorno, F., De Chiara, R., Di Matteo, A., Erra, U., Malandrino, D., Palmieri, G., Pirozzi, D., Scarano, V.: Collaborative Face2Face Educational Environment (CoFFEE). In: Proc. of First International Conference on Eclipse Tecnhologies (Eclipse-IT), Naples, Italy, October 4-5 (2007)
17. O'Donnell, A.M., Dansereau, D.F.: Scripted cooperation in student dyads: A method for analyzing and enhancing academic learning and performance. In: Hertz-Lazarowitz, R., Miller, N. (eds.) Interaction in cooperative groups: The theoretical anatomy of group learning, pp. 120–141. Cambridge University Press, London (1992)
18. Slagter, R., Biemans, M., ter Hofte, H.: Evolution in use of groupware: Facilitating tailoring to the extreme. In: CRIWG 2001: Proceedings of the Seventh International Workshop on Groupware, pp. 68–73. IEEE Computer Society, Washington (2001)
19. Slagter, R., ter Hofte, H., Stiemerling,: Component-based groupware: An introduction. In: Proc. of Component Based Groupware Workshop of CSCW 2000 (2000)
20. Smith, M., Cadiz, J.J., Burkhalter, B.: Conversation trees and threaded chats. In: CSCW 2000: Proceedings of the 2000 ACM conference on Computer supported cooperative work, pp. 97–105. ACM Press, New York (2000)
21. ter Hofte, G.H.: Working Apart Together: Foundations for Component Groupware. PhD thesis, Telematica Institute, Enschede, The Netherlands (1998)

Semantic Technologies for Socially-Enhanced Context-Aware Mobile Learning

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Abstract. In this paper, we present an extended ontological framework, m-LOCO, in which potentials of mobile devices as content delivery media have been utilized in the design of a context-aware learning environment, where the learning content and/or the learning environment are matched to the needs and requirements of the learning context. Moreover, we suggest the affordance of a socially-enhanced self-regulated learning approach as the most efficient pedagogical roadmap for ubiquitous learning environments, with the goal of helping the learners to be more productive through fostering both their individual and social collaborative competencies and expertise.

Keywords: Ontologies, Learning Context, Mobile Learning, Context-Aware.

1 Introduction

E-learning environments have aimed at providing learners with "any time any where" learning experiences and personalized services in comparison to traditional educational systems. With the advent of mobile technologies and the rapid growth of their usage in everyday life, the ubiquity of e-learning systems is now even more broadened. Based on the different pedagogical roles that they play (i.e., an assisting/recommender tool or the main delivery platform), mobile technologies can fill in the gaps observed during the learning process or in the learning outcome of a learner. Different information about learners and their interaction with an e-learning system, that is learning 'context', is required for such systems to reach the desired ubiquity and context-awareness. We define a mobile learning context as *all the situational information about the learners, learning objects and learning activities, captured with regards to its delivery medium, i.e., the mobile devices.* Accordingly, a context-aware learning environment should be built upon the following three major axes: pedagogical, delivery media and representation axes. First axis tries to define a pedagogically sound learning design that would best match a specific learning context with a specific learning goal. The second axis defines the way learners have access to educational materials and how those materials

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are to be delivered to the learners. The last one represents the domain knowledge and the data that the two previous axes capture and maps the available unstructured data into structured and meaningful contextual data.

To design a ubiquitous learning environment, we leverage an ontology-based framework, called LOCO [1]. We consider ontologies as the most suitable candidates for context representation in an open and ubiquitous environment. Being formal models they are flexible and extendible. Moreover, rules may be used for reasoning over ontological representation of context data, making the representation to be both scalable and extendableï Having an eye on the three primary axes of a ubiquitous learning environment along with analyzing the functionalities and potentials of this generic framework, we considered and designed other features, related to delivery media and pedagogical axes, to be added to this ontological framework, in order to support learners with personalized services in a broader range of contexts. We call this extended framework m-LOCO and build it upon the notion of learning context - a unique set of interrelated data characterizing a specific learning situation. Our work brings in novelty in this research area by signifying how this ontological framework can be extended to a generic ubiquitous learning environment capable of both capturing the contextual data occurring in a real learning system and exploiting the captured data for further inferences and functional usages.

2 m-LOCO Framework: Usage Scenarios

Our proposed ontological m-LOCO framework is advantageous both from learners and instructors' views. Fig. 1 exemplifies the overall architecture of a context-aware learning environment which utilizes the potentials of the m-LOCO framework. In this architecture, different pieces of knowledge and data from different ontology-based repositories are integrated and shape the overall learning context. For example, the user model repository contains data about the individual learners. The repository of learning objects includes information about the content structure (e.g., audio/video/text) and educational content types (e.g., example, overview or tutorial) of the learning content, whereas the delivery media repository contains data about specifications and features of different available delivery media (e.g., mobile devices and PDAs). To have a better illustration of this architecture, we explain the potential functionalities of the system in a few sample scenarios. For these scenarios to be functional we assume the presence of a learning object repository, from which teachers/learners or the system itself can select and retrieve appropriate learning objects.

Moreover, we need a context repository to perform further analysis or reasoning, in which learning objects' context-related data in accordance with the m-LOCO ontology is stored. This context-related data can be captured in different ways; one approach is that, every time a learner selects a learning object from the learning object repository, the related contextual data would be gathered and stored in the repository. The other alternative is when the system intelligently suggests or delivers a learning object to a learner based on the gathered data from the learner's (partial) contextual information and the available or inferred facts and rules that already exist in the system. In both of these cases, a learning object context instance is created in the repository of learning object contexts and all relevant context-related data for that usage is stored in it.

From the learners' perspective, the basic and initial function of the framework is to provide them with appropriate learning objects that not only match their personal information, but are most appropriate for that context. For instance, while the learner is using her PDA to connect to the LMS, related podcasts compatible with the specification of her device and the requirements of the activity she is supposed to perform, can be sent to her. In another scenario, during each activity, the system can pair the learner with those potential peers who are directly/indirectly linked to her in her social connections and, are doing the same activity. The idea in these scenarios is to enable learners to access small, but up-to-the-point pieces of information in addition to their regular learning activities performed in traditional learning environments.

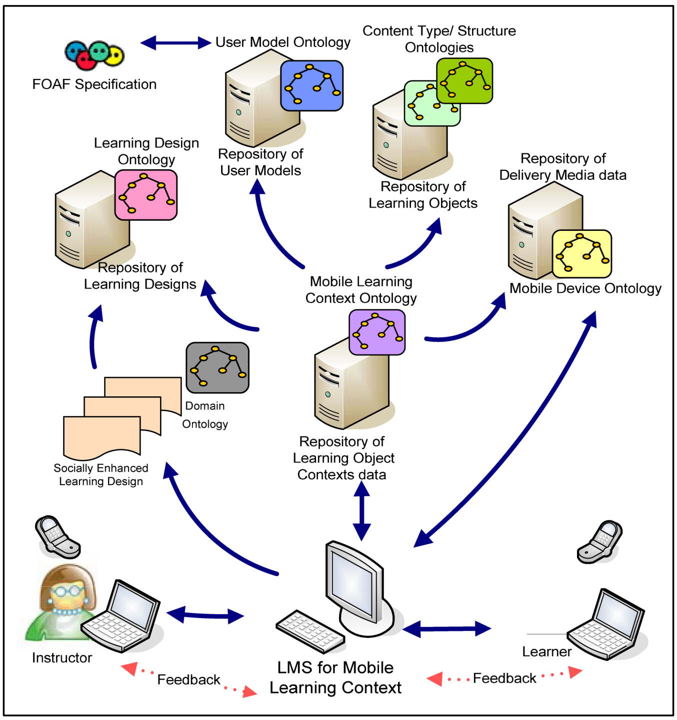

Fig. 1. The overall architecture of m-LOCO –based learning environments

In addition to the learners, instructors can also benefit from the framework capabilities. For example, a teacher would probably like to have an opportunity to review her notes for the next lecture on her way to the campus. By having insight into the teacher's weekly schedule, the system can provide the teacher with a quick link to the 'official' plan and/or her notes for the lectures that she has that day. The m-LOCO framework is also beneficial for 'participatory learning design'. In this case, content authors and instructors would be provided with detailed feedback about the actual usage of their content during the learning process [2] (Fig. 1). This feedback can be about learners' activities, their performance on those activities, their level of the collaboration and the way they have been socially interacting within a particular activity. Consequently, the instructors can apply this feedback to modify and improve their designs. This kind of design is called participatory as the learners, though implicitly (by feeding the feedback data into the system), play a prominent role in the process of the design, assisting in its improvement by applying it in the real usage.

3 m-LOCO: An Overview of the Framework

m-LOCO is built upon the Learning Object Context Ontology (LOCO) ontological framework, described in [2]. The heart of LOCO, the LOCO-Cite ontology, is an ontology of learning context aimed at capturing data about a specific context of use of a learning object in a specific learning design. The LOCO's learning object content ontology identifies the information objects within a learning object with the goal of making each component of the learning object directly accessible. The learning design ontology (of the LOCO framework), inspired by the IMS-Learning Design Specification, aims at formal representation of the basic building blocks of an instructional scenario. In the rest of the section we briefly present how we extended the LOCO framework to support socially-oriented mobile learning.

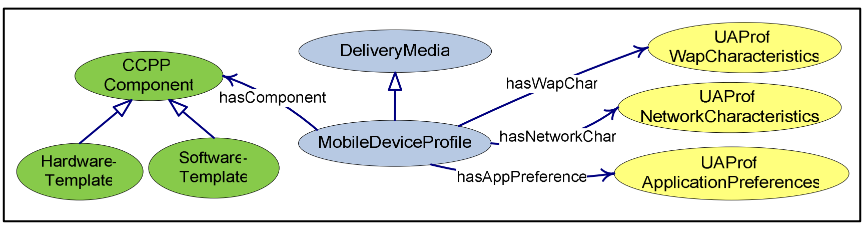

Fig. 2. The Delivery Media Extension

3.1 Delivery Media: Mobile Ontology

Integration of mobile technology in teaching/learning has the potential to offer significant advantages in learning environments where, the students are enabled to benefit from idle periods, such as commuting time with public transportation or waiting time before a meeting. However, before a mobile device could be considered as the candidate delivery media for learning materials, its feasibility according to some general constraints should be evaluated [2]. For example, size of the screen could be a limiting factor in the amount and the type of media that can be displayed; the lack of input devices could reduce usability and user interaction; limitations in collaboration activities and network connections, and hard/soft-ware compatibility issues.

To address the above issues, we have designed an ontology (Fig. 2) based on the W3C's CC/PP (Composite Capability/Preference Profiles [3] and User Agent Profile Specification (UAProf) [4], to be added to the LOCO framework. The ontology allows for formal description of device capabilities and user preferences.

3.2 Socially-Enhanced Self-regulated Learning

The "any time, any place" affordance of online education requires its learners to be self regulated. Self-Regulated Learning theory concerns how learners develop learning skills and extend their expertise in using those skills effectively [5]. The underlying notion of self-regulation is "learning how to learn" by defining and pursuing appropriate strategies. Different authors in this domain suggest different models for representing these strategies, among which the most famous ones are given in: [5] and [6]. We chose the model presented in [6] to capture different cognitive activities learners usually are engaged in within a cycle of self-regulated learning, as we believe this model is on a higher level of abstraction than the other alternative. Those activities include:

1. *Forethought*: during this phase salient characteristics of a task and environment are identified to inform the proper selection of learning and cognitive resources.
2. *Performance*: in this group of activities, students evaluate their own progress towards an established goal, making appropriate strategy changes as they proceed to regulate their learning effectively and,
3. *Self Reflection*, where students perform self evaluation against some standard, such as prior-, others' - or a standard of performance.

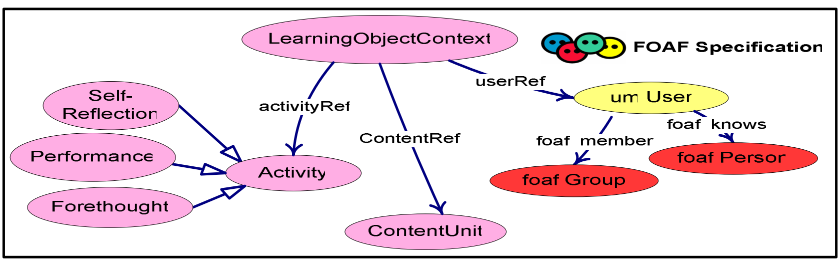

Fig. 3. The Extension to support Socially-enhanced Self Regulated learning

To cover these concepts along the representation axis, the Activity class of the LOCO framework is further extended to support the above cycle of cognitive activities (Fig. 3). However, successful students are not only those who define and practice proper strategies and reach the desired educational goals; effective learners should also be socially productive by means of interaction with peers within communities of practice and collaboration. In our proposed framework, we promote socially-enhanced self-regulated learning, in a 'self-organized learning' approach, a modified version of the 'Jigsaw' methodology [7], where more complex tasks or problems are broken down into parts and mastered individually, and at the end of a learning process, solutions are exchanged between the individuals and combined into a final solution. To support this methodology, we utilize the associated classes from the FOAF specification [8] to extend the *User* class of the learner ontology (Fig. 3). The FOAF specification provides basic expressions of personal information and relationships, and is a powerful and practical building block for modeling online communities.

4 Discussions and Future Work

To realize the requirements of ubiquitous learning contexts, we utilized an existing ontological framework (LOCO) to support learners in a broader range of situations; in mobile contexts (m-LOCO). It should be noted that the technical constrains in mobile learning (e.g. limitations in device-to-device interaction) would impose some additional limitations on the learning process. This clearly demonstrates the need of a deliberate pedagogical approach. Consequently, we have chosen the other extension to be related to the pedagogical axis, designed on the basis of a socially-enhanced self regulated approach. Thanks to the ontological formalization of m-LOCO which makes it flexible and extendible, designers can only use those features of the framework which are sufficient to fulfill their needs and requirement or can easily add other required features to the system for their own needs. To evaluate the effectiveness of the m-LOCO framework in comparison to today's systems along the lines of three mentioned axes, our next step is to integrate it into a real learning environment. As such an environment brings multimodality opportunities for its users, in addition to performing evaluation methods such as precision and recall, evaluating the usability of the system would also indicate the efficiency level of the interface.

References

1. Jovanović, J., Gašević, D., Knight, C., Richards, G.: Ontologies for Effective Use of Context in e-Learning Settings. Educational Technology & Society 10(3), 47–59 (2007)
2. Kramer, B.J., Strohlein, G.: Exploring the Use of Cellular Phones for Pervasive eLearning, In: 4th Annual IEEE international Conference on Pervasive Computing and Communications Workshops (2006)
3. http://www.w3.org/Mobile/CCPP/
4. User Agent Profile Specification, Wireless Application Group, Version 20 (October 2001)
5. Winne, P.H.: Experimenting to Bootstrap Self-Regulated Learning. Educational Psychology 89(3), 397–410 (1997)
6. Zimmerman, B.J.: Becoming a Self-Regulated Learner: An Overview. Theory into Practice 41(2), 64–72 (2002)
7. Huber, G., Huber, A.: Structuring Group Interaction to Promote Thinking and Learning During Small Group Learning in High School Settings. In: The Teacher's Role in Implementing Cooperative Learning in the Classroom, pp. 110–131. Springer, US (2007)
8. FOAF Vocabulary Spec, http://xmlns.com/foaf/0.1/
9. Open Mobile Alliance, http://www.openmobilealliance.org/

Knowledge Practices Environment: Design and Application of Technology for Trialogical Learning

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Abstract. Current networked society present learners with challenges that cannot be sufficiently coped with in educational contexts that are characterized by transmission or participation epistemologies on learning. To address these challenges, the trialogical approach to learning is introduced which focuses on the ways in which people and their communities create knowledge through the tool-mediated development of shared objects. Supporting sustained collaborative knowledge creation requires learning technology that is modular and extensible rather than monolithic and fixed in nature which characterizes most existent learning technologies. The current paper presents the design considerations and the application of the KP-environment which aims to support these object-oriented practices.

Keywords: Knowledge Creation, Design of Learning Technology, Knowledge Management, Pedagogical Scenarios.

1 Introduction

Rapid changes in current knowledge society present new challenges to human competencies. Productive participation in knowledge-intensive work requires that individuals, their professional communities, and their organizations develop new skills, advance their knowledge and their understanding as well as produce innovations. This is reflected in developments in professional communities wherein work is increasingly focused on the deliberate advancement of knowledge rather than on the mere production of material objects [1]. In order to conceptualize and understand the nature of work and activity in current knowledge society, one has to comprehend the various types of knowledge that intersect within complex and heterogeneous networks which consist of humans and various artifacts [2, 3]. In parallel with these changes in society, conceptions on learning, knowledge practices, and social organization of learning also have to be transformed so as to facilitate corresponding competencies which enable student to cope with these emerging challenges.

Educational institutions that make an attempt at addressing these knowledge practices in their pedagogical approach, are challenged to redesign (aspects of) their curriculum as well as to develop the practices and professionalism of their educators.

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However, although we are in a period of change, educational practice still has many characteristics of the transmission scenario [4] on the one hand or on mere social and cultural interaction on the other. These scenarios, which corresponds to the premises of respectively the acquisition and participation metaphors to learning [5] and which characterizes most formal education, centers on the acquisition of declarative knowledge and a limited number of critical skills, by a system of lectures, textbooks, and testing. As a consequence to cope with the cognitive, social, and motivational challenges of the emerging knowledge-based society, technological tools and educational methods are needed to improve the quality of learning and to transform the educational system accordingly.

Paavola & Hakkarainen's model of knowledge-creation [6] provides a framework to support educators to develop and advance their practices of learning and instruction. A central feature in the knowledge-creation approach is *mediation* [7]; meaning that people collaboratively create knowledge through the development and advancement of shared objects. It is characteristic of this kind of knowledge advancement that it takes place within innovative knowledge communities which are organized around shared objects whose creation and development defines their purpose [8]. The knowledge-creation view represents a 'trialogical' approach because the emphasis is not only on individuals or on community, but on the way people collaboratively develop epistemic artifacts.

Current learning technologies provide only limited support for these kinds of collaborative practices, but instead serve as repositories for knowledge objects or as virtual collaboration platforms instead.

The purpose of the present paper is to illuminate the design considerations and the application of technology which aims to support trialogical learning: the Knowledge Practices environment (KP-Environment). The KP-Environment is developed from within the frame of the Knowledge Practices Laboratory project, a 5 year IST project co-funded by the European Community.

The next section present an overview of the challenges involved in the design of the KP-environment. Subsequently, we describe its basic architecture and demonstrate how the KP-environment can support authentic trialogical practices employing a pedagogical scenario. Finally, we conclude with the ways in which empirical research will feed into the iterative re-design of the KP-environment.

2 Designing Technological Support for Trialogical Learning

The current approaches of working with knowledge in educational and workplace settings, however, are still focused on individuals' skills and knowledge structures on the one hand, or on social and cultural interaction on the other hand. The problem is that they do not provide sufficient models for facilitating processes of knowledge creation with related practical, organizational and technological means. As a consequence there is a lack of pedagogically and scientifically sound technological tools to foster competencies for knowledge creation among students and professionals alike.

Technological support for trialogical learning requires software tools that support spatially, socially and temporally distributed participation in trialogical processes and draw on the potential of emerging semantic web technologies. This involves mainly the need for a modular, flexible, and extensible ICT system that supports trialogical learning in educational and workplace settings. In specific, this means that in tools should be able to address collaborative work around shared objects and to support knowledge practices in various educational settings.

Current learning technologies such as the Moodle platform or Blackboard provide only limited support for collaborative knowledge practices. These tools typically provide support for information sharing and for participation in social interaction. The few existing eLearning applications that support specific models of knowledge creation processes such as the Future Learning Environment (FLE) or Knowledge Forum are of limited use because of their inflexible and monolithic software design. While many core technologies of the Semantic Web infrastructure are already available, there is vast amount of work ahead in making them more usable for learners and their instructors.

Learning technologies and knowledge management systems have each received a significant interest in research and development within the past two decades. However, they have been remarkably separated by their context specific applications and few linkages exploiting their synergies have been established. Software for managing knowledge processes is another poorly developed area. The workflow applications are designed to support structured business processes and do not provide support for dynamically evolving knowledge creation processes. There are some initiatives related to computer supported collaborative learning that have developed software to support specific models of knowledge creation processes. However, these tend to focus on one aspect of knowledge creation processes such as the “rise above” focus in Knowledge Forum.

One central way of developing new methodological solutions in the design of technology for the learning sciences is the use of *design principles* to guide the design of educational practices and technology. Various ways of developing design principles have been suggested, both top-down, i.e. theory driven [9], and bottom-up, i.e. empirically informed [10] approaches. A key challenge in the design of KP-environment is to capitalize on both theory as well as insights gained from educational practice to serve as guidance in the development of tools.

3 Design Principles for Pedagogical Scenarios of Trialogical Learning

Design of KP-environment was based upon design principles which are grounded in the perspective of trialogical approach on learning [6]. The design principles serve as guide and as generic criteria in the design process in the sense that they enable the creation of pedagogical scenarios which attempt to situate and contextualize the knowledge practices within particular educational contexts. Hence, these scenarios can be conceptualized as the concretization of the design principles for designing technology supporting trialogical learning.

Nevertheless, the design principles are provisional implying that they reflect the current understanding of trialogical approach to learning and will therefore be subject to continuously review and if necessary revision or extension based on empirical results. The design principles that were taken into consideration in the design of KP-environment were:

1. *Focus on trialogical activity around shared objects:* A central idea of the trialogical approach to learning is that work and learning are organized around developing some shared objects. Tools should facilitate work and learning around shared objects of activity, not just individual, cognitive processing nor social interaction as such;
2. *Interaction between personal and social level:* The aim is to develop tools, pedagogical models and spaces for combining developed social practices with room for individual initiatives for developing shared objects.
3. *Fostering long-term processes of knowledge advancement:* Processes of transforming existing knowledge practices and creating new knowledge are mostly longitudinal in nature. Tools and practices should be provided which support knowledge practices and collaboration around shared objects not just here-and-now but which moreover facilitate sustained knowledge creation;
4. *Development through transformation and reflection:* Models and theories belonging to the knowledge creation approach emphasize development through interaction between various forms of knowledge and between practices and conceptualizations which is the driving force in the process of knowledge creation. Tools and practices have foster such transformations;
5. *Eliciting (individual and collective) agency:* The trialogical approach to learning has its basis on epistemic agency of the participants; both agency of individual participants on their own efforts but also on collective agency supporting social processes and collaborative efforts. Therefore students have to engage themselves in planning, monitoring, and evaluating their collective and individual activities in order to develop higher-order competencies and knowledge practices;
6. *Cross fertilization of knowledge practices:* Tools and models have to be designed to assist people to solve complex, authentic problems and produce objects also for purposes outside educational institutions. It has its basis on cross fertilization of knowledge practices between various educational institutions (like polytechnics and universities), on the one hand, and between educational institutions and professional organizations, on the other hand;
7. *Flexible tool mediation for trialogical activity:* The trialogical approach has its basis on flexible tools which facilitate the integration between those aspects which are highlighted in other design principles, that is, long-term, cross fertilized work around shared objects which help an interaction between personal and social levels, and which support to make transformations between various forms of knowledge.

Scenarios can be employed to concretize the practices and pedagogical context in which the KP-environment is used and provide the background for the further design of the tool. Scenarios provide a mediating artifact to plan, implement and carry out a pedagogical or professional intervention and to describe the nature of the activities that are supported by the KP-environment.

A scenario that illustrates how these design principles of the trialogical approach to learning could be actualized in certain practices in higher education and that describes how the tools of KP-environment can support trialogical practices is the Bachelor Thesis scenario. This scenario is based on an existing third-year Bachelor course that is offered at the Department of Educational Sciences of Utrecht University, the Netherlands.

3.1 Short Description of the Bachelor Thesis Scenario

The main aim of this course is to support students to learn more about conducting research within the social sciences and to develop skills in collaborative academic writing. Students are required to collaboratively plan, conduct and report on a research project involving topics that are relevant within the field of education, supported by a team of educational scientists. The final product of each group is a collaboratively written scientific paper and a presentation of the paper during a Bachelor Thesis congress day.

Knowledge creation and knowledge advancement is reflected at the product as well as at the process level, while the pedagogical set-up offers opportunities for the team members to work together on shared epistemic artifacts (e.g. research plan, preliminary research report, final research report, and data collection instruments). Team efforts are required when making decisions, conducting analysis, processing data, when reporting on the collected data or brainstorming for constructing tools for analyzing the data. In addition, students are challenged to apply knowledge gained from previous courses in a new and more open-ended situation which requires them to create new understandings concerning issues related to conducting scientific research. Throughout the course the students are provided with web-based technological tools, which support their collaborative practices which are mediated by their objects of activity.

In the next section the KP-Environment will be presented in addition to how the Bachelor Thesis scenario can be applied to show how the design principles of trialogical learning are reflected in the ways the KP-environment can support students' knowledge practices.

4 The Knowledge Practices Environment

KP-environment is a virtual collaboration space offering facilities for interacting with knowledge artifacts, knowledge process models, users and the KP-environment itself during a trialogical learning or working process. KP-environment provides common tools for re-structuring and organizing knowledge artifacts based on their conceptual semantics. A KP-environment can be either both a personal space as well as a collective space. A collective space is created for the knowledge community involved in a trialogical process. The knowledge community can be formed around a group of people belonging to e.g. project team, students attending a class, or students of a university department, or any other type of collective. A KP-environment provides the user with a configurable set of tools for:

- Working with knowledge artifacts (e.g. creating, editing, storing, sharing, commenting, adding semantic descriptions or tags, disseminating and discussing);
- Managing the knowledge processes (e.g. creating, changing and executing process models);
- Managing the KP-environment itself (e.g. configuring the tools available).

At the level of the general graphical user interface (GUI) the KP-Environment consists of a set of shared spaces which involve collective workplaces for students to use. This means that in the KP-environment the different courses as well as all materials offered and produced are encapsulated in shared spaces as shown in Figure 1.

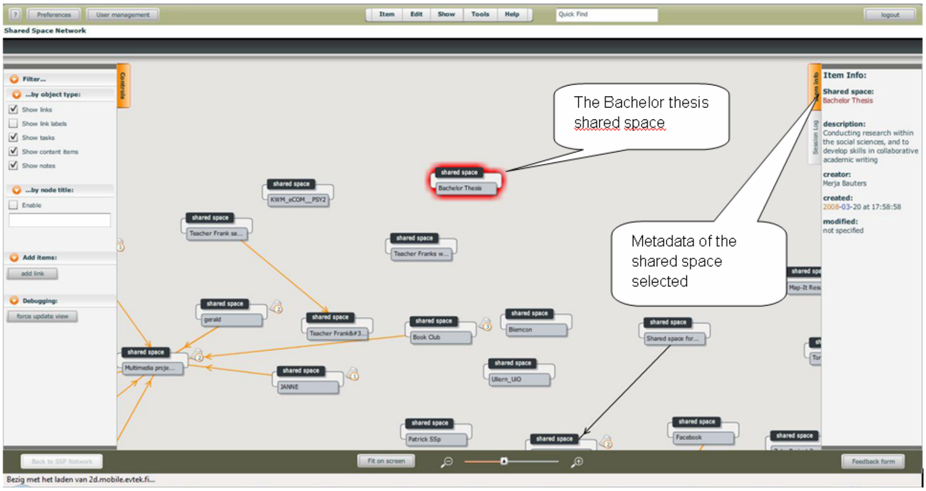

Fig. 1. Overview of shared spaces in the KP-Environment

Each shared space encompasses a workplace for students which presents them with three views: a Process view, a Content item view and a Community view. The process view presents students with a GANTT chart which specifies the tasks students have set for themselves, allocated responsibilities, artifacts to be produced and deadlines (see Figure 2). This functionality enables students to manage their knowledge creation processes themselves and fosters collective agency supporting social processes and collaborative efforts.

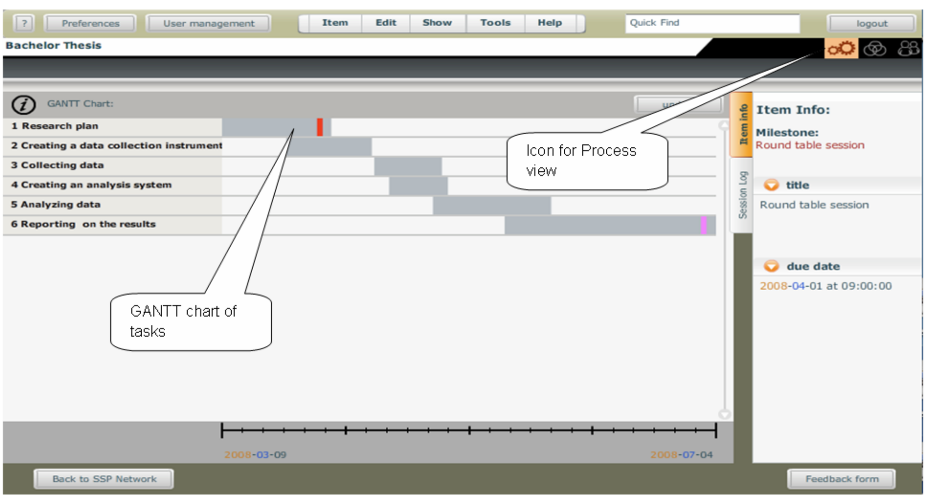

Fig. 2. Process view

The Content item view presents students with the tasks (light gray), a graphical representation of all the artifacts produced in service of performing these tasks and their linkages and metadata describing these artifacts (see Figure 3). The content items (dark grey) represent the artifacts students' have produced but also contain the semantics and contents of that particular artifact. Content items can contain documents, wiki pages, web links and notes and can be commented upon by other students.

The Community view provides a description of all members of the student group, explicating for each member: the tasks and content items created and responsibilities allocated. The community view thus offers insights into the interactions between the personal and social level of the groups' activities.

To demonstrate how the KP-environment can support trialogical practices we will provide a brief outline of students' practices during the Bachelor thesis scenario below. This is a generic description of the chronology of these practices and of how KP-environment offers support but the sequence and nature of the practices may vary depending on the topic and type of research each student group will be conducting. In addition, practices can be recurrent meaning that they can be revisited during the project depending on the necessity identified by the group members. All the research and other project activities described in the outline are supposed to be performed in collaboration and can be supported by KP-environment.

1. Project Initiation

The project initiation takes place at the beginning of the Bachelor thesis course where students are familiarized with the aims of the course. Students have a course manual at their disposal and receive explanations from their tutor about the course set-up. Forming teams and deciding on a research topic is left for students' to chose based on their interests. Student teams write a short essay for their choice, based on arguments found in the scientific research literature and which has to be approved by their tutor before they can continue conducting their research.

The KP-environment community view offers support for students to get acquainted to the other group members and increases awareness of their peers' activities. Groups or individual students who could not make a choice can use the shared space as a mind mapping tool to generate ideas and make a selection of possible topics. Literature sources can be uploaded as content items.

The KP-environment supports students to sketch their ideas directly in their space in the content item view employing the note-editor tool (see Figure 4). The students can compare the versions of the ideas they have produced, since they can be viewed in parallel. The note-editor also allows students to synchronously view notes while another student is editing it. In addition, similarly to the other content items inside the shared space, notes can be linked to other relevant material, such as articles students have taken into consideration related to the subject that they are discussing about.

Moreover, Figure 4 shows that students are afforded to rise above previous ideas generated by other groups' members. This gives the chance to rise above the concrete level of brainstorming and commenting. Such discussions, within the context and in relations to their semantic relations, enables collaborative idea generation already from the start of the project. The idea for having these features came from the end-users of previous field trials. Students reported that existing tools did not give them sufficient means for idea generating tasks. Thus, the note-editor tool exemplifies how the KP-environment allows students to collaboratively create, organize and advance their work on knowledge artifacts which increases their sense of ownership and agency over the activities they perform.

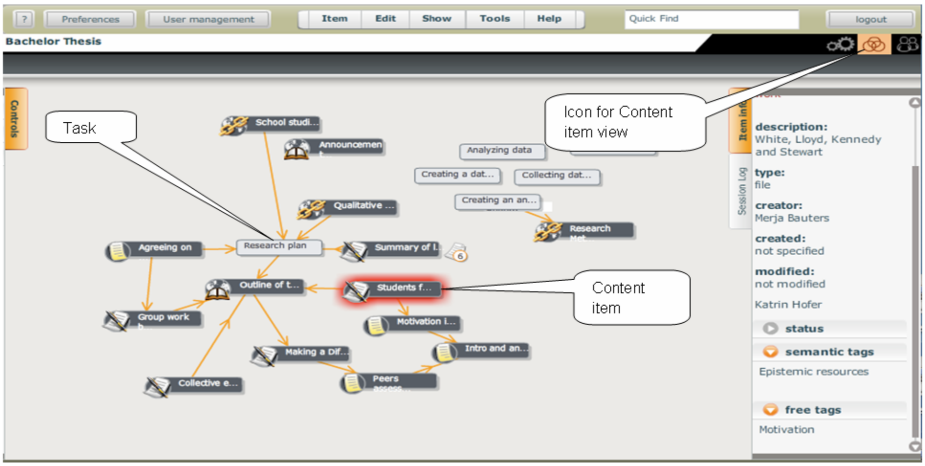

Fig. 3. Content item view

The collaborative brainstorming and rising above the previous ideas contributed well to the following design principles: focus on trialogical activity around shared objects (DP1), interaction between personal (DP2) and social level and eliciting (individual and collective) agency (DP5). By enabling contextualized work around shared artifacts (i.e., the notes) (DP1), by allowing individual contributions and idea development allowing others to view, share and contribute into it (DP2) and by engaging the group to collaboratively reflect on which aspects of the provided ideas they have to develop further and investigate (DP5).

2. Preparing the Research

The second phase in conducting the project is that students are going to plan and design their research activities. This phase includes writing a research proposal and plan, working out the research problem and elaborating on the theoretical foundations of the research and the sketching of a research design. These artifacts represent the first deliverables of the project. All knowledge necessary for producing these artifacts is collected into the shared space in the form of notes and various kinds of documents (i.e. content items) that can be added, re-arranged, tagged and linked with each other (see Figures 2 and 5). In case teams work together on a common research topic, each team will present their approach to the specific sub-topic they are investigating.

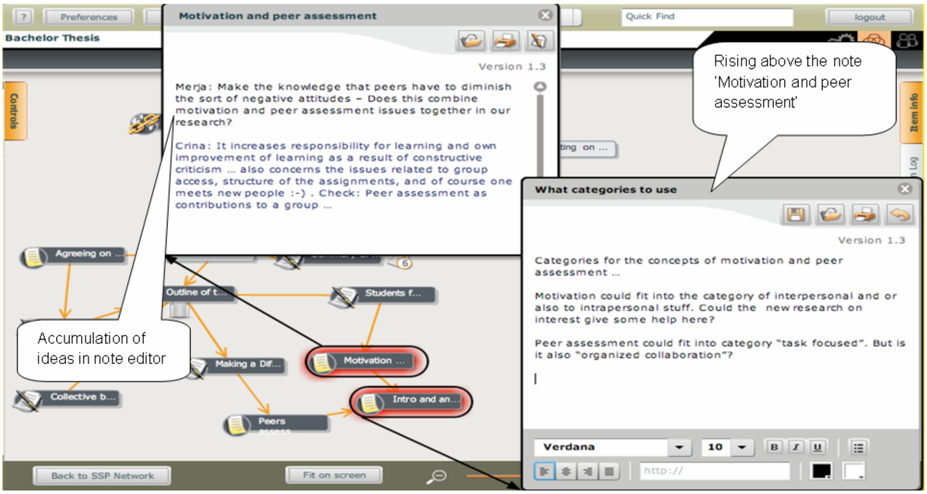

Fig. 4. Two notes that are uploaded in the Content item view. The note at the lower right is in the editing mode and rises above (i.e. categorizes) the note previously generated.

As shown in Figure 2, the KP-environment supports planning activities of the student groups since it allows them to create a GANTT chart. This chart enables students to define the tasks to be performed, the timeline associated to the tasks and the responsibilities associated with the particular tasks. Student groups, for instance, produce a research plan, a draft paper (their research report) and a final paper, which must be presented to the other groups and their tutor at a specified date. These critical artifacts can be indicated in the GANTT as milestones. Especially the functionalities of the content item view within the KP-environment provide the main support in this phase of the student groups' project.

Figure 5 presents the commenting tool and shows threads of comments that the particular shared object has promoted. In this case the shared artifact involves a summary of a particular article which receives appraisal of the other students to integrate this artifact in the writing of their final research report. The KP-environment thus supports the commenting of artifacts which enables students to review their work critically and to plan and organize their activities accordingly. The semantic tagging of the shared artifacts helps students to organize the material employing the semantics they assign to the content of the course. As such the KP-environment emphasizes both reflection on content-related work as well as supports the management of collaborative work.

The KP-environment allows the tutor to review the student groups' shared spaces so that he/ she can provide feedback on the artifacts that were created by them. The feedback received from the tutor and from possible other student groups will be used by each team for adjusting and improving the provisional research plans for instance.

3. Conducting the research

In this phase of the Bachelor thesis scenario, student groups perform activities necessary for the execution of their research. A number of artifacts will be delivered by students, such as data collection instruments, methods for data analysis, data analyses and interpretation reports. For initiating data collection activities a research instrument is needed, therefore brainstorming between the members of the group is important. In addition, students have to think about the design of their research, the nature of the empirical data they require and the ways in which they are going to analyze this data. This also means that the groups have to manage the logistics of conducting their research, which amongst others involves establishing contact with their research participants, collecting some general background information about their participants and the institution they conduct the research. Moreover, students have to plan and elaborate on the nature of their empirical endeavors and the ways in which they are going to extract and analyze data. The KP-environment supports these practices by means of functionalities offered by the GANTT chart in the process view (see Figure 2) and creation, tagging and commenting on content items (see Figures 3, 4 and 5).

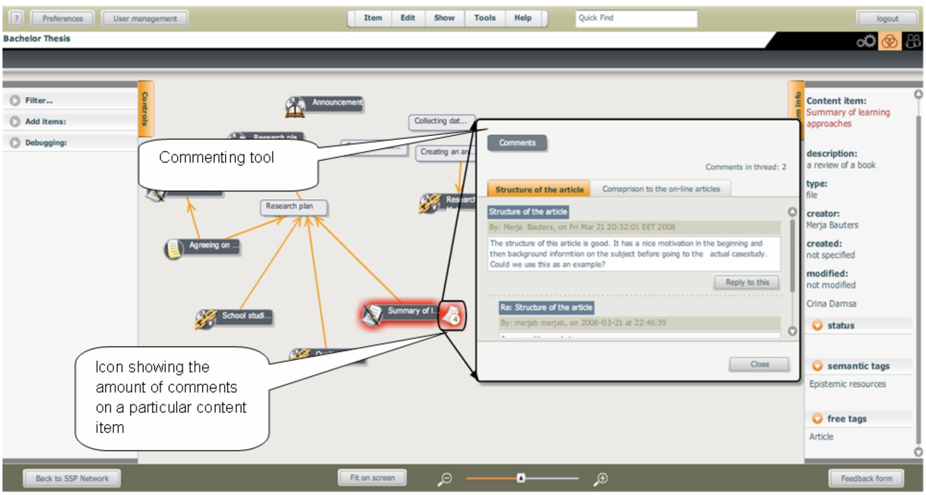

Fig. 5. Commenting on a content item in the KP-environment. As the above screenshot show s there can be more threads connected to one shared artifact allowing flexible discussion.

At this stage teams also must work on the writing of a provisional research report. This means that they can make intensive use of the note editing tool (see Figure 4). In addition, the KP-environment also affords the student group can to write collaboratively in a Wiki (see Figure 6). The Wiki can be created as content item in the content item view and offers the possibility to write in the same document. The progress and changes made to the document are visible to all group members.

4. Delivery

The delivery phase is dominated by the activities for writing the final research report. All the artifacts created by the student group serve to feed into the final research report. The tools offered in the KP-environment enable students to view all the artifacts produced, how they relate to each other, their semantics and their creation process. The research report is iteratively collaboratively revised and commented upon in the student groups' shared space. The collaborative writing activities prevail in this project phase which means that the collaboration tools in the KP-environment such as the note editor, the Wiki, the commenting and semantic tagging tools are important during this period. The Gantt chart in the process view of the KP-environment provides an insight in the advancement of the groups' collaborative object-related work. In the end, the report is published and the tutor and other groups can give evaluative feedback on the artifacts produced and on the main object delivered.

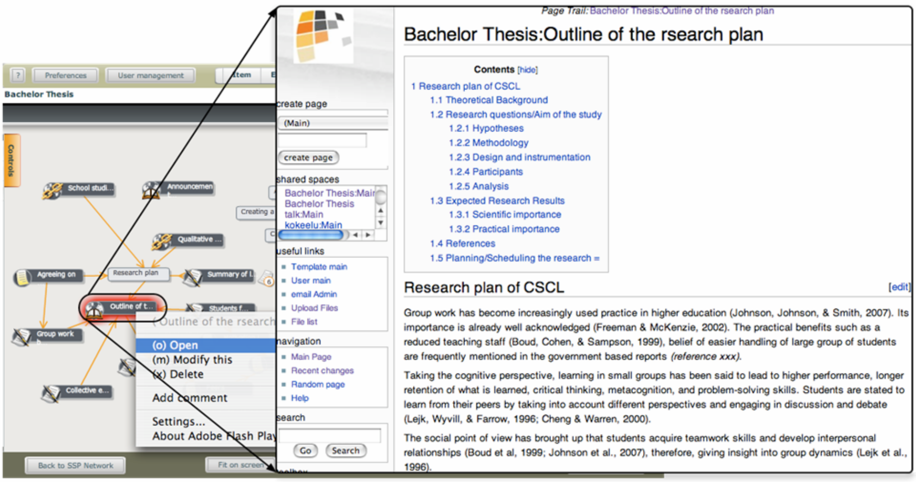

Fig. 6. Content item consisting of a Wiki which outlines a research plan of a particular group

5 Conclusion and Discussion

To design learning technologies in such a way that competencies, which are essential to be able to productively participate within this production oriented society, become more central necessitates for a reconceptualization of the way in which learners organize their knowledge work. The emphasis in designing technology should not merely focus on individual knowledge acquisition or on social interaction, but more on the way in which learners collaboratively create and advance knowledge objects [6]. In this paper we presented the KP-environment which is a virtual collaboration space which attempts to afford its users to manage, organize and elaborate on the artifacts they create during a trialogical learning or working process. The considerations that were taken into account in the design of the KP-environment for supporting these practices were described as well as its application for a concrete scenario in which students collaboratively construe a research report.

Although the KP-environment is part of the whole trialogical pedagogical context, it fosters those practices deemed essential in knowledge creation. This means that it focuses on the sustained trialogical activity around shared artifacts through offering flexible tools which support: a) elaboration on content related semantics of the tasks students decide they have to perform, b) communal practices to cross fertilize between different partners in a group, fostering sustained processes of knowledge advancement and move beyond the individual level, and c) management and organization of the groups' practices.

At present KP-environment represents a developmental trail towards supporting trialogical learning, which offers a perspective on preparing students for authentic knowledge management work. Nevertheless, it needs to be noted that the present paper presented the design considerations and the foreseen usage of the KP-Environment for particular practices in a specified pedagogical scenario that has to be implemented yet. In order to validate the KP-environment, empirical research is needed in which its educational significance is tested and evaluated.

References

1. Bereiter, C.: Education and mind in the knowledge age. Lawrence Erlbaum, Hillsdale (2002)
2. Engeström, Y.: Activity theory and individual and social transformation. In: Engeström, Y., Miettinen, R., Punamäki, R.-L. (eds.) Perspectives on activity theory, pp. 19–38. Cambridge University Press, Cambridge (1999)
3. Latour, B.: Pandora's hope. Harvard University Press, Cambridge (1999)
4. Andriessen, J.E.B.: Arguing to learn. In: Sawyer, R.K. (ed.) The Cambridge handbook of the learning sciences, pp. 443–460. Cambridge University Press, New York (2006)
5. Sfard, A.: On two metaphors for learning and the dangers of choosing just one. Educational Researcher 27(2), 4–13 (1998)
6. Paavola, S., Hakkarainen, K.: The Knowledge Creation Metaphor – An Emergent Epistemological Approach to Learning. Science & Education 14(6), 535–557 (2005)
7. Engeström, Y.: Learning by expanding. Orienta - Konsultit Oy, Helsinki (1989)
8. Star, S.L.: The structure of ill-structured solutions: Boundary objects ands heterogeneous distributed problem solving. In: Glasser, L., Huhns, M.N. (eds.) Distributed artificial intelligence, Pitman, London, vol. II, pp. 37–54 (1989)
9. Scardamalia, M.: Collective cognitive responsibility for the advancement of knowledge. In: Smith, B. (ed.) Liberal Education in a Knowledge Society, Open Court, Chicago, pp. 67–98 (2002)
10. Bell, P., Hoadley, C.M., Linn, M.C.: Design-based research. In: Linn, M.C., Davis, E.A., Bell, P. (eds.) Internet environments for science education, pp. 73–88. Lawrence Erlbaum Associates, Mahwah (2004)

Towards Lightweight LMS 2.0: A Blog-Based Approach to Online Assessment

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Abstract. Blogs have not been designed for online teaching and learning, yet they have recently become a "must try" component of learning environment in academic circles. This paper focuses on one of the challenges of blog-based e-learning: implementation of feedback and assessment workflows in distributed e-learning landscape. Some most typical assessment-related workflows are described and a prototype of an add-on module for an open-source blogging tool Wordpress is demonstrated.

Keywords: Web 2.0, blog, interoperability, learning management system, assessment.

1 Web 2.0 in Education

Although the use of Learning Management Systems has become the synonym of e-learning in universities around the world during the last decade, recently their dominance have been threatened by open, flexible and easy-to-use Web 2.0 tools. Web 2.0 is a metaphor contrasting the social and participative way [1] of using the new tools like blogs, wikis and recommendation systems to the first generation of Web applications. Web 2.0 applications are not revolutionary in the technical sense, but they have changed the patterns of users‘ behavior on the WWW. Web 2.0 is often referred as read-write Web, as opposed to read-only Web 1.0. As Cristóbal and Romaní have put it: ‚the Internet isn't just a reading source anymore: it extends itself into a constructivist space of writing and participation's interchange‘ [2]. From the perspective of educational science, Web 2.0 draws attention as an environment that has explicit social orientation, and its uses in the context of teaching and learning are supported by the mainstream educational theory called social constructivism. [3]

Most often, the Web 2.0 tools are used in the education as a suitable platform for a knowledge building and reflecting, but also for collaborative production and exchange of learning resources. Blogs have became increasingly popular among educators as an easy-to-use Web publishing platform that can be used both on the individual and group level. Yet, the blog is not just a publishing tool, but also a platform for discussions. If combined with RSS feed readers or aggregators, blogs can easily replace the traditional Web forums in the context of online teaching and learning. As Huffaker [4] has argued: ‚blogs can be an important addition to educational technology initiatives because they

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promote literacy through storytelling, allow collaborative learning, provide anytime-anywhere access, and remain fungible across academic disciplines‘.

The main challenge that raises from using blogs in the context of online teaching and learning is related with difficulties of conducting an iterative process of assessment and feedback given by a teacher to written assignments that are published by the students in the distributed learning environment. The usability of blogs in this setting is reduced because blogs have not been designed specifically for teaching and learning, which causes the following problems: (a) it is not so easy to separate student contributions from different courses that are running in parallel with each other, (b) there is no easy way to have a quick overview of all grades or feedback comments given by the teacher during one course, (c) there is no easy way to limit the access to the teacher‘s comments to a student’s blog post.

In this paper, we are going to propose a solution to these problems by adapting the Wordpess blog software so that it will support assessment-related workflow management between several blogs. We have started our search for solution with the following requirements: (1) the additional functionalities should be implemented with minimal intervention to the existing software architecture and the typical way of using the blogs, (2) we should take advantage of existing protocols, interfaces and techniques built into the Wordpress blog software, (3) we should increase the interoperability of our implementation by following the standards and specifications as much as possible, and (4) the typical character of assessment-related workflow should be maintained also in the distributed environment consisting of multiple blogs.

A successful implementation of blog-based assessment workflows will hopefully increase the pedagogical usability and effectiveness of blogs in the context of online teaching and learning.

2 The Assessment Workflow in the Classroom and in the Blog-Based Learning Environment

We argue that workflow management provides a suitable framework for describing and organising the iterative process of assessment in a blog-based distributed virtual learning environment. Van Aalst [5] is making a distinction between the terms ‚workflow‘ and ‚collaborative process‘. The latter is emphasizing only collaboration and information sharing, without explicitly describing or defining the processes. The workflows can be divided into three types according to their level of formalisation and automatisation [5]: (a) **ad-hoc workflows** that relate to processes where the procedure is not defined in advance, (b) **administrative workflows** that correspond to case-driven processes which follow a well-defined procedure, and (c) **production workflows** that are concerned with highly structured processes with almost no variations. The assessment process in an ordinary blog-based learning environment can be interpreted as a collaborative process, but our aim is to modify the blog software in order to achieve the level of semi-automated administrative workflow.

Assessment of learning outcomes in an online environment can be seen as a workflow involving two or more subjects: a teacher (or facilitator) and one or more students. The assessment workflow has three dimensions:

- **The case dimension**: an assignment,
- **The resource dimension**: a learning resource, a blog post, a comment or a grade, and
- **The process dimension**: a series of tasks accomplished by a teacher and students.

In the classroom setting, a teacher usually presents the goal and content of each assignment, as well as related tasks (with deadlines and other conditions) and resources. The students are usually present in the classroom while receiving the assignment and also when they submit their results. Teacher gives feedback to submitted works, possibly requesting for improving the ones that do not meet the criteria. The final step in this workflow is grading the student's work by the teacher. In order to make the workflow more flexible, many educational institutions have implemented an alternative communication channels for collecting assignments and distributing grades (e.g. dropboxes).

In case of implementing a similar assessment workflow in a blog-based learning environment, various approaches can be used. For example, authors of a *Class Blogmeister* [6] system suggest that a teacher should register all students as users of a single blog. In this setting, the assessment workflow is implemented on a simplest way: each student publishes his/her work as a blog post directly to the joint blog administered by the teacher. The teacher then gives feedback by submitting comments to the blog posts of students. In spite of simplicity of this approach, it has also weaknesses. In particular, the main advantage of blog as personal publishing tool is lost as there is no personal storage place for individual contributions. In case of participating in several blog-based courses, the student will lose the connection to his own works distributed between multiple blogs that belong to different teachers. Quite likely, this approach cannot be scalable beyond small single pilot courses.

According to Hirvela [7], today's students prefer to be assessed by presenting their works using a personal digital portfolios. Portfolio approach gives the student an additional motivation to personalise her learning environment and to document her learning history [8]. The easiest way to build one's own personal e-portfolio is to use blog, most of the special e-portfolio systems (e.g. ELGG) contain a blog tool.

Wordpress and Movable Type, the most popular blog engines, have two basic built-in methods called *trackback* and *pingback*, which allow automated data exchange between different blogs (or between a blog and another Web application like Technorati). The common feature of these two methods is that a publication of a new post in one blog is automatically announced within another blog.

Assessment-related workflow needs intercommunication between the blogs of the teacher and the student that can be organised by means of the above mentioned methods in case they can be enhanced by adding some specific functionalities. Such functionalities can be implemented to Wordpress software using plug-in architecture. The plug-in should work in a standard way: the data exchange between the blogs occurs by means of extended XML-RPC calls.

3 Implementing Assessment Workflow in Wordpress

In the following, we are going to describe a blog-based implementation of a simple assessment workflow that involves only one teacher and one student.

In order to specify a course as a container for a set of assignments (workflow cases), we suggest to use the *category* feature of Wordpress blog engine. This gives the teacher an opportunity to separate his lecture's materials and assignments for the different groups of the students in a different, logically separated virtual ‚classrooms'. Students can subscribe to RSS feed that filters out from the teacher's blog only those messages and assignments that are relevant to the course they have registered to.

All of additional functionalities can be used by the teacher through a special menu that was added by us to the Wordpress software. This menu will appear to the Dashboard after installation of our assessment workflow plug-in called LeFlow.

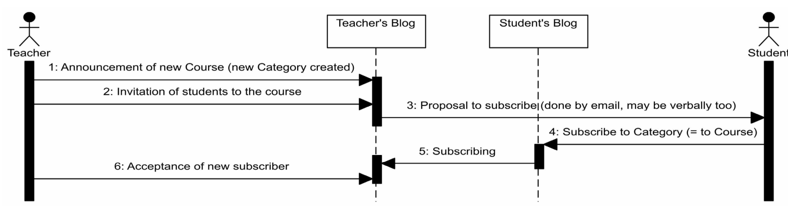


Fig. 1. Announcement of subscribing to the course

We propose the following workflow for subscribing the students to the course (Figure 1). The teacher creates a new course by opening a new category in his personal blog (1) and invites the students to subscribe their blogs to the RSS feed for this category (2). An e-mail invitation is sent by Wordpress after the teacher has filled in the special Web form (3). If the LeFlow plug-in has been installed to the blog of each student, they can subscribe to the course using the special LeFlow menu (4, 5). Then, the teacher accepts the course registration requests using a Web form (6). Since this moment, any post in the teacher's blog is forwarded to the blogs of students using the pingback method (Figure 2).

Now the teacher can publish a new assignment. The teacher submits a new post in his blog (task 1, Figure 2). If this post is marked as being an assignment, the teacher should provide some additional information such as a deadline or special conditions for this task. Publishing a new assignment creates an automatic announcement (2) that is instantly passed via pingback to each student registered to this course (3).

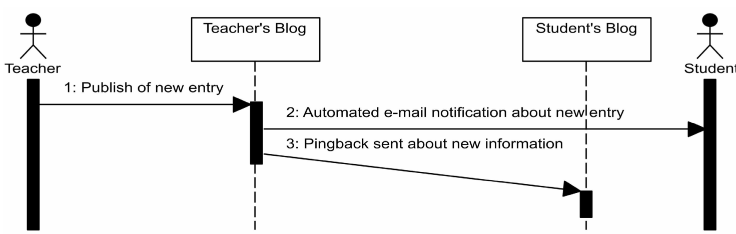


Fig. 2. Publishing of a new entry in the teacher's blog

If published entry is assignment (Figure 3), a student is invited to publish her response in her blog. It should be done through a special *Results* page that is created by LeFlow plugin. Student submits her response to assignment as a new blog post and marks it with the relevant category tag.

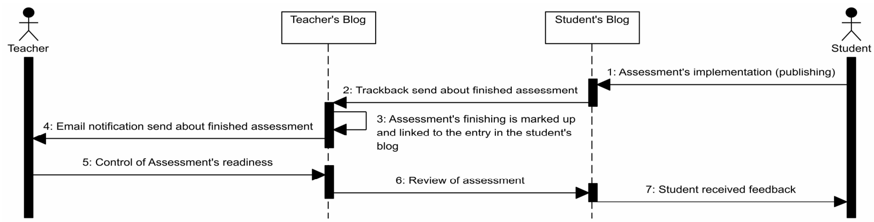
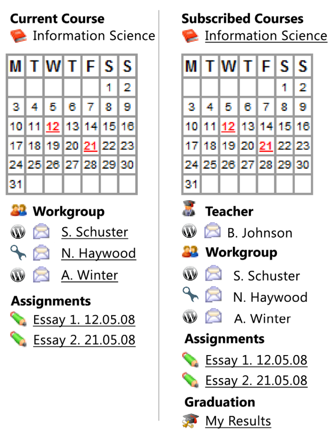


Fig. 3. Assessment's implementation and feedback

All assignments that are submitted by students are collected via trackback to the special *Results* page on the Dashboard of teacher's Wordpress as a list of links.



a) b)

Fig. 4. A prototype of the blog's control panel; a) for teacher, b) for student

Technically, our scenario enables that each blog user can act both as a teacher and as a student because we assume that all users of blogs have opportunity to open their own personal courses. This feature can be used e.g. for organising groupwork and peer-assessment between students. Yet, there are minor differences between the student's and teacher's Control Panel and Results page (see Figure 4 above).

4 Conclusions

This paper focused on the use of blogs in teaching and learning, as an alternative to large, monolithic and multi-functional Learning Management Systems like Moodle or

WebCT. Our approach is based on self-developed prototype of LeFlow plug-in to Wordpress blog system that enables to manage simple assessment-related workflows three native components of blog systems: Trackback, Pingback and Category. The plug-in will enhance functionalities of Wordpress: users will be able to create groups, invite other user to join their group and send them assignments. The group members can submit the completed assignments using their blog; teacher gives feedback in the same manner. The work is still in progress, our prototype is about to be tested in real-life situation with an international group of Masters students in winter term 2008.

References

1. Miller, P.: Web 2.0: Building the New Library. Ariadne Issue 45 (2005)
2. Cristóbal, J., Romaní, C.: Learning 2.0. Global Leapfrog Education 1(1), 7–14 (2006)
3. Jonassen, D., Davidson, M., Collins, M., Campbell, J., Haag, B.: Constructivism and Computer-Mediated Communication in Distance Education. American Journal of Distance Education 9(2), 7–26 (1995)
4. Huffaker, D.: The educated blogger: Using Weblogs to promote literacy in the classroom. AACE Journal 13(2), 91–98 (2005)
5. van der Aalst, W.M.P.: The application of petri nets to workflow management. Journal of Circuits, Systems, and Computers 8(1), 21–66 (1998)
6. Class Blogmeister, `http://classblogmeister.com`
7. Hirvela, A., Sweetland, Y.S.: Two case studies of L2 writers experiences across learning-directed portfolio contexts. Assessing Writing 10, pp. 192–213. Ohio State University, Ohio (2005)
8. Hamp-Lyons, L.: Scoring procedures for ESL contexts. In: Hamp-Lyons, L. (ed.) Assessing second language writing in academic contexts, pp. 241–276. Ablex, Norwood (1991)

CoChemEx: Supporting Conceptual Chemistry Learning Via Computer-Mediated Collaboration Scripts

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Abstract. Chemistry students, like students in other disciplines, often learn to solve problems by applying well-practiced procedures. Such an approach, however, may hinder conceptual understanding. We propose to promote conceptual learning by having pairs of students collaborate on problems in a virtual laboratory (VLab), assisted by a computer-mediated *collaboration script* that guides the students through the stages of scientific experimentation and *adapts* to their needs for support. We used the results from a small-scale study comparing how singles and dyads solve chemistry problems with the VLab with and without scripts to develop a scripted collaborative experimentation environment. A subsequent small-scale study compared an adaptive and a non-adaptive version of the system. Qualitative data analyses revealed a tendency for the dyads in the adaptive feedback condition to improve their collaboration and be more motivated than the non-adaptive dyads. In this paper, we present our research framework and report on preliminary results from the two small-scale studies.

1 Introduction

Chemistry educators face the challenge of teaching students to solve problems *conceptually* rather than simply applying mathematical equations, a common tactic taken by students. Students struggle with problems that are similar to those illustrated in a textbook or demonstrated in the classroom, because they do not grasp the similar underlying concepts [1]. Research in chemistry education has suggested that *collaborative* activities can improve conceptual learning [2, 3] and increase student performance and motivation [4]. While there have been very few controlled experiments investigating the benefits of collaborative learning in chemistry, evidence that collaboration is beneficial exists in other disciplines, such as physics [5] and scientific experimentation [6]. Our own experimental work has also shown promising preliminary results in the conceptual learning of algebra [7]. This evidence has led us to investigate the potential advantages of collaborative activities for the acquisition of conceptual knowledge in chemistry.

Unfortunately, collaborative partners often do not engage in productive interactions and thus miss the opportunity to benefit from their collaboration. This observation, taken together with research in the area of collaborative inquiry learning [8] and

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scientific scaffolding [9], suggests supporting students with *collaboration scripts*. By scripting collaboration we mean providing prompts and scaffolds that guide students through their collaborative work (e.g., [10]). However, it is also possible to *over-script*, that is to provide too many scaffolds [11]. Students may be overwhelmed by the concurrent demands of collaborating, following script instructions, and trying to learn [12]. To avoid the pitfalls of over-scripting but at the same time provide collaborative scaffolds, we propose to use *adaptive scripting*, i.e. scripting that adapts to the collaborators' needs for support. We intend to enforce and/or fade support based on real-time, dynamic estimations of the student's domain and collaborative knowledge. We believe that students at different levels of knowledge and skills will be supported better via varying degrees of collaborative scaffolding. Some studies by other researchers have pointed toward the benefits of such adaptive support [13]. More particularly, we want to adapt the script, the system support in terms of tools provided to the students, and the prompts. We hypothesize that this approach will increase the likelihood that students will capitalize on the learning opportunities offered by the experimental chemistry environment.

In the current paper, we describe the software we have developed, our pedagogical approach, the small-scale studies we have conducted so far together with a case analysis of adaptive human prompts and consequent student behavior, and our plan to extend our system to produce fully automatic adaptive feedback.

2 Technology Integration in the CoChemEx Project

We developed collaborative extensions to VLab, a web-based software tool that emulates a chemistry laboratory and supports chemistry experiments [14]. VLab was developed at Carnegie Mellon University. It provides virtual versions of many of the physical items found in a real chemistry laboratory, including chemical solutions, beakers, Bunsen burners, etc. It also includes meters and indicators for real-time feedback on substance characteristics, such as concentration and molarity. The idea behind the VLab is to provide the students with an "authentic" laboratory environment in which they can run experiments to solve chemistry problems much like in a real chemistry lab.

In order to allow students to collaborate during the simulation of chemistry experiments, we integrated the VLab into an existing collaborative software environment called FreeStyler [15], a collaborative software tool that is designed to support "conversations" and shared graphical modelling facilities between collaborative learners on different computers. Figure 1 illustrates the FreeStyler software and the VLab (in the middle). FreeStyler provides a variety of objects (top right in Figure 1), such as the *chat* shown in the lower left of the figure and a graphical *argument space*, which supports unfolding debates between users. All users have access to a shared workspace (essentially the entire window shown in Figure 1) that may be updated by any participant in the collaboration.

FreeStyler also supports the implementation of inquiry and collaboration scripts which are formally represented as an IMS Learning Design document, an e-learning standard for educational processes. These scripts are enacted using a third-party component for the scripting engine, the CopperCore learning design engine. As explained in more depth in [15], the scripts can control the tools available within FreeStyler (e.g., *chat*, *argumentation space*, or VLab) for each phase of a learning activity: actions conducted by the learners in the learning tool are propagated to the scripting engine, analyzed, and the learning environment is subsequently reconfigured based on the information contained in the script. That way, adaptive system behavior is achieved. We complemented this system-initiated option of regulating the learning processes with a possibility of having a human supervising the collaboration and giving advice in a Wizard-of-Oz fashion. This Wizard Component allows the human observer to send text messages and pictorial information directly to an arbitrary set of collaborators (see Figure 1). The use of the "Scalable Adapter" design pattern [16] and the cost-effective re-use of existing software code made this development possible.

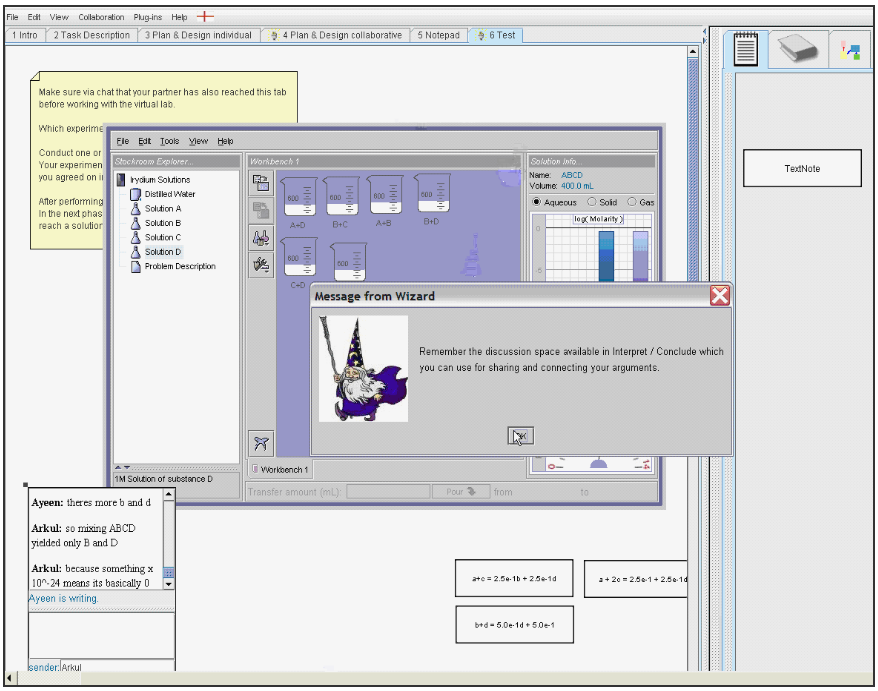

Fig. 1. A screenshot of the computer-based CoChemEx script, showing the *Test* tab (to be explained later)

3 The General Pedagogical Approach

Our approach to scripting, which we have tested in the two small-scale studies described in the following section, is to guide the collaborating students through phases of scientific experimentation and problem solving. More specifically, we base our script on the kinds of cognitive processes identified as typically used by experts when solving scientific problems experimentally [17, 18]. For instance, de Jong and van

Joolingen have identified Orientation (identification of main variables and relations), Hypothesis generation, Planning, Experimentation (changing variable values, predictions, interpreting outcomes), Monitoring (maintaining overview of inquiry process and developing knowledge), and Evaluation (reflecting on acquired knowledge) as steps that scientists do and should take in their work. Our experience with a first version of the script, which resembled this analysis of scientific steps a lot and asked students to follow them closely, led us to a necessary simplification. The main steps of the current script, illustrated at the top of Figure 1 as tabs, are: *Plan & Design*, where partners discuss their individual plans and agree on a common plan, *Test*, where the experimentation in VLab takes place, and *Interpret & Conclude*, for discussing the results in VLab and drawing conclusions. We also now guide students through the various steps in a less rigid manner to avoid overwhelming them with too much structure.

Our system gives students general guidance on the script and provides prompts on solving VLab problems collaboratively. This approach is similar to that of White *et al* [19] and Van Joolingen *et al* [20] which scaffold students who collaboratively solve scientific problems. However, our work differs to these prior efforts mainly in that we investigate how such an approach can be automated and if it can bolster specifically the collaborators' *conceptual knowledge* in the domain.

4 Studies and Script Development

4.1 Study 1

This was a preliminary study of the collaboration scripting approach described above. Data was collected on four conditions: scripted and unscripted dyads (4 dyads in each condition), scripted and unscripted singles (4 singles in each condition). The scripted conditions were given a paper-based script (without computer support) inspired by [17, 18]. It consisted of the steps *Orientation*, *Experimentation* (with substeps *Hypothesis*, *Design of Experiments*, and *Analysis*), *Drawing a Conclusion* and *Making an Evaluation*. The participants working in dyads sat next to each other and were asked to collaborate either freely, in the unscripted condition, or based on the script, in the scripted condition. They collaborated on solving problems that involved performing experiments in the VLab. The singles' problem-solving was supported by a similar script to test the effect of the script independent of the collaboration. The unscripted singles were the control; they solved the same tasks in the VLab with no further instructions. Students had to solve two problems: one on titration, and one on reaction stoichiometry and limiting reagents.

Perhaps unsurprisingly, the scripted conditions reported problems and frustration in dealing with the script in the overall complex situation. As mentioned earlier, previous work has shown that scripted dyads can be overloaded by the demand of getting acquainted with a computer-based learning environment, collaborating with a partner, attending to a script, and solving a task all simultaneously [12]. However, our results also indicated that, in spite of the perceived constraints of the script, it was still helpful. For instance, the scripted conditions were more efficient in solving problems; they took fewer steps to achieve similar results.

Improvement of the collaboration script based on study 1: The analysis of the first study led to three consequent adaptations of our script:

- First, we reduced the complexity of the script. More specifically, as mentioned above, we consolidated the experimental steps to three phases: *Plan & Design, Test, and Interpret & Conclude.*
- Second, we modified the script so that individual phases precede the collaborative ones, to allow students to formulate ideas first at their own pace, before entering the collaboration phases.
- Third, we added adaptive feedback to support students according to their individual needs in the different phases. This feedback is provided by a human "wizard"; later we intend to automate the production of adaptive feedback.

Figure 1 illustrates the resulting collaborative learning environment that we developed. Students are guided by static instructions in each tab. The first tab is the *Task Description*. The tabs *Plan & Design individual* and *Notepad* allow each of the participants to record private notes and ideas using free-form text, in preparation for collaborating. The tabs *Plan & Design collaborative*, *Test*, and *Interpret & Conclude* implement the script to guide the students' collaborative experimentation. Finally, in the tab *Check Solution* students submit their solutions and get error feedback. In the first cycle, the students are requested to follow this pre-specified order of the tabs and to click on a "done" button to activate the next tab. After the first cycle, all tabs are available for a more open exploration.

Collaborating students work on separate computers and have access to a number of tools. The *VLab* (in the middle of Figure 1) is the basic experimental tool and the core collaborative component; it is situated in the *Test* tab. The *chat* window in the lower left of Figure 1 supports free-form communication between the students in the *Test* tab, as a way to explain, ask/give help, and co-construct conceptual knowledge. An *argument space* is available in the tabs *Plan & Design collaborative* and *Interpret & Conclude* (Figure 1). It allows the collaborators to discuss their hypotheses and results and to communicate general ideas, so as to promote students' conceptual understanding of the experimental process. It provides students with different shapes and arrows of different semantics for connecting the shapes. By using them, students can make claims, provide supporting facts, and make counter-claims. In the shapes we provide sentence openers to guide the argumentation, such as "I think that the main difference between our approaches to the problem is..." The argument space has the potential to allow students to reflect on each other's ideas and understand them better [21]. Finally, a *glossary* of chemistry principles is available to the students at all times.

A human wizard provides adaptive support (see Table 3) using a flowchart to observe and recognize situations which require a prompt, and to choose the appropriate prompt. The situations are defined by observable problematic behaviors in the tab where the activity currently takes place, either with regard to the collaboration (*bad collaborative practice*, e.g. ignoring requests for explanations), or with regard to following the script (*bad script practice*, e.g. moving to the next tab without coordinating with the partner). The wizard prompts were focused on providing collaboration support. A top-down version of the flowchart of prompts was first developed by reviewing the literature on collaborative learning, for example [5, 22]. Moreover, we focused our adaptive feedback on prompting for communication (e.g., reminding to give and request explanations and justifications) and prompting after poor communication (e.g., reminding not to ignore requests for explanations or to contribute to the activities equally). This was a reaction to results from the small-scale study, which revealed that students did not exhibit the right amount and kind of communication. A few prompts specific to our script were added to the flowchart to remind students which tabs to use for their activities. Finally, domain-specific hints were added as a type of "dead end prevention" in case students submitted a wrong solution. Two wrong submissions were allowed; after that no more attempts were possible.

4.2 Study 2

In a second study our goal was to test our computer-based collaborative learning environment and to refine the scripting approach based on an in-depth analysis of the data, with a focus on the adaptive aspects of the script. We again planned a small study to get preliminary indications on whether an adaptive system would lead to conceptual learning gains. We recruited 3 dyads per condition. All participants were university students. The experimental process followed the standard pre-test – intervention – post-test paradigm. In the intervention phase, there were two conditions, one using the standard and one the adaptive version of the script. That is, the adaptive social prompts by the human wizard were unique to the adaptive condition. Both conditions had to solve two problems: one dealing with limiting reagents in Reaction Stoichiometry, and one dealing with molarity. Both problems were of average difficulty for the participants, with the latter being slightly more demanding. After the intervention phase a post-questionnaire and a post-test were administered. The post-test was equivalent to the pre-test, but included additional conceptual questions.

Quantitative Results. The results showed a tendency toward better conceptual understanding in the adaptive condition. Two conceptual questions were asked in the post-test for each of the problems. The concepts tested were all central to the tasks which students had encountered in the VLab. With a highest possible score of 6 points, the mean of the adaptive condition was M=4.6 (SD 1.63) whereas the non-adaptive condition scored in average M=3.5 (SD 2.81). Due to the small sample size we did not perform further statistical analyses. An interesting result from the analysis of the questionnaire was that the adaptive condition reported on a 6-point Likert scale a stronger impression that they did not have an equal chance to participate in solving the problems (M_{ad}=5.16, SD_{ad}=1.16 vs. $M_{non\text{-}ad}$=2, $SD_{non\text{-}ada}$=.89), although our process analysis revealed that such a difference is not real. This could be a cue that the common wizard prompts to participate equally raised the participants' awareness of instances when participation was not equal. That is a desirable effect especially if it leads to corresponding attempts to balance participation.

Table 1. Summary of the process analysis of the script and collaboration practice

Analysis Category	**Number of Occurrences**			
	Adaptive		**Non-adaptive**	
	M	**SD**	**M**	**SD**
Good script practice, e.g., coordinated actions in tab	6.33	2.51	5	2.64
Bad script practice, e.g., uncompleted actions	4.33	3.21	7.33	2.3
Good collaborative practice, e.g., ask for and give explanations	5.66	1.15	3	1
Bad collaborative practice, e.g., not explaining actions	2	1	1.66	1.15
Good reaction to a wizard message, e.g., improved practice after	8	4.58	(does not apply)	
Bad reaction to a wizard message, e.g., message has no apparent effect	6	4.7	(does not apply)	

Progress of individual dyads	***Ad-Dyad-1***: improved	***Ad-Dyad-2***: improved	***Ad-Dyad-3***: improved (slightly)	***Non-Ad-Dyad-1***: deteriorated	***Non-Ad-Dyad-2***: deteriorated (slightly)	***Non-Ad-Dyad-3***: stable

Process analysis of Study 2 Data. *The process analysis of the screen recordings of the collaborations* revealed interesting *differences between the two conditions, as shown in the summary in Table 1. Three members of our research team annotated different screen recordings independently. We counted the number of occurrences of good and bad script practice per dyad, that is, student's behavior relating to the script features (tab structure, argument space, and instructions). We also counted good and bad collaborative practice, that is, the kind of behavior expected and fostered by the prompts in the wizard's flowchart.*

As shown in Table 1, there was a big difference between conditions and for both problem-solving sessions in the aggregated occurrences of "good script practice" and "good collaborative practice" in favor of the adaptive dyads. "Bad script practice" was also considerably less frequent in the adaptive condition. However, the adaptive dyads showed slightly worse collaborative practice than the non-adaptive dyads. The category "Progress of individual dyads," at the bottom of Table 1, is a qualitative overall evaluation of each dyad as perceived by the annotators. It is a summary of the script and collaboration practice and the reaction to the wizard messages in the adaptive condition, per dyad. Notice that the adaptive dyads all improved, while the non-adaptive dyads remained stable or deteriorated.

To further illustrate these descriptive differences, we present a detailed analysis of two dyads, one in the adaptive (*Ad-Dyad-1* in Table 2) and one in the non-adaptive condition (Non-*Ad-Dyad-1* in Table 3). We indicate situations in which the wizard gave a prompt to the adaptive dyad and similar situations in which our analysis showed that a prompt could have been useful in the non-adaptive dyad. We compare the resulting behavior of the two dyads and their overall behavior as it evolved during their interaction with the system. Tables 2 and 3 outline the two sessions; Table 3 additionally includes the interventions of the wizard in the form of prompts.

Table 2. Outline of the collaboration process of a non-adaptive dyad

Elapsed Time	Student Behavior
15:32	They collaborate well, follow the script and make a plan, e.g., "Can we react two chemicals at a time or will the reaction be different when we mix all three together?"—*"I don't think it is different with two than with four"*
21:23	One partner asks the other to explain what he is doing, e.g., "Did you just make OH and H or were they there? And where did it all go?"
27:44	Their hypothesis is not well formulated. They don't say what they expect to happen, e.g., im gna add more d until it's a decent number and see what happens…because it seems to be limiting"
56:54	They do not explain their interpretations and start making conceptual mistakes, e.g., "ok be is going to be 2 on the left side" – *"well d has to be larger than 2 right?"* – "cant we just mix a certain amount on the left until we get an even ratio as a product…"
1:00:08	Error message after submitting a solution: "Remember that a chemical reaction describes a transformation from one /some compound/s to another. Note that no compounds should appear in the same side of the equation. Please correct the equation and try again"
1:01:08	They try to understand the error message together and collaborate again, e.g., "makes more sense now…so b and c are on one side and a and d are on the other" – *"so the coefficients for B and c on the left are zero?"*
1:07:35	They are demotivated and give up on finding the solution, e.g., "we have no chance its your turn to guess"

Non-adaptive Dyad: This pair of students collaborated well at the start and seemed motivated to follow the script. However, there were a few significant flaws in their interaction. To start with, they didn't have a well-formulated hypothesis. As a consequence, they had trouble interpreting their results. Conclusions were left without explanation as to how they were supported, and they divided labor so that they actually reduced the amount of thinking they did together. Explanations and requests for explanations decreased over time. They didn't use the designated tabs for their designed activities. Towards the end of the intervention period, they appeared to be discouraged and were not seriously trying to solve the problems. Adaptive scripting aims at avoiding such behavior and providing encouragement through appropriate help. Given the positive disposition of the dyad to collaborate at the beginning of the interaction, it may have been useful for this dyad to receive prompts to plan collaboratively, follow the script, use the designated tabs and so on in the situations mentioned above. In fact, they responded well to the "dead end" prevention hint from the wizard (Table 2, 1:00:08) after submitting an incorrect initial solution, and reported to have liked it a lot. This hint also encouraged them to collaborate again, as they tried to understand it together (Table 2, 1:01:08).

Adaptive Dyad: In contrast to the non-adaptive dyad, this dyad started out badly with a lot of conceptual gaps and almost no collaboration. They did not make a plan or propose a hypothesis. The "stronger" student started doing everything alone without agreement. They played around aimlessly in the VLab, and resisted taking the prompts into account. After a number of prompts, the "weaker" student started asking questions to understand what was going on and insisted on working together. His partner started explaining shallowly at first, but progressing into deeper explanations, including a recapitulation to bring his partner up to speed. Interestingly, the "weaker" participant never contributed much in terms of content, but started encouraging his partner in a way that induced collaboration and motivated the dyad to reach the correct solution, despite a very long session.

Table 3. Outline of the collaboration process of an adaptive dyad

Time	Student Behavior	Wizard	Reaction
9:06	The two partners are in different tabs. One starts doing everything alone in VLab.	"Remember to build your argument on your partner's argument."	The other partner expresses that he is having trouble following, e.g., "We already got them up there?"
17:22	The "stronger" partner does not explain his actions		The "weaker" partner insists on working together, e.g., "What do we want to do? Make them all equal?"
24:27	They don't have a hypothesis and they just "play" within the VLab.	"Don't forget to share the experimentation in the virtual lab."	They start working together and it transpires that one of the students is lost, e.g., "Do you want to pour them?" -- *"Which ones?"*
29:54	They don't have a good plan for experimenting.	"Discussing which experiment best addresses the problem will help you in solving the problem. Remember the discussion space available in Plan/ Design and Interpret/ Conclude"	They don't move tabs, but they do discuss their results, e.g., "Looks like A and C are in the same rations. And D is 1/3 of A and C"
37:48	They have trouble interpreting the results of their experimentation.		The students who had the lead until now starts asking for feed-back and recapitulates the actions for both, e.g., "I feel like it's [what he is doing] right, but I'm not quite sure" -- *"That's OK. Sounds right"* – "So we mixed them all together. Started of with 50 ml of each"
46:29	They seem to have a problem with mols.	"The chemical terms most relevant to the problem are explained in the glossary."	They don't use the glossary, but the "stronger" student asks his partner for help in calculating mols.

This outline of the two contrasting dyads, while certainly anecdotal, illustrates how a good collaboration can gradually deteriorate due to a lack of adaptive guidance and on the other hand, how a collaboration that starts poorly can improve with support. Given periodic prompts at strategic times, the second dyad was led to an almost model collaboration and showed great motivation to complete the task, notwithstanding a bad attitude towards the prompts. The non-adaptive dyad was not able to correct flaws in their collaborative or script practice. On the contrary, the tendency in the adaptive dyads in general was to start out mostly ignoring the prompts by the wizard and gradually begin considering them, probably as they realized that they *did* need help. Although a lot of prompts were ignored or not followed to the letter (see, for instance, Table 3, 29:54 and 46:29), considering at least some of them had a clear effect on this dyad's collaboration practice.

5 Discussion and Outlook

We presented our research framework and reported on preliminary results from two small-scale studies. We described how the knowledge gained from the first study led to a refined version of our collaboration script and the development of a collaborative computer-based environment. In the second small-scale study we collected data on an adaptive and a non-adaptive version of the script. We believe that our process analysis provides solid initial directions for the future development of the collaborative platform.

In terms of improvements to the script, we plan to keep its general structure,but make movements between tabs more flexible. Currently, the tabs are fixed to specific script phases. Yet, in our small-scale studies, we observed students' need to move back and forth between tabs to consult the content of previous work phases (e.g., notes taken). This practical need often prevented them from using the tabs as the script recommend. Also most of the prompts which were ignored were the ones that insisted on the use of the tabs in the prescribed sequence, which is another indication that this aspect needs to be changed.

Following such observations, Isabel Braun and Nikol Rummel conducted a study in Germany, where German students collaborated on solving a problem in a German translation of the VLab. In this study, dyads of students sat side-by-side in front of one computer, both having their own keyboard and mouse. A scripted collaboration condition was compared to an unscripted one. The script was, however, not implemented as part of the computer-supported environment, but was administered to participants in the form of a small booklet. Each phase of the inquiry cycle was presented on one page of the booklet (instead of the tabs). Students were instructed to work through the phases one by one but the sequence was not enforced through system restrictions. Instead, fidelity to the script was prompted only when students did not engage in the most important activities of each phase. Thus, learners in this study were freer to move around phases, as they felt appropriate. Also the paper-based version of the script made it easier for the learners to switch between phases. The *argument space* and the VLab were visible on separate computer screens, thus allowing students to look at the script (booklet), their notes and the VLab simultaneously. Data analysis is currently underway. We hope to gain further insights from this lower-tech study as to whether the proposed changes to our computer-based environment go into the right direction, and whether the strengths and weaknesses of our system lie on the implementation of the script in the environment or on its conceptualisation. According to Dillenbourg and Tchounikine [23], the first pertains to *extrinsic constraints* and would require changes in the system, whereas the second might pertain to *intrinsic constraints*, which would require changes in the pedagogical setting of the script.

We also plan to automate the feedback provided by the system based on the specific student actions of and the system knowledge about the collaborators. For the *Test* tab in particular, we will explore action analysis (e.g. [24]). We will extend Mühlenbrock's approach by analyzing the student actions in the VLab with machine learning techniques to identify situations in which prompts are necessary. To this end we will use the collaboration expertise in our group, which is already captured in the wizard flowchart in terms of feedback for particular situations, and we will improve it according to the new data.

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References

[1] Gabel, D.L., Sherwood, R.D., Enochs, L.: Problem-Solving Skills of High School Chemistry Students. Journal of Research in Science Teaching 21(2), 221–233 (1984)

[2] Fasching, J.L., Erickson, B.L.: Group Discussions in the Chemistry Classroom and the Problem-Solving Skills of Students. Journal of Chemical Education 62, 842–848 (1985)

[3] Kozma, R.B.: The use of multiple representations and the social construction of understanding in chemistry. In: Jacobson, M., Kozma, R. (eds.) Innovations in science and mathematics education: Advanced designs for technologies of learning, pp. 11–46. Lawrence Erlbaum, Mahwah (2000)

[4] Sumfleth, E., Rumann, S., Nicolai, N.: Kooperatives Arbeiten im Chemieunterricht [Cooperative Work in the Chemistry Classroom]. Essener Unikate 24, 74–85 (2004)

[5] Hausmann, R.G., Chi, M.T.H., Roy, M.: Learning from Collaborative Problem Solving: An Analysis of Three Hypothesized Mechanisms. In: Forbus, K.D., Gentner, D., Regier, T. (eds.) 26nd annual Conference of the Cognitive Science Society, pp. 547–552. Lawrence Erlbaum, Mahwah (2004)

[6] Saab, N., van Joolingen, W.R., van Hout-Wolters, B.H.A.M.: Communication Processes in Collaborative Discovery. British Journal of Educational Psychology 75, 603–621 (2005)

[7] Diziol, D., Rummel, N., Spada, H., McLaren, B.M.: Promoting Learning in Mathematics: Script Support for Collaborative Problem Solving with the Cognitive Tutor Algebra. In: Chinn, C.A., Erkens, G., Puntambekar, S. (eds.) Mice, minds and society, CSCL 2007, vol. 8(I), pp. 39–41 (2007)

[8] Bell, T., Slotta, J., Schanze, S.: Perspectives on Collaborative Inquiry Learning: An International Network for Research, Curriculum and Technology. Special Issue of the International Journal of Science Education (in press)

[9] Quintana, C., Reiser, B.J., Davis, E.A., Krajcik, J., Fretz, E., Duncan, R.G., et al.: A Scaffolding Design Framework for Software to Support Science Inquiry. Journal of the Learning Sciences 13(3), 337–386 (2004)

[10] Kollar, I., Fischer, F., Hesse, F.W.: Collaboration scripts - a conceptual analysis. Educational Psychology Review 18(2), 159–185 (2006)

[11] Dillenbourg, P.: Over-scripting CSCL: The Risks of Blending Collaborative Learning with Instructional Design. In: Kirschner, P.A. (ed.) Three worlds of CSCL. Can we support CSCL, pp. 61–91. Open Universiteit Nederland, Heerlen (2002)

[12] Rummel, N., Spada, H., Hauser, S.: Learning to Collaborate in a Computer-Mediated Setting: Observing a Model Beats Learning from Being Scripted. In: Barab, S.A., Hay, K.E., Hickey, D.T. (eds.) Proceedings of the Seventh International Conference of the Learning Sciences, pp. 634–640. Lawrence Erlbaum Associates, Mahwah (2006)

[13] Kumar, R., Rosé, C.P., Wang, Y.C., Joshi, M., Robinson, A.: Tutorial Dialogue as Adaptive Collaborative Learning Support. In: Proceedings of Artificial Intelligence in Education (2007)

[14] Yaron, D., Evans, K., Karabinos, M.: Scenes and Labs Supporting Online Chemistry. In: 83rd Annual AERA National Conference (2003)

[15] Harrer, A., Malzahn, N., Hoeksema, K., Hoppe, U.: Learning Design Engines as Remote control to learning support environments. Journal of Interactive Media in Education (2005); Tattersall, C., Koper, R. (eds.), Advances in Learning Design

[16] Harrer, A., Pinkwart, N., McLaren, B.M., Scheuer, O.: How Do We Get the Pieces to Talk? A New Software Architecture to Support Interoperability Between Educational Software Tools. In: Woolf, B.P., Aïmeur, E., Nkambou, R., Lajoie, S. (eds.) ITS 2008. LNCS, vol. 5091. Springer, Heidelberg (2008)

[17] De Jong, T., van Joolingen, W.R.: Scientific Discovery Learning with Computer Simulations of Conceptual Domains. Review of Educational Research 68(2), 179–201 (1998)

[18] Klahr, D., Dunbar, K.: Dual Space Search During Scientific Reasoning. Cognitive Science 12, 1–48 (1988)

[19] White, B.Y., Shimoda, T.A., Frederiksen, J.R.: Enabling Students to Construct Theories of Collaborative Inquiry and Reflective Learning: Computer Support for Metacognitive Development. International Journal of Artificial Intelligence in Education 10, 15–182 (1999)

[20] van Joolingen, W.R., de Jong, T., Lazonder, A.W., Savelsbergh, E., Manlove, S.: Co-lab: Research and Development of an On-Line Learning Environment for Collaborative Scientific Discovery Learning. Computers in Human Behavior 21, 671–688 (2005)

[21] de Groot, R., Drachman, R., Hever, R., Schwarz, B., Hoppe, U., Harrer, A., De Laat, M., Wegerif, R., McLaren, B.M., Baurens, B.: Computer Supported Moderation of E-Discussions: the ARGUNAUT Approach. In: The Proceedings of Computer-Supported Collaborative Learning (CSCL 2007), pp. 165–167 (2007)

[22] Weinberger, A., Stegmann, K., Fischer, F., Mandl, H.: Scripting Argumentative Knowledge Construction in Computer-Supported Learning Environments. In: Fischer, F., Kollar, I., Mandl, H., Haake, J.M. (eds.) Scripting Computer-Supported Collaborative Learning. Cognitive, Computational and Educational Perspectives. Springer, New York (2007)

[23] Dillenbourg, P., Tchounikine, P.: Flexibility in macro-scripts for CSCL. Journal of Computer Assisted Learning 23(1), 1–13 (2007)

[24] Mühlenbrock, M.: Shared Workspaces: Analyzing User Activity and Group Interaction. In: Hoppe, H.U., Ikeda, M., Ogata, H., Hesse, F. (eds.) New Technologiesfor Collaborative Learning. Kluwer, Dordrecht (2004)

Immediate Elaborated Feedback Personalization in Online Assessment

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Abstract. Providing a student with feedback that is timely, most suitable and useful for her personality and the performed task is a challenging problem of online assessment within Web-based Learning Systems (WBLSs). In our recent work we suggested a general approach of feedback adaptation in WBLS and through a series of experiments we demonstrated the possibilities of tailoring the feedback that is presented to a student as a result of her response to questions of an online test, taking into account the individual learning styles (LS), certitude in a response and correctness of this response. In this paper we present the result of the most recent experimental field study where we tested two feedback adaptation strategies in real student assessment settings (73 students had to answer 15 multiple-choice questions for passing the midterm exam). The first strategy is based on the correctness and certitude of the response, while the second strategy takes student LS into account as well. The analysis of assessment results and students' behaviour demonstrate that both strategies perform reasonably well, yet the analysis also provide some evidence that the second strategy does a better job.

Keywords: feedback authoring, feedback personalization, learning styles, online assessment, response certitude.

1 Introduction

Online assessment becomes an important component of modern education. Nowadays it is used not only in e-learning, but also within blended learning, as part of the learning process. Online assessment is utilized both for self-evaluation and for "real" exams and it tends to replace or complement traditional methods of evaluation of the student's performance.

Providing formative and summative feedback is especially crucial in online assessment as students need to be informed about the results of their (current and/or overall) performance. The existing great variety of the feedback functions and types that the system can actually support make the authoring and design of the feedback in e-learning rather complicated [13]. An important issue is that different types of feedback can have a different effect (positive or negative) on learning and interaction processes [3]. Badly designed feedback (and/or the lack of feedback) could distract

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the student from learning; it could provoke the students to stop using the e-learning system or even to drop the course (even in blended learning).

Feedback adaptation and personalization [10] is aimed to provide a student with the feedback that is most suitable and useful for his/her personality, the performed task and environment. The development of the personalized feedback requires having the answers to at least the following questions: what can be personalized in the feedback; and to which user or performance characteristics feedback should be personalized. Some answers to these fundamental issues can be found in [13].

In this paper we present the results of the experimental study where we tested two immediate elaborated feedback (EF) adaptation strategies in the online assessment of students through multiple-choice quiz within the (slightly altered) *Moodle* WBLS. In the quiz, students had to select their confidence (certainty) level and were able to receive different (adaptively selected and recommended) kinds of immediate EF for the answered questions. Our first strategy is based on the analysis of response correctness and response certitude only, while the second strategy, besides the analysis of the response, takes student's LS into account as well.

The analysis of the assessment data demonstrates that both strategies perform reasonably well. The results of our analysis however favor the second strategy and thus advocate the benefits of taking into account LS for selecting and recommending the most appropriate type of EF during the online assessment.

2 Tailoring Feedback in Online Assessment in WBLSs

Feedback may have different learning effects in WBLS; it can inform the student about the correctness of his responses, "fill the gaps" in the student's knowledge by presenting information the student appears not to know, and "patch the student's knowledge" by trying to overcome misconceptions the student may have [4, 5, 7].

The functions of the feedback imply the complexity of information that can be presented in immediate feedback: verification and EF [6]. Verification can be given in the form of knowledge of response (indication of whether the answer was received and accepted by the system), knowledge of results (KR) (correctness or incorrectness of the response), or knowledge-of-correct response (KCR) (presentation of the correct answers) feedback. With EF the system besides (or instead of) presenting the correct answer, provides also additional information – corresponding learning materials, explanations, examples, etc [9].

Different types of feedback can be differently effective (and can even be disturbing or annoying to the student thus having also negative influence) in learning and interaction [3]. E.g., an important issue in designing feedback is that it can draw attention away from the tasks, thereby increasing the time required to execute them.

Design of feedback assumes that the following questions can/must be answered: (1) when should the feedback be presented; (2) what functions should it fulfil; (3) what kind of information should it include; (4) for which students and in which situations would it be most effective? The variety of possible answers to these questions makes design of feedback rather complicated, especially in WBLSs.

Our recent studies [8, 10, 11, 12] were aimed at demonstrating the feasibility and benefits of designing adaptive feedback (with respect to the characteristics of an individual student) in online multiple-choice tests.

Adaptive feedback is aimed at providing a student with the most suitable feedback for his/her personality, the performed task and environment. The issues of (1) what can be personalized in the feedback and (2) to which characteristics should feedback be personalized are essential in the development of personalized feedback [13].

Response certitude (also called response *confidence* or response *certainty*) specifies the student's certainty in the answer and helps in understanding the learning behavior. The traditional scheme of multiple-choice tests evaluation, where the responses are being treated as absolutely correct or absolutely wrong, ignores the obvious situations when the correct response can be the result of a random or an intuitive guess and luck, and an incorrect answer can be given due to a careless mistake or due to some misconceptions the student may have. Such mistakes are especially crucial in the online assessment, where the evaluation of students' real knowledge and determining students' misconceptions become an even more difficult task for the teacher than in traditional in-class settings. Not allowing for discrimination of these situations may diminish the effects of personalized assessment.

The use of feedback in certitude-based assessment in traditional education has been actively researched for over 30 years [6, 7]. The researchers examined the student's level of confidence in each of the answers and analyzed (1) the differences in performance of students (not) receiving immediate/delayed feedback; (2) how much time a student spent on processing EF; (3) efficiency of feedback in confidence based assessment.

In our earlier pilot experiment and more recently a series of real online assessment studies in [10, 11, 12] we have been able to demonstrate that knowledge of response certitude together with response correctness allows to determine what kind of feedback is more preferable and more effective for the students, and EF may sufficiently improve the performance of students during the online tests. These encouraging results motivated us to develop a recommendation approach for tailoring immediate EF for students' needs in [12]. We presented empirical evidence in [12] that many students are eager to follow the recommendations on necessity or usefulness to read certain EF in the majority of cases, after following the recommendations some students were willing to state explicitly whether particular EF indeed was useful to understand the subject matter better or not (and in most of the cases it was found helpful), and last but not least recommended EF helped to answer related questions better.

Individual LS are one of the important characteristics of the student that characterize the ways in which the student perceives information, acquires knowledge, and communicates with the teacher and with other students. Incorporating LS in WBLSs has been one of the topical problems of WBLS design during recent years. There are currently several WBLSs that support adaptation to LS (AHA!, CS383, IDEAL, MAS-PLANG, INSPIRE). However, according to our knowledge, there is no system or reported research (in the e-learning context) that addressed the issue aimed at providing feedback tailored to the LS of the student except our own recent study [1].

3 Adaptive Selection and Recommendation of Immediate EF

3.1 Authoring Adaptive EF

Feedback adaptation can be based on the traditional user modeling approach in adaptive hypermedia [1]. One key component here is a feedback adaptation unit that has to include a knowledge base containing the adaptation rules that associate user (task, environment) characteristics with certain feedback parameters from the feedback repository. For this particular study we used a simple user model that includes information about student's LS, and certitude and correctness of the current response (which constitute two dimensions of possible cases; high-confidence correct responses (HCCR), high-confidence wrong responses (HCWR), low-confidence correct responses (LCCR), low-confidence wrong responses (LCWR)). Other individual characteristics can be added easily of course, however we tried to focus our study on a particular set of characteristics that allows us to verify our findings from previous experiments as well as to verify the feasibility of the EF adaptation approaches and to make some new observations.

We have studied different aspects of feedback tailoring during a series of experiments (preceding this study) in the form of eight online multiple-choice tests in the Moodle learning system organized as a complimentary yet integral part of three courses (with traditional in-class lectures and instructions) at the Eindhoven University of Technology, the Netherlands during the academic year 2007-2008. Our findings resulted in the implementation of 72 non-contradicting adaptation rules for two types of immediate EF: example-based and theory-based. The base of these rules is compactly summarized in Table 1 below. In the first column, the two dimensions of LS are presented: `<[active][balanced][reflective]/[sensing] [balanced][intuitive]>`. Cells in the other columns tell what will be directly shown or recommended (number of stars * in the brackets denote the strength of the recommendation) to a student upon the EF request.

3.2 Experiment Design

The online assessment (partial exam) of 73 students of Human-Computer Interaction (HCI) course was organized in March 2008. As in some of the earlier assessments we used feedback adaptation strategies based on student's response correctness and response certitude, and LS.

The online test consisted of 15 multiple-choice questions. The questions were aimed at assessing the knowledge of the concepts and the development of the necessary skills (like understanding of the basic usability rules and problems such as consistency, mapping (between interface and real world), response time problem, etc.). For each answer students had to provide their certitude (which affected the grade) and had a possibility to request and examine EF that could potentially help to answer the related (later) questions better.

Students were not provided with knowledge of (correct) response separately, but they had to infer it from EF instead (if case they were eager to do so). That is the students had to read the explanations of the EF to understand whether their answer

Table 1. The base for adaptation rules

LS	HCCR		LCCR		LCWR		HCWR	
	Show:	***Recom-mend:***	***Show:***	***Recommend:***	***Show:***	***Recommend:***	***Show:***	***Recommend:***
No L/S	-	-	-	Theory (*) Example (*)	Theory	Example (*)	Theory	Example (***)
Active/ Balanced	-	-	-	Example(**)	Example	Theory(*)	Example	Theory (**)
Reflective/ Balanced	-	Theory (*)	Theory	Example(*)	Theory	Example (**)	Theory	Example(***)
Balanced/ Sensing	-	-	-	Example(**)	Example	-	Example	Theory(**)
Balanced/ Intuitive	-	-	-	Theory(**)	Theory	-	Theory	Example(**)
Active/ Sensing	-	-	-	Example(**)	Example	-	Example	Theory(**)
Active/ Intuitive	-	-	-	Theory (**), Example(*)	Theory	Example (*)	Theory	Example (**)
Reflective/ Sensing	-	Example (*)	-	Example (**) Theory (*)	Example	Theory (**)	Example	Theory (***)
Reflective/ Intuitive	-	Theory (*)	Theory	Example (*)	Theory	-	Theory	Example (***)
Balanced/ Balanced	-	-	-	Theory(*) Example (*)	Theory	Example (*)	Theory	Example (**)

was correct or not. The results of our previous experiments suggested that it is beneficial for the students to embed KR into EF to increase the overall effect of EF on learning process during the assessment.

For every student and for each question in the test we collected all the possible information, including (besides the actual selected answer) correctness, certitude, grade (determined by correctness and certitude), time spent for answering the question, whether feedback was requested on not, and (if it was) which feedback was shown directly, which was recommended with which strength, and finally which one(s) were actually examined (including time spent for examining two each type of feedback in seconds).

Before passing the actual tests the students were asked to complete (not compulsory) Felder-Silverman's LS quiz (44 questions) [2]; 66 out of 73 students completed this questionnaire.

Adaptation of presentation and recommendation of feedback varied between the questions in the test used for this study. For questions 1, 3, 5, 7, 9, 10, 13, 15 presentation and recommendation of EF was based on student's LS (active/reflective and sensing/intuitive dimensions), response correctness and response certitude. For the other questions adaptation was performed based only on the response correctness and certitude. For those (few) students who did not complete the (non-mandatory) LS quiz, EF presentation/recommendation was based only on their response correctness and certitude for both groups of questions.

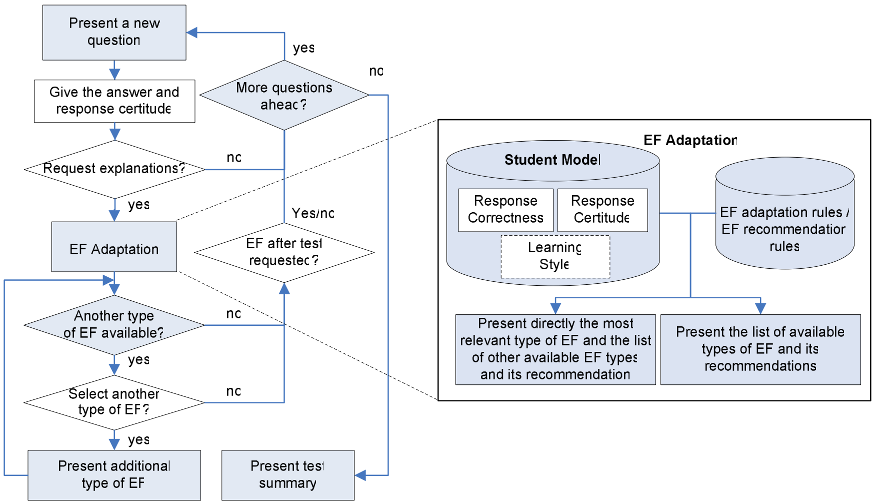


Fig. 1. Assessment process

Further (less important) details regarding the organization of the test, including an illustrative example of the questions and elaborated feedback, are made available in an appendix placed online at http://wwwis.win.tue.nl/~debra/ectel08/. Here we only present the flow chart of the assessment process (Fig. 1).

4 Results Obtained

We evaluated the effectiveness of adaptive selection and recommendation comparing the number of requests for the first EF (only in the cases where that EF was not already automatically shown as a result of the adaptation rules and thus did not have to be requested first) and the second EF; the time students spent for studying the adaptively selected or recommended EF (reading vs. scanning the EF); and usefulness of the EF according the students' feedback rating they provided. The results of earlier experiments already demonstrated that EF sufficiently *improves* the students' performance during the test. Here we analyze the students' *perception* of the EF usefulness.

In order to compare two personalization strategies (that is the focus of our analysis here) we analyzed the data from 47 of 73 students for 14 questions (the last question was excluded as an "outlier" in a sense that reading feedback can not help to answer other questions any more from the one hand and on the other hand students should not care about the time limit any longer at this point). We excluded from analysis data also the data of the 7 students who did not complete the LS questionnaire before the test, as for them the personalization/recommendation of EF worked identically for both groups of questions. We also ignored the data of 18 students whose LS was balanced according both dimensions used in personalization (active/reflective, sensing/intuitive), as adaptation rules used in such cases were the same as for personalization based only on response correctness and certitude.

Analysis of the EF requests. Figure 1 illustrates how different EF request-related situation occurred for the questions from Group 1, where adaptive EF selection and recommendation were based on two dimensions of LS (active/reflective, sensing/intuitive) besides the response correctness and certitude, and for the questions from Group 2, where EF adaptation was based only on response certitude and correctness. There were almost equal percentages of initial EF requests in both groups (79% vs. 75%) as well as requests for the explanations in the case no type of EF was directly shown (without the need to request it explicitly): 88% vs. 87,5%. The percentage of requests for additional feedback for Group 2 was higher than for group 1 (27% vs. 16%). This can mean that EF that was shown directly in Group 2 (EF personalization based on response correctness and response certainty) was not always suitable for the students, whereas for the questions from group 1 the type of directly shown feedback was (on average) more suitable for the certain students. Figure 1 also presents the distribution of the responses according to their correctness and certainty (HCCR, LCCR, LCWR, and, HCWR). It helps more clearly to see what the responses of the students were within and between the groups and to analyze how EF adaptation functioned in each case.

For a more detailed comparison of the two EF recommendation/personalization strategies we examine the two most interesting situations: (1) when EF was directly shown to the students (Figure 3 a, b) and (2) when EF was not directly shown, but the user could request one ore two available types of EF (Figure 4 a, b).

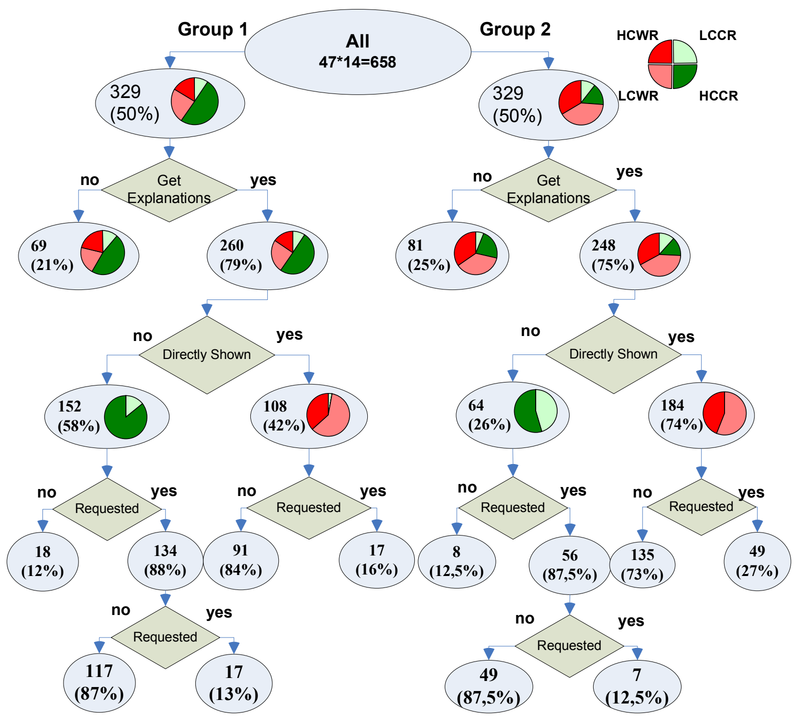
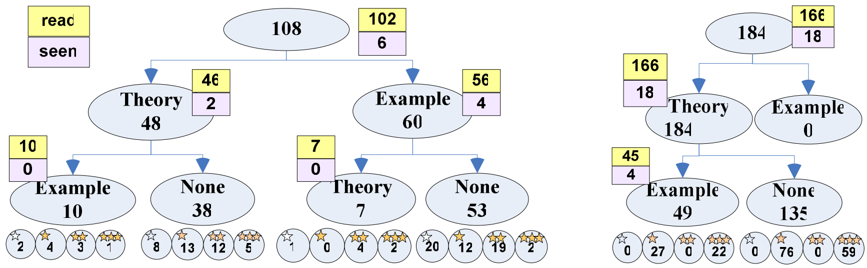


Fig. 2. EF requests related statistics for two groups of questions: Group1 (adaptation rules use LS information) and Group 2 (LS information is not used in adaptation)



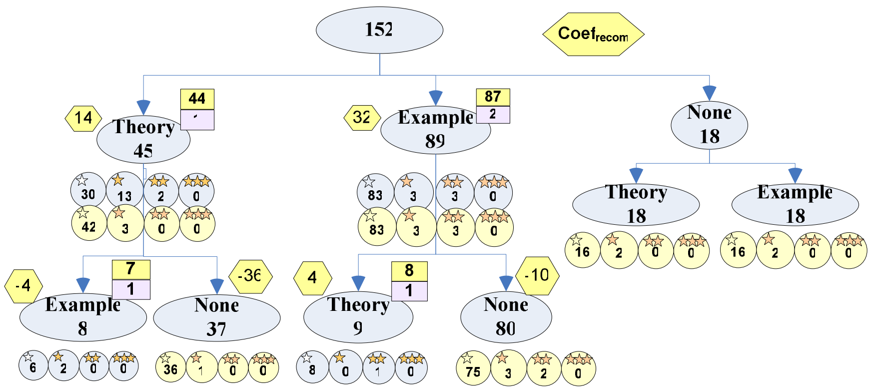
a) Group 1 *b) Group 2*

Fig. 3. Student behaviour when one type of EF has been shown directly

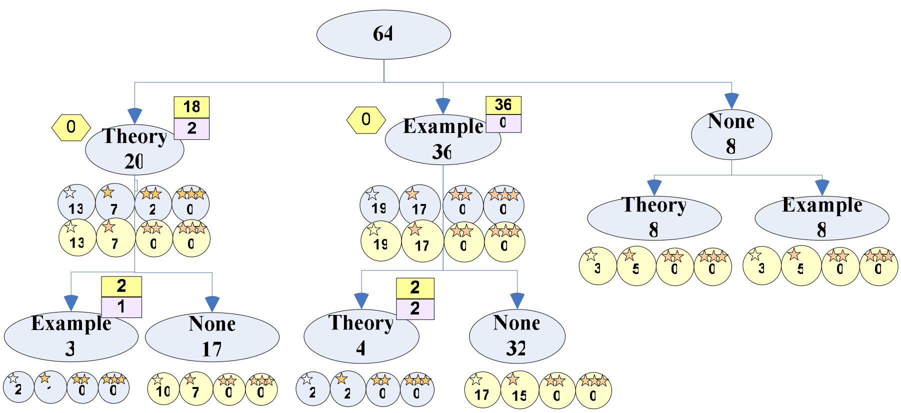
In Figure 3 (a,b) we can see that the number of cases where the student was just "scanning" the directly shown EF (marked as "seen" in the figure) was higher (18/166, i.e. 10.8%) for the questions from Group 2 than for the questions from Group 1 (6/102, i.e. 5.9%). This also suggests that the type of directly shown EF was more appropriate for the questions from Group 1 than from Group 2. The percentage of requests for the additional feedback after getting directly shown feedback is also higher for Group 2 with 26.6% (49/(149+35)) vs. 15.7% (17/(53+38+17)) for Group 1. The analysis of the recommendation strength of EF types (that students did or did not request after getting directly shown EF) illustrates that the students followed our recommendations quite well for both groups of the questions. The students requested another available type of EF more often when it was more strongly recommended (with higher number of stars).

In Figure 4 a, b we illustrate the situations when EF was not directly shown, but the students had a possibility to choose it from the two available types of explanations (theory-based and example-based) by either following our recommendations or not. The percentages of requesting theory-based (36% vs. 35 %) and example-based (64% vs. 65%) EF were very close (difference is not statistically significant) for Group 1 and Group 2.

In order to measure the quality (or appropriateness) of the recommendation strategies we calculated the corresponding scores as sums of differences between the strength of the recommendation of the requested type of EF and the strength of the recommendation of another available type of EF. The positive coefficient demonstrates that the recommendation strengths of the selected EF were in most of the cases higher than the recommendation strengths of the other available type of EF. For the Group 2 the recommendation of both theory-based and example-based EF were given the same number of stars in the cases where the EF was not shown directly. Thus the calculated scores are illustrative only for the Group 1 in this context. However, for Group 1 the score is positive both for the request of theory-based and example-based types of EF. It can be also seen from the figures that for theory-based EF recommendation with different strengths (blue circles below "Theory 45" in Figure 3a) and recommendations of the example-based EF that was given in those situations (yellow circle below "Theory 45 in Figure 3a) that the students did request feedback for which the strength of the recommendation was higher. Students requested the second type of feedback after reading or "scanning" the first with the same frequency in both groups (in 12.5% of cases) and followed the recommendation for the another type of feedback available also reasonably well. In general, the score for the next level should be negative, meaning that we can expect the student, after examining the first selected type of EF, would proceed directly to the next question (if the selected type was suitable). However, in one case (when example-based EF was requested after theory-based) this score was positive which indicates that students often believed that theory-based EF is not adequate or not clear (despite of its recommendation) and hoped that the example-based EF would shed more light on the subject matter.



(a) Group 1



(b) Group 2

Fig. 4. Student preferences in EF requests when no EF has been shown directly

Usefulness of EF. We analyzed the students' remarks about the usefulness of EF they were willing to provide during the test. 47 students left in total 82 remarks about EF usefulness; 39 for Group 1 and 43 for Group 2 (providing them was optional; 82 remarks correspond to 14% response rate with respect to the number of actually received EFs by the students). Surprisingly, in both groups in about 18% the students marked EF as not useful, and as useful respectively in 82% (i.e. percentages are almost the same). It is worth noticing that the remarks about not usefulness of EF together with other comments the students provided about the questions and the EF (as a free text typed in the designated places) are taken into account by the teacher for a possible improvement of the test (next year), and also for detecting possible confusion about the questions or answers. The free text comments about the questions and EF were taken into account in the manual re-grading in a few cases.

We also analyzed the recommendation strengths of the EF that the students found useful or not useful. The average recommendation strengths for the EF found to be not useful are higher than for the EF that was found useful. This contradicts an intuition that useful EF is expected to correspond to higher recommendation strengths, but this can be explained by the fact that students tried to provide their evaluation of such EF that was highly recommended but appeared to be not useful (according to the student's belief). Interestingly also, the ratios of these scores between usefulness/not usefulness for example- and theory-based feedback are very different in Group 1 and Group2 (see Table 2).

Table 2. Average strength of recommendation of EF marked as useful or not useful and percents of students' remarks about (not) usefulness for 2 groups of questions

		Group 1			Group 2		
		Theory	*Example*	*Total*	*Theory*	*Example*	*Total*
Avg. strength of EF recomm.	Useful	0.7	1.6	1.15	3.3	0.6	1.95
	Not useful	2.25	2.7	2.48	4	1.5	2.75
% of students' remarks	Useful	63.6	89.3	82	86.2	71.4	81.4
	Not useful	36.4	10.7	18	13.8	28.6	18.6

Besides the analysis of how students perceived the usefulness of the different types of EF, we estimated whether EF was helpful in answering related questions students answered. First, we estimated what the relative difference in the performance (grades G) of students is, i.e. the ratio of how many times a "hinted" question $k+c$ was answered better than the question k that contained "hinting" feedback by the students who read that feedback (m students in total) vs. those who did not (n students in total):

$$\sum_{i=1}^{m} G_{i,k+c} - G_{i,k} \Big/ m \qquad \text{vs.} \qquad \sum_{j=1}^{n} G_{j.k+c} - G_{j,k} \Big/ n \quad .$$

Although the relative improvement in Group 1 was more than twice as high (and the difference is statistically significant, $p < 0.05$) as in Group 2 we can not make any strong conclusions about the advantage of the first adaptation strategy over the second one in this context, because the absolute average improvement of the correctness and grade were rather low (less than 10% for Group 1).

Instead of the direct measurement of grade improvement within the groups as shown above, we also applied several data mining techniques [14], including classification, clustering and association analysis for finding additional evidence of EF usefulness. Mining assessment data appears to be a non-trivial task due to the high inherited redundancy (e.g. grade is identified by correctness and certainty; feedback adaptation/recommendation is defined by the set of rules which use response correctness and certainty and LS) and correlation between the attributes within groups and across the groups (e.g. due to the correlations between the questions). However, it was possible to find some patterns that provide indications of EF usefulness [11].

5 Conclusions and Further Work

Designing and authoring feedback and tailoring it to students is an important problem of online learning assessment. We have studied this problem through a series of experiments in the form of different online tests organized as part of four TU/e courses with traditional in-class lectures and instructions.

In this paper we focused on the immediate EF adaptation by means of adaptive selection and personalized recommendation of the appropriate type of EF for each question answered by the students. Adaptation rules that take into account students' response certitude, response correctness, and LS were designed according to the EF effectiveness and students' preference patterns observed during the preceding studies.

We implemented two adaptation strategies; the first strategy is based on the analysis of response correctness and response certitude only, while the second strategy, besides the analysis of the response, takes student LS into account as well.

Our experimental study demonstrated the feasibility and effectiveness of EF adaptation strategies. The results of the assessment data analysis and as well as feedback received from the students provide enough evidence that our EF adaptation strategies are feasible. In particular, the students (1) followed our recommendations of the type of EF they could select in most of the cases; (2) more often skipped careful examination of EF when it was not directly shown to them as well as EF which they chose by disregarding the recommendations; (3) gave sufficiently more positive than negative responses about the EF that was shown directly or that was recommended to them. According to each of the analyzed dimensions the results obtained either favor (more or less) or at least do not disfavor the second strategy and thus advocate the benefits of taking into account LS for selecting and recommending the most appropriate type of EF during the online assessment.

Our future work on feedback adaptation will be focused on the organization of the similar online assessment studies with more controlled settings for confirming our findings.

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References

1. Brusilovsky, P.: Adaptive hypermedia. User Modelling and User Adapted Interaction 11(1/2), 87–110 (2001)
2. Felder, R.M., Silverman, L.K.: Learning and teaching styles in engineering education. J. of Engineering Education 78(7), 674–681 (1988)
3. Hatie, J., Timperley, H.: The power of feedback. J. Review of Educational Research 87(1), 81–112 (2007)
4. Hummel, H.G.K.: Feedback Model to Support Designers of Blended Learning Courses. International Review of Open and Distance Learning 7(3) (2006)
5. Hyland, F.: Providing effective support: investigating feedback to distance language learners. Open Learning 16(3), 233–247 (2001)
6. Kulhavy, R.W., Stock, W.A.: Feedback in written instruction: The place of response certitude. Educational Psychology Review 1(4), 279–308 (1989)
7. Mory, E.H.: Feedback research revisited. In: Jonassen, D. (ed.) Handbook of research on educational communications and technology, pp. 745–783. Lawrence Erlbaum, Mahwah (2004)
8. Pechenizkiy, M., Calders, T., Vasilyeva, E., De Bra, P.: Mining the Student Assessment Data: Lessons Drawn from a Small Scale Case Study. In: Proc. of 1st Int. Conf. on Educational Data Mining EDM (to appear, 2008)
9. Shute, V.J.: Focus on formative feedback, Research Report (Retrieved January 15, 2008) (2007), `http://www.ets.org/Media/Research/pdf/RR-07-11.pdf`
10. Vasilyeva, E., Pechenizkiy, M., De Bra, P.: Adaptation of Elaborated Feedback in e-Learning. In: AH 2008. LNCS, vol. 5149, pp. 235–244. Springer, Heidelberg (2008)
11. Vasilyeva, E., De Bra, P., Pechenizkiy, M., Puuronen, S.: Tailoring feedback in online assessment: influence of learning styles on the feedback preferences and elaborated feedback effectiveness. In: Proc. of 8th IEEE Int. Conf. on Advanced Learning Technologies ICALT 2008. IEEE CS Press, Los Alamitos (2008)
12. Vasilyeva, E., Pechenizkiy, M., De Bra, P.: Tailoring of feedback in web-based learning: the role of response certitude in the assessment. In: Woolf, B.P., Aïmeur, E., Nkambou, R., Lajoie, S. (eds.) ITS 2008. LNCS, vol. 5091, pp. 771–773. Springer, Heidelberg (2008)
13. Vasilyeva, E., Puuronen, S., Pechenizkiy, M., Räsänen, P.: Feedback adaptation in web-based learning systems. Special Issue of Int. J. of Continuing Engineering Education and Life-Long Learning 17(4-5), 337–357 (2007)
14. Witten, I., Frank, E.: Data Mining: Practical Machine Learning Tools and Techniques, 2nd edn. Morgan Kaufmann, San Francisco (2005)

Application of Petri Nets on the Execution of IMS Learning Design Documents

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Abstract. In this work we present a Petri net-based approach for modelling the dynamic behavior of units of learning which are level A compliant with the IMS LD specification. The objective is to provide a *formal and explicit* representation of IMS LD operational semantics. The Petri net models defined are directly interpretable by Petri net engines thus decoupling units of learning behavior from their implementation and allowing consistency checking of the learning flow.

1 Introduction

In the last years, an important effort for the development and operationalization of Educational Modelling Languages (EML) has been made. The aim of this languages is to describe *from a pedagogic point of view* the learning design of a course: that is, the flow of the learning activities carried out by the students to achieve the objectives of a course using a given educational content. From these EMLs, the IMS Learning Design (IMS LD) specification [1] has emerged as the *de facto* standard for the representation of learning designs that can be based on a wide range of pedagogical techniques. However, the IMS LD does not provide an executable language (it is only descriptive), and therefore an interpreter is needed to be managed by a learning management system.

To deal with this issue some implementations (partially) compatible with the IMS LD specification have been proposed [2,3,4]. In these implementations the learning flow engine is directly coded in a programming language and therefore they are difficult to adapt and maintain if changes in the semantics of the IMS LD specification happen. To solve this drawback, proposals [5,6] that translate the IMS LD learning flow model into a workflow specification language [7] have been proposed, but (1) they do not define a *computational formal model* for describing the learning flow that represent the execution coordination of the learning activities carried out by teachers and students. Therefore it is not possible to check the consistency of the learning flow (for instance, whether it is deadlock-free or not), and (2) the language at which the IMS LD is translated cannot represent some elements of the learning flow model, such as the conditions and variables of the IMS LD level B.

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In this paper we present an approach where each learning flow element of the IMS LD, and particularly method, plays, acts, and activity structures, is modelled through a high-level Petri net [8] that represents explicitly its execution semantics, including the conditions in which the flow elements are finished. The complete specification of a learning design will be a *hierarchical* high-level Petri net [9] that represents the semantics of the overall IMS LD execution model. With this approach, on one hand, formal properties of the learning flow can be checked to guarantee its consistency and correctness, and on the other hand, the execution of the IMS LD depends on a general Petri net executor, which assures the separation between the IMS LD specification and the engine used to execute the learning designs.

2 Petri Nets for the Execution of Units of Learning

The execution of a unit of learning can be seen as the coordination of a set of activities with a set of participants. We approach this execution as a workflow modelling problem where the learning and support activities of a learning design will represent the tasks to perform whereas the methods, plays and acts will constraint the workflow structure. To model this workflow *high-level Petri nets* will be used.

2.1 Common Structure for the Execution

The Petri net depicted in Fig. 1 is used to model the execution of any method, play, act, role-part, activity-structure, or activity. We used this common structure to unify the way in which a method, play, etc. is executed and stopped independently of the level in which it is situated in the Petri net. This net has two input interfaces, the *initial* and *stop* places, one output interface, the *final* place, and has two distinguishable parts:

- The upper part performs the execution of a method, play, etc. in two steps: firstly with the firing of the *Start* transition which sets the time stamp token in which the task has been started; and secondly with the firing of the *Finish* transition which will create a token in the *final* place indicating the ending of method, plays, and so on.
- The lower part models the two ways in which a method, play, etc. can be stopped. The first one stops the execution if the period of activity of the task has exceeded the timeout. In this case, the *Time-out* transition is fired and produces a new token in the *final* place. The second one, stops the execution when a token is located in the $Stop_{running}$ place. This situation usually happens when the user decides to stop the execution.

This net acts as an intermediate step between two execution entities. For example, if this net controls the execution of a method it will substitute the transition that represents this method in an upper net whereas its *Finish* transition will be substituted by the subnet that represents the structure with the plays of the method.

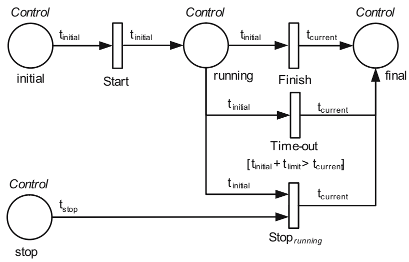

Fig. 1. Petri net structure that substitutes the *Method*, $Play_i$, Act_i, *Role-Part*$_i$, and *Activities*$_i$ transitions of the nets that model the learning flow of a unit of learning

2.2 Representation of a Method

A method describes the dynamics of the learning process and is composed of a number of plays. These plays can be interpreted as the run-scripts for the execution of the unit of learning and have to be interpreted concurrently and independent of each other. Taking this definition into account, Fig. 2 depicts the structure that models the core of the execution of a method.

The *AND SPLIT* transition of this figure enables the concurrent execution of a set of parallel branches where each of these branches models the execution of a play. There are two distinguishable set of branches: i the branches that are boxed represent the plays that must be executed mandatory, that is, it states

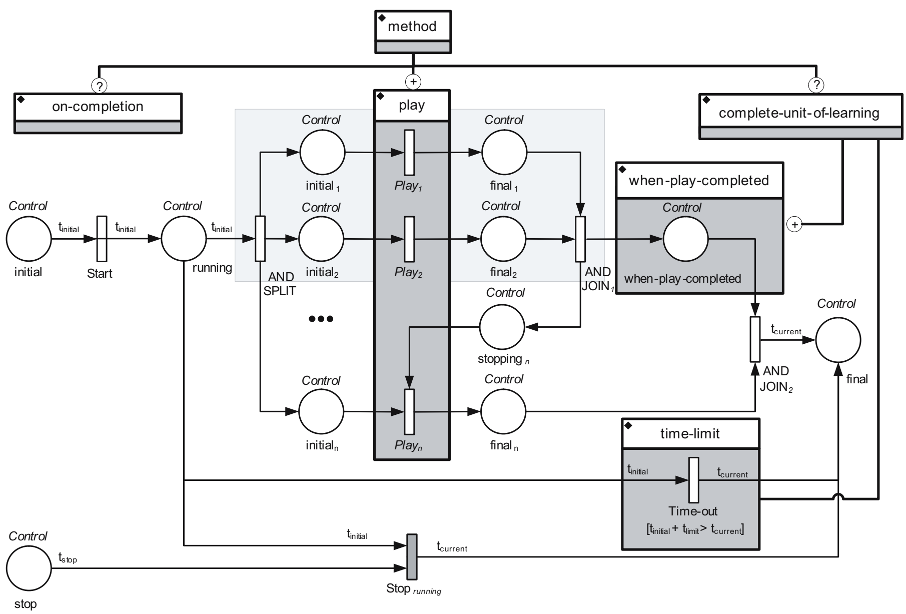

Fig. 2. Representation of the method Petri net

that an unit of learning is completed when this set of play(s) is (are) completed; and *ii* the other branches represent plays that are optional.

The *AND JOIN*$_1$ transition synchronizes the execution of the mandatory plays, so that when they all have finished its execution *(i)* a token is produced in the *when-play-completed* place and *(ii)* another one in each of the $stopping_i$ places. These last tokens will enable the stopping of the optional plays so when they all have finished (or stopped) their execution, the *AND JOIN*$_2$ can fire and thus put a token in the *final* place indicating that the method execution has reached the end.

2.3 Representation of a Play

Following with the composition of the workflow, the $Play_i$ transitions of Fig. 2 are substituted by the common net described in Section 2.1. Each of these substitutions models the steps a play must move to get the desired behaviour and, like methods, must substitute its *Finish* transition with a suitable subnet.

Plays model the core part of the learning design and are specified according to a theatrical perspective with acts and role-parts. Therefore, a play consists of a sequence of acts which is what is being depicted in the upper part of Fig. 3. This figure represents a ordered set of acts where each act is modeled by the Act_i transition and where each Act_{i+1} transition depends on the previous Act_i transition for $0 < i < n$.

The role-part of the theatrical structure is depicted in the lower part of Fig. 3. In each act, the different activities are set for different roles and are performed

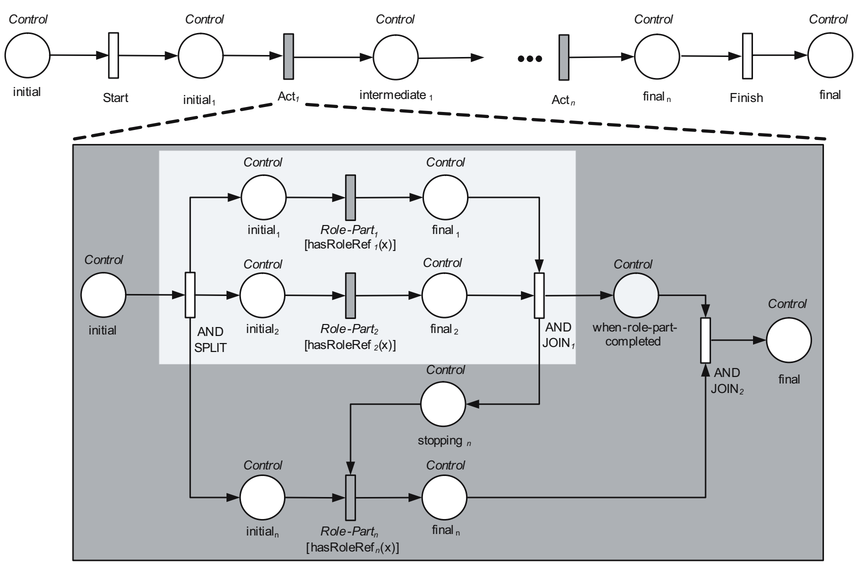

Fig. 3. Petri net for the execution of a play, where each Act$_i$ transition is substituted by a common net whose *Finish* transition is also substituted by this net

in parallel, that is, the act splits in parallel branches the *Role-Part*$_i$ transitions which will perform the activities of the act.

2.4 Representation of an Activity-Structure

An activity-structure groups the activities that a resource with a certain role will perform in an act. The IMS LD specification defines two types of grouping strategies for these activities: sequences and selections. The first strategy models an ordered set of *Execution-Entity*$_i$ transitions where each *Execution-Entity*$_{i+1}$ transition depends on the previous *Execution-Entity*$_i$ transition for $0 < i < n$ and where an execution-entity is an abstract representation of an activity, an unit of learning or another activity-structure.

The second strategy, depicted in Fig. 4, models a structure that limits the number of execution-entities that must be completed to complete the activity-structure. This structure has *(i)* a set of branches with the execution-entities that may be performed (concurrently) and *(ii)* a branch with the *number-to-select* place that contains a number with the activities to be done. When a user selects an execution-entity then the t_{i_2} is fired and a token is consumed from the p_i place and produced in the *initial*$_i$ place enabling thus the execution of the activity. However, this firing also consumes and produces a token in the *number-to-select* place, decreasing the number of activities to select in one unit.

The t_{i_1} transitions of the execution-entities branches are used to avoid the execution of more activities when the *number-to-select* value is zero, that is, when we already have executed the required number of activities. Note that the t_{i_1} and t_{i_2} transitions are an if-then-else pattern since their preconditions are complementary and thus when the value of the *number-to-select* matches the $x <= 0$ precondition then the execution of the *Execution-Entity*$_i$ transition is skipped.

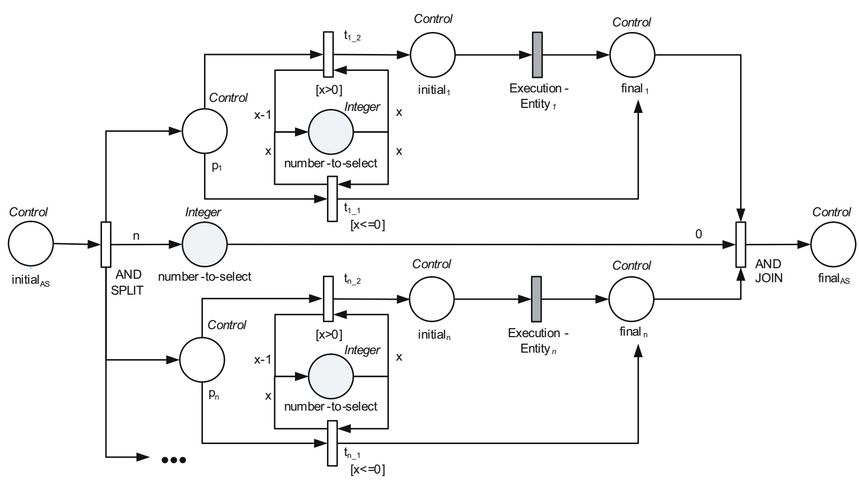

Fig. 4. Petri net for the execution of a selection activity structure

3 Conclusions and Future Work

In this paper a formal semantics for the execution of units of learning which are level A compliant with the IMS LD specification has been presented. This semantics is based on the high-level Petri nets paradigm which allow us represent explicitly the learning flow that can be executed by a Petri net engine, avoiding the re-implementation of the learning design executor when the semantics of the IMS LD is changed.

This work is part of a development that will execute IMS LD units of learning and will be integrated in a knowledge-enriched workflow framework built on top of a high-level Petri nets ontology [10]. Specifically, the units of learning are introduced in the system as instances of a learning design ontology, translated to the Petri nets ontology and managed and executed in a service-oriented architecture [11].

References

1. IMS Global Learning Consortium: IMS Learning Design Information Model. Version 1.0 Final Specification (March 2003), http://www.imsglobal.org/learningdesign/ldv1p0/imsld_infov1p0.html
2. Vogten, H., Martens, H.: CopperCore 2.2.2 (2005), http://www.coppercore.org
3. Hagen, K., Hibbert, D., Kinshuk, P.: Developing a Learning Management System Based on the IMS Learning Design Specification. In: Proceedings of the 6th IEEE International Conference on Advanced Learning Technologies, pp. 420–424. IEEE Press, Los Alamitos (2006)
4. Escobedo, J.P., de la Fuente Valentin, L., Gutierrez, S., Pardo, A., Delgado Kloos, C.: Implementation of a learning design run-time environment for the. lrn learning management system. Journal of Interactive Media in Education 1 (2007)
5. Karampiperis, P., Sampson, D.: Towards a Common Graphical Language for Learning Flows: Transforming BPEL to IMS Learning Design Level A Representations. In: Proceedings of the 7th IEEE International Conference on Advanced Learning Technologies, pp. 798–800. IEEE Press, Los Alamitos (2007)
6. Palomino-Ramirez, L., Martinez-Mones, A., Bote-Lorenzo, M., Asensio-Perez, J., Dimitriadis, Y.: Data Flow between Tools: Towards a Composition-Based Solution for Learning Design. In: Proceedings of the 7th IEEE International Conference on Advanced Learning Technologies, pp. 354–358. IEEE Press, Los Alamitos (2007)
7. van der Aalst, W.M.P., van Hee, K.: Workflow Management: Models, Methods, and Systems (Cooperative Information Systems). MIT Press, Cambridge (2004)
8. ISO/IEC 15909-1: High-Level Petri Nets - Concepts, Definitions and Graphical Notation (2002)
9. Gomes, L., Barro, J.P.: Structuring and Composability Issues in Petri Nets Modeling. IEEE Transactions on Industrial Informatics 1(2), 112–123 (2005)
10. Vidal, J.C., Lama, M., Bugarín, A.: A High-level Petri Net Ontology Compatible with PNML. Petri Net Newsletter 71, 11–23 (2006)
11. Lama, M., Sánchez, E., Vidal, J.C., Novegil, A.: Service oriented architecture to manage units of learning based on the ims ld specification. In: Proceedings of the 14th Conference of the European University Information Systems Organisation, Aarhus, Denmark (2008)

A Supporting Architecture for Generic Service Integration in IMS Learning Design

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Abstract. Learning Design offers the possibility of capturing the process, activities, user organization and resources used in a learning experience. But a wider set of scenarios appear when generic services are considered. Integrating such services in a Unit of Learning is difficult due to the lack of a defined bi-directional protocol for information exchange. In this paper the Generic Service Integration paradigm is presented. It extends the Learning Design specification to use generic services, first at the design stage of a Unit of Learning, and then at the deployment and run times. The framework allows for bi-directional exchange of information between a Unit of Learning and a service. The consequences of the approach are that services can be configured to suit the needs of activities in a learning environment, and a Unit of Learning may adapt its behavior based on the events that took place in any of the used services.

Keywords: service, integration, learning design, IMS LD, learning, course.

1 Introduction

In the evolution of e-learning technical standards, the release of the IMS Learning Design specification [1] (henceforth IMS LD, or simply LD) supposed a shift of focus from supporting content-centric learning to supporting activity-centric learning. Using IMS LD, multiple approaches to learning such as empirical, rationalist, pragmatic, cultural, historic, etc. can be formally modeled as a unit of learning (UoL) [2]. Once defined, a UoL can be instantiated and automatically executed at a run-time environment for scaffolding students to conduct online learning with the help of staff and other learners in a virtual learning context. A UoL prescribes how participants with various roles should individually or collaboratively perform activities in sequence or/and in parallel towards learning objectives within associated learning environments, where necessary learning objects and learning services are available [1].

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In certain learning activities, especially those present in rationalist, pragmatic and cultural-historic approaches, learners interact with each other and with learning objects through the use of a variety of learning services. Without these services, activities cannot be properly supported by the environment and the number of possible pedagogical strategies is severely reduced.

The use of learning services is available through the use of the LD specification. Only four types of services are included: send mail, monitor, index search, and conference. To support a wider range of activities, the specification should allow the inclusion of more services. A generic approach that fits with the current specification is required to allow any service to be integrated in a UoL. This is the goal of the architecture presented in this document.

The architecture described in this document aims at minimally extending the current Learning Design specification such that UoLs may instantiate generic services by describing the required functionality. Furthermore, a communication protocol is presented to allow a bi-directional communication between a LD run-time environment and a remote service. Thus, services can be tailored to the specific needs of a learning environment, and the environment can adapt itself depending on the information reported by the service.

The paper is organized as follows. Section 2 presents the main initiatives that have considered the problem of service integration in a learning context. Section 3 includes a formal definition of the problem of generic service integration. A software prototype for testing purposes is outlined in Section 4. Finally, Section 5 is devoted to conclusions and future work.

2 Background

Interaction among services is a research topic that applies to numerous scenarios. In the context of a learning experience, the IMS Tools Interoperability Specification [3] focuses on facilitating integration of third party tools with learning management platforms. The concept of Personal Learning Environment (PLE) [4] also considers the idea of service orchestration in a learning environment.

None of these initiatives are implicitly related to IMS LD. Interaction with generic services will allow additional pedagogical models to be expressed with LD, increasing the current scope of the specification. This section analyzes how other initiatives explore the problem.

CopperCore is a learning design engine that allows its output to be formatted and presented to the user. The CopperCore Service Integration Layer (or simply CCSI) is an additional functionality conceived to be used in conjunction with the LD engine. This layer allows new services to be added and extend the Learning Design Framework. Services are added through Interoperable Segments (APIS) [5], whose adapter allow synchronization between services.

Using this approach, QTI assessments have been integrated within an UoL. Synchronization between QTI outcomes and LD properties is specified at IMS Interoperability Guidelines [3]. In a similar way, SCORM functionality [6] and Adaptive Game Services [7] have been integrated in a LD defined course.

Although CCSI provides the necessary functionality, integrating a new service requires deep knowledge of the specific API. The framework also offers the possibility of writing special purpose functions to interact between the LD Engine and services. As it has been shown with concrete services, the effort required to perform integration using CCSI approach suggests that it is not a solution suitable for agile integration of a large number of services into IMS LD.

An alternative approach to service integration in LD has been explored within the framework of the TENCompetence project using Widgets as shared services. Widgets provide a very attractive and interactive user interface that could improve engagement with Learning Design-based systems and they offer an interesting new approach on adding interactive features to learning designs [8].

Widgets conception is focused on supporting architecture at runtime. Information that allows the inclusion of a widget in a LD course does not deal with concepts such as roles, permissions, multiplicity, life-span, etc. which are required to express all service behavior details and integrate them in the UoL.

3 Generic Service Integration

Generic Service Integration is proposed as a specification that complements IMS LD by providing a framework to design and deploy generic services and their inclusion on LD defined courses. UoLs are therefore created by teaching staff with experience not in technology but in pedagogy. In this context, course authors should use GSI only to specify the services that need to be included in a learning experience, and leave the details on how the service is instantiated and deployed to the run-time environment. The proposal is divided in **design** and **deploy**. This section details both elements of the proposal.

Design Time

There is no restriction in the type of services that can be used in the context of a UoL. Depending on the area, tools for simulation, benchmarking, communication, search and many other features are used to improve the learning process. Each of these services needs different settings to be configured. A data model including settings parameters from every type of service is too large to be managed, and too complex to be used in practice. Therefore, the GSI approach proposes the use of common attributes from all services and defines a model valid for any type of service. The required attributes are provided by the instructional designers to define the type of services that will be used in a learning activity. At deploy time, the LD player will use this information to search and instantiate a tool that complies with the given requirements.

The proposed data model, depicted in Figure 1, can be expressed in XML. This information binding is placed inside the *service* element on the LD manifest. Data model is structured as follows: **Group** element references to LD *roles* allowing to set different user rights; **Tool** section specifies service expected behavior and a set of defining keywords; **Constraints** element sets extra requirements such

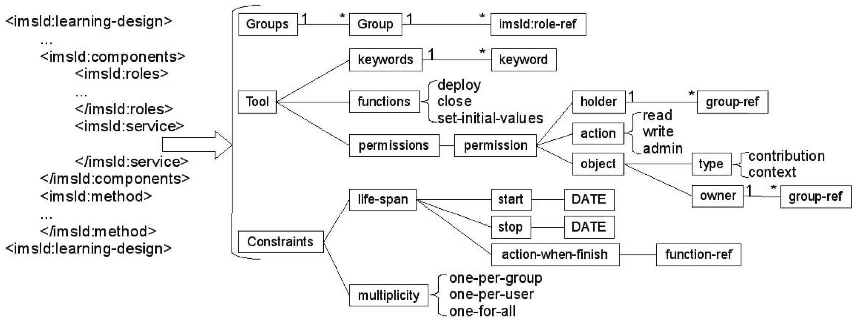

Fig. 1. The service element in the IMS manifest include the GSI information

as time limit or service multiplicity; finally, **Alternatives** are used to specify a secondary service used when main one cannot be properly deployed.

In a typical use case, the *group* element consist of references to the student and teacher LD roles. Tool description contains the functions to be called, usually *deploy* (at the beginning) and *close* (i.e. when time expressed by a constraint expires). Permissions will allow students to write contributions, and teachers to administrate the contributions of all participants. By setting multiplicity to *one-per-role*, each group of students will have their own service instance.

Deployment Time

UoLs are imported to a LD runtime environment, where the course can be instantiated several times (that is, several *runs*) with the participation of different users. The UoL defines how the course must behave and react to user's interactions. The course author is unaware of who will take part in the course and what runtime environment will be used.

Services require to be instantiated once per run. At design time, the author define that a learning activity will be supported by a tool (a service), but cannot ensure this tool to be available on the deployment platform, he can only introduces limits on service behavior. These limits are the information compiled in GSI; the deploy manager instantiates and configures a service based on service description. Shown in Figure 2, deployment steps can be summarized as follows.

First, the RTE must find a service that matches the requisites. A **keyword based lookup** (step 4) is performed on a registry, where GSI compliant services have been previously recorded. The retrieved data must include where to find the service (URL) and how to exchange information with it (plugin to use). Searching criteria is not enough expressive, so next step is negotiation with external services. Using the proper plugin to establish communication, a *check-request* is sent to all found services (step 5). The response contains the requirements that are supported by the service. Then, the LD runtime environment chooses the service that meets more appropriately the requirements, even if not all of them are available. Finally, a *deploy-request* is sent to the chosen service. The answer to such request must include - depending on multiplicity - a list of one or more

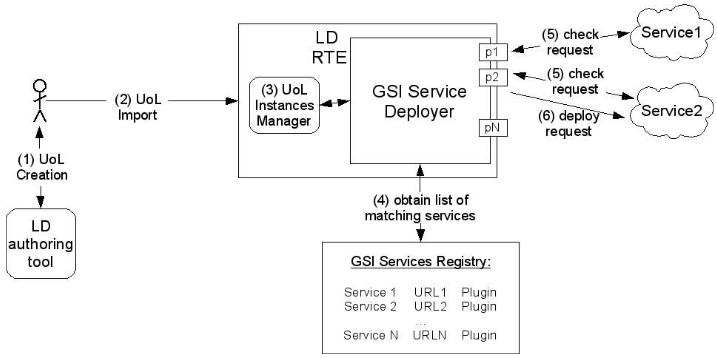

Fig. 2. GSI Supporting Architecture Diagram. The course life-cycle includes course creation and instantiation of services during UoL instantiation.

URL where the requested instances are available (step 6). With these URLs, the LD player inserts a link to the service in the environment of the UoL.

In most cases, user registration in services is simply not possible to be automated because the procedure includes a challenge-response test to ensure that registration is not being done by a computer. Shared identity initiatives such as OpenID[9] could offer the required flexibility to bypass this problem.

4 Software Prototype Description

GSI has been tested in a software prototype built, in GRAIL [10], developed to act as proof of concept of the specification. This runtime environment is fully integrated within the .LRN LMS [11]. The modularity of the OpenACS architecture [12] - the underlying technology of .LRN - facilitates the inclusion of new functionalities such as the one proposed in this document.

A plugin based architecture, where a simple API for the plugin layer is defined, allows service-independence. New services can be included without changing implementation of existing ones. Two functions must be implemented to build a new plugin: *check-request* to provide the GSI negotiation with services, and *deploy-request* to ask the service for a new instance.

In the implemented prototype, the service chosen to interact with is a wiki editor. The plugin has been built in a *simplified* way: the service only receives calls for functionality that already exists on the service API. Based on the answers obtained from the service, the plugin simulates an information exchange that fits the specified behavior in GSI. Thus, the service is compatible with GSI with almost no required modification. A different development approach can include *active plugins* which exchange information in a two-way communication, requiring the inclusion of GSI functionality on the service software.

The prototype requires the administrator to manually select the service for a set of options returned as a result of the registry lookup. However, this selection can be easily automated thus leaving the process with no human intervention.

Future versions of the prototype are expected to support customization of the amount of automated tasks.

5 Conclusions

This paper presents *Generic Service Integration* as the way to integrate the use of services into Learning Design courses. GSI recognizes the relevancy of UoL authoring in the course life-cycle and provides authors with the capability of capturing service behavior in a packaged UoL. Service definition given by authors is later used to find a proper tool that matches the expressed requirements. The negotiation of available functionality is then carried out with the available tools, which may be placed in a remote system. Instantiation of the service and URL retrieval is the last phase of deployment.

A plugin based implementation allows communication with different services. Using the public API of any tool, a one-way strategy can be performed in case the service cannot be modified. Otherwise, information exchange between service and LD player may result in a more powerful configuration of the service. In any case, the Learning Design runtime environment perceives the process as a request-response communication where the selected plugin hides the complexity.

A first prototype has been implemented and tested. The requested service was an instance of a wiki for each instance of a given role. GSI offered the proper functionality to be able to request such service at design time and perform the initialization of the different instances with almost no human intervention.

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References

1. IMS Learning Design specification (February 2003), http://www.imsglobal.org/learningdesign/
2. Koper, R.: Modelling units of study from a pedagogical perspective: The pedagogical meta-model behind EML, document prepared for the IMS Learning Design Working Group. Open Universiteit Nederland, Heerlen (2001)
3. IMS Tools Interoperability (February 2006), http://www.imsglobal.org/ti/
4. Wilson, S., Liber, O., Johnson, M., Beauvoir, P., Sharples, P., Milligan, C.: Personal Learning Environments: Challenging the dominant design of educational systems. In: Joint International Workshop on Professional Learning, Competence Development and Knowledge Management (LOKMOL and L3NCD) (October 2006)
5. Assessment provision through interoperable segments (May 2007), http://www.jisc.ac.uk/whatwedo/projects/apis.aspx
6. Sharples, P., Griffiths, D., Tattersall, C.: Integrating IMS Learning Design and ADL SCORM using CopperCore Service Integration. In: Proc. of the 2nd TEN-Competence Open Workshop (2007)

7. Moreno-Ger, P., Burgos, D., Sierra, J.L., Fernández-Manjón, B.: A Game-Based Adaptive Unit of Learning with IMS Learning Design and <e-adventure>. In: Duval, E., Klamma, R., Wolpers, M. (eds.) EC-TEL 2007. LNCS, vol. 4753, pp. 247–261. Springer, Heidelberg (2007)
8. Wilson, S., Sharples, P., Griffiths, D.: Extending IMS Learning Design services using Widgets: Initial findings and proposed architecture. In: Proc. of the 3rd TENCompetence Open Workshop on Current Research on IMS Learning Design and Lifelong Competence Development Infrastructures (2007)
9. OpenID specification (2006), http://openid.net/specs.bml
10. del Cid, J.E., de la Fuente Valentín, L., Gutiérrez, S., Pardo, A., Kloos, C.D.: Implementation of a Learning Design Run-Time Environment for the.LRN Learning Management System. Journal of Interactive Media in Education (2007)
11. The LRN platform (October 2007), http://dotlrn.org
12. Open Architecture Community System (October 2007), http://openacs.org

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