Learning Objects in Context

Edited by

Erik Duval, Stefaan Ternier, and Frans Van Assche

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Articles

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PREFACE

Special Issue: Learning Objects in Context
Guest Editors Introduction

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Welcome to this special issue on "learning objects in context"! The papers in this issue have their origins in a workshop we organized in March 2005, with the support of the ProLearn network of excellence on professional learning[1] and the iClass project[2].

The papers in this issue focus specifically on the *context* in which learning objects are deployed: this theme is quite varied and picks up on the message that "if content is king, then context is queen." Overall, the main aim is to exploit data available about user context to:

- generate metadata automatically,
  - either during the authoring process, from the author's context, when information about the intended use is more easily available; or
  - while the learner is working with the learning object, in order to capture his feedback, which can then be used later to help guide decisions on the appropriateness of the same object for other learners;
- personalize the selection of relevant learning objects, by selecting objects that satisfy conditions that reflect the requirements of the context; and
- adapt the behavior of a learning object to the specific characteristics of the context.

Some of the recurring themes in the papers that follow include:

- *Rich, "semantic" descriptions:* A number of initiatives try to exploit upcoming new semantic web technologies in order to support more sophisticated descriptions. Indeed, this is one of the two opportunities evoked in the short paper by Baker. It is the essence of the SIMBAD project presented by Bouzeghoub, Defude, Duitama and Lecocq. Similarly, Heller, Steiner, Hockemeyer & Albert rely on domain ontologies to identify skills and their interrelationships.

- *Adaptation strategies:* It is clear that, in order to exploit context, some kind of adaptation is key, either in the selection of relevant objects, or by a particular such object itself. Heller, Steiner, Hockemeyer & Albert focus on how Knowledge Space Theory can be used as a framework for defining and organizing adaptation structures. Their approach models skills and competencies and considers the use of learning objects from a psychological theory that emphasizes knowledge assessment. In the paper by Specht & Kravcik, different adaptation strategies are discussed: their overview helps in putting their own work in the RAFT project into context (!).
- *Pedagogical issues:* O'Keeffe, Brady, Conlan & Wade discuss "pedagogically informed" adaptation strategies that they have developed as iClass services. Muehlenbrock focuses specifically on the problem of dividing learners in groups for a collaborative learning setting, and how that process can be informed by contextual information. The paper by Põldoja, Leinonen, Väljataga, Ellonen & Priha presents a specific kind of "progressive inquiry learning object templates" that support social constructivist approaches. Türker, Görgün and Conlan focus on the pedagogical aspects involved with personalization, and how these are supported in the iClass approach.
- *Small granularity* of learning objects: By reducing the granularity, opportunities for adaptation to the context of use increase. Dahn details the slicing book approach that facilitates reuse of small text components in the domain of mathematics. The paper by Schluep, Bettoni & Schär presents a simple component model that defines "didactic content types": they have implemented this model in the dLCMS project, that also provides much appreciated guidelines to the authors. An alternative content model is the ALOCOM model presented in the paper by Verbert, Jovanovic, Duval, Gasevic & Meire: remarkable about this approach is that it enables automated dis-aggregation and re-aggregation of learning object components. The authors present a specific case study that works with Microsoft powerpoint documents.
- *Modeling of context:* One way to be explicit about the intended context of use is the definition of learning activities, which Sampson and Karampiperis consider to be the core of "next generation" learning systems. They discuss an early proposal for an architecture of such a system, and a toolset they have developed to experiment with it. Specht & Kravcik describe approaches for extending metadata with context information that can be captured automatically through sensors. Strijker &

Collis detail several context dimensions that their research in a wide variety of learning settings has revealed to determine success of reuse strategies.

- *Technical issues:* Of course, context support needs to be integrated into the overall technical infrastructure. The paper by Massart discusses the merits of a recently finalized standard for querying repositories, in order to obtain not only the metadata, but also the actual objects themselves. Ternier & Duval report on experiences with the same standard for the implementation of access to a heterogeneous set of learning object repositories. Baker mentions the use of Service Oriented Architectures (SOA's) for modeling the processes that define the context. Paulsson & Naeve actually propose a SOA framework for learning environments that reflects their learning object taxonomy and that separates data, presentation and logic.

This collection of papers provides a balanced overview of some of the more recent and exciting work on context related issues for learning objects. We hope that you will get a useful overview of the context (!) in which some of this work is carried out, and, above all, that you may be able to assess the relevancy of what is rapidly evolving to your own work, either as a researcher or as a practitioner.

We are very grateful to the authors and participants at the workshop, which was a testimony of the dedication, energy and insight of this community. We would welcome reactions, comments and feedback from you, the reader.

ERIK, STEFAAN & FRANS

Notes:

[1] http://www.prolearn-project.org/
[2] http://www.iclass.info/iclass01.asp

The Challenge of Content Creation to Facilitate Personalized E-Learning Experiences

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The runtime creation of pedagogically coherent learning content for an individual learner's needs and preferences is a considerable challenge. By selecting and combining appropriate learning assets into a new learning object such needs and preferences may be accounted for. However, to assure coherence, these objects should be consumed within pedagogically meaningful learning activity structures. There are a number of key aspects that need to be addressed in order to perform this kind of personalization, such as the appropriate modelling of the learner's needs and preferences, representation of pedagogical strategies, representation of learning designs and assets as well as the runtime reconciliation of these elements to produce effective and coherent learning activities. Moreover, preferences that teachers may have about the learner's studies should also be considered. iClass, an Integrated Project, funded by the European Commission under the auspices of the Information Society Technologies (IST) FP6, addresses this challenge with an innovative and ambitious suite of eLearning services. This article introduces iClass and its objectives.

Introduction

iClass has adopted the objective of formulating a new pedagogical approach by exploiting the potential of ICT to support a personalized, flexible and learner-centric approach (iClass, n.d.). This pedagogical approach strives to facilitate empowerment of both learners and teachers, while producing personalized learning experiences. Based on this, the iClass project aims to establish a framework to deliver personalized, adaptable and adaptive learning experiences in a collaborative environment for learners.

iClass includes a number of services that facilitate the modelling of learner information, such as the Monitor and Profiler services. These are responsible for completing a model of the learner's abilities, biases, preferences and needs that iClass can utilise as part of the personalization process. As a complimentary Teacher's Preference Tool enables control over the personalization features to ensure that iClass is properly integrated with the practices in the general managed learning environment of the school and the classroom. These preferences form the boundaries and constraints under which iClass may adapt. Students are allowed to influence these features as well, through the Student's Preference Tool to the extent determined by the teachers.

The key services for facilitating personalized eLearning experiences are the Selector and LO Generator. The Selector is responsible for formulating personalized high level strategies for facilitating learning. These strategies, or Personalized Learning Paths, comprise the set of concepts and learning activities that are appropriate for the learner's current goals and preferences. The LO Generator is responsible for assembling proper Learning Objects LOs) to compose the concepts and activities described in a learner's Personalized Learning Path (Brady, Conlan & Wade, 2004).

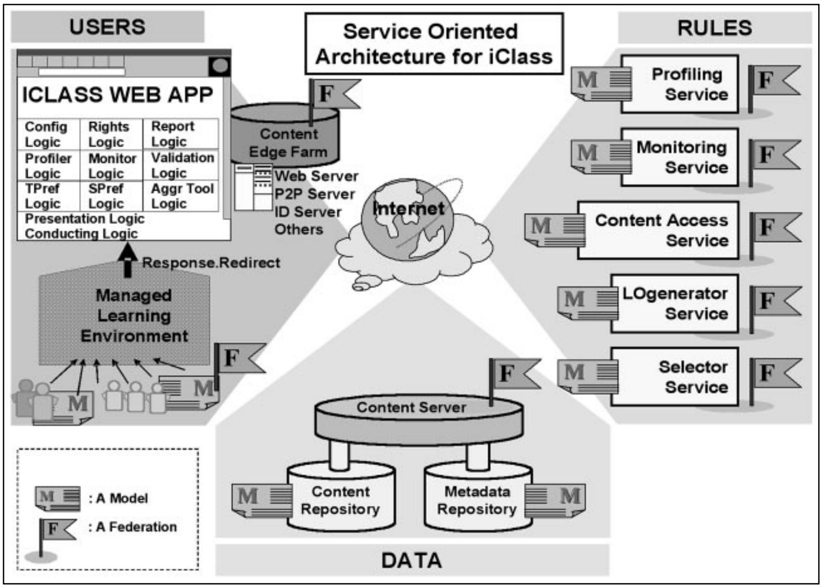

Figure 1. The iClass services and repositories

This article describes the objectives of iClass with respect to personalization of a learner's experience. The next section describes how iClass will cater towards a learner's needs by providing adaptable, as well as, adaptive solutions. The third section will look at the iClass framework and exemplify some workflows carried out by iClass. The fourth section will examine content issues that arise when developing personalized content. Finally, the last section will conclude the article.

Catering Towards Learner Needs

Pedagogical and contextual parameters of the learners are inputs to the reconciliation engine that creates the personalized content in the sense of picking the right learning design and activities (Conlan & Wade, 2004). Pedagogical parameters comprise the learning styles, habitual properties, and general aptitude of the learners. The aspects like cultural background, place of study, collaboration, timeliness and hour of study are some of the contextual parameters.

Adaptivity in learning experience is accomplished by choosing the learning path that suits the knowledge level and the acquired competencies of the learner. These are measured by the Monitor service based on the assessment results and learner's consumption performance of the LOs. Learning paths are portions of the concept domain ontologies. These ontologies essentially represent the curriculum constructs. In addition, adaptivity will also have to take into account the learners having "off-the-iClass" experiences. These are inquired through the Student's Preference Tool and are considered in the crafting of their iClass experiences. In order to achieve adaptivity at runtime, appropriate assessment techniques are continuously employed by iClass and the knowledge representation of the learner is continuously updated.

Adaptability in learning experience is accomplished by choosing learning activities that suit the pedagogical parameters and preferences of the learn-

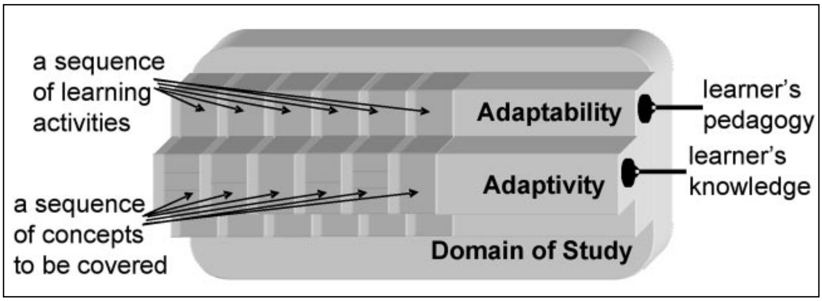

Figure 2. Models of the learner affect the choice of activities and concepts to be covered

er. Being adaptable implies that the learners assume responsibility within the designated limits, and have freedom, yet guidance. Providing the learners with the suitable learning tools such as annotation tool, a mind-mapping tool, or a history tool exemplifies this kind of support. The extent of the adaptability provided by iClass frames the scope of how adaptive iClass will be towards the learners. The strategy of iClass is to be adaptive in its support of the learning activities while remaining adaptable to the learning style variations of different learners. Learners with different learning styles react in different ways and therefore they require different kinds of support when consuming the same learning object. This differentiation in support is provided not only for the search of an appropriate learning object, but also for the consumption of that learning object.

Being both adaptive and adaptable, iClass aims to create learners who have the ability to learn from different types of learning materials even if s/he has a preferred style, yet the learner must remain active in the process of decision making, which allows the learner to own the responsibility of his/her learning experience.

iClass employs preferences tools for both the teachers and the learners so as to reinforce the personalization properties. Using the tool, learning choices such as contextual information, demands for collaborative learning, or preferences on the common practice activity structures can be captured. Moreover, the created learner models are shared with teachers and learners by means of these tools.

Example Workflow

Utilizing iClass services and supporting tools, a learner will be able to achieve a given set of educational objectives. The overall iClass system is a framework that accommodates certain processes for providing personalized units of study, yet assistance through the study is also provisioned.

Firstly, iClass determines and employs a pedagogical scenario in order to create a structure of activities to cover the unit of study. The unit of study represents a portion of the curriculum domain map. This portion of the curriculum domain map is evaluated with respect to the knowledge level and acquired skills of the learner in order decide upon the order and occurrence of learning objects to be delivered. The type of activities that harbour this chain of objects is determined by using the pedagogical and contextual parameters. For each section of the activity structure, iClass searches and finds learning objects that suit the activities involved. Since the activities suit the learner's model, the learning objects consequently suit the model. Nevertheless, the model comprise a rather large set of pedagogical and contextual parameters and hence some other conditions are still exerted on the objects other then the fitness criteria to the activities. Notice that, primarily the objects will have to suit the corresponding portion of the domain as well, which encompasses a set of concepts and skills.

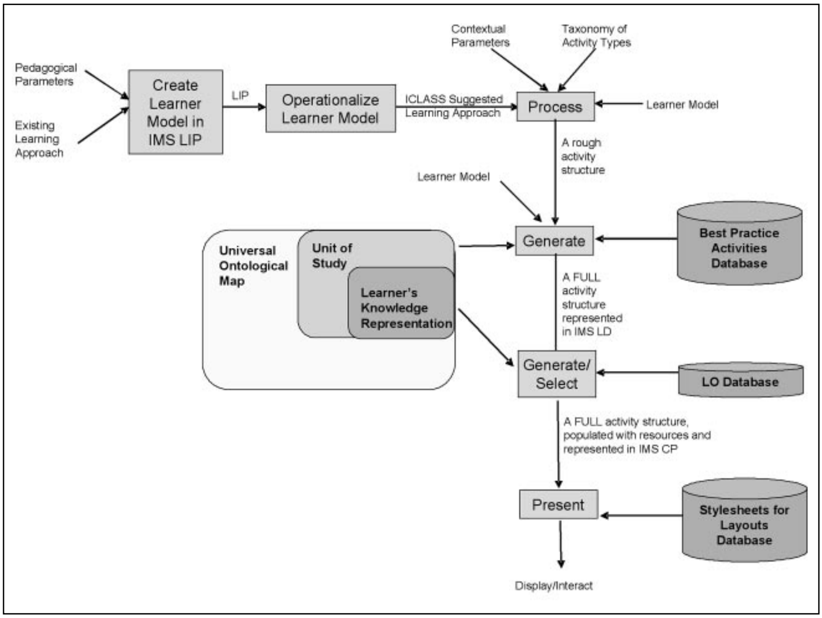

Figure 3. Utilization of content

The workflow presented in Figure 3, highlights the personalization process performed by iClass. The process is both standards-based and pedagogically aware. The key stages in creating a personalized eLearning experience are modelling the learner, choosing an appropriate learning approach, selecting appropriate content and activities to perform teaching and finally populating those concepts/activities with customized learning objects. Pedagogical properties of the learner are used in selection of the learning approach that yields a rough activity structure with the incorporation of contextual parameters. This rough structure is populated with best practice activities which in turn are populated with LOs. The selection of both activities and LOs is dependent on the domain and the learner's existing knowledge on that domain.

Content for Personalization

Targeting personalization, being adaptive and adaptable constrain the learning content to be developed and exploited by iClass. The content publishers in iClass are in charge of providing both user-readable and system-readable content. Pieces of the system-readable content are knowledge representations, ontological maps for representing a curriculum, instructional and learning designs, metadata and sequences of learning objects, while the user-readable content comprises the learning objects, learning resources and learning tools. iClass employs content formation (such as a video editing and text/graphics overlay tool), content aggregation, ontological map editing and learning activities authoring tools for both types of content. In order to achieve the interoperability of learning systems, iClass exploits the standardized technologies, such as OWL[1] for curriculum domain maps and knowledge representations, IMS Learning Design for activity structuring, SCORM[2] 1.3 for learning object manifests, and IMS Learner Information Package for learner profile recording.

In order to properly execute the scenario described in the previous section, both the user-readable and the system-readable content need to be created. The content creation, in this sense, covers the development of learning objects and learning designs that form the pavement of the introduced flow. The development of learning objects and learning designs should be coherent in order to prevent from disharmony between these two. The Frankenstein effect (otherwise known as the mosaic effect) that may occur due to sequencing learning objects at runtime with respect to a selected learning design implies a great challenge for content creation. When components of a course such as activities or learning objects are assembled by computer algorithms, the overall experience can be satisfactory in an objective sense, yet subjectively annoying for learners. The disturbance may be not only in look and feel but also pedagogical in that individual activities which seem proper can be bothering as they occur one after another. To overcome the Frankenstein effect iClass employs hierarchies in content structuring such as confining LOs within activities, confining activities within activity structures and confining activity structures within learning designs that bear specific strategies.

iClass determines the sequence of the learning objects during the execution of the workflow, even though there are suggestive sequences provided by the content creators. The tool for content aggregation also allows for suggesting sequences. This nature of iClass necessitates a well-formed co-operation between the separate modules of iClass that are involved in content creation. Co-operation is achieved by using a shared and controlled vocabulary of special metadata types specific to iClass.

A primary aspect of content creation involves the curriculum analysis, and accordingly the development of the ontological domain maps. The curricular variations imply a challenge for this process, particularly for a system like iClass, that is chartered to serve schools in different countries.

Another aspect of content creation is the development of knowledge representations for domains and learners. In order to match a learner's knowledge to the knowledge designated for the domain, there should be a common representation model. However, the representation for the learner will be left to evolve while the domain representation is bounded by the curriculum.

The learning objects are developed according to the created domain knowledge representations and ontological domain maps. As for the creation of learning designs, possible variations in the learner model parameters are taken into account and a suit of generic pedagogical strategies (scenarios) are developed for iClass. Moreover variations due to cultural and contextual differences are considered.

Finally, a number of learning tools complete the personalized learning experience, and provide feedback to the overall iClass system.

CONCLUSION

This article has described the role of content in creating an eLearning experience that is personalized towards the learner's needs as part of the iClass project. Specifically it has discussed how the iClass framework facilitates the tailoring of eLearning experiences towards learner's needs with preferences that can be set both by the teachers and also the learner himself/herself. The iClass IST project, funded under the European Commission's 6th Framework, is striving to provide educators and learners with a personalized learning environment built using pedagogically sound principles.

References

Brady, A., Conlan, O., & Wade, V. (2004). *Dynamic composition and personalization of PDA-based elearning – personalized mlearning.* E-Learn 2004, World Conference on E-Learning in Corporate, Government, Healthcare and Higher Education, Washington, D.C., November 2004.

Conlan, O., & Wade, V. (2004). *Evaluating the multi-model, metadata-driven approach to producing adaptive elearning services.* Third International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems (AH2004) Proceedings, Eindhoven, The Netherlands, 2004.

iClass. (n.d.). iClass Integrated Project, Annex 1, Description of Work, http://www.iclass.info

Notes

[1] Web Ontology Language
[2] Sharable Content Object Reference Model

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Learning Group Formation Based on Learner Profile and Context

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An important but often neglected aspect in Computer-Supported Collaborative Learning (CSCL) is the formation of learning groups. Until recently, most support for group formation was based on learner profile information. In addition, the perspective of ubiquitous computing and ambient intelligence allows for a wider perspective on group formation, broadening the range of addressed features to include learner context information.

An important but often neglected aspect in Computer-Supported Collaborative Learning (CSCL) is the formation of learning groups. Most CSCL systems focus on mediating and supporting collaborative learning while the activity is going on, or after the activity has ended, by proving system functionality ranging from mirroring to guiding (Jermann, Soller, & Muehlenbrock, 2001). However, if support could also be given prior to the actual collaborative learning activity by suggesting appropriate group arrangements, many problems might be solved even before they arise and beneficial group processes might be boosted.

Until recently, most support for group formation was based on learner profile information such as gender, class, and so forth, including more sophisticated approaches based on the complementarity or overlapping of knowledge and competencies. This will be described in the following section. In addition, the perspective of ubiquitous computing and ambient intelligence allows for a wider perspective on group formation, broadening the range of addressed features to include learner context information such as location, time, and availability. This new perspective will be addressed in the third section.

GROUP FORMATION BASED ON LEARNER PROFILE

A general conceptual and formal framework for student model integration has been introduced in Hoppe (1995) under the notion of multiple student modelling, and has been extended in Muehlenbrock, Tewissen, and Hoppe (1998) for open distributed learning environments. The general premise is that individually assessed learner models can be used to support the configuration or parameterization of collaborative learning settings. These are prototypical cases:

- Given a number of students working on comparable problems in an open learning network, find pairs of students that could potentially benefit from cooperation in a joint session. The selection can be based on such criteria as complementarity or competitiveness.
- Given a group of students, select or generate a problem that forms an adequate challenge for the group as a whole. The problem should not be solvable by one student's knowledge alone, but rather through the union of all the students' individual knowledge bases. In this case, the challenge for the group consists in knowledge exchange and integration.

Selection criteria for these prototypical cases can be formulated on the basis of general modelling primitives such as *knows(Student, Topic)* or *has_difficulty(Student, Topic)*, which can be inferred from different standard types of student models. A simple case of knowledge integration is exemplified by the rule

```
can_help(Student1, Student2, Topic) _
        knows(Student1, Topic) & has_difficulty(Student2, Topic).
```

Interestingly, there is a wide range of different support functions that can be implemented based on such a rule and further extensions:

- *Intelligently mediated peer help:* The individually assessed learner models are used to match pairs of learners that should maximally benefit from each other when working together. The prediction can be based on different criteria such as complementary skills/knowledge or competition.
- *Intelligently mediated expert tutoring:* Formally, this case can be considered as a specialization and simplification of matching peer learners, since only one of the models (the learner's) has to be dynamically assessed, whereas the tutors' profiles may be predefined.
- *Teacher/tutor support for supervising individual exercises:* Essentially a decision support function for the teacher. To achieve this it is sufficient to aggregate the individual learner models in a form that allows for filtering out specific features, for example, frequent problems. The support mechanism can also actively inform the teacher if adequate.

- *Group formation around given problems:* This is a generalization of mediating peer help in that the number of group members is not restricted to two. Also the problem requirements must be analytically specified.
- *Selection of adequate problems for a given group:* A problem is for example, selected or generated in such a way that it could serve as a challenge to the group as a whole but should still be feasible if the group were able to combine individual strengths.

This framework was used in different learner grouping scenarios. For instance, see Figure 1 for a user interface suggesting peer helpers for a learning task in mathematics. Accordingly, the architecture of the intelligent subsystem must allow for combining elements from different individual student models. In the original example, individual diagnosis did not require backtracking and modelling was cumulative for all learners at a time. However, diagnosis with backtracking and user interaction needs a more flexible, parallel or multi-threaded architecture. Such architecture has been presented in Muehlenbrock et al. (1998).

Massive practical applications of group formation based on similar principles as described here have been reported by McCalla et al. (1997). An ontology-based representation of group formation principles has been presented by Inaba, Supnithi, Ikeda, Mizoguchi, and Toyoda (2000).

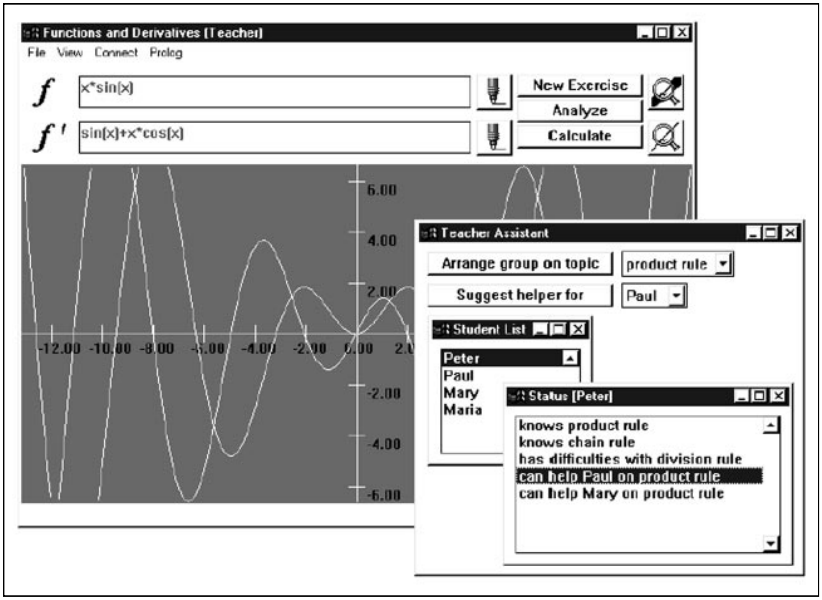

Figure 1. User interface for learning group formation including peer helper suggestion and topic selection

GROUP FORMATION BASED ON LEARNER CONTEXT

The concept of ubiquitous computing envisions a new computing era where computational and communication power is available in devices and objects of every size and purpose (Weiser & Brown, 1995). One of the biggest challenges in ubiquitous computing is the automatic detection of a user context (Salber, Dey, & Abowd, 1999). A typical contextual variable of a user that is frequently addressed is location, driven by many advances in device and sensor technology. Further interesting context features of a user and in a user's environment include, among others, activity, availability, stress, and emotional parameters as well as temperature, noise, weather, colocation of other people, and availability of devices, respectively. For learning group formation, these contextual features provide an additional source of learner information, which could help in improving the quality of the grouping.

Using a networked infrastructure of easily available sensors and context-processing components, an application has been developed for peer helper suggestion and opportunistic group formation based on contextual parameters such as location, activity, and availability (Muehlenbrock, Brdickza, Snowdon, & Meunier, 2004). These notions of location, activity, and availability have both been detected automatically based on sensor information and learned automatically based on users' feedback to the system.

To detect a person's location, activity, and availability, different sensing techniques have been used in a prototypical application. All of these sensors are already available in many environments or can be installed without much effort, such as:

- *PC usage:* Detection of users' keyboard and mouse activity on personal computers.
- *Phone usage:* Detection of phone usage by using a switch connected to an input port of a computer.
- *PDA location:* Determination of the location of user's PDA (personal digital assistant) by using signal strength information related to several base stations.
- *PDA ambient sound:* Detection of ambient sound in the PDAs' surroundings by using the built-in microphone.
- *PDA user feedback:* Explicit feedback on some context variables provided by the users (Figure 2).

The various sensors send their information to a database residing on a server that can be accessed from both the wired and the wireless networks. The database contains static profile data, as well as the dynamic event data. The static profile data may vary over time (e.g., if someone is allocated a new PC or changes office) but comparatively slowly compared to the event data. The profile data names the entities (people and devices) and places that are referred to by the dynamic event data. Furthermore the profile establishes links between devices and places and people. For example the profile indicates that particular computers, PDAs, and phones are associated with a particular user and that that user has his/her office in a particular place. It also indicates the normal function of places so that our software can find out if a user is in a place that is someone's office or in a public space such as a meeting room or coffee area. The tables associated with the dynamic event data store information about events generated by the sensors and events generated by higher-level components predicting activity and availability.

Figure 2. Feedback on context variables

The context processing consists of combining information from different sources and deriving an estimation of the users' situation. Of particular interest for the application are the activities and availabilities of the users. The set of relevant activities is comprised of single-person activities such as using a PC, using a PDA, and working at the desk, multi-person activities such as phoning, discussing, or being in a meeting, and intermediate activities such as walking from one place to another, which result in a drastic change of context. These activities are assumed to have a major influence on the level of a person's availability. Relevant classes of availabilities that are considered to be useful are being available for a quick question, being available for a longer discussion, being available soon, or not being available at all. By using machine-learning methods the system is to find a connection between sensed information and situations as perceived by users, including also information on people's habits (Muehlenbrock et al., 2004). In order to test the sensing infrastructure and the feasibility of the availability estimation, several one-day experiments have been conducted with different sets of users including typical user situations like PC work, meeting, phoning, and so forth.

SUMMARY

The combination of learning group formation based on information from learner profiles and information on the learner context has a potential of improving the quality of the grouping. It allows for the adhoc creation of learning groups, which is especially useful for peer help for immediate problems, by reducing the risk of disruptions. It also leverages the forming of face-to-face learning groups based on the presence information.

References

Hoppe, H. U. (1995). The use of multiple student modeling to parameterize group learning. In J. Greer (Ed.), *Proceedings of the 7th World Conference on Artificial Intelligence in Education*, (pp. 234-241), Washington, DC.

Inaba, A., Supnithi, T., Ikeda, M., Mizoguchi, R., & Toyoda, J. (2000, August). An overview of "learning goal ontology". In M. Muehlenbrock, (Ed.), *Proceedings of the Workshop Analysis and Modelling of Collaborative Learning Interactions at the European Conference on Artificial Intelligence ECAI-2000.* Berlin, Germany.

Jermann, P., Soller, A., & Mühlenbrock, M. (2001, March). From mirroring to guiding: A review of the state of art technology for supporting collaborative learning. In P. Dillenbourg, A. Eurelings, & H. Kai Hakkarainen,.: *Proceedings of the European Conference on Computer-Supported Collaborative Learning, EuroCSCL-2001*, (pp. 324-331), Maastricht, The Netherlands.

McCalla, G. I., Greer, J. E., Kumar, V. S., Meagher, P., Collins, J. A., Tkatch, R., et al., (1997). A peer help system for workplace training. In D. Boulay & R. Mizoguchi (Eds.), *Proceedings of the Conference on Artificial Intelligence in Education AIED 97*, (pp. 183-190), Kobe, Japan.

Mühlenbrock, M., Brdiczka, O., Snowdon, D., & Meunier, J.L. (2004, March). Learning to detect user activity and availability from a variety of sensor data. In *Proceedings of the Second IEEE Conference on Pervasive Computing and Communications*, Orlando, FL.

Mühlenbrock, M., Tewissen, F., & Hoppe, H. U. (1998). A framework system for intelligent support in open distributed learning environments. *International Journal of Artificial Intelligence in Education, 9,* 256-274.

Salber, D., Dey, A., & Abowd, G. (1999, May). The context toolkit: Aiding the development of context-enabled applications. In *Proceedings of the 1999 Conference on Human Factors in Computing Systems CHI 99,* (pp. 434-441), Pittsburgh, PA.

Weiser, M., & Brown, J., (1996, July). Designing calm technology. *PowerGrid Journal, 1*(1).

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Authoring of Learning Objects in Context

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Learning objects and content interchange standards provide new possibilities for e-learning. Nevertheless the content often lacks context data to find appropriate use for adaptive learning on demand and personalized learning experiences. In the Remotely Accessible Field Trips (RAFT) project mobile authoring of learning content in context has shown the relevancy of contextual metadata for flexible access to learning objects. This article describes approaches for extending current metadata schemas with context metadata that can be captured together with the assets on the fly, giving them a learning context.

New requirements for personalized adaptive learning include (Information Society Technologies Priority, 2003) development of semantic-based and context-aware systems to acquire, organise, personalise, share, and use the knowledge embedded in web and multimedia content, achievement of semantic interoperability between heterogeneous information resources and services, and pioneering intelligent content, which is self-describing, adaptive to context and user needs, and exhibits a seamless interaction with its surroundings and the user. This research line addresses the boundaries between knowledge and content, combining new content architectures with emerging knowledge technologies to progress towards context-aware, self-describing, and adaptive "atomic" content objects that can seamlessly aggregate to create new content and services, for which the traditional boundaries of different media cease to exist.

Mobile technologies and ubiquitous computing raise new requirements regarding extensions on current standards and exchange formats for *contextualisation* of resources. The current metadata sets should be extended for capturing and handling additional context data. Authoring toolkits for creating contextualized materials should support contextualized collaboration and live interaction among users performing various roles. One of their primary objectives is to generate as much metadata as possible automatically, based on the current context and by means of sensors. This will enable more precise retrieval of the data when resources are elaborated by users or provided to learners.

In the last years several initiatives researched scenarios for learning and mobile information support in the classroom. According to Kling (2003), the classroom and research in the classroom might be one of the key drivers for a next generation of social software. The classroom gives a variety of scenarios and situations where ad hoc collaboration and the contextualization of information play an important role. In a study conducted in the PEP program (Tatar, Roschelle, Vahey, & Penuel, 2003) 84% of teachers strongly agreed that the quality of teaching was improved by handheld devices in the classroom. New possibilities where seen in the live interaction about data and the reflection about easily exchangeable and copied data sets. In the context of the m-Learn project, user studies analyzed the different scenarios that were relevant in the working context for learning (Atewell & Savoll-Smith, 2000). Most of such studies show a high potential and acceptance for supporting new forms of mobile and contextualized learning approaches in the classroom. From our point of view, the integration of focused applications with specialized interfaces and their integration in more complex task contexts are crucial for the design of contextualized learning experiences.

In the following, we mention personalization issues and challenges, describe our experience with contextualized learning in the Remotely Accessible Field Trips (RAFT) project, and outline an extended system architecture related to learning objects.

ADAPTIVE METHODS FOR PERSONALIZATION

The major aims of personalized adaptive learning are improvements in effectiveness and efficiency of learning together with higher learner satisfaction. To increase the quality of technology enhanced learning it is important to distinguish *what* should be adapted, *to what features* should it be adapted, and *how* should it be adapted.

Additionally, to the traditional adaptive factors such as adaptive content selection, adaptive navigation support, and adaptive presentation, we should consider some new ones, like adaptive learning activity selection, adaptive resource recommendation, and adaptive service provision. According to the *Adaptive Hypermedia Application Model* (AHAM, [DeBra, Houbon, & Wu, 1999]) it is common to base the adaptation process on the domain model and the user (learner) model, possibly enhanced by the goal (task) model, but to provide adaptive services in mobile and ubiquitous computing the context model has to be added (Figure 1). To specify the adaptation itself in a reusable way the adaptation model has to be separated from the domain one and in educational settings enhanced by a pedagogical model (more generally it might be an activity or scenario model).

Integration of context modeling and user modeling with adaptation (Figure 2) will enable new forms of personalized and adaptive learning experiences. The user and context model specify *to what* parameters the application should adapt. The main challenges regarding context management include:

- extensions on current standards and exchange formats for *contextualisation* of resources;
- automatic acquisition of context metadata;
- understanding contexts and situated cognition;
- creation of tools for development of contextualized applications; and
- designing context-based activities involving groups of users interacting within a set of collaborative environments.

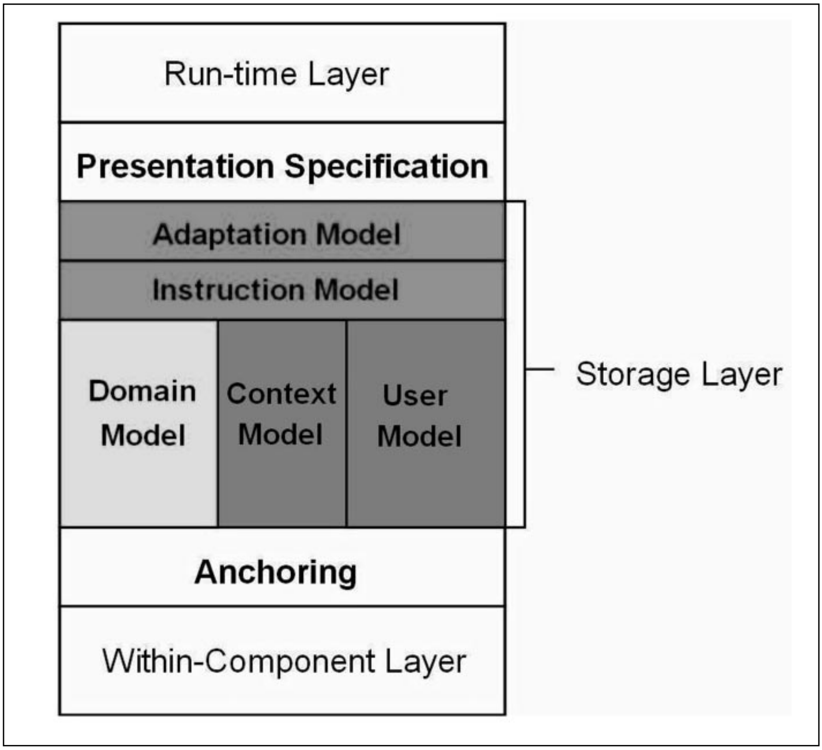

Figure 1. Enhanced Adaptive Hypermedia Application Model

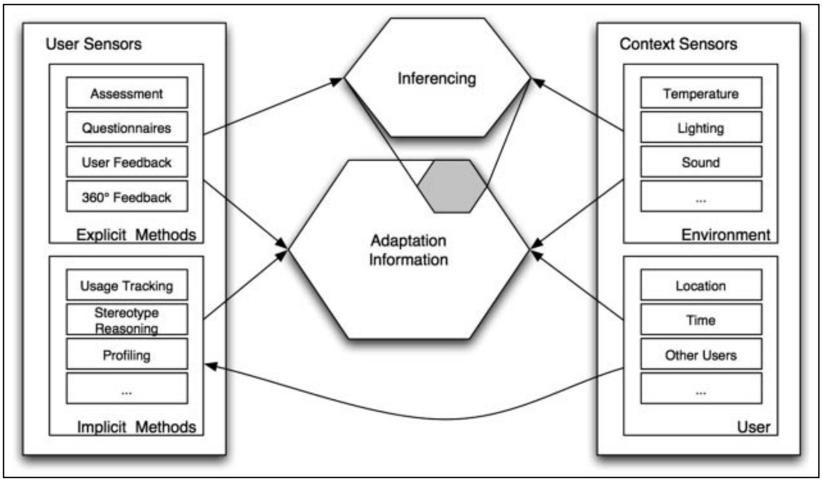

Figure 2. Integrating context data, user modeling, and adaptation

MOBILE AUTHORING IN RAFT

In the European project RAFT (RAFT, 2002), the consortium has created learning tools for field trips in schools. The system supports a variety of learners with different tasks either in the classroom or in the field. The main objectives of the RAFT project were to demonstrate the educational benefits and technical feasibility of remote field trips, to establish extensions on current learning material standards and exchange formats for contextualization of learning material (this is combined with the embedding of learning and teaching activities in an authentic real world context), and to establish new forms of contextualized learners' collaboration with real time video conferencing and audio communication in authentic contexts.

Through the RAFT trials, different phases (Figure 3) for preparing the field trip, experiencing the field trip in the classroom and in the field, and the evaluation after the field trip were identified. In those phases a variety of stakeholders and participants contribute to the field trip and take an active role in it.

From the usage of the RAFT applications by end users the following main activities can be considered as new qualities of contextualized learning approaches:

- *Cooperative task work:* The distributed work on a task focuses the interaction and communication between the learners, technology get into the background, the curiosity about the given task and its exploration in physical and knowledge space become the main interest. The context in this sense allows the learners to immerse in the learning subject at hand.

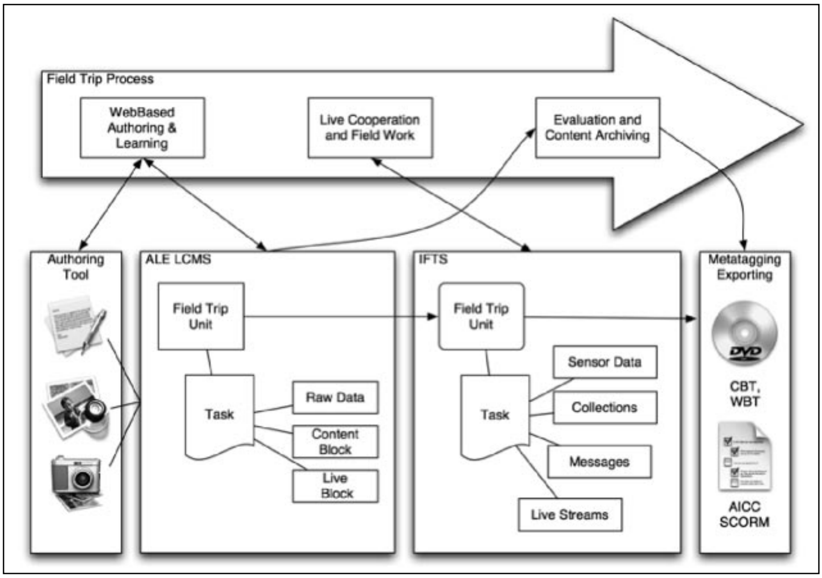

Figure 3. RAFT workflow process

- *Active construction of knowledge and learning materials:* Users are much more motivated when "self made" learning material get integrated in the curriculum.
- *Field trips are a blended learning process:* Teachers need to specify preparation materials, distribute user roles, and define field and classroom tasks. After the field trip the collected materials need to be reviewed and archived in standardized formats to ensure reuse and quality assurance.

The RAFT tools support different phases of the whole process: preparation, field trip activity, or evaluation. Therefore different interfaces and widgets give the user access to the backend system and the live communication channels. The interface and interactions design depends heavily on the type of activity. During the field trip the selection of information and collaboration tools is based on the current position and user role. The implementation of different interfaces is not based on a software solution for intelligent rendering of interface components, but is developed specially for the different roles and role specific devices to fulfill the assigned tasks. The RAFT tools can be seen as different components in a blended learning process that is distributed in time, location, and social context in the different phases of the field trip.

The basic architecture in RAFT enables the creation of various widgets using different modalities for input and output. All messages go in a common backend by way of a web services interface and can be used with different rendering and display widgets. This ensures the most flexibility for communicating between different interfaces in the classroom and the field. Furthermore all clients are notified by a notification service when new messages are available and can subscribe to different communication channels.

EXTENDED LEARNING OBJECT ARCHITECTURE

Development of contextualized learning materials was a major focus in RAFT. Besides the traditional learning object metadata (LOM, SCORM) attached to materials, additional metadata were required for contextualized learning objects. Such metadata include information about the location where the materials were collected, information regarding the current time, or maybe the weather conditions on that day.

Already in an early prototype, called Mobile Collector (Kravcik, Kaibel, Specht, & Terrenghi, 2004), the learner could annotate a photo (Figure 4). The photo was shown together with all its metadata. The learner could assign the name and the related concepts (keywords) to the photo, or record audio annotation. Because of the difficulties with text input while on the move, the user could assign the concepts by simply checking them in a pre-

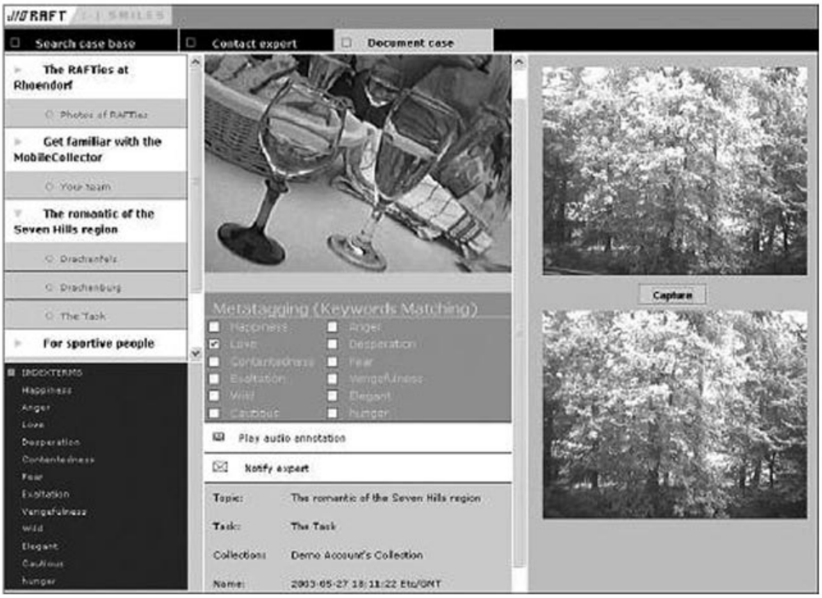

Figure 4. Manual annotation with subjective metadata

defined list. Based on this manual indexing users could easily find all the photos related to a particular concept.

Later on, the RAFT consortium developed a specialized framework for collecting context sensor data (Figure 5) in real time together with the learning materials and used the context metadata to make the collected information accessible to other participants of a field trip (Specht, Kaibel, & Apelt, 2005). As an example, a learner performing the scout role can collect small pictures or audio annotations and tag them with the location information (sensor metadata) from a GPS device. This information instantly appears on the task lists of other team members and is highlighted in the user interface. Traditional learning object metadata can be helpful for adaptive methods on sequencing and selecting the appropriate learning objects for a learner. Context metadata enable new approaches for structuring and accessing shared assets and learning objects.

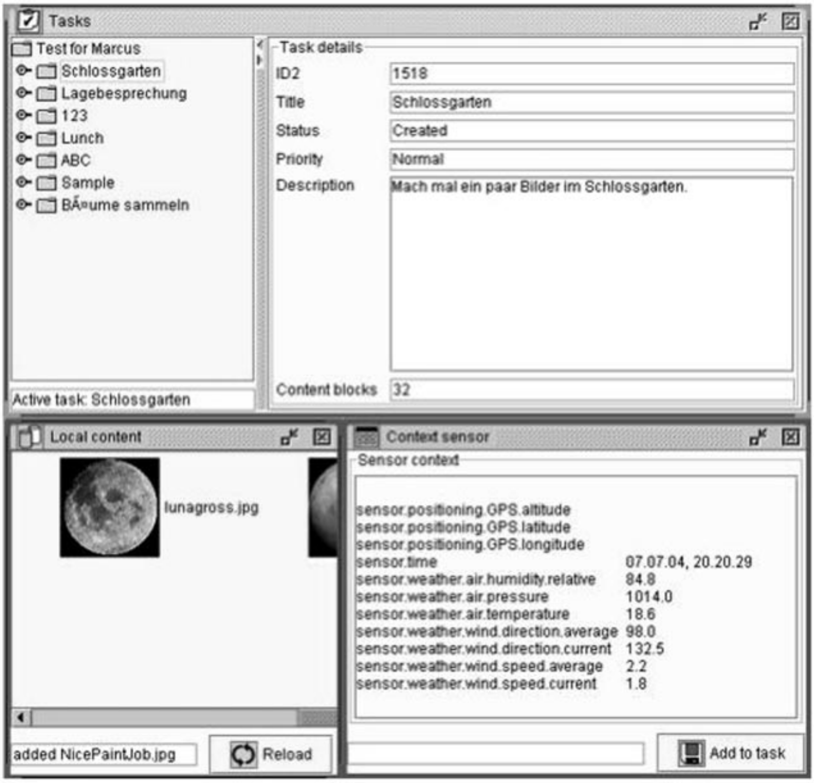

Figure 5. Automatic annotation with objective metadata

To realize the support for different metadata schemas and their usage in various learning scenarios it was needed to extend the existing learning object architecture with several new components:

- *Flexible metadata schema support:* In the LCMS ALE (Kravcik, Specht, & Oppermann, 2004; Kravcik & Specht, 2004) we implemented a framework to support different metadata schemas and a tool allowing creators of learning content to choose from different metadata schemas that are available.
- *Sensor integration and sensor server:* Based on the context metadata available on a field trip we integrated the possibility to record sensor measurements (Zimmermann, Lorenz, & Specht, 2005; Zimmermann, Specht, & Lorenz, in press) and combine them with data collections.
- *Context metadata based filtering and presentation of learning objects:* For simple mobile exploration tools based on PDAs or mobile devices we implemented content presentation tools that allow filtering of information based on contextual metadata.

As one example learners could browse a database of pictures in a biology field trip filtered by the location and the time of the year. Using this approach students could explore and learn about simple questions for example, "Which flowers grow here at a certain time of the year?"; additionally metadata such as the precise time when the picture was taken and the weather conditions on that day can give interesting materials for exploring and learning about important factors of flower growth.

CONCLUSION

The RAFT project revealed several technical and interaction issues related to the design of learning experiences for mobile and collaborative learning. Beside the backend technology that enables the combination of different client technologies from electronic whiteboards to mobile telephones, the synchronization and notification of heterogeneous clients accessing a persistent and consistent learning object repository became very important. Additionally, the distribution over the different phases of the field trip (preparation, field trip activity, and evaluation) appears to be an important aspect of nomadic activities for learning and exploration.

First insights have been gained on the extension of current learning material standards based on the semiautomatic collection of contextual metadata and their combination with assets and learning objects. As mentioned in (Duval et al., 2005) it is important to generate as much relevant metadata (both objective and subjective) as possible automatically, but also to enable manual creation of certain metadata. Metadata should enrich not only learning objects (and assets), but also queries to improve the precision and recall of information retrieval on one side, as well as personalization and adaptation on the other. Metadata generation has to be supported also by such facilities as inheritance, copying, default values, and by automatic generation from the (physical and semantic) context through appropriate sensors. User tracking is a way to collect usage metadata, especially important for adaptive delivery of learning.

According to our results, we suppose that integrating context modeling and user modeling will enable new forms of learning experiences, that mobile situated collaboration is a key for integrated learning support in nomadic activities, and that multimodal interfaces are crucial for ubiquitous information access and contextualized learning experiences. These hypotheses have to be further tested and verified.

References

Atewell, J, & Savoll-Smith, C. (2003). m-Learning and social inclusion – focussing on learner and learning. In *Proceedings of MLEARN 2003.* London: Learning and Skills Development Agency.

De Bra, P., Houben, G. J., & Wu, H. (1999) AHAM: A dexter-based reference model for adaptive hypermedia. *Proceedings of the ACM Conference on Hypertext and Hypermedia. ACM*, (pp. 147-156).

Duval, E. et al. (2005) A Learning Object Manifesto, this issue Information Society Technologies Priority (2002). Retrieved October 1, 2005, from http://www.cordis.lu/ist/

Kling, A. (2003) *Social software.* Tech Central Station. Retrieved October 1, 2005, from http://www.techcentralstation.com/042103C.html

Kravcik, M., Kaibel, A., Specht, M., & Terrenghi, L. (2004). Mobile collector for field trips. *Educational Technology & Society, 7*(2), 25-33. Retrieved October 1, 2005, from http://ifets.ieee.org/periodical/7_2/5.pdf

Kravcik, M., & Specht M. (2004). Authoring adaptive courses – ALE approach. *Advanced Technology for Learning, 1*(4), 215-220. Retrieved October 1, 2005, from http://www.acta-press.com/PaperInfo.aspx?PaperID=20673

Kravcik, M., Specht, M., & Oppermann, R. (2004). Evaluation of WINDS authoring environment. In P. De Bra & W. Nejdl (Eds.), *Proceedings of Adaptive Hypermedia and Adaptive Web-Based Systems*, (pp. 166-175), Eindhoven, The Netherlands. Heidelberg, Germany: Springer. Retrieved October 1, 2005, from http://www.springerlink.com/index/5151H7EVRREABEAJ

Remotely Accessible Field Trips (RAFT) Project (2002). Retrieved October 1, 2005, from http://www.raft-project.net

Specht, M., Kaibel, A., & Apelt, S. (2005). Extending LCMS for remote accessible field trips in RAFT. In *Proceedings of the Third IEEE International Conference on Perasive Compputing and Communications Workshop*, (pp. 302-306). Retrieved October 1, 2005, from http://doi.ieeecomputersociety.org/10.1109/PERCOMW.2005.37

Tatar, D., Roschelle, J., Vahey, P., & Penuel, W.R. (2002). Handhelds go to school: Lessons learned.*IEEE Computer, 36*(9), 30-37.

Zimmermann, A., Lorenz, A., & Specht, M. (2005). Applications of a context-management system. In A.K. Dey, B. Kokinov, D. Leake & R. Turner (Eds.), *Proceedings of the Fifth International and Interdisciplinary Conference on Modeling and Using Context* (CONTEXT-05), (pp. 556-569), Paris, France.

Zimmermann, A., Specht, M., & Lorenz, A. (in press). Personalization and context-management. *User Modeling and User Adaptive Interaction.*

Modularization and Structured Markup for Learning Content in an Academic Environment

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This article aims to present a flexible component model for modular, web-based learning content, and a simple structured markup schema for the separation of content and presentation. The article will also contain an overview of the dynamic Learning Content Management System (dLCMS) project, which implements these concepts. Content authors are a key factor for the successful application of these concepts. To support the authors creating modular contents the learning unit development guidelines were developed as part of the dLCMS project. An evaluation of the dLCMS and the guidelines from the point of view of learning content authors in an academic environment and a student evaluation of learning units which are composed of small, self-contained learning components is presented.

Introduction

The basic idea of a *learning object* is it being a small, modular and self-standing chunk of learning content, which flexibly can be assembled into electronic courses (Downes, 2001; Hamel & Ryan-Jones, 2002). Today several learning object repositories give public access to a wide variety of existing learning resources (ARIADNE, 2001; EducaNext, 2004; MERLOT, 2004). The learning objects contained in these repositories come in a variety of types of learning resources (lectures, presentations, reference material, simulations) and data formats (HTML with JavaScript, PowerPoint, Flash, Java, etc.). Most of the learning objects are individually designed and styled, and navigational and user interface controls are directly integrated into the learning objects. Aggregating such learning objects from different origins to larger coherent learning units is hardly possible, due to inconsistencies in the graphical and navigational design. To overcome these problems Duval states that "a more sophisticated component oriented model … that will enable seamless integration of document fragments from diverse origins" as well as "the separation of content, presentation" is needed (Duval, 2004).

The *dynamic Learning Content Management System (dLCMS)* project (Schluep, 2005) provides an implementation of a simple and flexible component model, and defines a standard level of granularity based on *didactic content types*, such as examples, exercises, self assessment, etc. As a flexible data format for the learning contents contained in the components, the dLCMS also specifies a simple XML-based structured markup schema to separate contents and presentation. In the following, the dLCMS content model and structured markup scheme as well as the functional architecture of the system are briefly outlined. Then we present the *learning unit development guidelines*, which aim at supporting authors to create modular contents for the dLCMS. An evaluation of the component model, the structured markup schema and the development guidelines from the point of view of learning content authors in an academic environment and a student evaluation of learning units which are composed of small, self-contained learning components is presented. The last section of this article will contain our conclusions on the work presented.

Component Model

In order to be able to successfully aggregate learning objects from various origins to larger learning units, these objects must have similar *granularity* and they must be *self-contained* (ADL, 2001; Chitwood, May, Bunnow, & Langan, 2000; Hamel & Ryan-Jones, 2002; Polsani, 2003). Unfortunately there is no generally accepted specification for granularity. A level of granularity proposed by many researchers is to base learning objects on a single *learning objective* (Barritt & Lewis, 2000; Baruque & Melo, 2003; LSAL, 2003). Another approach to a level of granularity supporting reuse might be based on *didactic content types* (e.g., definition, example, exercise, simulation, self assessment, etc.) (Schulmeister, 2003). A *didactic content type* may be seen as a piece of learning content which relates to one of Gagné's nine instructional events (Gagné, 1985).

A good example to show how *didactic content types* can be combined to serve different learner groups' needs is the subject matter of statistics. Students of pedagogy, medicine, psychology, sociology, and economics need to learn the same theoretical concepts, definitions and principles. Therefore a learning object representing a definition, (e.g., for the "standard deviation") can be reused for students of different disciplines. However examples, which are used to illustrate the theoretical concepts, should apply to the domain familiar to the student – one might want to present a patient population in medicine, while enterprise performance data will suit the needs of students in economics better. Using *didactic content types*, we can flexibly combine components with a high potential for reuse together with elements which apply to a scientific discipline more specifically.

Our learning content component model defines three component types: *assets, content elements*, and *learning units* (see Figure 1).

Assets are media elements such as images, videos, animations, simulations, etc. They are basically binary data objects, which cannot easily be divided into smaller entities. Generally they contain pictorial or auditory information, which can be static (image, graph) or dynamic (video, audio, animation). Further they can be interactive programs to be embedded into *content elements*.

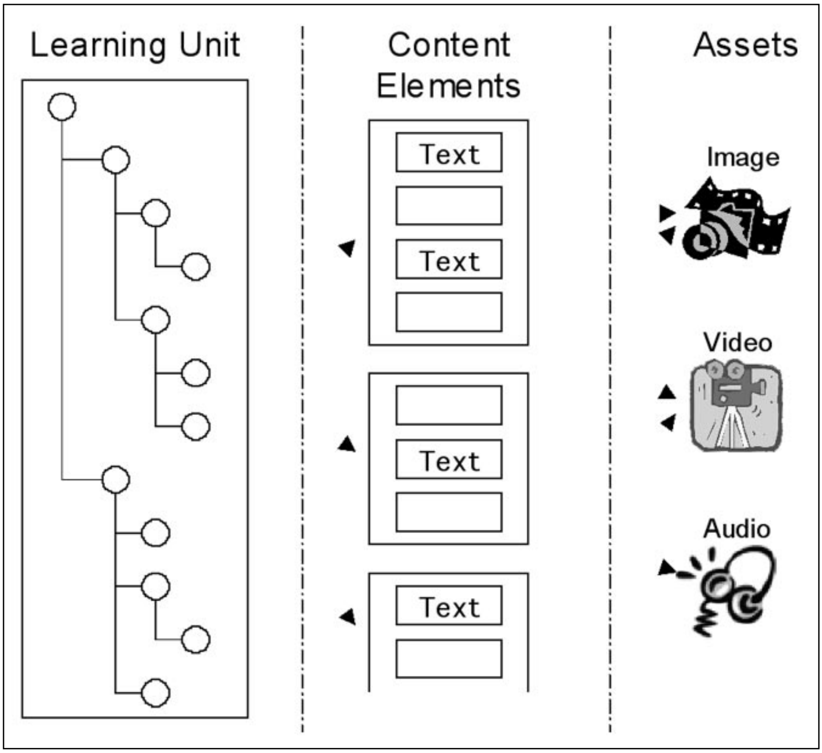

Figure 1. Component model consisting of assets, content elements, and learning units

Content elements are defined as small, modular pieces of learning content, which: (1) serve as basic building blocks of learning content, (2) can be aggregated to larger, didactically sound learning units, (3) are self-contained, (4) are based on a single *didactic content type*, (5) are reusable in multiple instructional contexts, and (6) may contain *assets*. We propose that a content element comprises a single didactic content type because of the anticipated higher potential of reuse, and the hope that this will promote the development of content elements with a similar level of granularity. A content element is designed as a single webpage. The page length is not fixed. Being a single page, content and navigation are consequently separated. The navigation structure will solely be defined by the aggregation into *learning units*.

We define a *learning unit* as an aggregation of *content elements*, which is presented to the learner. Typically a *learning unit* serves as an online lesson and may be used to teach several learning objectives. A *learning unit* provides a way to define a chapter-like, hierarchical structure of nodes. Each node will be associated to a *content element* through reference. The *content elements* are not copied into the *learning unit* but are referenced by links. At the moment, our component model does not define any further level for the aggregation of *learning units*.

Structured Markup

Generally structured markup is used in order to separate contents from presentation and navigation. Although HTML is a widely accepted markup standard, it allows content creators to mix structured markup with graphical styling thus not truly separating content and presentation. XML, too, is a markup language for contents containing structured information. Other than HTML, no specific set of elements is specified. XML provides means to define markup schemas, which will be well adapted to the structure of specific types of information (Walsh, 1998). This allows a specification of markup which designates the type of content in a meaningful way. For example, a markup schema for learning content could specify tags assigning the didactic purpose to the content. In the past some work has been done to define specific XML-schemas for learning content (Rawlings, Rosmalen, Koper, Rodriguez-Artacho, & Lefrere, 2002; St-Pierre, Hope, & Skublics, 2002). But up to now no proposed schema could be established as a basis for further standardization.

We propose to define the data structure of *content elements* by an XML *structured markup* schema and a set of *metadata* elements. The schema is simple, based on standard typographical elements, such as headers, paragraphs, list, and tables. As a *content element* should comprise only a single *didactic content type*, didactic information can be assigned to the content element as a whole using didactic metadata. The structured markup schema thus contains block elements (headings, paragraphs, annotations, lists, tables, images, multimedia elements) and inline elements (strong, emphasis, underline, superscript, subscript, links). Using standard typographical elements, the schema is anticipated to be familiar to content authors. Further, contents using this schema are likely to be easily convertible to possible future data formats. The markup schema remains stable, even if new didactic content types are needed – new types can flexibly be assigned using metadata.

The dLCMS Project

The *dLCMS* project aims at providing an implementation of the *component model* and the *structured markup schema* described above. It provides functionality for *flexible aggregation* of content elements to learning units, *centralized content management* which allows authors and teachers to collaboratively use and reuse learning resources, *flexible graphical design* through layout templates, and *export of learning units* in standardized packaging formats such as IMS Content Packaging (IMS, 2004) and SCORM (ADL, 2001). Authors shall be able to create contents using structured markup concentrating on their subject matter and without having to care about programming languages and graphical design issues.

The dLCMS functional architecture is based on four main components (see Figure 2). An *online editor* enables authors to create structured markup for content elements, without having to care about programming languages and graphical design issues. The *centralized repository* provides easy access to the learning resources. The *learning unit assembly* stage allows content elements to be aggregated in a sequential or hierarchical, chapter-like manner. The *publishing and export* stage provides flexible graphical styling using layout templates and an export function for learning units delivering standardized packaging formats.

The dLCMS is an extension of the open-source Silva content management system (Infrae, 2005). The main reasons to choose Silva as a basis for the implementation of the dLMCS were the integrated online XML editor and the extendibility of the open-source software product.

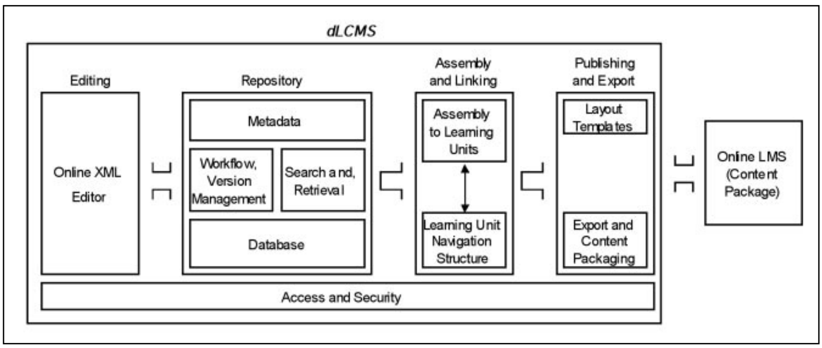

Figure 2. dLCMS functional architecture

Learning Unit Development Guidelines

Learning objects are a new way of thinking of learning content. Authors of learning resources might need guidance to adapt their thinking of learning material, which traditionally had been whole courses or lecture notes (Chitwood et al., 2000; Polsani, 2003). In order to support content authors to create self-standing learning objects, the "SCORM Best Practices Guide for Content Developers" (LSAL, 2003) suggests to start with an instructional strategy or with existing material and then to identify the learning objects based on learning objectives and on an analysis of the potential audiences. But it is still left open which level of granularity learning objects should have. The ISMELDO methodology to create learning objects (Baruque & Melo, 2003) is based on Instructional System Design (ISD). Using a top-down approach, the methodology analyses the task and contents to be taught and breaks the contents down into different "elaboration levels." Here learning objects are based on learning objectives and contain multiple didactic content types.

As in our case, content elements are based on single *didactic content types*, we have developed *learning unit development guidelines*, which should help authors to chunk learning content accordingly. In order to support the chunking process and the assembly of *content elements* to *learning units*, the *design* and the *development* phase of the general ISD model were extended. Thus our learning content development process can be divided into seven phases: *learning unit (LU) analysis, LU concept, content chunking, LU assembly, teaching,* and *evaluation* (see Figure 3).

Special attention was given to the modularization process, which was defined using a three step procedure:

1. First the content should be broken down into topics and subtopics, each of which is centered around a single objective. As a help to identify single objectives, the items should be labeled by their *knowledge type (concept, fact, procedure, process, and principle)*.

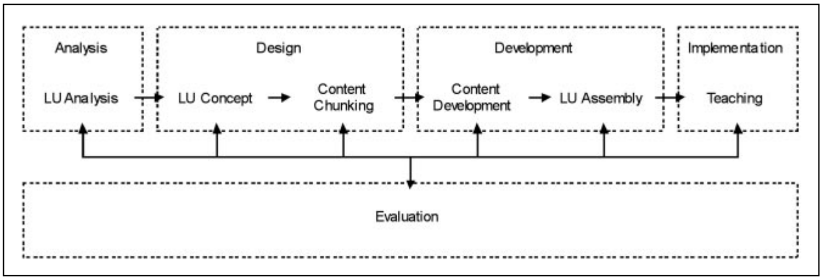

Figure 3. The seven phases of the learning unit development process: learning unit (LU) analysis, LU concept, content chunking, LU assembly, teaching, and evaluation

2. Then the *didactic content types* to be used should be assigned to every topic or subtopic. For every single *didactic content type* a separate *content element* should be created.
3. At last three to five other potential learner groups for the subject matter should be identified. The *content elements* specified so far should be analyzed for reuse with the potential learner groups. If only some parts of a *content element* fit the needs of a group it should be considered to divide it into two or more pieces.

Evaluation with Learning Content Authors

We have committed an evaluation of the *dLCMS* and the *learning unit development guidelines* described above, focusing on modularization and structured markup. The following questions guided this research: (1) Do authors understand the concept of modularization? (2) Can authors be supported by the guidelines to create modularized content? (3) Can small, self-contained *content elements* be aggregated to didactically coherent learning units? (4) Are specialized didactic content types and markup needed? (5) Do authors perceive structured markup as an aid or as constraint to creativity?

Authors from three different scientific domains (natural sciences, social sciences, engineering sciences) as well as one author working in the ICT services department of an academic environment used the *dLCMS* to create a web-based learning unit for the education of students or university personnel. The authors' task was the development of a *learning unit* used to teach a topic of their knowledge domain. The participants were free to choose the didactic strategy and methods, which they believed would suit their purposes best.

Preliminary analysis suggests that the proposed steps to modularize content described in the guidelines did not work well. The assignment of *knowledge types* was difficult and the analysis for other potential learner groups did not have any effect on the modularization structure. Anyway the participants reported that the guidelines would improve the didactic quality of the *learning unit*, having a structuring effect on the planning of the learning unit and the singular elements. Generally the participants were able to create modular, self-standing *content elements*, suggesting that they did understand the concept of modularization. These *content elements* could be aggregated to larger learning units, which corresponded with the authors expectations. In a few cases the participants stated that it should be possible to combine several *content elements* on a single page. Markup elements reported as missing concerned mainly specialized markup for literature and glossaries. Further, markup for multiple-choice like questions were missing. No author perceived the structured markup as constraining creativity.

Student Evaluation

One of the learning units created above was also evaluated by students. The driving question of the evaluation was: Do students perceive *learning units* which are based on modular *content elements* as didactically coherent? The *learning unit* was an introduction to usability evaluation and was used to teach students of an post-graduate study in ergonomics. A questionnaire, containing 17 items on students' previous computer and e-learning experience and on the didactic quality of the *learning unit*, was handed out to the students after they have worked with the *learning unit*. The results of the investigation were analyzed using descriptive statistics.

As a result, the students were able to easily detect the logical relationship between the pages. Therefore it may be concluded that it is possible to aggregate self-contained *content elements* to a larger coherent *learning unit*. The results further suggest that it is possible to provide a good didactic quality, provided that such a *learning unit* makes use of the advantages that e-learning can offer, such as the use of multimedia and elaborate interactive elements, and the possibility to learn anytime and anywhere. Further, modularized contents may yield to a good comprehensibility of the contents and a clear structuring of the subject matter. As the investigation looked at only one *learning unit*, which was specially developed for this instructional context by a single author for a specific target learner group, further research will be needed to generalize these findings.

CONCLUSIONS

The *dLCMS* provides an implementation of a simple and flexible component model based on three component types: *learning units, content elements*, and *assets*. *Content element*, comprising single *didactic content types* may provide a basis to define a standard level of granularity which, together with a structured markup schema based on standard typographical elements, allows contents from different sources to be coherently aggregated to *learning units*. The benefits of such a system allows different authors and institutions to define a corporate styling of their e-learning courses, even if the original contents come from sources all over the world.

The evaluation suggests that content authors in an academic environment understand the concept of modularization and that they are able to create modular building blocks of learning content which can be aggregated to larger *learning units*. It should be considered to provide possibilities to combine multiple *content elements* on a single page. The simple structured markup schema seems to be sufficient, provided it contains markup elements for literature references, and glossary entries. A separate markup schema for self-assessments and tests is desirable, it could be based on the IMS Question & Test Interoperability specification (IMS, 2005). In the content, authors opinion a good modularization methodology enhances the didactic quality of the *learning unit* and therefore pays-off. However further research is needed to provide better support for authors to create modular contents.

References

ADL (2001). *Sharable Content Object Reference Model (SCORM) version 1.2. The SCORM Content Aggregation Model* [Online]. Available: http://www.adlnet.org/

ARIADNE (2001). *ARIADNE Foundation for the European knowledge pool* [Online]. Available: http://www.ariadne-eu.org/

Barritt, C., & Lewis, D. (2000). *Reusable learning object strategy. Definition, creation process, and guidelines for building:* Cisco Systems Inc [Online]. Available:. http://www.reusable-learning.org/Docs/Cisco_rlo_roi_v3-1.pdf

Baruque, L. B., & Melo, R. N. (2003). *Learning theory and instructional design using learning object.* Paper presented at the Learning Objects 2003 Symposium: Lessons Learned, Questions Asked, Honolulu, Hawaii. Available: http://www.cs.kuleuven.ac.be/~erikd/PRES/2003/LO2003/Baruque.pdf

Chitwood, K., May, C., Bunnow, D., & Langan, T. (2000). Battle stories from the field: Wisconsin online resource center learning objects project. In D. A. Wiley (Ed.), *The Instructional Use of Learning Objects* [Online]. Available: http://reusability.org/read/chapters/chitwood.doc

Downes, S. (2001). Learning objects: Resources for distance education worldwide. *International Review of Research in Open and Distance Learning* [Online], 2(1). Available: http://www.irrodl.org/content/v2.1/downes.html

Duval, E. (2004). *We're on the road to….* Paper presented at the ED-MEDIA 2004, Lugano, Switzerland.

EducaNext (2004). *EducaNext: A service for knowledge sharing* [Online]. Available: http://www.educanext.org/whitepaper.pdf

Gagné, R. M. (1985). *The conditions of learning* (4th ed.). New York: Holt, Rinehart & Winston, Inc.

Hamel, C. J., & Ryan-Jones, D. (2002). Designing instruction with learning objects. *International Journal of Educational Technology (IJET), 3*(1).

IMS (2004). *IMS Content Packaging Information Model* [Online]. Available: http://www.imsglobal.org/content/packaging/cpv1p1p4/imscp_infov1p1p4.html

IMS (2005). *IMS Question & Test Interoperability: An overview* [Online]. Available: http://www.imsglobal.org/question/qti_v2p0/imsqti_oviewv2p0.html

Infrae (2005). *The Silva open source content management system* [Online]. Available: http://www.infrae.com/products/silva

LSAL (2003). *SCORM best practices guide for content developers:* Carnegie Mellon Learning Systems Architecture Lab [Online]. Available: http://www.lsal.cmu.edu/lsal/expertise/projects/developersguide/

MERLOT (2004). *Multimedia educational resource for learning and online teaching* [Online]. Available: http://www.merlot.org/

Polsani, P. R. (2003). Use and Abuse of Reusable Learning Objects. *Journal of Digital information* [Online], 3(4). Available: http://jodi.ecs.soton.ac.uk/Articles/v03/i04/Polsani/

Rawlings, A., Rosmalen, P. V., Koper, R., Rodriguez-Artacho, M., & Lefrere, P. (2002). *Survey of educational modelling Languages (EMLs)* [Online]. Available: http://www.cenorm.be/cenorm/businessdomains/businessdomains/isss/activity/emlsurveyv1.pdf

Schluep, S. (2005). *Modularization and structured markup for web-based learning content in an academic environment.* Aachen: Shaker Verlag. Available: http://e-collection.ethbib.ethz.ch/show?type=diss&nr=16062

Schulmeister, R. (2003). *Lernplattformen für das virtuelle Lernen: Evaluation und Didaktik.* München: Oldenbourg.

St-Pierre, R., Hope, P., & Skublics, S. (2002). *SCORM Dynamic Appearance Model. White Paper* [Online]. Available: http://www.online-learning.com/papers/SCORMModel.pdf

Walsh, N. (1998). *A technical introduction to XML* [Online]. Available: http://nwalsh.com/docs/articles/xml/

Virtual Workshop Environment (VWE): A Taxonomy and Service Oriented Architecture (SOA) Framework for Modularized Virtual Learning Environments (VLE) – Applying the Learning Object Concept to the VLE

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Based on existing Learning Object taxonomies, this article suggests an alternative Learning Object taxonomy, combined with a general Service Oriented Architecture (SOA) framework, aiming to transfer the modularized concept of Learning Objects to modularized Virtual Learning Environments. The taxonomy and SOA-framework exposes a need for a clearer definition of the aggregation and granularity of Learning Objects together with a clearer separation of data, presentation and application logics. The Virtual Workspace Environment (VWE) demonstrator shows that there is a necessity to unite fundamentals from computer science and pedagogical theories to achieve this.

The concept of Learning Objects has gained wide spread acceptance in the world of education. The main objective of Learning Objects is to provide a modularized model and standards that enhances flexibility, platform independence, reuse of learning content, and a higher degree of control for teachers and students.

Learning Objects have been around for a number of years now and the terms, definitions and meanings of the concept have changed over time. Much of the changes are due to the fact that standards have matured, implementation has shown that everything didn't work as expected, or depending on focus and theoretical perspective. A couple of things have never changed however, Learning Objects are always about modularized content and the focus is on small chunks of fairly context-independent content that can be assembled, reused, and is platform and vendor independent. An important condition to realize this, is the use of Learning Technology Standards such as IMS[1], IEEE/LTSC[2], SCORM,[3] and others. Learning Objects are also about the freedom of teachers and students – the freedom to choose, assemble, and contextualize.

The metaphor of Lego™ is often used to describe the characteristics of Learning Objects. The supporters of the Lego™ metaphor claim that anyone should be able to put together a *Learning Module* for a specific pedagogical context – simply by assembling the Learning Objects of their choice. The Lego™ metaphor is often criticized for being to simplified, which has lead to the development of more sophisticated metaphors. One that is commonly used is the metaphor of the atomic Learning Object, first addressed by Wiley (1999) and then refined (Song, 1999). The atomic Learning Object is submitted too much stricter rules and regulations. Not anyone can assemble Learning Objects and every Learning Object cannot be assembled with any other Learning Object – they must have certain attributes and possess certain properties to fit. The atomic view makes the e-learning life more complicated, but at the same time more realistic.

A slightly different approach to Learning Objects is taken by Song and Andersson (Song, 1999). Their definition of Learning Objects is in some respects similar to the Virtual Workspace Environment (VWE) taxonomy, since they mean that Learning Objects should be regarded as decomposable, and that there must be a separation between data, operations, and the carrier of the data. They also mean that an object should be described using a set of attributes and relationships to other objects. While they focus mainly on the *internal structure* of Learning Objects and their *relations to other objects*, the VWE taxonomy proposes a *general architecture model* and a taxonomy focused on the *architecture for composing* Learning Objects as well as on *the interaction* between objects.

Most of the discussion on Learning Objects is focused on modularized *content*. This view – about Learning Objects being exclusively about content – is in most cases unchallenged. There are however, several problems with Learning Objects that make it important to broaden the discussion. Many of the problems relate to how Learning Technology Standards are shaped and how Learning Objects architectures are designed, based on existing Learning Object taxonomies.

Two major problems were identified. The first problem is a problem related to pedagogy and the use of Learning Objects: *why do we have a modularized concept for content, where the aim is to attain maximum pedagogical flexibility, when we at the same time continue to accept nonmodularized, inflexible, and clumsy Virtual Learning Environments (VLE) that enforce pedagogical constraints and limitations?* It is an impending risk that teachers and learners may have content that suits the pedagogical approach of their preference, but which they are forced to fit in to a Virtual Learning Environment that doesn't. One basic assumption is that each teacher has his/her own favourite pedagogical methods and that he/she must be able to continue to use and enhance it even if he/she uses e-learning. This assumption is reversible and we can assume that most students have their own favourite methods for learning. Hence, the VLE must be able to support these methods, and we cannot allow the VLE to put limitations on the pedagogical possibilities created by Learning Objects.

The second problem is a more technological type related to architecture and the separation of data (information), presentation (context), and logics (interactivity). Most of the Learning Objects that were studied were typically a Flash-animation, a PowerPoint, or a simple Java-applet that implements an architecture where data, application logics, and presentation were shamelessly mixed into an architectural mishmash. This raises a couple of questions: What is content? Where does the content end and the VLE start? Should application logics rather be a part of the VLE?

The issues raised are complex and cannot be answered in a simple and obvious way, but hopefully they will initiate an important discussion. We believe that the present concept of Learning Object is too narrow to fulfil the vision of modularization and flexibility. Maybe we must "go the whole hog"? What if we apply the same modularized concepts to the VLE?

In Schluep, Bettino, Guttorsmen Schär (2005). emphasises the importance of the separation between content and presentation. Their suggested Component Model is very similar to the taxonomy suggested in this paper. Three component types are defined at different levels of granularity in Schluep et al. (2005): Assets, which are media elements; Content Elements, which are small modular pieces of learning content; and Learning Units which are aggregations of content elements. The components are kept together using a structural mark-up scheme defined in XML.

In this article we argue that the concept of modularization and Learning Objects must be expanded to comprise parts of the Virtual Learning Environment as well. To accomplish this, there is a need to modify the Learning Objects taxonomy. This is the view that constitutes the basis for the VWE project and the VWE Learning Object taxonomy (Berglund, 2003).

Learning Objects and Modularization of the VLE

The VWE project was initiated in 1998 to examine how to transfer the modularized concept from Learning Objects to the Virtual Learning Environment by tying them closer together.

To accomplish this, different definitions and models for Learning Objects and related concepts were examined in order to derive an altered model that suits a component-based learning architecture where both the content *and* the learning environment is considered within the same model. The resulting model was tested through the implementation of a framework for construction and use of component-based Virtual Learning Environments and learning content.

Based on existing Learning Technology Standards, as well as general technology standards, a prototype for a modularized framework was developed – the VWE (Paulsson, 2001). The VWE framework is *service-oriented* and consists of a set of *common services* that are needed for communication and interaction between different modules ("objects").

The main objective of the VWE-project was to develop a concept and a framework for the construction of component-based (or module-based) VLE that adapt to specific pedagogical contexts, includes all necessary functionality for a VLE and that supports the use of modularized content in a transparent way (Paulsson, 2002). A learning environment that is assembled using VWE consists of both functionality *and* content. The metaphor for such a learning environment is a *VWE Workspace*. The VWE workspace is what teachers and learners interact with. A VWE workspace can be personal, shared, or both. The components that provide functionality are referred to as *VWE Tools*. VWE Tools can provide any functionality, for example the functionality to communicate and collaborate, the functionality to produce, organize, use and manipulate content as well as the functionality for typical Learning Management System (LMS) tasks, such as to register courses, to enlist, assess, and grade students, and so forth. What is unique, however, is that both the functionality and the content are assembled in the same manner, based on the same taxonomy and within the same conceptual space.

THE VWE LEARNING OBJECT TAXONOMY

The development of the VWE framework started out in the same conceptual domain as Learning Objects, using the same Learning Technology Standards, using metaphors that are similar to the Atomic Learning Object metaphor and with the same aims for flexibility, adaptability, reuse, independence of technology, and software platforms, and so forth. A slightly modified Learning Object taxonomy, based on Wiley's taxonomy for the atomic Learning Object (ADL, 2001) was used in combination with a service-oriented architecture model to accomplish the goal. Wiley's taxonomy turned out to be suitable as a starting point since it categorises the different types according to their complexity and level of interactivity (and application logic).

The problem with the Atomic Learning Object Model is that its only foundation is Instructional Design Theory and it doesn't really consider architectural and Computer Science aspects, which makes it unsuitable for a concept like VWE in its original shape.

To enable the development of the VWE-framework there was a need to make a clearer definition of different concepts in the part of the *learning architecture*, where the Learning Object plays an important role. The analysis gave four basic categories of constituents that serve as building blocks:

Simple Learning Object

Simple Learning Objects are the smallest pieces of content that can be isolated and used as building blocks. A Simple Learning Object is an arbitrary *digital building block* that is described for use in a learning context. It is typically a picture, an animation, a text, an XML-file, and so forth. A Simple Learning Object can be equivalent to a *Fundamental Learning Object* – described by Wiley and Nelson (1998) as the most fundamental Learning Object – or it can be a *Fundamental Data Object* that is *not* a Learning Object by definition, but still relevant in a specific context.

Resource Object

The Resource Object has been added to the VWE LO taxonomy to allow separation of content, application logics, and presentation – as shown in Figure 1. The Resource Object is the building block that adds functionality (application logics) to the VLE as well as to the content in terms of Learning Objects. There are two different types of Resource Object, which are used in slightly different ways. The first type is the Helper Resource Object, which is used as a support component for content and especially for Simple Learning Objects. Examples of such use are an explorer/viewer for chemical molecules, for example using the Chemical Markup Language (CML), or an application that interprets and renders tests, for example using the IMS QTI specification. In this way the Resource Objects can be used for making Simple Learning Objects usable in a learning context through the construction of Grouped Learning Objects. The second type of Resource Object is the Creator Resource Object, which is used for adding functionality to the VLE, such as whiteboard functionality, authoring tools or tools for teacher/student planning, and so forth. The Creator Resource Object can be used as stand-alone – which may be the case with a whiteboard – where it can even be used to produce new Simple Learning Objects. It can also be used together

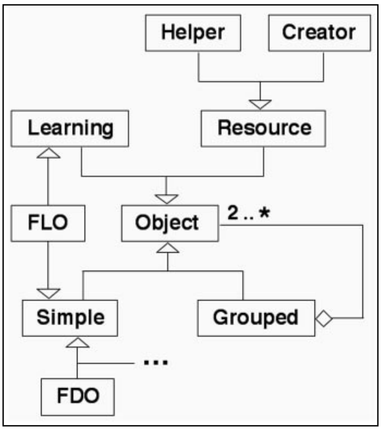

Figure 1. A concept map outlining the VWE Learning Object Taxonomy

with Fundamental Data Objects, such as student data, using the IMS Reusable Definition of Competency or Educational Objective (RDCEO,[IMS, 2002]). The Resource Object is also responsible for acting as a link between the Learning Objects and the rest of the Virtual Learning Environment, which means that the Resource Object must implement the required interfaces for interacting with relevant services. A Resource Object may provide both client and server functionality.

The Grouped Learning Object

At the next level of granularity in the VWE LO taxonomy there is the *Grouped Learning Object.* A Grouped Learning Object is the result of the combination of two or more Objects, such as Simple Learning Objects and Resource Objects. It is at the level of the Grouped Learning Object that the pedagogical context of the content starts to be shaped. The Grouped Learning Object embraces the rest of Wiley's Atomic Learning Objects taxonomy in the sense that all of the remaining types of Learning Objects *(Combined-Closed Learning Object, Combined-Open Learning Object, Generative-Presentation Learning Object and Generative-Instructional Learning Object* [Wiley, 2002]) can be assembled from Simple Learning Objects together with Resource Objects. The Grouped Learning Object can be regarded to be at the same level of granularity as the *Shareable Content Object* (SCO) defined in SCORM (Maise's Consortium, 2005). In the same manner as the Shareable Content Object, the Grouped Learning Object represents the lowest level of granularity that can be tracked by the VLE or LMS which is the term used by SCORM (ADL, 2001).

Learning Module

The final level of granularity is the Learning Module. A Learning Module is a collection of Grouped Learning Objects that are prepared for a specific learning context. They may contain content as well as parts of the functionality that constitutes the VLE itself. This is the level that concerns students. A Learning Module is typically an isolated part of a course such as e.g., a case scenario, one of the seven steps in Problem Based Learning (PBL, [Engdelius, 1999]) or anything else that a teacher or learner decides to regard as a clearly defined and isolated part of the learning experience. The Learning Module is actually a sort of Grouped Learning Object as shown in Figure

The relationship between the different levels of granularity and their implementation in VWE is illustrated in Figure 1 and Figure 2. Figure 3 shows a concept map describing the VWE Learning Object Taxonomy.

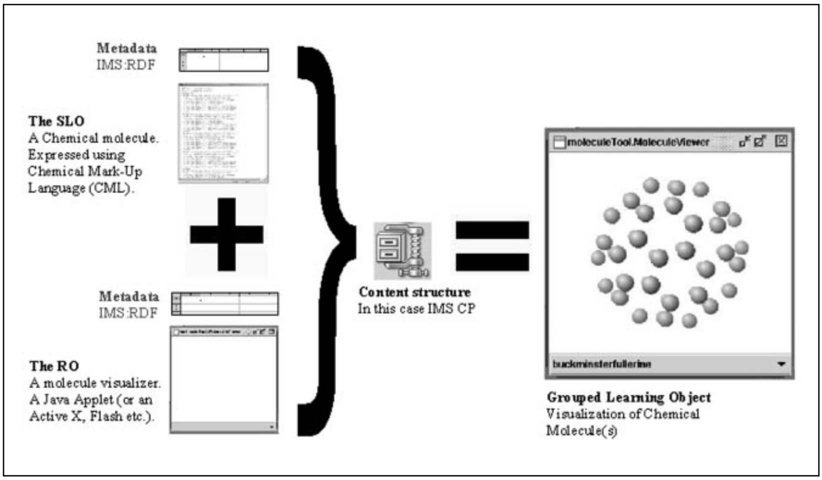

Figure 2. Shows the relation between a Fundamental Learning Object – in this case a CML/XML-file and a Helper Resource Object – in this case a generic CML Viewer. These are kept together by an IMS Content Packaging structure to form a unit that is a Grouped Learning Object.

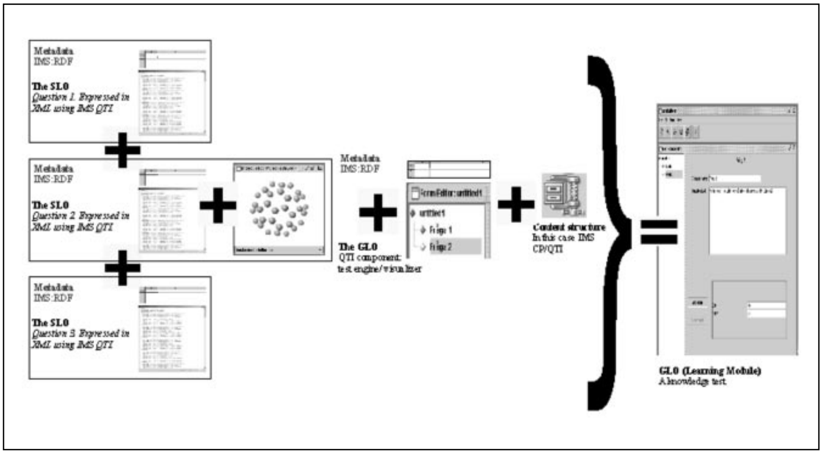

Figure 3. The relationship between several VWE Objects – in this case test questions which are Grouped Learning Objects – assembled using a Fundamental Learning Object and a Helper Resource Object. The second question uses another Grouped Learning Object to visualize chemical molecules. The result of the assembled and sequenced questions is a Learning Module – a knowledge test.

THE VWE ARCHITECTURE

There is a need for a general architectural model to implement Learning Objects according to the modified VWE taxonomy. The reason for this is that the new taxonomy addresses a common architecture as well, and the communication between Resource Objects and other parts of the Learning Environment (including Learning Objects based on other Resource Objects) becomes vital. The VWE learning architecture can diagrammatically be divided into three main parts: *VWE Services, VWE Kerne,l and VWE Tools*.

VWE Services

The *VWE Services* are needed to allow different components of the VWE workspace to interact with the VWE Objects. VWE has four basic services that are all implemented by most Resource Objects through a simple web service interface (Berglund, 2003).

User Service. The User Service handles issues concerning users (e.g., learners, teachers, and others), such as personal data, access, and rights. The User Service is linked to a login service, which may be linked to a local catalogue service.

Tool Service. The Tool Service keeps track of *VWE Tools.* Each VWE Tool is linked to a specific instance of a VWE Workspace. A VWE Tool is typically a Resource Object or a Grouped Learning Object.

Workspace Service. The Workspace Service handles common issues related to workspaces. Each user has access to one or more workspaces. The structure of a workspace is described with an IMS Content Packaging (IMS Global Learning Consortium, 2004) structure as well as with IMS Metadata, using the IMS RDF-binding (Nilsson, Palmer, & Naeve, 2002, http://kmr.nada.kth.se/el/ims/metadata.html).

Message Service. The Message Service is used for communication between different components of a workspace. Communication occurs between different VWE Tools and/or VWE Objects. The communication is handled through passing SOAP messages by way of the Message Service, which functions as a mediator between collaborating tools.

File Service. The File Service is actually a distributed file storage, which stores resources and metadata. The File Service is transparent to the type of resources, and it is used for storing user files, learning content, VWE Tools, and so forth. The File Service uses Semantic Web technology and is based on the SCAM[4] system (Palmer, Naeve, & Paulsson, 2004; Paulsson & Naeve, 2003). This means that the VWE File Service can be directly connected to other archive systems and Brokerage Services for Learning

Objects. The effect of this is that an instance of a VWE Workspace is not isolated and exclusively dependent on what is stored in its local storage. Learning Objects and Resource Objects can be seamlessly discovered and retrieved from other archives, such as archives in a P2P based *Edutella network* (Kraan, 2003) in which VWE can be set up as a peer. All VWE Services have been implemented using Web Service technology. This choice was made to obtain a service interface that is as standard-based as possible and at the same time avoids the problems that might be caused by firewalls and other bottlenecks in the learning infrastructure.

VWE Kernel

The VWE Kernel is a light-weight Java application that is downloaded to the browser as VWE is initialized. It is a "middle-layer" that handles the communication between the workspace, the tools on the client (the web browser), and the server-side services.

VWE Tools

VWE Tools are the most central from the user's perspective. VWE tools provide the functionality as well as the interactivity and presentation to the content. Most of the VWE-tools are Java-based and therefore executable in a web browser. However, it would be fully possible to use other browser-based technologies, such as ActiveX or Flash, to implement the VWE Service interfaces. The model that is facilitated by the VWE Learning Object Taxonomy enables functionality (tools) to be "installed" in a workspace at any time in the same fashion as new content can be added to a traditional LMS.

CONCLUSIONS AND FUTURE WORK

Our work demonstrates that it is possible to extend a Learning Object based model to embrace not only learning content, but the virtual learning environment as well, making it possible to construct a completely modularized learning environment that works in the same way as – and together with – Learning Objects for modularized content.

A model where the Learning Object concept is extended to include, at least parts of the virtual learning environment, provides a much higher level of flexibility and strengthens the characteristic of Learning Objects in terms of reusability, modularization, and decontextualization. The experience gained from the VWE project and the modified VWE Object Taxonomy indicates that the Learning Object concept and taxonomy cannot be based solely on instructional design theory (Wiley, 2002), but must also consider various architectural design aspects. The work done by Song and Andersson (Song, 1999) indicates this as well as the work by Schluep et al. (2005). The Component Model suggested Schluep et al., is in fact very similar to the

VWE taxonomy and the main difference is that the VWE taxonomy introduces the addition of the Resource Object address the separation of application logics. Altogether this indicates a need to unite fundamentals from computer science and pedagogical theories, such as instructional design and methodology, to find the extricating mix for Learning Objects.

Future research should continue to address the problem that the Learning Object concept still is too fuzzy, which has a restraining effect. There is a need to specify how concepts like objects, components, and modules interrelate to each other as well as to different standard specifications. There is also a need for more clearly defined architectural guidelines and best practices, where issues such as layering and interaction between components are addressed. Our work has resulted in some ideas in this area as well as some suggestions for a slightly altered object taxonomy that makes some of their interrelations between a bit more distinct.

One obstacle is that existing Learning Technology Standards are not sufficiently developed for this. Several of the specifications are still immature and in some cases still untested. Specifications such as IMS Content Packaging are limiting in the way that they are only able to describe very simple package structures, but more sophisticated specifications such as *IMS Learning Design* (IMS Global Learning Consortium, 2003) are interesting for future development. There is a need for additional standards, especially regarding architecture and interfaces for learning architecture. One step in this direction is the upcoming IMS General Web Services specification that will provide a basic structure for the definition of Web Services for e-learning systems (IMS General Web Services Public Draft Specification, 2005).

The main advantage of an architecture/framework such as VWE is that it enables the same conceptual model for the *entire* learning environment. The separation of data from application logics and presentation throughout the whole learning environment makes it possible to support various types of Learning Objects and related components to construct Learning Objects – as well as Virtual Learning Environments – that adapt better to most learning contexts. The modular approach together with the use of standards and interoperability frameworks, such as the Schools Interoperability Framework (SIF[5], [Software & Information Industry Association,]), facilitates the integration and interaction with other systems. It is relatively easy to develop a Resource Object that mediates between an external system and the VWE Message Service and that can be used by Learning Objects to interact with external systems – such as library systems or systems for student administration.

The VWE architecture suggests a Service Oriented Architecture (SOA) approach as SOA adapts well to the concepts of modularization (Smythe, Evdemon, Sim, & Thorne, 2004; Wilson, Blinco, & Rehak, 2004). There is an ongoing development within the learning architecture area, where similar problems are addressed. One of the most exiting projects is the work done in the O.K.I project (Thorne & Kahn, 2003) at MIT and especially O.K.I OSIDs and the way they are intended to be used (Kahn, 2004). O.K.I is similar to the VWE Services. Another, related project is the Sakai project (SAKAI Project,2004), where the O.K.I OSIDs are implemented. The work done in the "E-learning framework" (Wilson et al.; Wilson, Olivier, Jeyes, Powell, & Franklin, 2004) is another interesting SOA-initiative by the British *Joint Information Systems Committee* (JISC). The E-learning framework addresses similar problems as O.K.I. and both the frameworks will be evaluated for future use with VWE.

The primary reason for developing VWE as a demonstrator was to get a proof-of-concept for an alternative Learning Object Taxonomy and SOA-frameworks for Virtual Learning Environments. Of course, VWE is just one of potentially many ways to implement this, and there are still several unsolved problems. One of the more challenging ones is to replace the VWE interface with a suitable standard. The current VWE demonstrator uses SOAP and Web Service technology together with Java RMI (Govindaraju, Slominski, Choppella, Bramley, & Gannon, 2000), which is not good enough. Web Service technology is, in part, not powerful enough and creates overhead, while RMI is too Java specific. Since the overall objective is to provide a general model, it is important that the resulting architecture becomes as transparent and independent as possible.

A general problem affecting VWE is the lack of interoperable, sophisticated systems for metadata mark-up, archiving, search and retrieval, as well as for sequencing of learning resources (Resource Objects, Learning Objects and Learning Modules in the case of VWE). This reduces the flexibility and power of the VWE Learning Objects Taxonomy as well as the VWE framework itself, by preventing the existence of powerful, distributed networks of learning resources. One way out of this could be an increased use of Semantic Web technology, which can better support distributed metadata and Semantic interoperability. This is shown by the work done by the Edutella team (Nejdl et al., 2002) and the Knowledge Management Research Group[6] at KTH (Kraan, 2003; Palmer et al., 2004; Nilsson et al., 2002).

The details of the VWE SOA-framework, implementation and related findings will be addressed in future articles.

References

Advanced Distributed Learning (ADL). (2001). *Shareable content object reference model (SCORM) Version 1.2* Retrieved September 28, 2005, from http://www.adlnet.org/scorm/index.cfm

Berglund, M. (2003). *Virtual workspace environment: VWE 2 Book.* Retrieved September 29, 2005, from http://www.frepa.org/projects/vwe/vwe2.pdf

Engdelius, H. (1999). *Problembaserat lärande.* Lund: Studentlitteratur.

Govindaraju, M., Slominski, A., Choppella, V., Bramley, R., & Gannon, D. (2000). *Requirements for and Evaluation of RMI protocols for scientific computing.* Bloomington, IN: Indiana University, Department of Computer Science.

IMS Global Learning Consortium Inc. (2002). *IMS reusable definition of competency or educational objective – best practice and implementation guide.* Retrieved September 28, 2005, from http://www.imsglobal.org/competencies/rdceov1p0/imsrdceo_bestv1p0.html

IMS Global Learning Consortium Inc. (2003). *IMS learning design information model, Version 1.0 Final Specification.*

IMS Global Learning Consortium Inc. (2004). *Content packaging specification.* Retrieved September 28, 2005, from http://www.imsglobal.org/content/packaging/index.html

IMS Global Learning Consortium Inc. (2005, July). *IMS general web services public draft specification.* Retrieved August 28, 2005, from http://www.imsglobal.org/gws/index.html

Kahn, J. (2004). *Managing complexity and surviving technology change.* Cambridge, MA: MIT.

Kraan, W. (2003, November). *Using SHAME to fill your SCAM.* Retrieved September 28, 2005, from http://www.cetis.ac.uk/content2/20031105152216

Maise's Consortium. (2002). *Making sense of learning specifications & standards: A decision maker's guide to their adoption.* Retrieved September 28, 2005, from http://www.masie.com/standards/S3_Guide.pdf

Nejdl, W., Wolf, B., Qu, C., Decker, S., Sintek, M., Naeve, A., et al. (2002). *Edutella: A P2P networking infrastructure based on RDF.* Paper presented at the 11th World Wide Web Conference (WWW2002), Hawaii, USA.

Nilsson, M., Palmér, M., & Naeve, A. (2002). *Semantic web meta-data for e-learning – some architectural guidelines.* Paper presented at the 11th World Wide Web Conference (WWW2002), Hawaii, USA.

Palmer, M., Naeve, A., & Paulsson, F. (2004, 10 May 2004). *The SCAM Framework: Helping Semantic Web Applications to Store and Access Metadata.* Paper presented at the the European Semantic Web Symposium 2004, Heraklion, Greece.

Paulsson, F. (2001). *The Virtual Workspace Environment. VWE for Learning - Tomorrows learning environment today?* Paper presented at the I3 -2000, Jönköping, Sweden.

Paulsson, F. (2002, November 25-27). *The Learning Object: bridging the gap between vision and reality.* Paper presented at the NetLearning 2002, Jönköping, Sweden.

Paulsson, F., & Naeve. A. (2003). Standardized content archive management – SCAM. *IEEE Learning Technology Newsletter, 5*(1), 40-42.

SAKAI Project. (2004). Retrieved 20 February, 2005, from http://sakaiproject.org/

Schluep, S., Bettino, M., & Guttormsen Schär, S. (2005, March). *Modularization and structured markup for learning content in an academic environment.* Retrieved September 28, 2005, from http://www.cs.kuleuven.ac.be/~hmdb/ProlearnIClass/papers/Schluep.pdf

Smythe, C., Evdemon, J., Sim, S., & Thorne, S. (2004). *Basic architectural principles for learning technology systems* (Whitepaper): IMS.

Software & Information Industry Association (2002). *Schools interoperability framework implementation specification version 1.1.* Washington, DC: Software & Information Industry Association.

Song, W. W. (1999). *Metadata for the management of electronic documents in the governmental organisations and learning objects in the learning domain* (Research report No. SITI 99:03). Kista: SITI, SISU.

Thorne, S., & Kahn, J. (2003). O.K.I. ™ *architectural concepts*: Cambridge, MA: MIT.

Wiley, D.A. (1999). *The post-LEGO learning object*. Retrieved September 28, 2005, from http:/ /wiley.ed.usu.edu/docs/post-lego.pdf

Wiley, D.A. (Ed.). (2002). *The instructional use of learning objects* (1st ed., pp. 15-19). Bloominton, IN: Agency for Instructional Technology and Association for Educational Communications & Technology.

Wiley, D. A., & Nelson, L. M. (1998). *The fundamental object.* Retrieved September 28, 2005, from http://wiley.ed.usu.edu/docs/fundamental.html

Wilson, S., Blinco, K., & Rehak, D. (2004, July). *Service-oriented frameworks: Modelling the infrastructure for the next generation of e-learning systems,* Retrieved August 28, 2005, from http://www.jisc.ac.uk/uploaded_documents/AltilabServiceOrientedFrameworks.pdf

Wilson, S., Olivier, B., Jeyes, S., Powell, A., & Franklin, T. (2004). *A technical framework to support e-learning.* Retrieved August 28, 2005, from http://www.jisc.ac.uk/uploaded_documents/Technical%20Framework%20feb04.doc

Notes:

[1] http://www.imsproject.org/
[2] http://ieeeltsc.org/
[3] http://www.adlnet.org/
[4] http://scam.sourceforge.net/
[5] http://www.sifinfo.org
[6] http://kmr.nada.kth.se

A Metadata Profile to Establish the Context of Small Learning Objects: The Slicing Book Approach[1]

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In order to re-use small learning objects their correct technical and semantic context must be preserved. The paper discusses this problem based on the experience of re-engineering a large corpus of pre-existing texts into learning objects of fine granularity.

WHAT IS THE CONTEXT OF A LEARNING OBJECT?

There are a number of definitions of what a learning object is. All of these definitions emphasize the reusability of learning objects. Only few of them require that learning objects must be self-contained in some sense. In our view learning objects, which are literally self contained, that is, do not require any prerequisites, do not exist. To learn from a learning object, the learner needs the ability to integrate the information contained in this object into his/her view of the world. This requires establishing connections of the new information with existing knowledge. But that is only possible if the learning object is somehow related to other information in a way that can be exploited to connect it also with the learner's prior knowledge.

In his speech "Food for Thought" March 3rd 2005 at the Prolearn workshop in Leuven Wayne Hodgins promoted the use of learning objects, which are so small that they could not be made any smaller without loosing their re-usability. The following article describes some of the context related problems encountered when dealing with such small objects.

In fact there are good reasons to handle small learning objects. An example of a small re-usable learning object is a single line exercise from a textbook which may be re-used in an online test. The smaller the learning objects are, the more flexibly they can be combined and re-used. However, this does not come without a price. When learning objects are small, it is likely that an application will need many of them, and all of them have to be described by metadata, which may be costly to achieve.

But on the other hand, when small learning objects are embedded in larger structures, it may be possible to attach many of the required metadata to the fewer but larger aggregations of learning objects, which can be seen also as learning objects themselves, and to let this metadata be inherited by the small learning objects which make up the aggregation, thus saving a lot of the costs of manual metadata assignment.

It is also worth noting that there may not be a general optimal granularity of learning objects. A beginner trying to understand a certain subject may need the complete story with all arguments enclosed while an expert may want to lookup and reuse just the few small learning objects which are relevant for his/her actual case.

Small learning objects almost always are too small to contain all relevant information which must be understood in order to learn from them. Consider the following example.

If x and y are negative integers

- what is the sign of $x*y$?
- what is the sign of $x+y$?

We may consider this as a self contained learning object if we presume that the learner knows what are negative integers, addition, and multiplication.

When we consider instead just the question "what is the sign of $x+y$?" taken from this exercise it may not be reused without the information that x and y denote negative integers. Re-establishing this context is necessary for a proper reuse.

Let us slightly modify this example and look at it's source code, say from an HTML page:

If <i>x</i> and <i>y</i> are negative integers, <i>f</i> and <i>g</i> are the functions introduced in Chapter 2, Definition 1, then

 what is the sign of <i>f(x,y)</i>?

 what is the sign of <i>g(x,y)</i>?

We observe that each of the questions in this example has two strictly different kinds of context:

- To produce a technically correct document containing any of the list items, the … context must be restored. We call this the technical context of the learning object in question.
- To produce a semantically correct document containing any of the list items, the introductory sentence and the required definition from Chap-

ter 2 must be included. We call this the semantic context of the learning object in question.

We shall explain below how open specifications can be profiled to allow restoration of the technical as well as of the semantic context of learning objects for Slicing Book Technology.

BASICS OF SLICING BOOK TECHNOLOGY

Slicing Book Technology (Dahn, 2000, 2001) consists basically of the following four steps.

1. Existing documents are sliced into reusable learning objects.
2. The learning objects are augmented with metadata
3. Declarative rules describe which content should be presented to users depending on the user profile and the users's learning objectives (learning scenario)
4. On request of the user an automated inference system combines available information about the user and metadata of the available learning objects with the rules describing the requested documents in order to recommend a selection of learning objects to be presented to the user and possibly also to recommend an available style for presentation. The document is generated, possibly after further modification requested by the user, on the fly, and delivered to the user over the network.

We mention that Slicing Book Technology includes all elements of Semantic Web Technology, except that it is not assumed that the repository of objects is distributed. Slicing Book Technology can be applied to all well structured documents. Such documents are frequent in natural sciences, but also in some fields of social sciences, legal documents, or technical documents. Also documents in public administration or internal documents in companies frequently have a standard prescribed structure. Especially XML documents can be prepared for the application of Slicing Book Technology with a high degree of automation.

During the years 2000-2003, the European project Trial-Solution investigated the particular issues which emerge when this technology is applied to a number of books which have been previously created by different authors without regard to the technology. The Trial-Solution sliced books library contained 25,000 learning objects from 5,000 pages of text.

During the project a complete workflow was established, which covered automated and manual reengineering, metadata maintenance, and delivery. The tools developed in the Trial-Solution project exchanged sliced books in the form of IMS Content Packages. To meet the needs of the technology, the IMS Metadata DTD of that time had to be considerably modified. Current versions of IMS and IEEE LOM Metadata Schema and the new IMS VDEX

Vocabulary Definition Exchange specification offer more possibilities for profiling.

We will explain how these possibilities are applied to map the Trial-Solution Metadata to a profile of current IMS Metadata.

RESTORING THE TECHNICAL CONTEXT – THE HIERARCHICAL TREE FORMAT

The Hierarchical Tree Format is a simple format for the representation of sliced books. It is conceptually fundamental for Slicing Book Technology, though it is technically frequently replaced by other representations for efficiency reasons. So this format is not intended to prescribe any particular kind of implementation.

The Hierarchical Tree representation of a sliced book consists of a tree. The upper levels of this tree are in a one-to-one correspondence with the items in the table of contents of the original integrated preexisting document. Depending on the intention of reuse and on the possible reengineering efforts, this hierarchy may be further refined. Thus for the example given there would be a node in the tree for the group of questions and this node has for each of the questions a separate child node.

The content of the document to be sliced is distributed into files which are attached to these nodes. Usually this slicing process can be done with a high degree of automation. After this process each node can have a number of files attached. Usually there will be a file to be included into a document before any content taken from the subtree rooted at this node (a start file) and a file (the end file) to be included after all content from that subtree. For example the start file of the example above would contain:

```
If <i>x</i> and <i>y</i> are negative integers, <i>f</i> and <i>g</i> are the
functions introduced in <a href="definition2p1">Chapter 2, Definition 1</a>, then

  <ul>
```

while the end file would contain just

```
  </ul>
```

The leaves of the Hierarchical Tree will have attached content files, in our example the list items.

Before we continue we note that each learning object represented by a node of the tree may consist of a number of files, which are to be used in different roles (start or end file or also a variant suited for a particular presentation mode). The metadata application profile will have to take this into account.

The important feature of the Hierarchical Tree Format is, that for any selection of nodes of the tree the required technical context is recreated whenever the smallest subtree containing the selected nodes and rooted in the root of the complete tree, is traversed in a depth first manner and files attached to it's nodes are used according to their role. We note that all information necessary to reconstruct the technical context of a learning object are contained in the nodes on the path leading from the root of the Hierarchical Tree to the directory representing this object. Therefore we can state the following:

Path Inclusion Principle: Whenever a learning object is extracted from a sliced book for reuse, all information on the path leading from the root of the Hierarchical Tree to the node representing this object must be extracted too.

Quoting parts from a sliced book can be more precise than quoting a conventional text since the smallest reusable part can be referenced directly. To support a human readable form of such quotation, the concept of a *sourcereference* has been introduced and added to the metadata definition. The *sourcereference* of a node in the Hierarchic Tree is an integer, which denotes the position of this node among all nodes having the same parent directory. This *sourcereference* in combination with the path inclusion principle and the *sourcereferences* found on the path to an object assigns a unique sequence of numbers to each learning object, which describes exactly its position in the original work. *Sourcereferences* are also necessary to determine the sequence in which the nodes of a Hierarchical Tree have to be traversed.

RESTORING THE SEMANTIC CONTEXT – RELATIONS

Unlike for the technical context, restoring the semantic context requires domain expertise. In Slicing Book Technology this expertise is captured in assigning relations between learning objects and in defining declarative rules which specify how these relations are to be used to reconstruct an appropriate semantic context. The following set of relations has been selected as a minimal independent set. Other relations are inferred at runtime as needed or precalculated.

- To understand object A, the content of object B must be understood. We note that this is closely related to the surmise relation between topics discussed in Heller, Steiner, Hockemeyer, & Albert (2006, this issue).
- Each document containing object A must include object B.
- To understand object A, some part of the content of object B must be understood but A may be understood without understanding all of B.
- Object B contains an explanation for object A.
- Object B is a translation of object A.

Besides these, *External* relations are established between slices and external objects like external HTML pages.

The rules that are used to construct the semantic context also make use of other information that must be encoded in metadata. These are:

- key phrases taken from a structured thesaurus, and
- information about the semantic type of an object, for example whether it is an exercise or an example.

DEFINING METADATA

The Hierarchical File Tree Format can be encoded easily as an IMS Content Package, mapping the hierarchy to the default organization of the package. This gives the possibility to add metadata to the items of the default organization representing the directories of the file tree as well as to the individual files. Now the Path Inclusion Principle previously stated implies that with each item of a content package representing a sliced book also all metadata on the path to this item is extracted.

This gives the possibility to distribute the relevant metadata on this path and to avoid duplications. For example, information about the author and about the terms of reuse need to be kept only once at the top item. This leads to the following:

Metadata Inheritance Principle: Metadata can be inherited downward in the default organization of a content package. Inheritance must be declared.

PROFILING SPECIFICATIONS

The structure of sliced documents can be defined completely using the IMS Content Packaging specification. However it was not possible to capture all the metadata described above using one of the usual metadata schemas. Hence the IMS Metadata Specification was profiled. This IMS metadata profile consisted, in accordance with the forthcoming IMS Application Profiling Guidelines, of a description of the deviations from the IMS Metadata Specification.

The application profile suggested for supporting Slicing Book Technology is a mild extension of the IMS Metadata Specification 1.2.2, that is, the specification is only extended at the defined extension points. The *relation* and *classification* elements are optionally extended by information specifying the author of the metadata assignment, the status (whether it is authorized by some metadata maintenance authority), a declaration of inheritance and by a human readable description of the metadata assignment. The *kind* of a *relation* element is to be taken from a fixed flat vocabulary.

For the *learningresourcetype* element the use of a domain specific multilingual flat vocabulary is prescribed. The *technical* element is extended by an integer denoting the *sourcereference* as explained earlier and by a *resource* element, which in turn is extended by information about the role of the resource for a specific requested form of output.

Key phrases are described as *taxons* where the *source* refers to a multilingual hierarchical VDEX vocabulary. The aforementioned use of extension points for the *relation, classification*, and *technical* elements requires the addition of schemas for three new namespaces, which are referenced by the application profile. Note that the requirement of usage of a correct vocabulary is an additional constraint, which cannot be described as a modification of a single XML schema.

The problem that now remains to be solved is to handle multiple files that make up a learning object where these files have different roles. Unfortunately, the IMS Metadata *location* element does not have an extension point. Therefore, to modify the base specification as little as possible, it is proposed to let *location* point to a directory in the content package and to let the values of the *resource* element point to the files which make up this learning object.

No other changes of the IMS Metadata specification are required.

The Path Inclusion Principle and the Metadata Inheritance Principle constitute an intimate connection between the structure and the metadata. In contrast with the Content Packaging and Metadata Specification and their profiles they do not pose restrictions on the structure of documents but rather on allowed uses of sliced documents. Therefore they may be rather seen as specifications, which prescribe a certain behaviour of services using these sliced documents – the Path Inclusion Principle sets a condition for further disaggregation and the Metadata Inheritance Principle is relevant for services which search for the small learning objects inside sliced documents.

BENEFITS OF METADATA FOR SMALL LEARNING OBJECTS

While Slicing Book Technology has been mostly applied to add value to preexisting textbooks it is by no means restricted to texts. For example, it has been used within the German project In2Math to create on the fly interactive pdf documents where the content of some parts of was created dynamically on the server taking the user input and the user profile into account. One of the simplest applications of this is the dynamic random generation of examples or exercises adequate for the knowledge and interests of a particular user. More complex applications realized in In2Math permit the user to call an interface to an interactive system such as a computer algebra system, theorem prover, or note taker and to incorporate the output of this system as a new learning object into new course material.

Even if only a flat list of combinable learning objects with metadata and relations between them is available, the technology can be applied since the rule based inference engine used in Slicing Book systems can make use of the metadata and relations to produce content packages or documents for a particular learning purpose. As an application of the same technology in a different field, a congress planner was developed by Slicing Information

Technology GmbH, which created for participants of the Dutch Kennis-congress a selection of the many concurrent sessions according to the participant's interest.

For historic reasons it may be worth mentioning that the Trial-Solution project in 2001 decided to develop its own metadata DTD since the available metadata specifications did not allow an encoding of the required information explained earlier. Only recently with the availability of extension points in the specifications and with the support for structured vocabularies in the VDEX specification the mapping to an application profile of the IMS Metadata specification previously described became feasible.

This mapping was developed within the European project Telcert. A moderate collection of 500 small learning objects from the Trial-Solution project now serves within the Telcert project as a set of test data for a content test system which is to be automatically adapted to application profiles of eLearning specifications.

References

Dahn, I. (2000). Symbiose von Buch und Internet. *Proceedings of Learntec 2000*, (pp. 551-558), Karlsruhe, Germany

Dahn, I. (2001). Automatic textbook construction and web delivery in the 21st century. *Journal of Structural Learning and Intelligent Systems, 14(*4), 401-413

Heller, J., Steiner, C., Hockemeyer, C., & Albert, D. (2006). *International Journal of E-Learning, 5*(1).

Note

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Ontology-Based Learning Content Repurposing: The ALOCoM Framework

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This article reports on the development of a framework for repurposing learning object components, more specifically components of slide presentations. Unlike the usual practice where learning object components are assembled manually, the framework enables on-the-fly access and repurposing of learning object components. In earlier work, we have developed an ontology that formalizes structural aspects of learning objects. In this article, we present a framework that disaggregates slide presentations into this ontology format and reassembles their components (e.g., definitions, references) into new slide presentations.

Introduction

Issues concerning learning object (LO) re-use and repurposing are currently among the most important research topics in the learning technology community (Duval & Hodgins, 2003). In many cases, we need specific parts of a LO instead of the LO in its entirety. In that case, a definition, example or illustration is repurposed by copy and paste in new and different LOs. This approach is non-scalable in terms of maintenance, since each time a component is copied, a new place is created that needs to be maintained. It is possible to re-use LOs in a much more sophisticated way if we can access the components of a LO and repurpose them on-the-fly. This requires a more innovative and flexible underlying model for LO components (Duval & Hodgins, 2003).

In earlier work, we have developed an ontology that is an abstract learning object content model (ALOCoM), defining a framework for LOs and their components (Verbert & Duval, 2004). The ontology provides an explicit definition of the LO content structure, formally specifying both LO component types and relationships between those components. In this article, we present a framework that uses the developed ontology for composing and decomposing slide presentations. The framework transforms existing LOs from their tool specific formats (MSOffice, OpenOffice.org) into a representation compliant with the ALOCoM ontology. In this transformation process, the framework disaggregates LOs and provides direct access to their components, enabling their reuse in dynamic compositions of new LOs.

In the next section, we briefly outline the ALOCoM ontology. In the third section, we present the transformation framework, while we elaborate on LO repositories in the fourth section of the article. In the fifth section, the aggregation process and the generation of new MS PowerPoint and OpenOffice.org slide presentations is described, and the sixth section illustrates a scenario applying the framework. Related work, conclusions and remarks on the future work conclude this article.

The ALOCoM Ontology

In earlier work, we developed the ALOCoM ontology as a generic abstract learning object content model for learning objects and their components (Verbert & Duval, 2004). Figure 1 illustrates this model. The ontology distinguishes between content fragments (CFs), content objects (COs) and learning objects (LOs). CFs are learning content elements in their most basic form, like text, audio and video. These elements can be regarded as raw digital resources and are uncombined with other elements. COs aggregate CFs and add navigation. Navigation elements enable structuring of CFs in a CO. Besides CFs, COs also include other COs. Finally, LOs aggregate COs and add a learning objective.

We defined content types for each of these components. We introduced CF types such as image, text, audio and video. For defining CO types, we investigated existing information architectures, like the Information Block Architecture developed by (Horn, 1998) and the IBM Darwin Information Typing Architecture (Priestley, 2001). These architectures define information types (e.g., concept, principle, task) and their building blocks (e.g., example, definition, analogy). As a starting point, we defined CO types and their structure using DITA concepts, since DITA is a recent architecture with

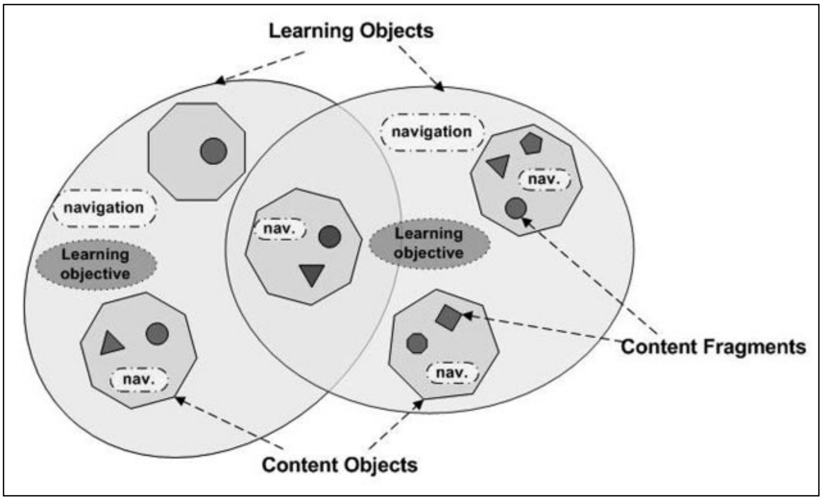

Figure 1. The Abstract Learning Object Content Model (ALOCoM)

rich documentation and online support (Priestley, 2001). Besides CF and CO types, the ontology defines LO types. For now, only a slide presentation LO type is defined. Finally, the ontology defines the relationships between the LO components. Aggregation and navigation relations are specified. Aggregation relationships between components are represented in the form of a *hasPart* and its inverse *isPartOf* ontology properties. Navigational relationships are specified as a list that defines the order of components in a CO or LO. For more information about the ontology, see (Jovanovic, Gasevic Verbert, & Duval, 2005).

The ALOCoM Framework

Our main focus is on the development of tools for extracting/transforming LO content into ontology-aware content (we call these tools disaggregators) as well as for repurposing ontology-aware content in real-world applications (aggregators). The ALOCoM framework supports both the process of aggregating and the process of disaggregating LOs. The framework maps different tool specific formats into representations compliant with the ALOCoM ontology and vice versa, ALOCoM instances into tool specific formats. For now, the framework supports slide presentations. Figure 2 illustrates the ALOCoM framework.

Since the most popular tools for slide presentation authoring are MS PowerPoint and OpenOffice.org (Najjar, Ternier, & Duval, 2002), the framework focuses for now on slide presentations authored using these tools. The process of content disaggregation performed inside the framework has an

OpenOffice.org (OO) or a MS PowerPoint slide presentation as its input. The slide presentation is parsed and disaggregated into clear segments (slides, paragraphs, lists, list items, images, diagrams, tables, etc.). Text patterns are applied to categorize these segments into more meaningful components like definitions, examples, references, introductions, and summaries.

Finally, components are described by metadata using the Automatic Metadata Generation framework (Cardinaels, Meire, & Duval, 2005). For more information about this disaggregation process, we refer to (Verbert et al, 2005). The annotated components are stored in LO repositories. Currently, there are two different LO repositories (LORs). These LORs are described in the next section. Once we have LO components available, these components can be retrieved and reassembled into new LOs. Export functions to MS PowerPoint, OpenOffice.org, SCORM[1], HTML, PDF and PS are provided as illustrated in Figure 2. The fifth section of this article elaborates on aggregating new LOs.

ALOCoM Learning Object Repositories

Two LO repositories (LORs) for storing ALOCoM components are presently available, serving different purposes and different communities. The first one is an ontology-based LOR that stores ALOCoM RDF/OWL instances. The ALOCoM framework uses Jena, a Java Semantic Web Frame-

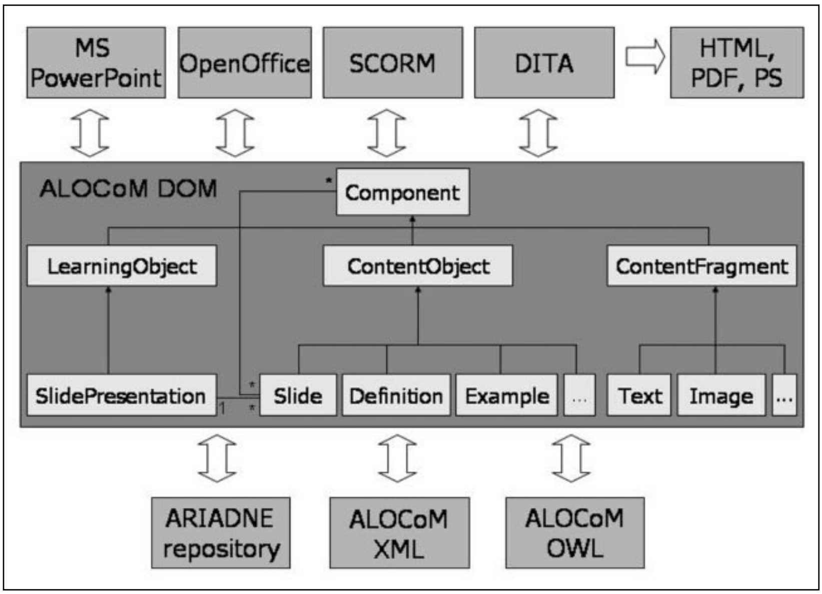

Figure 2. The ALOCoM framework

work (http://jena.sourceforge.net/) to manage this repository. Jena offers persistent storage models, which are continually and transparently persisted to a backing store. Persistent models can be maintained in a file system, or in a relational database. We query the LOR using RDQL, a query language for RDF. While not yet a formal standard, RDQL is widely implemented by different RDF frameworks. RDQL allows complex queries to be expressed concisely, with a query engine performing the hard work of accessing the data model (McCarthy, 2004).

ALOCoM components are also stored in an ARIADNE Knowledge Pool System (http://www.ariadne-eu.org/). The ARIADNE Search-and-Indexing Tool (SILO) can be used by teachers and authors to search for fine grained components like definitions, examples, references, images or single slides. Furthermore, any other application that wants to have access to ALOCoM components can search for components in the repository using the Simple Query Interface (SQI). For more information about SQI, we refer to (Ternier & Duval, 2005).

Aggregating New Learning Objects

LOs disaggregated in an ALOCoM format provide us with a flexible solution for repurposing LO components. LO components at different levels of granularity are available (CF, CO, LO). For instance, we can retrieve complete slide presentations at the LO level, definitions and examples at the CO level or just text fragments or images at the CF level. These components need to be reassembled in new LOs. Currently, all selected components are assembled in a new slide presentation. The framework supports MS PowerPoint, OpenOffice.org, HTML, PDF, PS, and SCORM output formats. For more information about the export functions to SCORM, PDF, PS and HTML, we refer to (Verbert, Jovanovic, Gasevic, Duval, & Meire, 2005). We will illustrate the generation of a new MS PowerPoint and OpenOffice.org slide presentation in the rest of this section.

Export of an ALOCoM slide presentation to a MS PowerPoint or OpenOffice.org slide presentation proceeds similarly. To generate OpenOffice.org slide presentations, we use the OpenOffice.org Application Programming Interface (API). This API is a comprehensive specification that describes the programmable features of OpenOffice.org (http://api.openoffice.org). MS PowerPoint presentations are generated using the MS PowerPoint .Net API. The generation of PowerPoint and OpenOffice.org Presentation Objects is analogous, as manipulating and interacting with these objects is similar. In both cases *slides* can be added to a *presentation object* and a *slide object* is a collection of shapes. This is a presentation-oriented representation of a slide, in the sense that every component that is placed or inserted on a slide is a kind of shape with presentation properties. Structure related information in ALOCoM components is mapped to the aforementioned presentation elements of the OpenOffice.org/MS PowerPoint format. For instance, the title and the body of an ALOCoM slide are mapped to two different rectangles in a slide object. Since we do not keep track of presentation related information, we use default presentation styles for the title of a slide, list items and other components.

Scenario

We use the framework to repurpose existing LO components in new LOs. Currently, we enable uploading of both MS PowerPoint and OpenOffice.org slide presentations. All components of these presentations are available for repurposing.

A typical usage scenario of the proposed framework goes as follows. Suppose an author is creating a slide presentation on differential equations. He/she wants to start with a definition, followed by three examples. The author enters “differential equations” as keywords and selects “definition” and “example” as types of components that he/she is interested in. The system then searches the LOR and retrieves all components of the selected types dealing with the selected topic. The author chooses the most relevant components from the set prepared for him/her. Furthermore, the author wants to include a reference to a book (s)he wants to recommend and an image of the book. Again the author searches the LOR and selects the component he/she wants to repurpose from the set of retrieved components. The author is free to choose the presentation form of the generated content assembly among MS PowerPoint, OpenOffice.org, HTML, SCORM, PS and PDF formats. The author enhances the automatically generated slide presentation with some additional information on the topic, and the presentation is finally ready for in-class use.

Related Work

The TRIAL-SOLUTION project is developing tools to create and deliver personalized teaching materials that are composed from a library of existing documents on mathematics at undergraduate level (Lenski & Wette-Roch, 2001). Analogously to the ALOCoM work, the TRIAL-SOLUTION project defines an ontology for LOs that includes mathematical categories like a definition, theorem, proof, or example. The focus of the project is on document (de)composition and exchange of LOs for reuse. The TRIAL-SOLUTION System contains a splitter that decomposes document source files into a hierarchy of slices. For this decomposition, the presentation style of a particular author is taken into account. Also, it takes care of counters and key phrases assigned by the author. As such, the methodology for decomposing LOs is more accurate but less scalable than the ALOCoM methodology presented in (Verbert et al., 2005).

The dynamic Learning Content Management System (dLCMS) project is implementing a component model that is similar to the ALOCoM model. The dLCMS component model distinguishes between assets, content element, and learning units (Schluep, Bettoni, & Guttormsen Schär, 2005). Assets are media elements such as images, videos, animations and simulations and are equivalent to ALOCoM content fragments. Content elements can be associated to ALOCoM content objects as they are aggregations of assets. This component type is based on didactic content types, such as examples, exercises, self-assessments, etc. The dLCMS component model imposes more specific constraints to this component type. Finally, learning units aggregate content elements and can be associated with ALOCoM LOs. With the implementation of this component model, functionalities for flexible *aggregations* of content elements to learning units are provided. The project is not concerned with the *disaggregation* of LOs however, and assumes the availability of fine grained components.

CONCLUSIONS

In this article, we presented the ALOCoM framework as a solution for repurposing LO components. The framework enables repurposing of LO components (e.g., definition, example, reference) in existing slide presentations. Furthermore, these components are automatically reassembled into new LOs and launched in the authoring tool the author is using. Next steps will extend the framework to support MS Word and OpenOffice.org Text Documents. This extension needs to incorporate some additional component types that are not used in slide presentations, for instance different levels of headings. Furthermore, the efficiency and effectiveness of this approach for LO repurposing will be evaluated. This work will then result in a general framework for reusable LOs, that allows not only automatic repurposing of LOs, but also their components and that will enable the dynamic generation of LOs, adapted to the needs of learners.

References

Cardinaels, K., Meire, M., & Duval, E. (2005). *Automating metadata generation: The simple indexing interface.* In Proceedings of the 14th International World Wide Web Conference, Chiba, Japan, 2005, pp. 1140-1141.

Duval, E. & Hodgins, W. (2003). A LOM research agenda. In *Proceedings of the twelfth international conference on World Wide Web,* Budapest, Hungary, 2003, pp. 1-9.

Horn, R. E. (1998). Structured writing as a paradigm. In *Instructional development: The state of the art.* Englewood Cliffs, N.J.

Jovanovic, J., Gasevic D., Verbert, K., & Duval, E. (2005). Ontology of learning object content structure. In *Proceedings of the 12th International Conference on Artificial Intelligence in Education,* Amsterdam, Netherlands, pp. 322-329.

Lenski, W. & Wette-Roch, E. (2001). The TRIAL-SOLUTION approach to document re-use principles and realization. In *Proceedings of Electronic Media in Mathematics, 2001.*

McCarthy P. (2004). *Use RDF models in your Java applications with the Jena Semantic Web Framework.* Retreived from http://www-128.ibm.com/developerworks/java/library/j-jena/

Najjar, J., Ternier, S., & Duval, E. (2002). The actual use of metadata in ARIADNE: An empirical analysis. In *Proceedings of the 3rd Annual ARIADNE Conference*, Leuven, Belgium, pp. 1-6.

Priestley, M. (2001). DITA XML: A reuse by reference architecture for technical documentation. In *Proceedings of the 19th Annual International Conference on Computer Documentation,* Sante Fe, USA, pp. 152-156.

Schluep, S., Bettoni, M., & Guttormsen Schär, S. (2005). Modularization and structured markup for learning content in an academic environment. In *Proceedings of the PROLEARN-iClass thematic workshop on Learning Objects in Context,* Leuven, Belgium.

Ternier, T. & Duval, E. (2005). Interoperability of repositories: The Simple Query Interface in ARIADNE. In *Proceedings of the PROLEARN-iClass thematic workshop on Learning Objects in Context,* Leuven, Belgium.

Verbert, K. & Duval, E. (2004). Towards a global architecture for learning objects: A comparative analysis of learning object content models. In *Proceedings of the 16th ED-MEDIA 2004 World Conference on Educational Multimedia, Hypermedia and Telecommunications,* Lugano, Switzerland, pp. 202-209.

Verbert, K., Jovanovic, J., Gasevic D., Duval, E., & Meire, M. (2005). Towards a global component architecture for learning objects: A slide presentation framework. In *Proceedings of the 17th ED-MEDIA 2005 World Conference on Educational Multimedia, Hypermedia & Telecommunications,* Montreal, Canada, pp. 1429-1436.

Verbert, K., Jovanovic, J., Gasevic D., & Duval, E., (2005). Repurposing Learning Object Components. *OTM 2005 Workshop on Ontologies, Semantics and E-Learning,* Agia Napa, Cyprus.

Notes

[1] Sharable Content Object Reference Model

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Competence-Based Knowledge Structures for Personalised Learning

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Competence-based extensions of Knowledge Space Theory are suggested as a formal framework for implementing key features of personalised learning in technology-enhanced learning. The approach links learning objects and assessment problems to the relevant skills that are taught or required. Various ways to derive these skills from domain ontologies are discussed in detail. Moreover, it is shown that the approach induces structures on the assessment problems and learning objects, respectively, that can serve as a basis for an efficient adaptive assessment of the learners' skills, and for selecting personalised learning paths.

Personalised learning aims to tailor teaching to individual needs, interests, and aptitude to ensure that every learner achieves and reaches the highest standards possible. It usually proceeds by assessing the learner's current knowledge state and probably other individual characteristics or preferences, and by using the results of this assessment to inform further teaching. Knowledge Space Theory (Doignon & Falmagne, 1985, 1999; Falmagne, Koppen, Villano, Doignon, & Johannesen, 1990) provides a foundation for personalising the learning experience. The theory, in its original formalisation, is purely behaviouristic. Various approaches have been devised in order to theoretically explain the observed behaviour by considering underlying cognitive constructs (e.g. Falmagne et al., 1990). These approaches focus on items' difficulty components, their underlying demands, and skills or competencies, and processes for performing them.

The following section will give an introduction to the basic concepts of Knowledge Space Theory. Subsequently, an extension of Knowledge Space Theory is suggested as a formal framework that can serve as a basis for implementing personalised learning into a technology-enhanced learning system. This approach incorporates explicit reference to underlying skills and competencies and integrates learning objects into an originally behaviouristic formal psychological theory with its focus on knowledge assessment. Its discussion covers the derivation of skills and their structure from ontological information, and elaborates on the impact of skill assignments on both the assessment problems and the learning objects. It is shown that these assignments induce structures, which allow for designing efficient procedures for adaptive assessment of the learner's competencies, and for generating personalised learning paths.

BASIC NOTIONS OF KNOWLEDGE SPACE THEORY

Knowledge Space Theory provides a set-theoretic framework for representing the knowledge of a learner in a certain domain, which is characterised by a set of assessment problems (subsequently denoted by Q). In this framework the knowledge state of an individual is identified with the set of problems the person is capable of solving. Due to mutual (psychological) dependencies between the problems not all potential knowledge states (i.e., subsets of problems) will actually be observed. If a correct solution to a certain problem can be inferred given another problem is mastered, then each knowledge state will contain the first problem whenever it contains the second one (i.e. the first problem may be considered a prerequisite to the second). To capture the relationships between the problems of a domain the notion of a surmise relation was introduced. Two problems a and b are in a surmise relation whenever from a correct solution to problem b the mastery of problem a can be surmised. A surmise relation can be illustrated by a so-called Hasse diagram (see Figure 1 for an example), where descending sequences of line segments indicate a surmise relation. According to the surmise relation shown in Figure 1, from a correct solution to problem b the correct answer to problem a can be surmised, while the mastery of problem e implies correct answers to problems a, b, and c. A surmise relation restricts the number of possible knowledge states and forms a quasi-order on the set of assessment problems.

The collection of possible knowledge states of a given domain Q is called a knowledge structure, whenever it contains the empty set Ø and the whole set Q. The knowledge structure K induced by the surmise relation depicted in Figure 1 is given by

$$K = \{ \emptyset, \{a\}, \{c\}, \{a, c\}, \{a, b\}, \{a, b, c\}, \{a, b, d\}, \{a, b, c, e\}, \{a, b, c, d\}, Q\}.$$

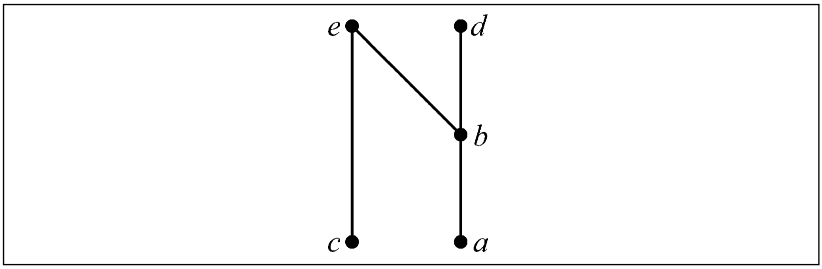

Figure 1. Example of a Hasse diagram illustrating a surmise relation on the knowledge domain *Q = {a, b, c, d, e}*

The possible knowledge states are naturally ordered by set-inclusion, which results in the diagram shown in Figure 2.

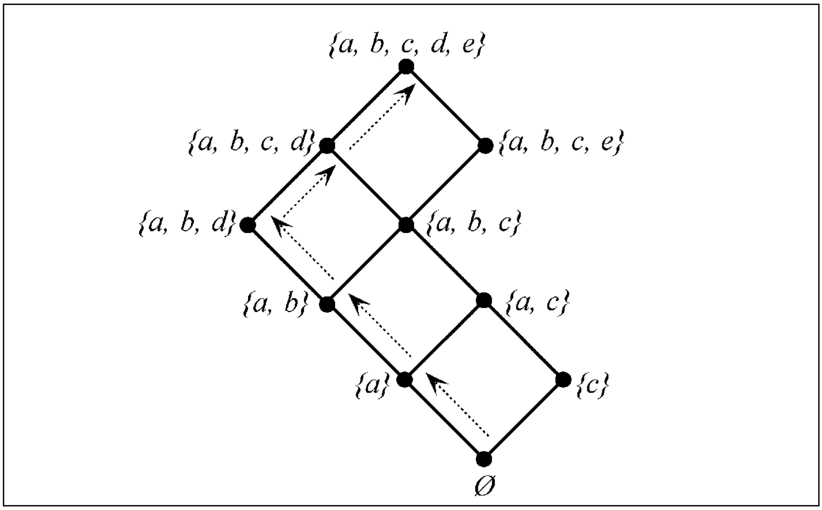

Figure 2. Knowledge structure *K* induced by the surmise relation of Figure 1. The dashed arrows indicate a possible learning path.

Figure 2 illustrates that there are various possible learning paths for moving from the naive knowledge state (empty set Ø) to the knowledge state of full mastery (set *Q*). One of the possible learning paths is indicated by arrows describing the possible steps of a learning process. It suggests to initially present material related to problem *a* (or, equivalently, *c*), followed by material related to problems *b* or *c* (*a*, respectively), and so on. Notice that the knowledge structure of Figure 2 is somehow special, as it allows for gradual learning. On the one hand, each knowledge state (except state *Q*) has at least one immediate successor state that comprises all the same problems plus exactly one. On the other hand, each knowledge state (except state Ø) has at least one predecessor state that contains exactly the same problems, except one. A knowledge structure with these properties, in which learning can take place step by step, is called well-graded. According to Figure 2, for instance, the states $\{a, b, c, d\}$ and $\{a, b, c, e\}$ are the immediate successor states to the knowledge state $\{a, b, c\}$. The set $\{d, e\}$ constitutes the so-called *outer fringe* of the knowledge state $\{a, b, c\}$. It consists of exactly those problems that a learner having knowledge state $\{a, b, c\}$ should tackle next, and can thus form a basis for generating personalised learning paths. The knowledge state $\{a, b, c\}$ has also two predecessor states, which are $\{a, b\}$ and $\{a, c\}$. The set $\{b, c\}$ represents the so-called *inner fringe* of the knowledge state $\{a, b, c\}$. Its problems may be seen as corresponding to the most sophisticated content that has been learned recently. This is the content that the learner should revisit, when previously learned material is to be reviewed.

Besides providing the information relevant for generating personalised learning paths, a knowledge structure is at the core of an efficient adaptive procedure for knowledge assessment. It allows for uniquely determining the knowledge state by presenting the learner with only a subset of the problems (for more details see “Problem-Based Skill Assessment”).

COMPETENCE-BASED EXTENSIONS OF KNOWLEDGE SPACE THEORY

Although there is a commercial learning system that is based on Knowledge Space Theory, which is the ALEKS system (http://www.aleks.com), this approach suffers from its limitation to a purely behaviouristic perspective. In its original formalisation, Knowledge Space Theory focuses completely on the observable solution behaviour, and does not refer to both learning objects and skills or competencies that are to be taught. To overcome these limitations Knowledge Space Theory may be extended so that it incorporates explicit reference to learning objects and underlying skills and competencies. The subsequent considerations are based on previous work by Falmagne et al. (1990), Doignon (1994), Düntsch and Gediga (1995), Korossy (1997, 1999), Albert and Held (1994, 1999), Hockemeyer (2003), and Hockemeyer, Conlan, Wade, and Albert (2003). It not only integrates these different contributions, but also derives their implications for implementing a personalised learning system, and clarifies the role of domain ontologies.

Extended Knowledge Space Theory is dealing with three different sorts of entities, which are:

1. the set Q of assessment problems,
2. the set L of learning objects (LOs),
3. the set S of skills relevant for solving the problems, and taught by the LOs.

Notice that the skills in the set *S* are meant to provide a fine-grained, low-level description of the learner's capabilities. Usually, it is a whole bunch of skills that is tested by an assessment problem, or taught by a LO.

Each of these basic sets is assumed to be endowed with a structure, which we conceive as a collection of subsets of the respective set. In particular, we consider

- a knowledge structure on the set *Q* of assessment problems,
- a learning structure on the set *L* of LOs,
- a competence structure on the set of skills *S*.

As outlined, the knowledge structure constitutes the collection of possible knowledge states and forms the basis of the problem-based assessment of a student's competency (see "Problem-based Skill Assessment"). Usage of the notion "competency" in the present context is in line with the terminology of Doignon and Falmagne (1999), which refers to subsets of skills that are collected in the competence structure, and which may also be called competence states. A competence structure may either be explicitly established by identifying prerequisite relationships between skills (see "Deriving Skills and their Structure from Domain Ontologies") that restrict the set of possible competence states, or it may be indirectly induced by assigning skills to assessment problems (or LOs) (see "Assigning Skills to Assessment Problems" and "Assigning Skills to Learning Objects"). The learning structure together with a student's current competence state is used to generate a personalised learning path. Learning and competence structures are defined in complete analogy to the knowledge structure previously introduced. Now, the main goal is to identify the pieces of information that are needed for establishing those structures.

SKILLS AND SKILL ASSIGNMENTS

Deriving Skills and their Structure from Domain Ontologies

This section addresses the question of how to identify skills that are relevant and suitable for modelling the underlying constructs of assessment problems and learning object regarding a certain domain. As an alternative to cognitive task analysis (Korossy, 1999), querying experts (Zaluski, 2001), and systematic problem construction by applying the component-attribute approach (Albert & Held, 1994), we propose to utilise information coming from domain ontologies.

An ontology allows structuring a domain of knowledge with respect to its conceptual organization. It constitutes a specification of the concepts in a domain and the relations among them and thus, defines a common vocabulary of the knowledge domain. A common and natural way of representing ontologies is by concept maps. The ontological information provided by a concept map can be used for identifying skills and for establishing a competence structure, respectively. In the sequel we outline two approaches, which differ with respect to the level of granularity of the underlying concept map.

Identifying skills with substructures of a concept map. Skills in terms of competence-based Knowledge Space Theory may be identified with substructures of a concept map representing the ontological information of the respective domain. This actually assumes a quite fine-grained representation, as it is necessary for a detailed characterisation of learning content, for example. A specific skill that is required for solving problems, or that is taught by learning objects, can be identified with a subset of the propositions represented by the concept map. Consider, for instance, the knowledge domain of right triangles. Figure 3 illustrates a possible assessment problem from this domain.

Solving this geometry problem requires to know the Pythagorean Theorem and how to apply it. Knowing the Pythagorean Theorem may be assumed to constitute a skill, which corresponds to a substructure of a concept map. Figure 4 provides an exemplary concept map that highlights the substructure representing this skill. Note that not all the relevant skills can be constructued in this way. The ability of applying the Pythagorean Theorem, for example, may be regarded as a related, but separate skill, which has to be added to the set of considered skills.

The representation of skills in the concept map may also be used for deriving dependencies between skills, e.g. by set inclusion. If the representation of a skill x in the concept map is a subset of that of a skill y, then skill x constitutes a prerequisite to skill y.

Using the component-attribute approach. Concept maps provide a tool for modelling the content of a knowledge domain, which is an essential part of curriculum and content analysis. Within this context the construction of concept maps aims at uncovering the prerequisite relations among the basic concepts within a topic, and between different topics of a subject. Such a con-

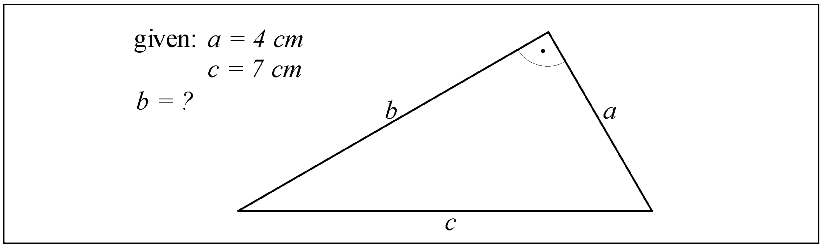

Figure 3. Example of an assessment problem for the knowledge domain "right triangles"

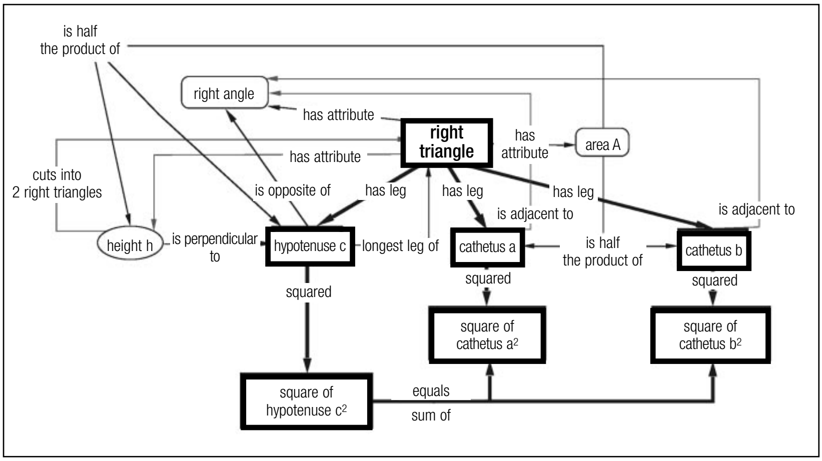

Figure 4. Concept map of the knowledge domain "right triangles." The marked substructure refers to the skill "knowing the Pythagorean Theorem."

cept map most probably will contain concepts on a higher level of abstraction, for example, Theorem of Pythagoras. This is in contrast to the more fine-grained concept map presented before, which also captures the definition or content of these general concepts.

Curriculum and content analysis not only reveal the basic concepts of a domain, but also the learning objectives that are related to these concepts. Learning objectives include required activities of the learner and may be captured by so-called *action verbs*. Action verbs (e.g., *state*, or *apply* a theorem) describe the observable student performance or behaviour and may be annotated to the nodes of the concept map representing the concepts that are to be taught. The information provided by the concept map then again can be used for establishing a competence structure in the sense of Knowledge Space Theory.

The concept map provides a hierarchical structure on the concepts of a domain. For instance, according to the curriculum the Pythagorean Theorem constitutes a prerequisite to the Altitude Theorem. This induces an order on the set of concepts C. The relation between the concepts may be represented graphically as in Figure 5(a). Additionally, a relation may be introduced on the set of action verbs A that induces a structure on it. For instance, to "state" a particular theorem is most likely a prerequisite to "apply" the respective theorem, and therefore, the action verb "state" can be considered as a prerequisite to the action verb "apply." The structure defined on the action verbs can also be illustrated by a graph (see Figure 5(b) for an example).

Based on these considerations, a skill in terms of extended Knowledge Space Theory may be identified with a pair consisting of a concept and an action verb (e.g. c_1a_2). As an example for a skill consider "apply the Pythagorean Theorem," which consists of the concept "Pythagorean Theorem" and the action verb "apply." Formally we define the set of skills by $S \subseteq C \times A$ to reflect the fact that not all combinations of concepts and action verbs may be meaningful, or even realisable. A crucial question is how to merge the two kinds of structures, that is, the structure on the set of concepts and the structure on the set of action verbs, to establish a structure on the set of skills.

To resolve this issue we suggest the component-attribute approach (Albert & Held, 1994, 1999). According to this approach components are understood as dimensions, while attributes are the different values these dimensions can take on. In the present context, the set C of concepts and the set A of action verbs are considered as the components, and the attributes are identified with the respective elements (e.g. c_1, c_2, c_3, c_4 in C and a_1, a_2 in A). On each component a relation is defined that orders the attributes (see Figure 5). A structure on the set of skills is then established by forming the direct product of these two components, which results in a prerequisite relation on the Cartesian product $C \times A$. The product of the two graphs displayed in Figure 5 is the relation depicted in Figure 6. From this you can see, e.g. that skill c_2a_2 is a prerequisite to the skills c_2a_1, c_1a_1, and c_1a_2, but to none of the other skills.

If S is a proper subset of the Cartesian product $C \times A$ then we consider the prerequisite relation that the direct product shown in Figure 6 induces on S. In the framework of extended Knowledge Space Theory the prerequisite relation on the skills is interpreted as a surmise relation that gives rise to the competence structure. The competence states contained in it have to respect the ordering illustrated in Figure 6, which means, for example, that with the skill c_3a_1 each competence state has to contain the skills c_3a_2, c_4a_1, and c_4a_2, too.

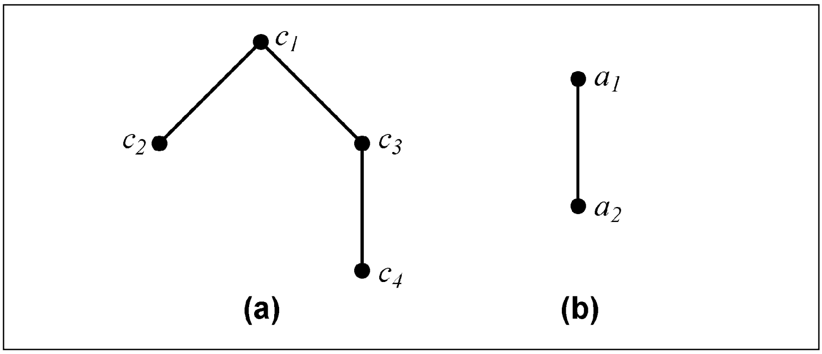

Figure 5. Concept structure (a) and structure defined on action verbs (b)

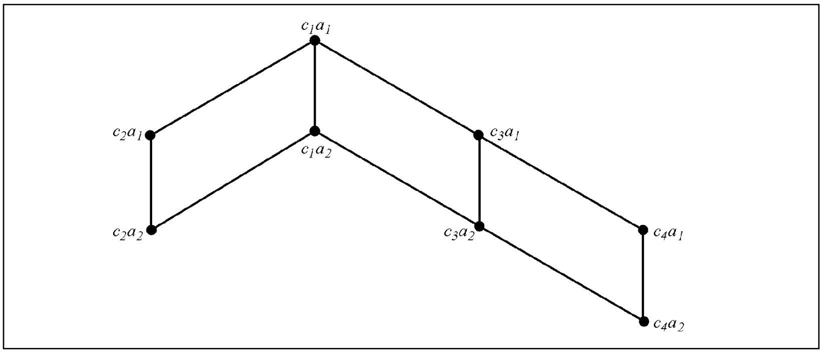

Figure 6. Example of a prerequisite relation on the skills induced by the structures on concepts and action verbs displayed in Figure 5.

Note, that from a psychological point of view, pairs consisting of a concept and an action verb, like “state Pythagorean Theorem” or “apply Pythagorean Theorem,” describe rather global skills. Applying the Pythagorean Theorem might require several more elementary skills, which are in correspondence with the distinct steps in a solution path (e.g., extracting a root, transforming). It may thus be necessary to characterise the skills at a more fine-grained level. Further research is needed to decide upon an optimal level of granularity of the skills.

Assigning Skills to Assessment Problems

Let us now consider the assignment of skills to the set of assessment problems. The relationship between assessment problems and skills can be formalised by two mappings.

- The mapping s (skill function) associates to each problem a collection of subsets of skills. Each of these subsets (i.e., each competency) consists of those skills that are sufficient for solving the problem. Assigning more than one competency to a problem takes care of the fact that there may be more than one way to solve it.
- The mapping p (problem function) associates to each subset of skills the set of problems that can be solved in it. It defines a knowledge structure because the associated subsets actually are nothing else but the possible knowledge states.

It has been shown that both notions are equivalent (Düntsch & Gediga, 1995), which means that, given the skill function, the problem function is uniquely determined, and vice versa. Consequently, only one of the two functions needs to be known to build the respective knowledge structure. Consideration is confined to the skill function, because it may be interpreted as representing the assignment of metadata to the problems. It follows that assigning (semantic) metadata to assessment problems puts constraints on the possible knowledge states that can occur.

We illustrate the intimate relationship between skill function and problem function by a simple example. Consider the knowledge domain $Q = \{a, b, c, d\}$, and let the skill function s on the set $S = \{x, y, z\}$ of skills be given by

$$s(a) = \{\{x, y\},\{x, z\}\},\ s(b) = \{\{x, z\}\},\ s(c)= \{\{x\},\{y\}\},\ s(d) = \{\{y, z\}\}.$$

This means, for example, that each of the skill sets $\{x, y\}$ and $\{x, z\}$ is sufficient for solving problem a. From the skill function we can derive the corresponding problem function, which yields

$$p(\varnothing) = \varnothing,\ p(\{x\}) = \{c\},\ p(\{y\}) = \{c\},\ p(\{z\}) = \varnothing,$$

$$p(\{x,y\}) = \{a, c\},\ p(\{x,z\}) = \{a, b, c\},\ p(\{y,z\}) = \{c, d\},\ p(S) = Q.$$

The assignment of skills to the assessment problems induces a knowledge structure on the set of problems, which is actually given by the subsets of problems in the range of the problem function. The knowledge structure for these examples is given by $\{\varnothing, \{c\}, \{a, c\}, \{c, d\}, \{a, b, c\}, Q\}$. Whenever a competence structure is available, e.g. as a result of exploiting ontological information (see "Deriving Skills and their Structure from Domain Ontologies"), the domain of the problem function is restricted to the actually occurring competence states. This puts additional constraints on the set of possible knowledge states.

In principle, the skill function for a given set Q of assessment problems may introduce dependencies between skills, too. It may be the case that a certain skill is required for solving a problem only in connection with another skill. In the above example the skill z is available only if either x or y is available. These dependencies, however, may only crop up in the given set Q, and it remains unclear whether they are valid in general. If capitalising on incidental dependencies between problems is to be avoided then the constraints the skill function puts on the possible subsets of skills should be neglected.

Problem-Based Skill Assessment

A knowledge structure can form the basis for devising an efficient adaptive procedure for knowledge assessment (Doignon & Falmagne, 1999; Dowling & Hockemeyer, 2001). Problem-based skill assessment proceeds in two steps. First, the knowledge state of a learner, which refers to the observable behaviour, is adaptively assessed. After identifying a learner's knowledge state, the knowledge state can be mapped to the corresponding competence state in a second step.

Considering the knowledge structure given in Figure 2 for the knowledge domain $Q = \{a, b, c, d, e\}$, in the beginning of an assessment phase all states of the structure may correspond to the knowledge state of an individual learner. According to a deterministic procedure, the assessment starts by selecting a problem that is contained approximately in half of the states of this structure and by posing this problem to the learner. Dependent on the learner's answer, the next problem will be selected. If the learner is capable of solving problem *b*, for example, then only the knowledge states containing problem *b* are still feasible. If subsequently problem *e* is solved, states $\{a, b, c, e\}$ and $\{a, b, c, d, e\}$ remain. The learner's knowledge state is uniquely identified after presenting problem *d*. For instance, state $\{a, b, c, e\}$ results if problem *d* cannot be solved by this learner. Thus, for a set of five assessment problems, the presentation of only three problems allows for identifying the knowledge state of a learner. Formally, the number of questions for determining the knowledge state of a learner is approximately the dual logarithm of the total number of knowledge states.

Aside from the outlined deterministic assessment procedure, assessment may also be embedded into a probabilistic framework. A probabilistic assessment method allows for considering that the knowledge states may occur with different frequencies within a population as well as that a subject sometimes may be careless in answering a problem or may guess the correct answer. Such an assessment method assumes an a priori likelihood function (e.g. probability distribution) on the knowledge states. Initially, this likelihood may depend on the learner's profile, for example, the age, or grade of this learner. Later, this probability distribution is updated consistent with the learner's answers to the posed problems. The questioning continues until there is a pronounced peak in the likelihood function that suggests a unique knowledge state for an individual learner.

The knowledge state identified for a learner then can be mapped to his/her competence state by using the skill function. This means that, given a knowledge state, we are looking for the subset of skills that are sufficient for solving the problems contained in the knowledge state. However, there may be more than one such subset. In this case the skills cannot be recovered uniquely given the assessed knowledge state. To provide an example, consider the skill function defined in "Assigning Skills to Assessment Problems." If we assume that the assessment converged to the knowledge state $\{c\}$ then it is unclear, which skills the learner is endowed with. According to the skill function either skill *x* or skill *y* may be responsible for solving problem *c*. This nonuniqueness occurs whenever a problem function is not one-to-one. Using additional information may lead to a unique identification of the available skills (e.g. looking up the learning history, checking for the skills actually taught). The best strategy, however, would be to select a proper set of assessment problems that avoids the nonuniqueness. Once the competence state of a learner has been determined it may serve as a basis for selecting a personalised learning path.

Assigning Skills to Learning Objects

The relationship between learning objects and skills is different from that between assessment problems and skills. The relationship between the set *L* of LOs and the skills in *S* is mediated by two mappings (Hockemeyer, 2003; Hockemeyer et al. 2003). The mapping *r* associates to each LO a subset of skills (required skills), which characterise the prerequisites for dealing with it, or understanding it. The mapping *t* associates to each LO a subset of skills (taught skills), which refer to the content actually taught by the LO. In a similar way as previously outlined, the mappings *r* and *t* induce a learning structure on the set of LOs, which plays a central role for generating personalised learning paths. The pair of mappings *r* and *t* also imposes constraints on the competence states that can occur. Again, these constraints are tied to the given set *L* of LOs. The imposed competence structure characterises the learning progress that may be achieved by studying the learning objects in *L*.

Generally, the assignment of skills to learning objects allows for deciding upon which learning objects are to be presented next, given a certain competence state. The concepts of inner and outer fringes (see "Basic Notions of Knowledge Space Theory") of a competence state may provide the basis for implementing personalised learning. The inner fringe of a competence state may be interpreted as "*what a learner can do*," while the outer fringe represents "*what this learner is ready to learn*." Therefore, proceeding in the learning process the next skills to be learned should be chosen from the outer fringe of the current competence state. Thus, a suitable learning object has to be selected that is characterized by required skills that the learner has already available and by taught skills that correspond to the outer fringe of the current competence state. If previously learned material has to be reviewed, then the content corresponding to the inner fringe of a learner's actual competence state seems to be a natural choice, because it contains the most sophisticated skills acquired by the learner.

CONCLUSIONS

The present article proposes a competence-based extension of Knowledge Space Theory that provides a formal framework for explicitly linking assessment problems and learning objects to the relevant skills and competencies. It is demonstrated that the assignment of skills to assessment problems (which are sufficient for their solution) induces a knowledge structure characterising the possible answer patterns of the learners. Moreover, it is shown that assigning required and taught skills to learning objects allows for generating personalised learning paths. Introducing skills provides a general framework for relating models of the domain, the learners, and the learning objects, as described by Bouzeghoub, Defude, Duitama, and Lecocq (2006, this issue). These authors also refer to information about what is required and what is provided by a LO, which is perfectly in line with the assignment of required and taught skills to LOs as discussed in "Assigning Skills to Learning Objects." The proposed skill assignments also contribute to the reusability of LOs (see Strijker & Collis, 2006, this issue).

The article provides a detailed discussion of how to derive relevant skills and their structure from domain ontologies. Two possible approaches are outlined. On the one hand, skills are identified with substructures of a concept map. On the other hand, skills are identified with pairs of concepts and action verbs, and a skill structure is established by merging the structures given on both sets. Assigning these skills to assessment problems and LOs, as suggested by the competence-based extension of Knowledge Space Theory, yields a framework for an efficient adaptive assessment of the skills and competencies of a learner, and for selecting personalised learning paths. This framework constitutes a valuable model for implementing personalised learning within an open technology-enhanced learning system. The implementation of the outlined theoretical framework within the iClass project is discussed by Türker, Görgün, and Conlan (2006, this issue), while Brady, O'Keeffe, Conlan, and Wade (2006, this issue) focus on the personalisation of the presented learning material via skill- or concept-based services offered by the Selector and the LO Generator module of the iClass system. A discussion of how to handle and integrate multiple skill assignments that characterize (partially overlapping) learning material coming from distributed resources is contained in Heller, Mayer, Hockemeyer, and Albert (2005).

References

Albert, D., & Held, T. (1994). Establishing knowledge spaces by systematical problem construction. In D. Albert (Ed.), *Knowledge structures* (pp. 78–112). New York: Springer Verlag.

Albert, D., & Held, T. (1999). Component based knowledge spaces in problem solving and inductive reasoning. In D. Albert & J. Lukas (Eds.), *Knowledge spaces: Theories, empirical research applications* (pp. 15–40). Mahwah, NJ: Lawrence Erlbaum.

Bouzeghoub, A., Defude, B., Duitama, J.F., & Lecocq, C. (2006). A knowledge-based approach to describe and adapt learning objects. *International Journal on E-Learning, 5*(1).

Doignon, J. (1994). Knowledge spaces and skill assignments. In G. H. Fischer & D. Laming (Eds.), *Contributions to mathematical psychology, psychometrics and methodology* (pp. 111–121). New York: Springer Verlag.

Doignon, J.P., & Falmagne, J.C. (1985). Spaces for the assessment of knowledge. *International Journal of Man-Machine Studies, 23*, 175-196.

Doignon, J.P. & Falmagne, J.C. (1999). *Knowledge spaces*. Berlin: Springer.

Dowling, C. E., & Hockemeyer, C. (2001). Automata for the assessment of knowledge. *IEEE Transactions on Knowledge and Data Engineering, 13*, 451–461.

Düntsch, I., & Gediga, G. (1995). Skills and knowledge structures. *British Journal of Mathematical and Statistical Psychology, 48*, 9–27.

Falmange, J.C., Koppen, M., Villano, M., Doignon, J.P. & Johannesen, L. (1990). Introduction to knowledge spaces: How to build, test, and search them. *Psychological Review, 97*, 201-224.

Heller, J., Mayer, B., Hockemeyer, C., & Albert, D. (2005). Competence-based knowledge structures for personalised learning: Distributed resources and virtual experiments. In G. Albano, P. Ritrovato, & S. Salerno (Eds.), *Proceedings of the 1st International EleGI Conference on Advanced Technology for Enhanced Learning.* Swindon Wiltshire, UK: The British Computer Society (BCS).

Hockemeyer, C. (2003). Competence based adaptive e-learning in dynamic domains. In F. W. Hesse & Y. Tamura (Ed.), *The Joint Workshop of Cognition and Learning through Media-Communication for Advanced E-Learning (JWCL), 2003*, 79–82, Berlin.

Hockemeyer, C., Conlan, O., Wade, V., & Albert, D. (2003). Applying competence prerequisite structures for eLearning and skill management. *Journal of Universal Computer Science, 9*, 1428-1436.

Korossy, K. (1997). Extending the theory of knowledge spaces: A competence-performance approach. *Zeitschrift für Psychologie, 205*, 53-82.

Korossy, K. (1999). Modeling knowledge as competence and performance. In D. Albert & J. Lukas (Eds.), *Knowledge spaces: Theories, empirical research, applications* (pp. 103-132). Mahwah, NJ: Lawrence Erlbaum.

O'Keeffe, I., Brady, A., Conlan, O., & Wade, V. (2006). Just-in-time generation of pedagogically sound, context sensitive personalized learning experiences. *International Journal on E-Learning, 5*(1).

Strijker, A., & Collis, B. (2006). Strategies for reuse of learning objects: Context dimensions. *International Journal on E-Learning, 5*(1).

Türker, A., Görgün, I., & Conlan, O. (2006). The challenge of content creation to facilitate personalized eLearning experiences. *International Journal on E-Learning, 5*(1).

Zaluski, A. (2001). Knowledge spaces mathematica package. In *Proceedings of PrimMath 2001 - Mathematica in Science, Technology and Education*. Zagreb, Croatia, University of Zagreb.

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Strategies for Reuse of Learning Objects: Context Dimensions

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Based on research in ten projects in a university, corporate learning, and military context, a set of dimensions is found that can help decision makers to develop strategies for reuse (Strijker, 2004). This article describes how these dimensions and their relation with human and technical aspects can be used in a reuse strategy. The dimensions can be used as a starting point to identify various aspects of reuse, but also to predict if a strategy for reuse can be successful in a certain organization. The following five different dimensions are identified: cultures within the context, learning scenarios, incentives for reuse, work processes, and how learning objects are stored. The context for each dimension can be more systems oriented or personal-oriented depending on the situation.

Projects Related to Reuse of Learning Objects

During the development of the specifications for learning technology during the period of 1997-2004 such as SCORM[1] and IMS QTI[2], various organizations started implementation projects to see if such specifications could be used to enhance reuse of learning material (Strijker, 2004). The projects primarily focused on the technical implementation, but gradually the human aspects became more important when tools could be actually used. A research project sponsored by military clients, Shell EP, and the University of Twente was started to see if there were differences between or similarities within the various organizations related to reuse of learning objects (Strijker, 2004). The research project was based on ten different projects that were initiated within a university, corporate learning, and military organization. The research projects used an action research approach and the researcher fulfilled different roles such as developer, analyst, and consultant within the projects. During the projects, information was gathered using structured interviews with system developers, course developers, and subject matter experts. In total, 57 participants were interviewed: 14 from a university context, 21 from a corporate-learning context, and 22 from a military context. Also the hands-on experiences with various learning management systems (LMS), learning content management systems (LCMS), authoring tools, and course management systems (CMS) in the various projects provided valuable information about technical aspects related to reuse of learning objects. The main research question was defined as: What are key dimensions to guide the selection of tools, technologies, and human procedures to support users in reuse of learning objects in different usage contexts, particularly university, corporate learning, and military training?

Dimensions for Reuse Strategies

The research of Strijker (2004) focused on the differences and similarities in the university, corporate learning, and military contexts. Besides the specific differences and similarities between the organizations, a set of more general dimensions were distilled that may be applicable for various strategies for reuse in different contexts. It was proposed that the following dimensions can be used as key indicators for a reuse strategy: cultures within the context, learning scenarios, incentives for reuse, work processes, and how learning objects are stored. The broader relations can be visualized as dimensions and each dimension can have at least two extreme values. In Strijker (2004), each dimension and its possible values is described in detail. Figure 1 shows the five dimensions related to a system and personal orientation combined as Learning Object Context Profiling Model.

As hypothesis for further research, the researcher proposed that the endpoints of the dimensions could be aligned so that the left extreme is related to a context that can be *systems-oriented* and the right extreme of each can be *personal-oriented*. The system orientation focuses on technical specifications, rules, policy, formality, and procedures as the key identifiers and can be the basis for a reuse strategy, the personal orientation is related to human interaction, personal needs, personal incentives, and personal values, and can support an individual user but does not support a reuse strategy. The two orientations can be seen as the end points of each dimension where also values between the endpoints can reflect the involvement of both orientations. The dimensions in Figure 1 can be used as a tool to profile the context of learning objects. From the research that has been carried out, it can be concluded that a systems-oriented setting is more favourable for a successful reuse strategy. The Learning Object Context Profiling Model can help increase awareness of stakeholders align the dimensions in a systems-oriented way can help to make a reuse strategy successful. This is described in the following sections.

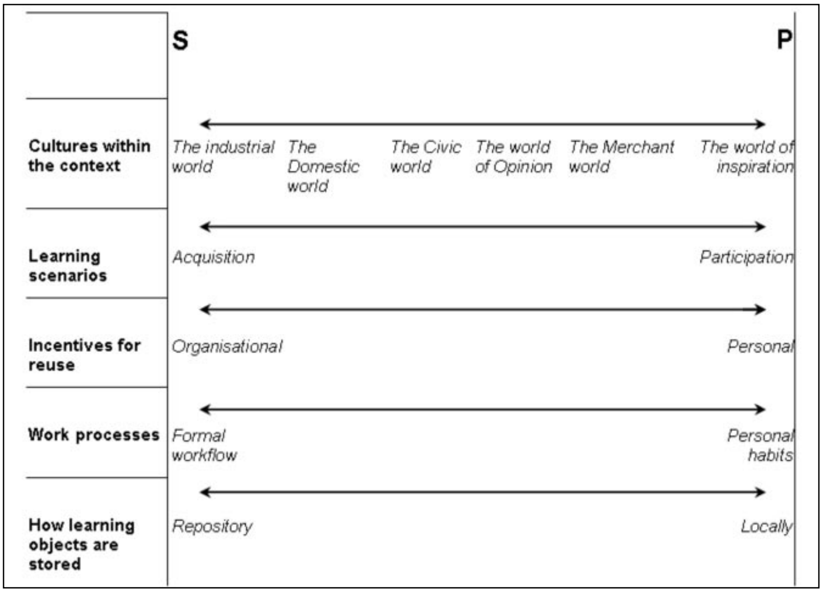

Figure 1. Learning Object Context Profiling Model

Learning Object Context Profiling Tool

The Learning Object Context Profiling Model has been deliberately presented as a set of parallel dimensions, each of which has a left-hand extreme value that corresponds to a systems orientation toward learning objects and reuse, and a right-hand extreme value that corresponds to a personal orientation. The tool is no more than the same graphic representation of the Model, but each dimension can be labelled 1 to 5, with 1 corresponding to systems oriented, with a vertical grid running through all of the 1 values on each dimension, and similarly all of the 2, 3, 4, and 5 values as shown in Figure 2.

These gridlines are used to plot the representation of a context involved with reuse and learning object, by marking each dimension on a scale of 1 to 5. By plotting the scores (usually obtained through a researcher's subjective assessment rather than a formal measurement) the characteristics of a course or curriculum or other setting can be placed on the different dimensions in the Learning Object Context Profile Model (see Figure 2). The profile of the particular context can be found when all dimensions are filled in and connected with a line and can show if the particular context for learning objects is systems oriented or personal-oriented. Thus the profiling process supported by the tool can be used to predict how learning objects can be specified in a certain setting and what type of learning objects can be expected to be effective and efficient for reuse. The model can also be used to observe, explain, or pre-

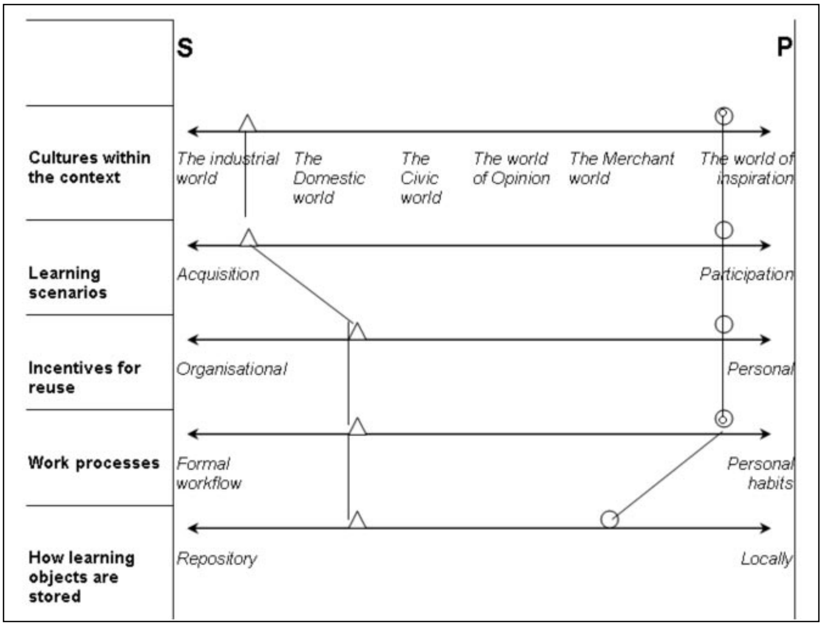

Figure 2. Learning Object Context Profiling Tool for descriptive purposes

dict how dimensions interrelate. When a course object is analyzed and found to be mainly on the left side of the scale, it is expected that a specific specification of learning objects can be made including a various set of characteristics such as a predefined instructional model, time constraints, testing, tracking, structure, and interactivity within the learning object rather than with humans as they make use of the learning object. Reuse is expected to be on an asset level because of the specific requirements. If a context or object is analyzed and is found to be mainly on the right side of the scale, the specification of learning objects has to be more general but specification of learning objects is still possible with descriptors such as subject and description. Reuse can occur with assets, but also sets of objects with a larger granularity can be reused. Because of the general nature of the object it is expected that reuse will be interesting if course developers/instructors can change or add pedagogical annotations to make a learning object useful for their own contexts.

The profiling that is possible with this tool can be used for descriptive, explanatory, or prescriptive tasks related to reuse, as described in the following sections.

Descriptive Task

The Learning Object Context Profiling Tool can be used to describe a certain context by filling in the values on each dimension. Plotting the values for each dimension can give insight about a certain context and help to describe the characteristics of a given context. An example is given for a computer based training (CBT) course from the military context and a blended-learning approach in the university context. The CBT course is represented in the model as a set of triangles. The blended-learning course is represented with circles. Figure 2 shows the Tool with the two different courses represented.

The differences in profiles of the two courses on the dimensions have a large impact on the specifications for the learning objects. For the CBT course the profile is shown as a systems-oriented orientation on the different dimensions. This can be seen in the figure; the more a profile is systems-oriented, the more likely that aspects of reuse will proceed smoothly in a particular context. Problems for a reuse strategy are the incentives for reuse, the lack of a formal workflow, and no central repository. In the university context reuse was occurring, but in a personal-oriented way. This means that the developers themselves may profit from reuse but exchange with other organizations or people may be problematic. Even though the advantage of this approach is that the use of a central repository can support reuse on a technical domain, reuse strategy may be problematic because no further dimensions are systems-oriented.

Explanatory Task

For the explanatory task, the Learning Object Context Profiling Tool can be used to do more than describe, but also to explain certain outcomes based on the orientation of values of the dimension. When the values for a given context are plotted on the dimensions, the tool can explain the reasons for failure or success of a reuse strategy.

The Learning Object Context Profiling Tool identifies important aspects for a reuse strategy. At the same time it is possible that not all dimensions have the same orientation because of the complexity of organisations and the different blends in learning scenarios. The results of the profiling with the tool may be difficult to interpret when such complex contexts are analyzed. The tool can be used to give information about courses and curricula in order to help explain why reuse may or may not be likely to take root. For example, problems may arise when a curriculum covers a very large cognitive domain of which the objectives range from knowledge to evaluation. This means that for one sub-context in the setting, one dimension may be systems-oriented and for another, a dimension may have a personal orientation. Such complex profiles are likely to explain why reuse strategies fail to become embedded in an organisation. On the other hand, a personal-oriented culture within a specific setting can influence the values of other dimensions, or when a particular organisational context has different world views in different subsets of the organisation. Boltanski and Thevénot (1991) describe how opinions about the underlying values of a culture can be influenced by the culture which dominates one's way of thinking. When a personal-oriented culture can be identified, it does not explain that reuse does not take place, it is expected that an overall reuse strategy is more difficult to implement because the lack of policy, incentives, and workflow. In Figure 2, the university is identified as a personal-oriented culture and that most dimensions are also on the right side. A reuse strategy depends on a more systematic approach supported by incentives that are part of an organizational policy, and an organized workflow. The dimensions mainly focused on the personal orientation explain why a reuse strategy is problematic in this setting.

Prescriptive Task

The tool can also be used to predict success or failure based on the system orientation or personal orientation of the profile, mapped on the five dimensions of the tool. For example, as shown in Figure 2 where the triangles are focused on a system orientation, it is expected that a reuse strategy within this setting can be very successful. However, suggestions can be made to improve the likelihood of success if a repository is used to share and exchange learning material.

CONCLUSION

For each context the strategy for reuse may be different because the cultures within the context can differ. The learning scenarios, the incentives for reuse, the work processes, and how learning objects are stored do not have to be the same. Identifying these dimensions as indicators for reuse strategy can be seen as a decision support tool for planning the reuse strategy. The dimensions can also be used to explain or predict why reuse is difficult in a certain setting. From the research that has been carried out it can be concluded that a systems-oriented setting is more favourable for a successful reuse strategy. The Learning Object Context Profiling Model can help increase awareness of stakeholders align the dimensions in a systems-oriented way can help to make a reuse strategy successful.

References

Boltanski, L., & Thevénot, L. (1991). *De La justification, Les economies de la grandeur.* NRF Essais, Gallimard.

Strijker, A. (2004). *Reuse of learning objects in context: Technical and human aspects.* PhD dissertation, Faculty of Behavioural Sciences, University of Twente, Enschede, Netherlands. ISBN 90-365-2090-9. [http://allardstrijker.nl/proefschrift].

Notes

[1] Sharable Content Object Reference Model (SCORM™)
[2] IMS Question and Test Interoperability

A Knowledge-Based Approach to Describe and Adapt Learning Objects

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Our claim is that semantic metadata are required to allow a real reusing and assembling of learning objects. Our system is based on three models used to describe the domain, learners, and learning objects. The learning object model is inspired from knowledge representation proposals. A learning object can be reused directly or can be combined with other learning objects using composition operators with well-defined semantic. Using these models we are able to define powerful search tools and an adaptive environment taking as input the learner model to construct the learning object to deliver. We are currently implementing this system using Sesame, an RDF repository.

The development of technology-enhanced learning has been very high these last years. There are now numerous pedagogical materials available on the Web (the so-called learning objects – LO). An important problem is to offer tools allowing users (learners and authors) to search for existing learning objects. Authors are interested in existing objects to reuse them directly or to combine them with other objects. Learners of course want to use these objects to improve their knowledge. To facilitate the search and reuse, some standards for metadata have been proposed such as LOM (IEEE, 2002) and SCORM (Advanced Distributed Learning Initiative, 2001). Learning objects are stored into repositories such as Ariadne knowledge pool (Duval et al., 2001) or Educanext (Law, Maillet, Quemada, & Simon, 2003) which implement LOM like metadata. In our opinion these proposals are not so powerful because the description of learning objects does not include their semantic. In the SIMBAD project (SIMBAD, 2004) we are investigating semantic extensions to existing metadata standard such as LOM. This will allow us to define powerful search mechanisms, to propose formal composition operators to create new objects, to offer different learning strategies to learners and to adapt learning objects content to learners (one to one delivering).

This article is structured in the following way. In the first section "The Three-Levels Model," we present our approach based on a three-levels model (domain model, learner model, learning object model). In the next section "Learning Strategies and the Adaptive Process," we present the different learning strategies proposed to learners and the associated adaptive process. Finally we conclude and present some discussions about the manipulation of learning objects distributed across several repositories.

THE THREE-LEVELS MODEL

Our claim is that semantic metadata are required to allow a real reusing and assembling of learning objects. Our system is based on three models presented in detail in (Bouzeghoub, Carpentier, Defude and Duitama, 2003): (a) the domain model, which represents the concepts covered by the LO, (b) the learner model, which keeps the profile of learners, and (c) the learning object model, which describes LO content related to the domain model. Using this knowledge we can propose sophisticated tools for searching and browsing into the LO repository. Authors can reuse and compose existing LO using operators (such as sequence, alternative, parallel) to produce new LOs. A LO may be automatically adapted to a specific learner.

In the following we present successively the domain model, the learner model, the learning objects model, and the associated properties.

Domain Model

Our approach uses ontologies to describe the domain model. The goal of this model is to define a normalized and common referential among all learners of the system (administrator, authors, and learners). The precision level of the model defines the precision of the system; that is, if we choose a very precise domain model, the system will be able to provide a more sophisticated inference task.

We define a terminological ontology for every specific knowledge domain; it is intended to describe its most relevant concepts. This ontology defines concepts and relationships among them. We use two types of relationships: a narrower/broader relationship to support hierarchical links between concepts and a set of rhetorical relationships such as contrast or extend.

Learner Model

An adaptive e-learning system may adapt contents depending on learners' background, preferences, and goals. Our approach considers the three aspects. It uses an overlay model to maintain an evaluation of learners, and allows the learner to select preferences such as language, format, and maximal learning time. Finally, a learner selects goals from concepts of the domain model.

We describe a learner under two facets. The first one, called his/her preferences, describes facts (name, e-mail, language, ethnicity…) and is modelled with a set of couples (attribute-value). The second one called knowledge, describes concepts known by the learner qualified with one or several roles (e.g., introduce, define, resume) and a weight (learner level for this concept-role). A learner knowledge grows dynamically when he/she acquires new concepts.

Learning Object Model

To be found and reused, a LO must be described by a set of metadata. In the LO model, we distinguish two types of metadata: the first one describes LO general characteristics (e.g., author, title, language, media) using LOM standard and the second one describes the semantic of the LO. This semantic is structured in three parts and described in the same way as software components: prerequisites are the LO inputs (what is required by the LO) whereas content and acquisition functions are its exits (what is provided by the LO).

The LO prerequisites are a set of triples (concept, role, level); the content is described with a set of couples (concept, role); the acquisition function indicates which triple (concept, role, level) will be added to the learner model if a condition of validation is satisfied.

A LO can be a set of web pages, a file, or a program (a simulator for example). We just suppose that it is a unit accessible by the way of an URL. This unit can be used independently or for composition by third parties. We have defined composition operators (SEQ, ALT, and PAR) to compose recursively LOs. A composed LO is an acyclic oriented graph where nodes are learning objects, or operators. Failure nodes can be added to the composition graph to define an alternative path if a LO is not successfully visited.

Intensional LOs have been introduced in order to support more generic and flexible LOs for authors and to increase flexibility in the adaptation process. It allows authors to define a virtual LO, which can be considered as views on actual LO.

An intensional learning object (ILO) is a composed LO whose composition graph has at least one node defined by a query instead of a specific object. In other words, an ILO can have three kinds of nodes: an *operator-node* (SEQ, ALT, or PAR), a *LO-node* and a *query-node*. A *query-node* is defined by an intensional query (IQ) specifying the condition to be satisfied by candidate LOs. An IQ is defined by:

$IQ = Q_{content} \wedge (Q_{prerequisite} \vee Q_{educational})$

$Q_{content} | Q_{prerequisite} = (c_{1,1}, r_{1,1} \wedge \ldots \wedge c_{1,k}, r_{1,k}) \vee \ldots \vee (c_{n,1}, r_{n,1} \wedge \ldots \wedge c_{n,m}, r_{n,m})$,

where c is a concept, r a role, k, n and m ≥ 1.

$Q_{educational}$ is a logical combination of attribute – value comparisons.

$Q_{content}$ cannot be empty but $Q_{prerequisite}$ and $Q_{educational}$ can.

The semantic of a query-node is partly defined at authoring time: it has always a content (its $Q_{content}$) but the other parts of its description may be undefined. At delivering time, all query-nodes of an ILO will be processed. If (at least) one query-node is empty (its corresponding query returns an empty set), the ILO is undefined and cannot be delivered. If all query-nodes return some LOs, these LOs will be composed by an ALT operator (the ILO is fully instantiated). A fully instantiated ILO can be adapted and delivered as a classical LO.

Learning Objects and Learners Properties

Our models of learners and LOs allow us to define several properties (in the following LO_1, LO_2 are two learning objects and L is a learner):

- satisfaction: L *satisfies* LO_1 when his model includes prerequisites of LO_1. This property is mainly used during the adaptive process (see next section);
- master: L *masters* LO_1 when his model includes LO_1 content;
- substitution: LO_1 may be *substituted* to LO_2 when LO_1 prerequisites are equals to LO_2 prerequisites;
- equivalent: LO_1 is *equivalent* to LO_2 when LO_2 can be substituted by LO_1 and LO_1 content is equals to LO_2 content;
- weak precedence: LO_1 *weakly precedes* LO_2 if LO_1 content is included inside LO_2 prerequisites; and
- strong precedence: LO_1 *strongly precedes* LO_2 if LO_1 content is equals to LO_2 prerequisites.

The four last properties (from substitution to strong precedence) are used to automatically classify the set of learning objects. This is the basis of our browsing tool.

LEARNING STRATEGIES AND THE ADAPTIVE PROCESS

Our approach supports two learning strategies: concept-based and goals-based learning. The latter allows learners to define their goals from the domain model, whereas the former provides guidance and helps to meet course objectives. (Duitama, Defude, Bouzeghoub and Lecocq 2005), describes in detail our vision of LO adaptation and learning strategies. This section describes the learning object model and introduces scenarios where adaptation is required. The adaptive system is materialized by combining the three levels of modeling previously described, which are the domain model, the learner model, and the learning object model.

In course-based learning strategy, a learner selects a learning object LO_j from the learning objects repository. At authoring time, authors may have specified a LO as a composition graph (CG) of learning objects. When a LO is chosen by the learner, its composition graph is transformed to obtain a set S_1 of delivering graphs (a delivering graph is a graph without the ALT operator). This set of delivering graphs will be filtered at delivering time in order to select the "best" composition according to the learner model. This filtering process is called "the adaptive process," and is divided into several steps shown in Figure 1. First, the system builds S_2, the set of delevering graphs meeting prerequisites satisfied by the learner model. Second, the learner preferences (e.g., the type of media, the language) are applied to construct S_3. If there are several graphs satisfying this step, the system (or the learner in an interactive process) will choose only one. If the resultant set is empty, it implies that the current learner cannot access this course because he/she has not sufficient knowledge (the system can state the missing knowledge). Finally, the selected graph is simplified, that is all the nodes having their content already known by current learner are annotated (see adaptive navi-

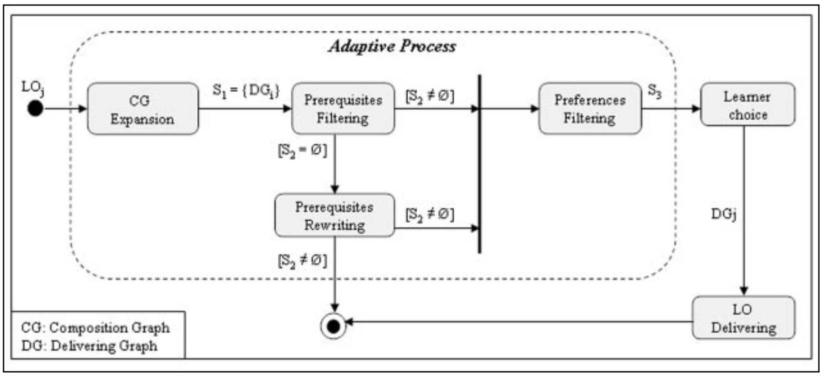

Figure 1. Activity diagram of course-based interaction

gation and presentation in (Brusilovsky, 1996). Of course, if the same conceptual graph is delivered to another learner, the selected delivering graph can be different.

In goals-based learning strategy, a learner formulates a query over concepts of the domain model. The general form of this query is the following:

$$Q = (c_{1,1}, r_{1,1} \vee \ldots \vee c_{1,k}, r_{1,k}) \wedge \ldots \wedge (c_{n,1}, r_{n,1} \vee \ldots \vee c_{n,l}, r_{n,l}),$$

where c denotes a concept, r a role, k, n and $l \geq 1$.

This query is a conjunction of disjunctions of concepts and roles; where negation is not allowed. Goals-based learning process is separated in two distinct processes depending on the number of conjunctions included in the query, either single or multiple. In single goal mode, the process is the same than course-based except that the query may return an empty set. In this case, the system has to rewrite the query (using adaptation rules) to obtain a non empty set (if possible). In multiple-goals mode, the process is more complex because in some cases the query cannot be satisfied by any existing LO but may be satisfied by a composition of existing LOs. In this case the system has to dynamically construct a new LO using composition operators.

CONCLUSION AND ONGOING WORK

Our claim is that semantic metadata are required to allow a real reusing and assembling of learning objects. This semantic allows describing domain model, learner model, and LO model and provides authors and learners with powerful mechanisms to manage learning objects, concepts, and learners (e.g., browsing, querying, composing, classifying, etc.). An adaptive process has been defined allowing to adapt a specific LO to a learner considering his/her preferences and knowledge. A similar approach, integrating also pedagogical models, is proposed in (O'Keeffe, Brady, Conlan, and Wade 2006).

We are currently implementing a prototype using Sesame (Broekstra, Kampman, & Van Harmelen, 2001) that will allow us to validate our approach. Sesame offers a storage layer for RDF statements and RDFS. SeRQL query language is the only reasoning layer of Sesame. This language has interesting capabilities but lacks in expressivity to handle all type of queries we are interested in. RDF allows us to easily support our three models see (Bouzeghoub, Ammour, Defude, Duitama, and Lecocq, 2004), for a detailed presentation of our RDF mappings. DAML+OIL will be a better candidate to support our approach but existing tools are not so mature.

For the moment our proposal is based on a centralized architecture as we suppose that the domain model, the learners, and all LOs are defined and stored on the same system. Of course this is a very restrictive view. We are currently investigating different distributed architectures for our system. One possible solution is to use SQI (Simon, Massart, & Duval, 2004) to allow access in both directions between our repository and other ones. Prototypes have already been developed to federate existing learning repositories (Massart, 2006; Ternier & Duval, 2005). The problem is that SQI is just a language neutral API, that is, it does not resolve problems of heterogeneity between repositories (e.g., at the metadata level). Another solution consists in adapting a mediation architecture. Mediation is widely used in distributed database systems to allow access to distributed and heterogeneous data sources. In this architecture, the mediator implements a generic view of the system it exposes to users. Users send queries to the mediator using a generic query language. The mediator uses information about the different data sources to optimize and split the query into subqueries. These subqueries are then sent to the data sources. An adapter is used at each data source to transform subqueries into queries processable by the source. It is also used to transform results into the mediator model. We propose to use our approach to construct such a mediator. A new model is introduced to describe repositories capabilities in terms of query language, metadata model, and so on. We suppose that all repositories use LOM as their metadata model (or some LOM extensions). Adapters will define the mappings between our model and a repository model (the problem is simpler because we know that both models are LOM extensions). The problem is much more complex if the mediator implements the adaptive process. In this case, we suppose that all repositories describe semantic information about learners and LOs and that the mediator is able to construct mappings between these models.

References

Advanced Distributed Learning Initiative (2001). Sharable Content Object Reference Model. The SCORM Content Aggregation Model. Version 1.2 Retrieved October 3, 2005 from http://www.adlnet.org/

Bouzeghoub, A., Ammour, S., Defude, B., Duitama, JF., & Lecocq, C. (2004). An RDF description model for manipulating learning objects. *Proceedings of the International Conference on Advanced Learning Technologies,* Joensuu, Finland.

Bouzeghoub, A., Carpentier, C., Defude, B., & Duitama, JF. (2003). A model of reusable educational components for the generation of adaptive courses. *Proceedings of the First International Workshop on Semantic Web for Web-Based Learning in conjunction with CAISE'03 Conference,* Klagenfurt, Austria.

Broekstra, J., Kampman, A., & Van Harmelen, F. (2001). Sesame: An architecture for storing and querying RDF data and schema information. In D. Fensel, J. Hendler, H. Lieberman, & W. Wahlster (Eds.), *Semantics for the WWW.* Cambridge, MA: MIT Press.

Brusilovsky, P. (1996). Methods and techniques of adaptive hypermedia. *User Modeling and User Adapted Interaction, 6*(2-3), 87-129.

Duitama, J.F., Defude, B., Bouzeghoub, A., & Lecocq, C. (2005). A framework for the generation of adaptive courses based on semantic metadata. *Multimedia Tools and Applications, 25*(3), 377-390.

Duval, E., Warkentyne, K., Haenni, F., Forte, E., Cardinaels, K., Verhoeven, B., et al. (2001). The ARIADNE knowledge pool system. *Communication of the ACM, 44(*5), 72-78.

IEEE (2002). *Draft standards for learning object metadata* (IEEE P1484.12.1.) Retrieved October 3, 2005, from http://ieeeltsc.org/

Law, E., Maillet, K., Quemada, J., & Simon, B. (2003). EducaNext: A service for knowledge sharing. *Proceedings of the 3rd Annual ARIADNE Conference.* Leuven, Belgium: ARIADNE Foundation.

Massart, D. (2006). Accessing learning contents using a "simple query interface" adapter. *International Journal on E-Learning, 5*(1).

O'Keeffe, I., Brady, A., Conlan, O., & Wade, V. (2006) Just-in-time generation of pedagogically sound, context sensitive personalized learning experiences. *International Journal on E-Learning, 5*(1).

SIMBAD (2004). *Semantic Interoperability for coMponent-Based and ADaptive resources.* Retrieved October 3, 2005, from http://www-inf.int-evry.fr/SIMBAD/English

Simon, B., Massart, D., & Duval, E. (2004). *Simple query interface (SQI) for learning repositories.* Retrieved October 3, 2005, from http://nm.wu-wien.ac.at/e-learning/interoperability

Ternier, S., & Duval E. (2005). Interoperability of repositories: The simple query interface in ARIADNE. *ProLearn-iClass Thematic Workshop, Leuven*

Progressive Inquiry Learning Object Templates (PILOT)

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In most cases digital learning objects are used for individual learning (reading, looking, playing, quizzes) or by teachers in their class-room or online teaching (presentations). In PILOT project we argue that learning objects should be designed and presented in a special way in order to promote truly social constructivist learning. The project is based on the concept of progressive inquiry learning object templates (PILOTs). These learning objects support progressive inquiry knowledge building process in computer and database supported Knowledge Building environments, found for instance in Fle3 and IVA virtual learning environments. Design research methods such as participatory design and scenario-based design are used in the project to generate distributable and reusable PILOTs. The developed learning objects will be tested and evaluated by schools, teachers, and their pupils.

PEDAGOGICAL FOUNDATIONS

In most cases learning objects are used for individual learning (reading, looking, playing, quizzes) or by teachers in their teaching (presentations).

For example in ARIADNE knowledge pool system, the majority of learning objects are narrative texts, excercises, hypertexts, and slides (Najjar, Ternier, & Duval, 2003). At the time of writing only 1.4 % of more than 4,400 existing learning objects in ARIADNE were described as project statements, which means that they are most likely based on constructivist pedagogy.

In UIAH Media Lab our views are based on the social constructivist theory that sees learning as the participation in social processes of knowledge construction. We have developed the Fle3 learning environment (see http://fle3.uiah.fi), which is designed for social constructivist learning. The environment contains three learning tools: *WebTop, Knowledge Building,* and *Jamming*. *WebTops* can be used for storing different items (files, links, notes). With the *Knowledge Building* tool groups can carry out knowledge building discussions to debate on the given context and build their own theories. Jamming tool is used for collaborative design and construction of digital artefacts (images, sound, etc.) (Leinonen, Kligyte, Toikkanen, Pietarila, & Dean, 2003). The tools originally created in Fle3 are present also in IVA learning management system (see http://www.htk.tlu.ee/iva/), which was developed based on Fle3 source code in Tallinn University (Laanpere, Põldoja, & Kikkas, 2004).

The main tool of Fle3 is *Knowledge Building*, where discussions can be carried out with different thinking type sets. These are sets of labels with associated instructions for structuring the discussion process towards a process that the thinking type set tries to support. The most commonly used thinking type set in Fle3 is progressive inquiry. In progressive inquiry students can choose the the proper knowledge type for their note from five knowledge types (Figure 1).

The progressive inquiry pedagogical model was developed in the department of psychology, at the University of Helsinki. It is a model of learning where students are encouraged to engage in the process of question and

Figure 1. Choosing the knowledge type in Fle3 Knowledge Building

explanation driven inquiry (Muukkonen, Hakkarainen, & Lakkala, 1999). As a method of teaching and learning this means that the pupils are encouraged to make their conceptions of the topics studied explicit, and then the study group works together to improve the presented ideas and explanation.

The conceptual framework of progressive inquiry is often presented (Muukkonen et al., 1999; Hakkarainen, Lonka, & Lipponen, 1999) as six steps that loosely follow each other. The steps are:

1. creating context,
2. engaging in question-driven inquiry,
3. generating one's own working theories,
4. critical evaluation of knowledge advancement,
5. searching new scientific information, and
6. engagement in deepening inquiry.

All six aspects of inquiry are shared with fellow inquirers. The aim of the process is accumulation and deepening of knowledge of all the pupils. As the students are encouraged to start the process with some open-ended research questions that are driving the inquiry, pupils may present with the help of their teacher questions that are suitable, challenging, and motivating for them.

THE DESIGN RESEARCH PROBLEMS

The use of Fle3 and IVA in classroom learning has shown that the environment would be easier for teachers to exploit if there are ready-made content packages that frame the context and give a starting point for the progressive inquiry process. The idea of the ready-made content is not to provide material that students should study in a traditional manner, but to open problems and questions that the students want to solve during the inquiry study process. The content should generate desire to present their own hypothesis on the topics and find out scientific information on them. This way the ready-made content may help teacher and pupils carry-out the first two steps of the progressive inquiry and give some hints to the third one.

The design problems of the research are:

- How is progressive inquiry supported with ready-made rich media content packages (LO's)?
- How should the ready-made rich media content package be?
- How is easy localization and reusability provided while retaining authentic context?
- What are the general features of the package?
- Would the package help teachers and pupils, who do not yet know the

progressive inquiry model very well to use it in their teaching and learning practice?

The design research is looking for answers to the questions by building up concepts and developing prototypes of a package. In the following section we will present the concept and the prototype developed.

DESIGN AND DEVELOPMENT OF PILOTS

Our concept is called progressive inquiry learning object templates (PILOTs). PILOTs are the ready-made content packages made to facilitate progressive inquiry learning inside virtual learning environment. The word *template* emphasizes the reusability (using, editing, modifying, and sharing) of learning objects. The teacher is able to change the learning object before starting the context. PILOTs can be seen as a metaphor for guiding the knowledge building process.

The aim of the PILOT project is to develop several content packages for use in secondary school level. The learning objects are developed in cooperation between UIAH Media Lab Learning Environments research group and the Uusimaa Regional Environment Centre on the topic of wetlands. The school subject where PILOTs is primarily planned to be studied is biology or geography, but can also be used in environmental education study projects that are integrating several school subjects. There is a plan to translate the example PILOTs from Finnish to Estonian and create an English masterfile for future localizations.

The design process was carried out by the principles of participatory design by thinking and discussing among the design team about the scenarios of the possible use of the PILOTs in a primary school education. Our context scenario is a concrete story of use. The strength of scenario-based design lies in it's ease and accessibility. It does not require any special knowledge to understand a scenario. Scenarios are easy to change, they evoke discussion, and raise various questions (Carroll, 2000). The scenario was shared among the design team members to reflect and clarify the concept (Figure 2).

The project is done in close cooperation with the existing learning technology standard development, which is important in the context of PILOTs: IEEE Learning Object Metadata standard, IMS Content Packaging, and IMS Learning Design specifications. The aim of the IMS Learning Design Specification is to prescribe various activities for learner and staff in a certain order. It can be seen as the lesson planning for e-learning. The description for the wetlands learning event was developed on IMS Learning Design Level A (IMS, 2003). It describes a six week learning event, in which the PILOTs are used (see Figure 3). IMS Learning Design is designed to work together with IMS Content Packaging, because Learning Design itself does

According to the national educational curriculum, the six-grade teacher is starting a course in her classroom on wetlands. The course should have a perspective of environmental conservation and lead student to understand what are the wetlands and why they are important. Teacher is an expert of progressive inquiry learning method and has been using Fle3 with her students for several years. She starts the planning of the course by searching from Internet ideas on how to organize the course with her students. With search engine she finds from the learning material database of the Finland's Environmental Administration a PILOTs with a title "wetlands". She looks for the description and realise that it could be a suitable for her needs. As the PILOTs is offered by the Environmental Administration she may trust that it is well designed and contains valid information. She downloads the PILOTs in her own computer and brings it to her Fle3. She takes a closer look of the content of the PILOTs inside Fle3, makes some minor editing to some ready-made research questions of the PILOTs. Now she is ready to use the PILOTs. She starts the course with her students.

Figure 2. Scenario of the use of PILOTs in a six-grade environmental education

not specify information about the content. The use of PILOTs as content packages has not been implemented yet in Fle3.

Based on the scenarios and learning design description we started to design the first prototype of PILOTs. The main content of PILOTs, the knowledge building context, were written in cooperation with environmental experts and pedagogy experts. The texts were refined in several iterations. Context has a title, short description, and a long description. When the contexts were ready, short scenarios were written to describe the multimedia part of PILOTs. It was expected that a teacher will shortly describe the topic before launching the PILOTs, therefore long description of the context was used as a voiceover text in the scenarios. The voiceover texts were divided into three or four parts. Important keywords from the voiceover text were highlighted and relevant photos selected for all the parts.

Technically multimedia part of PILOTs was implemented in Macromedia Flash 7. Flash was used for multimedia content because it is the most popular browser plug-in for rich media playback. Recent studies show that 98.0% of web users have Flash Player installed (Macromedia, 2004). According to the scenario the most important keywords from the voiceover text are displayed in the movie. It is possible to navigate between the different parts of the movie and see the timeline. At the end of the movie all the ready-made research questions are displayed on the screen (Figure 4).

The Wetlands
Introduction

The Wetlands is designed as a six-week progressive inquiry learning event (2 lessons in a week) for students at the age of 13-15.

The learning event has three main phases:

1. Finding out what is a wetland? ("Kosteikko - maan ja veden välissä")
2. Studying different kind of wetlands and their differences ("Suo siellä, kosteikko täällä")
3. Why wetlands are important? ("Kosteikossa kuhisee")

These three main phases are also the contexts in the Fle3 Knowledge Building.

The resources and facilities needed include:

- Content:
  - Aims and Objectives of the learning activity itself.
  - Short and full descriptions of the course contexts.
  - Ignition questions, which aim is to help to get the KB on the run
  - Multimedia PILOTs of the course contexts
- Tools:
  - Learning environment with Knowledge Building tool.
  - Image processing software
  - Pen and notebook
  - Microscope
  - Binoculars
  - Ph test kit
  - Rubber boots
  - Recording equipment
- Communications:
  - Small groups and classroom discussions
  - Knowledge building discourse
  - Presentations

PILOTs is the new type of learning object developed to introduce the topic and to encourage the Knowledge Building discussions.

The basic sequence of the learning event is:

1. Introduction to the wetland's topic
   a. Multimedia "teaser" about the wetlands in general
   b. Classroom discussion about the wetlands
   c. Introduction to progressive inquiry learning
   d. First progressive inquiry session in KB
2. Different types of wetlands
   a. Multimedia "teaser" about the wetlands in general
   b. Classroom discussion about the wetlands
   c. Introduction to progressive inquiry learning
   d. First progressive inquiry session in KB
3. The biodiversity of wetlands
   a. Multimedia "teaser" about the wetlands in general
   b. Classroom discussion about the wetlands
   c. Introduction to progressive inquiry learning
   d. First progressive inquiry session in KB

Figure 3. The IMS Learning Design description for wetlands learning event (Level A)

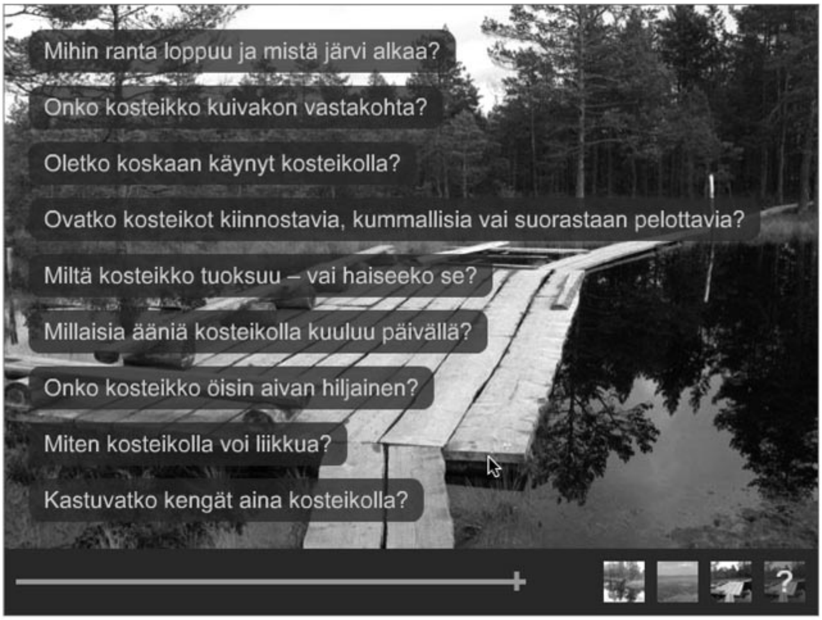

Figure 4. Research questions displayed at the end of the movie

In the first version, voiceover and images were linked to the main movie, which made it possible to start the playback as soon as the main movie was downloaded. The main drawback of this solution was impossibility to guarantee, that the voiceover text will be exactly synchronized with the keywords, which were displayed only for a short period of time. In the second version voiceover and images were included to the main file. Typical duration of the movie is around 2 minutes and size between 500...700 KB.

The PILOTs approach emphasizes the modularity, reusability, and distributability of learning object templates. With PILOTs teacher can build up a progressive inquiry course framework by bringing different kind of PILOTs to the one course. Currently this is possible by inserting the PILOTs text to Fle3 knowledge building context and adding a link to the Flash movie. Teachers can also save the PILOTs movie from the web, upload it to their Fle3 webtop and point the link in knowledge building to the webtop. It is also possible to make ready course frameworks, which already include context texts and movies. The administrator can export and import those courses in XML format, which is compatible with Educational Modelling Language. In the future we plan to change Fle3 Knowledge Building so, that it becomes possible to export/import individual PILOTs (both text and multimedia part) as content packages.

Editing, Localizing, and Reusing PILOTs

The main idea behind teaching is to offer students learning material in an appropriate context. The awareness of learning context in a learning situation is not a new idea, but researches rarely pay attention to the framework of learning contexts or activities and emphasize more on content, neglecting context (Afonso, 2002).

From a pedagogical point of view incompatible context proved to be a serious problem (Christiansen & Anderson, 2004). According to the instructional design, context is crucial to provide sense and structure to content (Afonso, 2002). Contextualized learning material helps students catch the meaning and deep understanding of the concept, procedure, information, or skill that learners are required to learn (Martin, 1998).

The PILOT model forestalls the critical issues in terms of contextualizing learning objects. Referred to the technology-based anchored instruction, PILOTs consists of a similar idea by setting up an authentic learning context. Anchored instruction was developed by the Cognition and Technology Group at Vanderbilt and stresses the importance of placing learning within a meaningful context (Bransford, 1990).

Learning objects with provided pedagogical context enable reuse of objects, as it also becomes possible for the teacher to modify the learning methods according to the other contextualized issues such as learner group, background, and so forth (Wilson, 2001).

PILOTs can be modified and edited according to the target group and objectives of the lesson by localizing the content and providing an appropriate learning context without needing to modify the original template of an object. Editing PILOTs does not mean that teachers have to know how to use Flash or other multimedia authoring tools. In most cases the teacher will edit only the text part of PILOTs. It must be seen as a template for the progressive inquiry context, not the ready-made learning object.

CONCLUSIONS

PILOT is currently work-in-progress. The first rich media content PILOTs have been developed and internally tested in the design team.

The development process has shown that participatory design and scenario-based design methods, which include experts from different fields is suitable for developing this kind of learning objects. The design research still requires evaluation and iteration of the first prototypes.

More research is needed on testing PILOTs with teachers. First, the research should look for teachers' ways of taking the PILOTs in use, ways of editing and improving them, and testing how the improvements could be shared among other teachers. Second, research should focus on the actual use of the PILOTs among the pupils. Do the pupils find it easier to adapt in the progressive inquiry process with PILOTs or do PILOTs actually lead students to a process that is no more progressive inquiry within their own framing of the topics under study. In this case learning process may end up being only simple gathering of information to find answers to the ready-made questions without deeper cognition and regulation of the groups' work.

The evaluation of PILOTs in school lessons was planned for Autumn 2005. Additional information and the rich media part of example PILOTs are available on the project homepage: http://fle3.uiah.fi/pilot/

References

Afonso, A. P. (2002). Models for the development of learning contexts: Managing learning and knowledge in virtual environments through learning communities. *Proceedings of the International Conference on Computers in Education,* (pp. 1504-1505), Auckland, New Zealand.

Bransford, J. (1990). Anchored instruction: Why we need it and how technology can help. In D. Nix & R. Spiro (Eds.), *Cognition, education, and multimedia.* Hillsdale, NJ: Lawrence Erlbaum.

Caroll, J.M. (2000). *Making use. Scenario-based design of human-computer interactions.* Cambridge, MA: The MIT Press.

Christiansen, J. A., & Anderson, T. (2004). Feasibility of course development based on learning objects: Research analysis of three case studies. *International Journal of Instructional Technology and Distance Learning.* Retrieved February 21, 2005, from http://www.itdl.org/Journal/Mar_04/article02.htm

Hakkarainen, K., Lonka, K., & Lipponen, L., (1999). *Tutkiva oppiminen.* Älykkään toiminnan rajat ja niiden ylittäminen. Porvoo: WSOY.

IMS (2003). *IMS learning design information model.* Retrieved January 20, 2005, from http://www.imsglobal.org/learningdesign/ldv1p0/imsld_infov1p0.html

Laanpere, M., Põldoja, H., & Kikkas, K. (2004, August). The second thoughts about pedagogical neutrality of LMSs. In *Proceedings of the 4th IEEE International Conference on Advanced Learning Technologies,* (pp.807-809). Joensuu, Finland. Los Alamitos, CA: IEEE.

Leinonen, T., Kligyte, G., Toikkanen, T., Pietarila, J., & Dean, P. (2003). *Learning with collaborative software - A guide to Fle3.* Helsinki, University of Art and Design Helsinki.

Macromedia (2004). *Macromedia flash player statistics.* Retrieved October 26, 2004, from http://www.macromedia.com/software/player_census/flashplayer/

Martin, K. (1998). Learning in context. *Issues of Teaching and Learning, 4*(8). Retrived February 21, 2005, from http://www.csd.uwa.edu.au/newsletter/issue0898/learning.html

Muukkonen, H., Hakkarainen, K., & Lakkala, M. (1999). Collaborative technology for facilitating progressive inquiry: Future learning environment tools. In C. Hoadley & J. Roschelle (Eds.), *Proceedings of the CSCL '99: The Third International Conference on Computer Support for Collaborative Learning* (pp. 406-415). Mahwah, NJ: Lawrence Erlbaum. Retrived January 19, 2004, from http://web.archive.org/web/20000916210308/http://kn.cilt.org/cscl99/A51/A51.HTM

Najjar, J., Ternier, S., & Duval, E. (2003). *The actual use of metadata in ARIADNE: an empirical analysis.* Retrieved January 20, 2005, from http://rubens.cs.kuleuven.ac.be:8989/ariadne/CONF2003/papers/NAJ2003.pdf

Wilson, S. (2001). *Comment & analysis: Why context Is king.* Retrived February 21, 2005, from http://www.cetis.ac.uk/content/20010827123828

Just-in-Time Generation of Pedagogically Sound, Context Sensitive Personalized Learning Experiences

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The just-in-time generation of personalized learning experiences requires the assembly of atomic learning assets into coherent learning activities for a learner, based on his/her preferences and requirements. Through the appropriate application of pedagogical strategy to a learner's learning activities the effectiveness and efficiency of his/her learning can increase significantly. The strategies behind this process should be pedagogically informed to ensure the learning experience is suitable for the learner and the environment in which they are carrying out his/her learning. By utilizing appropriate pedagogical strategies in the personalization process, learning objects generated for a learner will not only be appropriate to what they wish to learn, but also to how they should learn it. This article describes the Selector and LO Generator services of the iClass IST project and the approach taken to producing pedagogically sound personalized learning experiences using a standards based approach.

In the past, Adaptive Hypermedia Systems (AHS, [Brusilovsky, 2001]) have attempted to customize courses to a learner's prior knowledge (Kayama & Okamoto, 1998), goals (Vassileva, 1996) and personal preferences (Specht & Oppermann, 1998) without taking into consideration any form of pedagogy. As a result, such systems neglect the entire body of research that exists in the educational field and fail to take advantage of the benefits that the application of pedagogy has for the learning experience (Conlan &

Wade, 2004). iClass (iClass, 2004) is an open learning system which utilizes pedagogical strategies to adapt to learners' needs, both intelligently and cognitively. This article describes the LO Generator and Selector services, which facilitate the delivery of customized learning experiences as part of iClass. The Selector Service is responsible for building a personalized path for a learner through a knowledge domain, consisting of concepts. This is carried out in accordance with the learner's objectives and preferences while also taking into account the preferences of the teacher involved. Specifically, the teacher's preferences allow him/her to scope the boundaries and the extent to which the personalization of the learning experience will occur, thus providing the teacher with control over the iClass system and the manner in which it carries out personalization. The Selector Service will approach the production of a personalized learning path by applying a sound pedagogy. This approach will be similar to that taken by systems such as APeLS (Conlan, Wade, Bruen, Gargan, 2002) and WINDS (Kravcik & Specht, 2004) to produce complete courses. APeLS is an AHS that employs the Multi-Model, Metadata driven approach (Conlan, 2005), in other words APeLS maintains a set of models describing the necessary learner, content and pedagogical information, which the system can then reconcile, at run-time, to generate a personalized course for an individual learner. The key advantage of APeLS is the separation of pedagogy from the adaptive system as opposed to systems such as AHA! (De Bra & Calvi, 98) and ELM-ART (Brusilovsky, Schwarz, & Weber, 1996), which generally embed the models/rules in the engine. This provides APeLS with the flexibility to use many different pedagogical strategies.

Unlike APeLS, the design of the Selector Service separates pedagogy and the description of the knowledge domain into two distinct entities. The knowledge domain is described in terms of an ontology, which describes the skills, concepts, facts, and so forth. that make up the domain as well as the relationships between them. The knowledge domain is described in a pedagogically neutral manner emphasizing its separation from any description of pedagogy. The pedagogical neutrality of the knowledge domain ontology helps to reduce biases towards a particular approach to teaching/learning, thus enabling the successful application of different pedagogies to the knowledge domain. Pedagogies are encapsulated in Pedagogical Strategies; these are sets of rules that determine the approach to be taken in order to present a concept as part of a pedagogically based course. A Pedagogical Strategy should be considered as a high level guidance that may be applied to concepts or subconcepts and which is selected based on the preferences of both the teacher and the learner. Through the accommodation of both teacher and learner preferences in the selection of a pedagogical strategy, the personalized course produced should fit both the teacher's preferred mode of teaching and the learner's preferred mode of learning.

The separation of pedagogy and concept domain brings several significant benefits; it speeds up the time taken to develop courseware, reduces the cost of development and also introduces a new axis of adaptivity upon which adaptation/personalization can occur. The time and cost reductions are brought about because pedagogies can be developed independently of knowledge domains and vice versa. For example, a course developer (knowledge domain expert) need not have any specialist knowledge of the pedagogical strategies that may be applied to the knowledge domain they are developing. Further reductions in the expense of creating personalized educational courseware come from the ability to reuse any preexisting pedagogical strategy or domain ontology. Improved personalization is realised through the application of many different pedagogical strategies to the same concept domain. This means that it is possible to adaptively select the most appropriate pedagogical strategy for a specific learner, irrespective of what they are learning, which will enhance his/her learning experience.

The learning path produced by the Selector is only half of the "story." To present the learning experience to a learner, the concepts contained in the learning path need to be associated with learning objects. As part of iClass, the LO Generator aims to provide pedagogically sound, personalized, and context sensitive learning objects. The function of the LO Generator is to select the most appropriate learning content from the learning object space, which corresponds to the specific needs of the Selector. The LO Generator interacts with various distributed information repositories, using a variety of metadata formats and ontologies, to assemble appropriate LOs that facilitate the teaching of each concept in a learning path in a manner that is appropriate to the learning preferences of the learner. It is the role of the LO Generator to select or create appropriate learning objects to instantiate the pedagogically influenced concepts in the PLP. The LO Generator also accounts for learner and contextual preferences selecting or generating learning objects. In summary, the Selector guides the overall pedagogical strategy of the learning experience, while the LO Generator personalizes towards the learner's preferences and current context.

This article describes the workflow between the Selector and LO Generator services and describes the just-in-time generation of pedagogically sound, context sensitive personalized learning objects, which are based on personalized learning paths. The next section describes the reconciliation of multiple models towards the creation of a personalized learning path. The following section "Producing Personalized Learning Objects," details how appropriate personalized learning objects are created/selected for this personalized learning path. Then a section describes a worked example of how personalized learning objects are produced, followed by a section that describes the standards and specifications most relevant to the Selector and LO Generator; and then a section highlights how the Selector and LO Generator cooperate with other services in the iClass framework to achieve personalized experiences. Finally, is the section that concludes the article.

RECONCILIATION TOWARDS PERSONALIZED PATHS

The role of the Selector, within the iClass framework, is to produce a Personalized Learning Path or PLP. The aim of a PLP is to allow the learner to obtain a skill or set of skills through his/her engagement in activities as part of a pedagogically sound learning experience. The PLP itself is a structured sequence of concepts that is dynamically generated based on a set of requirements. Each concept in a PLP is associated with a type of learning activity as well as being related to a specific skill. A key aspect of the PLP generation process is the personalization of the PLP towards an individual learner to support and enhance the learning experience.

As iClass is a tool to be used within the context of a classroom, it is important that any PLP produced by the Selector should be appropriate for use within that environment. As such, the Selector must take account of the requirements of the teacher in conjunction with accepted pedagogical best practice as well as the needs of the learner. Figure 1 illustrates how the Selector allows all of its stakeholders to influence the generation of a PLP through the models that it uses.

Each of the models consumed by the Selector provides it with information as follows:

Teacher model. Provides details of the skills which a teacher wishes learners to attain within a given Concept Domain. This model also allows the teacher to influence the selection of Pedagogical Strategies by the Selector.

Learner model. Provides information about the learner's competencies/prior knowledge as well as details of any learning biases, and so forth, that a learner might have.

Concept domain ontology. A pedagogically neutral representation of a subject domain including the appropriate semantic relationships between skills and concepts. It acts as a "map" that allows the Selector to generate paths through the subject domain.

Pedagogical strategy. An expression of how pedagogy may be used to influence the creation of a PLP. The strategy will provide the Selector with a description of how concepts should be manipulated and arranged so that they fit into a given pedagogy.

To better understand how the Selector can reconcile all of these models to produce a PLP it is necessary to understand the Selector's workflow.

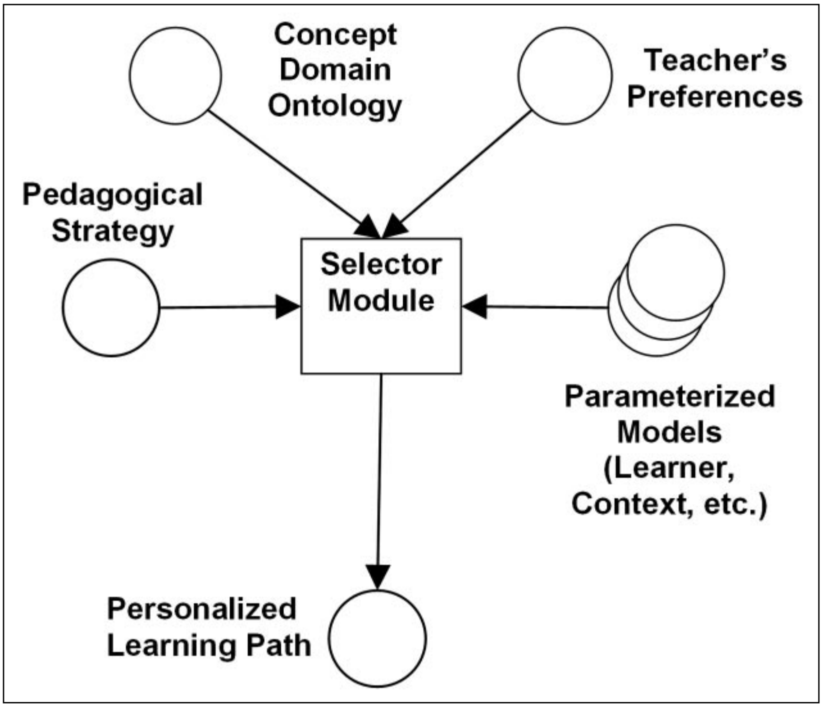

Figure 1. The Selector service and its associated models

When the Selector is invoked, it first identifies the appropriate Concept Domain Ontology. This provides the Selector with the contextual information necessary for it to interpret both the Learner and Teacher Models, which are retrieved next from their respective repositories. Following this, it is necessary for the Selector to retrieve an appropriate Pedagogical Strategy; this selection can be influenced by both the Teacher and Learner Models. It is possible for the teacher to explicitly state that a specific pedagogy be applied or alternatively this decision can be left to the Selector which will then base the selection of a Pedagogical Strategy on the characteristics of the learner. In the latter case, the Selector will choose a pedagogy that is most appropriate for the individual learner.

At this point the Selector has retrieved all of the models necessary for the creation of a PLP. The next step in the process is to identify the set of skills which the PLP should cover. This is a two stage process consisting of first removing any skills which have already been attained by the learner and secondly adding any prerequisite skills that the learner does not yet have. Skills that have already been attained are identified by comparing the skills listed in the teacher model with the competencies defined in the Learner Model. Necessary prerequisite skills are identified through the use of the concept domain ontology to first find prerequisites and then, as before, comparing the prerequisite skills with the competencies of the learner. This is an iterative process which continues until a point is reached at which the learner has the appropriate skills to being learning.

Once a complete set of skills has been built, the equivalent set of concepts is generated through the use of the concept domain ontology, which contains the relationships between skills and concepts. The final stage in the production of a PLP is to generate the PLP structure based on the selected Pedagogical Strategy and to populate that structure with concepts and their associated activity types. The activity type can be defined by the teacher in the Teacher Model or can be selected by the Selector is a similar way to the selection of the pedagogical strategy.

As the Selector populates the PLP with concepts it "validates" each concept with the LO Generator. This validation ensures that the Selector does not include a concept, activity pair in the PLP which the LO Generator could not produce an appropriate Learning Object for. If a concept, activity pair is invalidated by the LO Generator, the Selector will have to rework the PLP, but this should rarely happen. The process involved in validation and the creation of new learning objects by the LO Generator will be discussed in the following section.

PRODUCING PERSONALIZED LEARNING OBJECTS

The role of the LO Generator, within the scope of the iClass project, is to provide an appropriate learning object (LO), which can be presented to a Learner, as well as to provide an identifier for each LO to the Selector during its generation of a PLP, as described in the previous section. This process may be as simple as selecting an appropriate preexisting LO and returning its identifier. If an appropriate LO does not already exist, the LO Generator may be able to "morph" a preexisting LO into one which is more appropriate. Alternatively, if this is not possible, the LO Generator must create a completely new LO. These learning objects are adaptively tailored towards the preferences of an individual learner as well as his/her competencies within the given knowledge domain.

The LO Generator makes use of the Learner Model to obtain information about the pedagogical preferences of the learner and also to get information about his/her prior knowledge. Information from the repository of contextual data, which stores information about environment, device type, and so forth, is also accessed. An important repository with which the LO Generator communicates is the actual learning object space, which provides access to the metadata associated with the content needed for the generated learning object. This metadata represents atomic level SCOs (SCORM, 2000), which are not necessarily educationally complete, but when combined together with other SCOs can be formed into coherent LOs. The importance of maintaining separation between the pedagogy, the knowledge domain ontology and the content stems from the need to make maximum use of each of these elements through reuse (Dagger et al., 2003). This separation also provides the ability to replace any of these aspects when necessary (Figure 2).

When the LO Generator is asked to validate a concept by the Selector, it is given the appropriate information to fulfill this task. The validation step is necessary as it ensures that the concepts and activities added to a PLP by the Selector can be realized by the LO Generator. This iterative process, carried out for each concept/activity pair added to a PLP, guarantees that the PLP can be populated with appropriate LOs at execution time. As inputs, the LO Generator is given a learner identifier, a concept or set of concepts, and also the relevant activity. Based on the concept(s) and the activity, the LO Generator determines whether an appropriate LO can be chosen or created from existing SCOs.

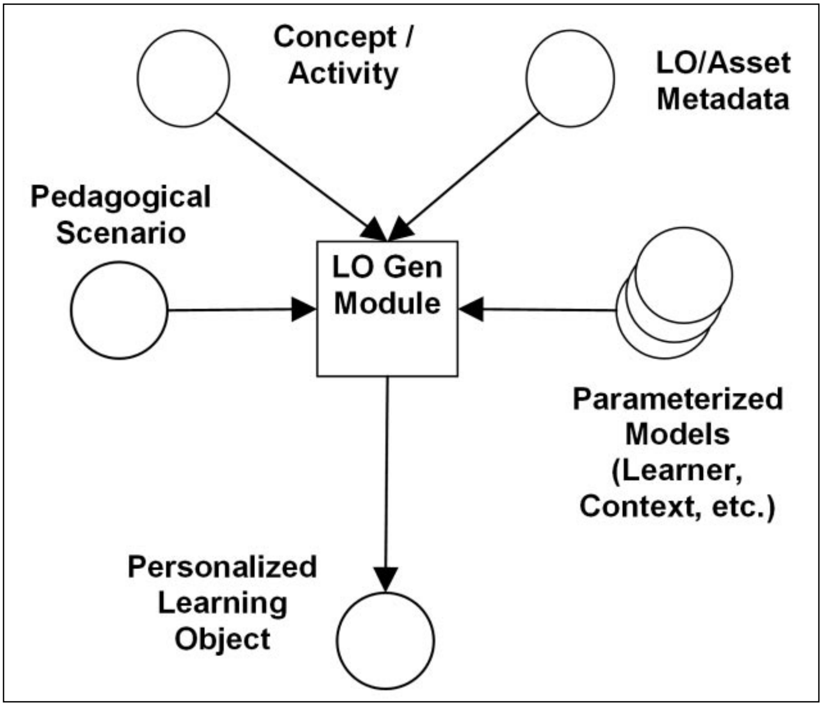

Figure 2. The LO generator service and its associated models

The initial step involved in the process of validation is to get the information from the Learner Model which will be necessary for the personalization of the learning object. This information includes the preferences of the learner as well as his/her prior knowledge on the given concept. This information can be obtained from the Profiler and Monitor services within the iClass system.

The behavior of the LO Generator depends on the selection of a relevant pedagogical scenario which dictates the steps that will be undertaken by the service to reconcile the concept(s) and activities into real LOs. These scenarios, characterized as narratives, can be chosen adaptively based on the preferences of the learner that the content is being adapted to. These scenarios interpret the preferences and provide criteria for searching the learning object space for suitable SCOs or LOs.

Where an appropriate LO is available that requires no modification, its unique identifier is returned to the Selector. When simple changes are necessary, the modifications are implemented, the new LO is added to the learning object space and the new identifier is returned to the Selector. This LO is added to the learning object space as a metadata manifest describing the new LO and its re-sequenced/modified SCOs. If an existing LO does not exist and it is not possible to alter an existing LO to satisfy the requirements, a new LO must be created. This creation is also executed by the appropriate selection of a pedagogical scenario. These scenarios will guide what type of SCOs should be sequenced together based on the preferences of the learner, these will be aimed at the concept(s) and activity supplied by the Selector service, and will be based on the relevant concept domain ontology that the concept(s) belong to. The first step in the process involved in the production of a new LO is to select an appropriate pedagogical scenario. This is done by reconciling the concept/activity pair that the new LO is to cover, the learning preferences of the learner and the metadata describing the different pedagogical scenarios available. The pedagogical scenario will describe the types of SCOs that should be assembled together to fulfill the concept/activity requirement of the Selector. During the assembly process the pedagogical scenario will also describe how learner preferences should be accounted for, thus helping to refine SCO selection and assembly. Once the new LO is assembled a manifest describing its structure and the sequence of SCOs is uploaded to the learning object space and the identifier is returned to the Selector.

WORKED USE CASE

In the example of a case study, it is necessary for the Selector to restructure the concepts in a manner such that the structure of the concepts reflects the format of a case study. A generic case study might be broken up into the following parts: an introduction to the topic, contextual information, a problem statement, support/framework for solving the problem and an evaluation of the solution. In this scenario, the Selector would have to take the concept(s) and break them up, duplicate them or otherwise manipulate them so that each of the sections of the case study included the appropriate concepts.

For example, if a case based approach was applied to set of physics concepts the PLP may include *introduce Newton's Third Law, present the problem of colliding objects,* and so forth. In this case, *introduce* and *present problem* are elements of a pedagogical strategy. Figure 3, shows the interactions primarily between the Selector and LO Generator and their repositories. This section describes the workflow between the Selector, LO Generator and Presenter to produce a personalized learning experience.

When using the iClass system to create learning episodes, teachers are given the option of specifying the scope of the course across an existing knowledge domain and to specify the required learning outcomes for the course. At this point, the Selector service interprets this teacher information, along with the available learner information to produce a subset of the knowledge domain. A pedagogical strategy is then selected by the Selector, also based on learner and teacher preferences. In our example, the concept domain is *Physics* and the subdomain is *Newton's Third Law* and the chosen pedagogical strategy selected by the Selector service is a *case-study*, which introduces a concept, presents a problem statement, provides resources to the learner and may provide an example solution.

The pedagogical strategy and the subdomain are reconciled together by the Selector to create a narrative or Personalized Learning Path that consists

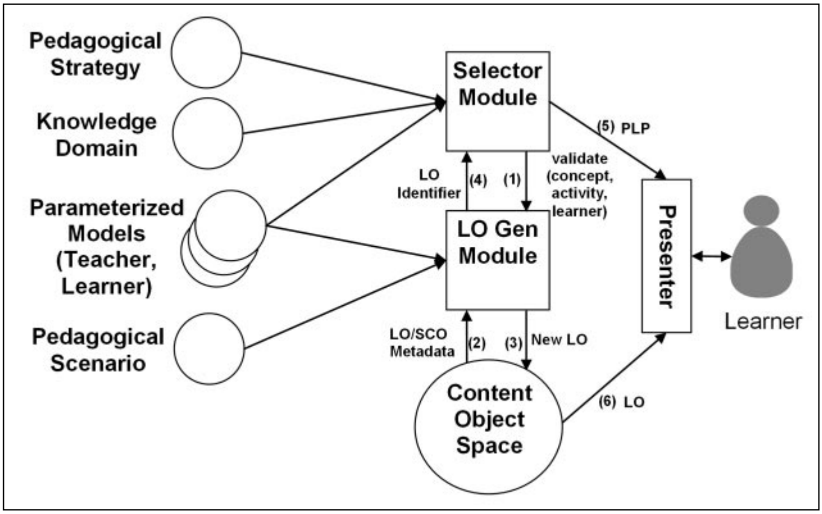

Figure 3. The iClass personalization services and their related models

of concepts and the pedagogical relationship between them. The prior knowledge of the learner will have to be taken into account at this stage; it makes no sense to describe something to the learner that they already know. Furthermore, it is also ineffective to present concepts which the learner does not yet have the prerequisite knowledge to understand. Using the pedagogical strategy, the Selector may specify that the first LO in this PLP will i*ntroduce Forces*. In this case *introduce* is an activity in the pedagogical strategy being employed and *Forces* is the concept it is being applied to.

After specifying the first concept, the Selector makes a request to the LO Generator to check and see whether that concept exists in the learning object space, which is shown as step 1 in Figure 3. The LO Generator then assembles information about the learner. This information differs from that which the Selector used as it relates primarily to the presentation of the LO. In this case, for example, the learner prefers visual instruction (the use of diagrams, etc.), other relevant contextual information utilized by the LO Generator might including the fact that, for example, the learner in our use case is using a black and white display PDA to access the course (Brady, Conlan, & Wade, 2004).

Using these additional parameters, the LO Generator now conducts a search of the learning object space (provided by the Content Access Service (CAS) in iClass) to look for learning assets that can be combined to fulfill all of these requirements. Upon receiving the metadata information from the learning object space, shown in step 2 of Figure 3, the LO Generator returns one of two possible results to the Selector service (a) the LO does not exist and no variation can be generated, or (b), it returns the LO identifier for either a modified LO or a newly created LO. In this case, an LO exists that satisfies the pedagogical strategy and the visual preferences of the learner. To fill the contextual needs, in this case the screen limitations of the device, the LO will have to be "morphed," so the LO Generator sends back a return call citing option (b) above. The LO Generator creates a skeleton of this morphed or new LO, adds it to the learning object space (step 3 in Figure 3), and returns the LO identifier to the Selector (step 4 Figure 3). The skeleton LO created will be used at run time to create a complete LO containing content assets.

After confirmation from the LO Generator, the Selector proceeds onto the next step in the pedagogical strategy, which is to state *Newton's Third Law*, and the cycle begins again, stepping onto the *definition of the law, examples that illustrate the law,* and *a quick test to see if the learner understood the law.* At the end of this, a full Personalized Learning Path (PLP) exists for teaching this concept to this learner through this concept domain.

The LO Generator has several options available to it to deal with the PLP. In the first case, a new service available in iClass needs to be introduced, the Presenter service, which will allow for just-in-time generation of personalized LOs. The Presenter is a service that can interpret the PLP and present the navigation embodied within the PLP. It invokes the Selector in the first place, and after the

Selector has finished it returns a PLP identifier to the Presenter, which can be seen in step 5 of Figure 3. Using this PLP identifier the Presenter can query the CAS for the relevant PLP. Embedded in the PLP will be several LO identifiers and, again, the Presenter can query the learning object space to get back the appropriate LOs (step 6 in Figure 3). Another option which will be available in the LO Generator service will be the possibility to deliver a complete content package with the personalized LOs and the IMS Learning Design (IMS LD) to govern their delivery. For the PLP to be effective, the LO Generator must fulfill all of the required aspects of the scenario or strategy embedded in it.

THE ICLASS FRAMEWORK

The iClass system consists of a framework of services that support all the major stakeholders in the provision of eLearning in a structured educational environment. These stakeholders include the learners, teachers, parents, school administrators, and legacy learning management system (LMS) vendors.

As services within the iClass framework (Türker, Görgün, & Conlan, 2006), both the Selector and the LO Generator must interact with the other available services to carry out their respective tasks.

Figure 4, illustrates the relationships between the Selector, LO Generator and the iClass services which they depend on. From the point of view of the Selector and LO Generator, the other services can be considered as either producers or consumers. The Teacher Preference Tool, which provides the teacher

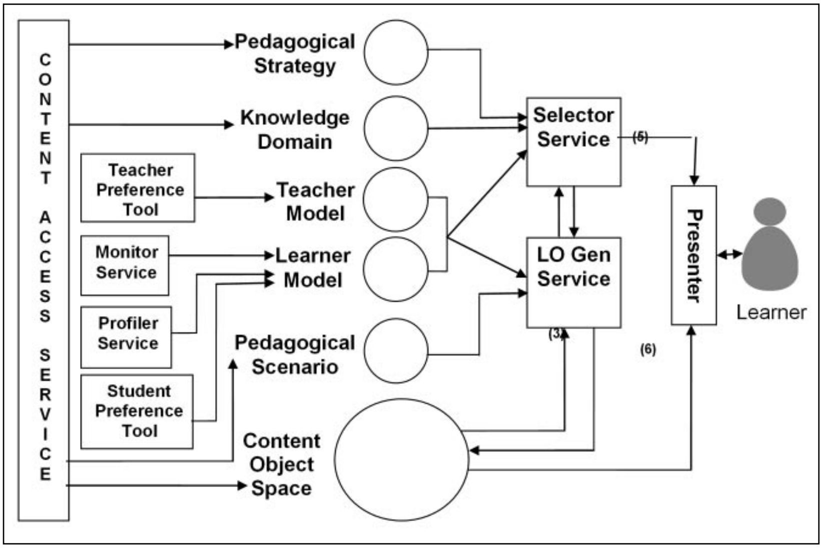

Figure 4. Interaction of personalization services with other iClass services

with the control over the iClass system mentioned previously, is a consumer of the Selector. The Presenter, as the Learner interface to iClass, consumes both the Selector and the LO Generator, which in turn is consumed by the Selector as part of the validation process. As shown, the Learner Model discussed previously as a data source for both the Selector and LO Generator are obtained from the Profiler and Monitor (Muehlenbrock, 2006) services. It is necessary to query both of these services in order to build a complete model of the learner as both services track different aspects of the learner. The Profiler supplies data about the learner's preference and portfolio details, while the Monitor is responsible for tracking the learner's competencies (prior knowledge) in a given skill. The information about the Learner captured by the Profiler and Monitor is complemented by further information that is provided by the Learner through the Student Preference Tool. Unlike the learner information, the Teacher Model, which is produced by the Teacher through their use of the Teacher Preference Tool, is stored in the Profiler alone. The other models needed by the Selector and LO Generator are the pedagogical model and the knowledge domain ontology as well as the metadata models from the learning object space. All of these models are stored in the Content Access Service (CAS) (Türker et al., 2006) and can be retrieved using the SQI (Massart, 2006) interface which the CAS implements.

The CAS is also utilized by the Selector and the LO Generator in order to store the PLPs and LOs produced by the services respectively. When this occurs the CAS provides a globally unique identifier for the resource being uploaded. This can then be used by other services, primarily the Presenter, to retrieve necessary PLPs or LOs.

RELEVANT STANDARDS AND SPECIFICATIONS

As the iClass framework consists of many different services developed by different members of the iClass consortium, the interoperation of these services is an important consideration, as is interoperability with a broader set of eLearning services. One step that has been taken to facilitate this interoperation is the adoption of open standards and specifications. Another advantage associated with the use of open standards and specifications is improved communication between the partners in the consortium due to the common terminology they provide.

In the case of the Selector and LO Generator services, all of the models that they utilize, as well as their outputs, will be based on the relevant open standards. It is intended that the Knowledge Domain Ontology will be based on the W3C's OWL Web Ontology Language Recommendation (McGuinness & van Harmelen, 2004). OWL is intended to be used in cases where the meaning of terms and the relationships between them need to be processed by an application. The advantages of using OWL for the Knowledge Domain

Ontology are that it is very expressive in terms of describing concepts as well as relationships; it also supports properties such as cardinality and equality. There also exist many tools that can be used in creating OWL ontologies. The PLP produced by the Selector will be based on the IMS Learning Design Specification (IMS, 2003). Learning Design (LD) is a framework that describes the workflow of the teaching/learning process while supporting different kinds of pedagogical models and the personalization of learning activities (Koper, 2004). LD does not restrict the use of pedagogies by prescribing a specific set of pedagogies, as the Selector will make use of many different Pedagogical Strategies which makes LD a suitable basis for the description of a PLP LD also supports blended learning, that is, the use of nondigital learning resources within the learning experience, this too is a feature of the iClass framework. LD will also facilitate the inclusion of decision points within the PLP (rules that are resolved at run time depending on the value of a property within the Learning Design). It is envisaged that decision points within the PLP will allow for dynamic adaptation towards the learner at run time. For example, the path taken by student might change depending on the result of a quiz that the student takes. This information could not be known when the PLP is being generated and so the decision point is left in the PLP to be resolved later. In the case of the LO Generator, its output will be in the form of IMS content packages with the relevant LDs and metadata included.

CONCLUSIONS

This article has described the workflow between the Selector and LO Generator services of iClass and described the just-in-time generation of pedagogically sound, context sensitive, personalized learning experiences. The Selector and LO Generator services described in this article are key elements of the iClass vision. The benefits of applying appropriate and sound pedagogy to a learning experience have been shown to improve the performance of the learner. In many existing AHS a “one size fits all” approach is often taken to pedagogy. Such an approach cannot hope to address the needs of all learners, nor does it integrate well with every teacher’s teaching methods. Enabling the teacher to personalize the pedagogical strategy applied to a course towards his/her own needs will allow the teacher to better integrate eLearning with his/her traditional classroom teaching. An added benefit of adaptive pedagogical strategies is that it gives the teacher the ability to tailor the delivery of a course towards an individual student's needs. This can be advantageous if a student is not responding well to the traditional pedagogical approach to a subject domain and where they might benefit from an alternative strategy.

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References

Brady, A., Conlan, O., & Wade, V. (2004, November). Dynamic composition and personalization of PDA-based eLearning – Personalized mLearning. *Proceedings of E-Learn 2004, World Conference on E-Learning in Corporate, Government, Healthcare and Higher Education,* (pp. 234-242), Washington, DC.

Brusilovsky, P. (2001). Adaptive hypermedia. In A. Kobsa (Ed.), *User Modeling and User Adapted Interaction, Ten Year Anniversary Issue, 11*(1/2), 87-110.

Brusilovsky, P., Schwarz, E., & Weber, G. (1996). ELM-ART: An intelligent tutoring system on the World Wide Web. In *Proceedings of the Third International Conference, ITS, 1996.*

Conlan, O. (2005). *The multi-model, metadata driven approach to personalised eLearning services.* Unpublished doctoral dissertation University of Dublin, Trinity College.

Conlan, O., & Wade, V. (2004). Evaluating the multi-model, metadata-driven approach to producing adaptive eLearning services. *Proceedings of the Third International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems (AH2004)* Eindhoven, The Netherlands.

Conlan, O., Wade, V., Bruen, C., & Gargan, M. (2002, May). Multi-model, metadata driven approach to adaptive hypermedia services for personalized eLearning. *Proceedings of the Second International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems,* Malaga, Spain.

Dagger, D., Conlan, O., & Wade, W. (2003). An architecture for candidacy in adaptive eLearning systems to facilitate the reuse of learning resources. *Proceedings of E-Learn 2003, World Conference on E-Learning in Corporate, Government, Healthcare and Higher Education,* Phoenix, AZ.

De Bra, P., & Calvi, L. (1998). AHA: A generic adaptive hypermedia system. In *Proceedings of the 2nd Workshop on Adaptive Hypertext and Hypermedia*, (pp. 5-12), Pittsburgh, PA. (Proceedings available as CSN 98-12, TUE, or Retrieved October 3, 2005, from http://wwwis.win.tue.nl/ah98/DeBra.html)

iClass Integrated Project, Annex 1, Description of Work (2004). Retrieved October 3, 2005, from http://www.iclass.info

IMS Global Learning Consortium, Inc. (2003). *IMS global learning consortium: IMS learning design specification.* Retrieved October 3, 2005, from http://www.imsglobal.org/learningdesign/

Kayama, M., & Okamoto, T. (1998). A mechanism for knowledge-navigation in hyperspace with neural networks to support exploring activities. *Proceedings of Workshop "Current Trends and Applications of Artificial Intelligence in Education" at the 4th World Congress on Expert Systems* (pp. 41-48), Mexico City, Mexico.

Koper, R. (2004). IMS learning design: What it is & update on current activities. *Proceedings of Unfold and Surf Six Joint Meeting,* Heerlen, The Netherlands.

Kravcik, M., & Specht, M. (2004) Flexible Navigation Support in the WINDS Learning Environments. In P. De Bra & W. Nejdl (Eds.), *Proceedings of the Third International Conference on Adaptive Hypermedia and Adaptive Web-Based Systems (AH2004), LNCS 3137*, 156-165.

Massart, D. (2006) Accessing learning contents using a "simple query interface" adapter. *International Journal on E-Learning, 5*(1).

McGuinness, D.L., & van Harmelen, F. (2004, February). *OWL web ontology language overview.* W3C Recommendation.

Muehlenbrock, M. (2006). Learning group formation based on learner profile and context. *International Journal on E-Learning, 5*(1).

Sharable Content Object Reference Model (SCORM, 2000). Retrieved October 3, 2005, from http://www.adlnet.org/

Specht, M., & Oppermann, R. (1998). ACE – adaptive courseware environment. *The New Review of Hypermedia and Multimedia 4*, 141-161.

Türker, A., Görgün, & Conlan, O. (2006). The challenge of content creation to facilitate personalized eLearning experiences. *International Journal on E-Learning, 5*(1).

Vassileva, J. (1996). A task-centered approach for user modeling in a hypermedia office documentation system. In P. Brusilovsky & J. Vassileva (Eds.), *Special Issue on Adaptive Hypertext and Hypermedia, User Modeling and User-Adapted Interaction, 6*(2-3), 185-223.

Towards Next Generation Activity-Based Learning Systems

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The need for e-learning systems that support a diverse set of pedagogical requirements has been identified as an important issue in web-based education. Until now, significant research and development effort has been devoted to aiming towards web-based educational systems tailored to specific pedagogical approaches. The most advanced of them are based on the IEEE Learning Technology Systems Architecture and use standardized content structuring based on the ADL Sharable Content Object Reference Model (SCORM) in order to enable sharing and reusability of the learning content. However, sharing of learning activities among different web-based educational systems still remains an open issue. On the other hand, existing Learning Management Systems (LMS) provide authoring tools that are only tailored to the capabilities of the specific system in hand. The open question is how web-based educational systems should be designed in order to enable reusing and repurposing of learning activities. In this article we first discuss the limitations of the current state-of-the art learning systems and authoring tools and investigate the use of the Learning Design framework as a mean to address those limitations. Then, we present a high-level architecture of a SCORM-compatible authoring and runtime system that utilizes the Learning Design principles to provide the means for designing activity-based learning systems. Finally, we discuss the use of ASK-LDT, an authoring system developed based on the proposed architecture, in the design of complex learning activities.

Introduction

During the last years, several tools have been developed in order to support the process of web-based authoring and several learning systems have been implemented tailored to specific pedagogical approaches. Several systems already exist supporting the process of web-based authoring for providing active learning, constructive learning, collaborative learning, intentional learning, conversational learning, contextualized learning, and reflective learning (Jonassen, Hernandez-Serrano, & Choi, 2000; Marra & Jonassen, 2001; Carr, 2001; Melis, Andrus, Bodenbender, Frishauf, Goguadse et al., 2001; Gonzalez, Suthers, & Escamilla De Los Santos, 2003).

Currently, there are several educational e-content repositories and networked infrastructures available ranging from federated or distributed learning repositories to brokerage platforms (Duval, Forte, Cardinaels, Verhoeven, Van Durm et al., 2001; Guth, Neumann, & Simon, 2001; Friesen, Roberts, & Fisher, 2002; Nejdl, Wolf, Qu, Decker, Sintek et al., 2002; Olivier & Liber, 2003; Quemada & Simon, 2003, Simon, Dolog, Miklos, Sintek, & Olmedilla, 2004). Nevertheless, the level of learning content reusability remains relatively low, due to the fact that sharing of learning activities across systems has not been addressed yet. This limitation prevents systems from reusing the same learning scenarios, leading to significant extra pedagogical effort for reusing learning content in different contexts. On the other hand, existing Learning Management Systems (LMS) provide tools for web-based authoring that are tailored to the capabilities of the specific system in hand. As a result, reusing and repurposing of learning activities and content is not supported in a consistent manner (Brusilovsky & Nijhawan, 2002).

In this article we first examine the limitations of the current state-of-the art learning systems and authoring tools and investigate how the Learning Design framework can be incorporated in the architecture of a SCORM-compatible authoring and runtime system in order to address those limitations. To this end, we define an abstract high-level architecture that utilizes the Learning Design principles to provide the means for designing pedagogical scenarios that can be reused in different contexts and across different web-based educational platforms.

The article is structured as follows: in the second section, we discuss the problem of sharing learning activities based on the current state-of-the-art learning systems' architecture, investigating the limitations of those systems. The third section presents the principles of the Learning Design framework, emphasizing in modeling of learning activities and briefly discusses the need of standardizing the low-level notation schema used to describe learning activities. In the fourth section we present an architectural definition of a SCORM-compatible authoring and runtime system that addresses the identified limitations incorporating the Learning Design framework. Finally, we discuss the use of ASK-LDT, an authoring system for learning scenarios developed to implement the proposed architecture, in the design of complex learning activities.

Sharing Learning Activities

Content Repositories

Currently, there are many systems which are intended to collect, share and reuse the dispersed learning resources and present the end-user with a uniform interface to search, access and evaluate the resources, including the ARIADNE Knowledge Pool System (http://www.ariadne-eu.org/en/system), the Campus Alberta Repository of Educational Objects (CAREO) (http://www.careo.org), the U.S.-based Science, Mathematics, Engineering and Technology Education Digital Library (http://www.smete.org), the Educational Network Australia (http://www.edna.edu.au), the Gateway to Educational Materials (GEM) digital library (http://www.geminfo.org), the Scottish electronic Staff Development Library (SeSDL) (www.sesdl.scotcit.ac.uk), the LearnAlberta Portal (www.learnalberta.ca), the COLIS (www.edna.edu.au/go/browse/0), the Multimedia Educational Resource for Learning and Online Teaching (MERLOT) (www.merlot.org), the Universal Brokerage Platform for Learning Resources (www.educanext.org), the World Lecture Hall (www.utexas.edu/world/lecture/), the Globewide Network Academy (www.gnacademy.org), the McGraw-Hill Learning Network (MHLN) (www.mhln.com) and others. Most of them offer high quality resources in the form of learning objects (Richards, 2002; Littlejohn, 2003; McGreal, 2004) that are also metadata tagged (Friesen et al., 2002; Olivier & Liber 2003; Sampson, Papaioannou, & Karadimitriou, 2002; Sampson & Karampiperis, 2004; Sampson, 2004).

Nevertheless, although the available content repositories offer high quality learning objects, and moreover, those objects are tagged using a common metadata schema, (that is, the IEEE Learning Objects Metadata standard (IEEE, 2002)), reusing learning content in different contexts requires significantly extra pedagogical effort (Mohan, Greer, & McGalla, 2003). The authors of this article believe that this is due to the fact that most existing state-of-the-art web-based educational systems architectures rely on the content delivery and the metadata used for describing it, but come short in supporting the proces of web-based authoring of learning activities and their inter-exchanges.

Current State-of-the-Art Learning Systems

For the purpose of our work, a learning activity can be formally defined as a triple containing the content that is delivered by an educational system, the actors participating in the learning activity (such as the learner or a group of learners, the tutor, etc.) and their corresponding interactions. These interactions include three types, namely, interactions with the learning content, interactions with the educational environment and interactions between the participating actors.

In this section we present the current state-of-the-art learning systems' architecture investigating the limitations of those systems in the process of sharing learning activities.

Currently, there are several vendors that provide learning platforms, such as such as Blackboard (Blackboard, 2005), WebCT (WebCT, 2005), Lotus Learning Space (IBM Lotus, 2005) and Learn eXact (Learn eXact, 2005), being standard conformant. Those platforms are based on the IEEE Learning Technology Systems Architecture (LTSA) standard (IEEE LTSA 2001; O'Droma, Ganchev, & McDonnell, 2003). This standard specifies an architecture for information technology-supported learning, education and training systems that describes the high-level system design and the components of these systems, using a five-layer structure. The LTSA Layer 3 specifies the main components and interfaces in the architecture of learning systems. These components (shown in Figure 1) form a model that describes how the different entities in the learning system interact with each other.

There are three types of components defined in the LTSA Layer 3:

- *Processes* (depicted as oval shapes in Figure 1) are the boundaries, services, inputs, and outputs of the learning system. Processes refer to users' and system components that cause changes in the state of the system.
- *Stores.* Two types of stores (represented as rectangular shapes in Figure 1) are described in the reference model. These relate to repositories of data that can be accessed by users using search, retrieval, and updating methods. In practice, the stores correspond to the system's database structures.

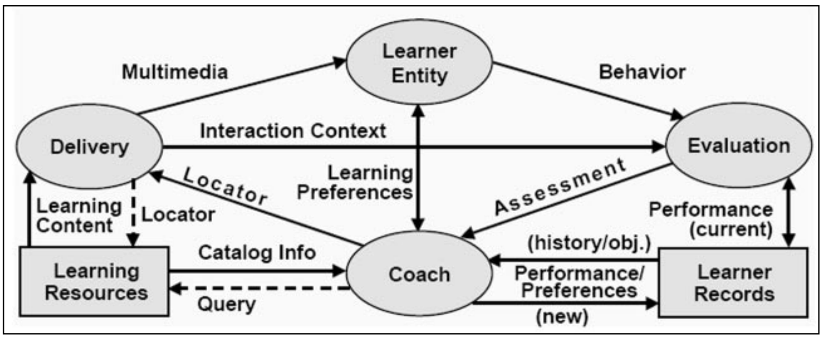

Figure 1. LTSA system components (IEEE LTSA 2001)

- *Flows* are described in terms of connectivity and the type of information exchanged. These are illustrated as arrowed lines between the processes and stores in Figure 1. Essentially, flows depict the interactions that take place between the various processes and stores of the IEEE LTSA system design.

In the LTSA reference architecture the element "content" of a learning activity is represented as a store called *learning resources* and the interaction of a participating actor with the content is represented as a flow called *multimedia*. This flow is a unidirectional flow from the delivery system to the actor. This means that interactions from the actors to the content are not supported by the reference architecture. Moreover, the element "actors" of a learning activity is represented in the reference architecture as two processes called *learner entity* and *coach* respectively. The learner entity represents an abstraction of a human learner and the coach entity an abstraction of a human teacher. The interaction between the learner and the teacher is represented directly as a flow called *learning preferences* and indirectly through the process of evaluation and the behavior and assessment flows. The IEEE LTSA architecture considers two actors, namely, the learner and the teacher and defines interactions between them. Interactions between individual learners are not described in the system components layer. Instead, they are abstracted in layer 1 (see Figure 2)

From Figure 2 we can notice that interaction between the environment and the learner entity is unidirectional, while interactions between individual learners are abstracted with no reference on how the learning system should support those interactions.

ADL Sharable Content Object Reference Model (SCORM) refines the IEEE LTSA reference architecture by specifying missing interactions. More precisely, the SCORM 2004 (ADL SCORM, 2004) provides a reference interaction model between participating actors and learning content, and describes within a common technical framework for computer and web-based learning the creation process of reusable learning content as instructional objects called *sharable content objects* (SCOs). SCORM describes that technical framework by providing a harmonized set of guidelines, specifications, and standards based on the work of several distinct e-learning specifications and standardization bodies. SCORM consists of three parts:

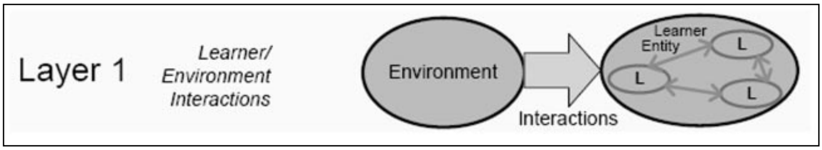

Figure 2. LTSA Learner/Environment interactions (IEEE LTSA 2001)

- *Content Aggregation Model (CAM).* The SCORM CAM describes the content components used in a learning activity, how to package those components for exchange from system to system and how to describe those components to enable search and discovery. The CAM promotes the consistent storage, labeling, packaging, exchange and discovery of learning content. The SCORM CAM model contains information on Metadata, Content Structure and Packaging.
- *Run-Time Environment (RTE).* The purpose of the SCORM RTE is to provide a means for interoperability between SCOs and LMSs. SCORM provides the means for learning content to be interoperable across multiple learning systems regardless of the tools used to create the content. The three components of the SCORM RTE are *Launch, Application Program Interface* (API) and *Data Model*. Launch includes defining the relationship between learning systems and SCORM content such that all SCORM-conformant content is dependant upon a SCORM-conformant learning system to be delivered and displayed to the learner. The SCORM API provides a set of predefined methods for purposes of communication between a learning system and the SCOs it launches. The SCORM Run-Time Environment Data Model, provides the data elements that can be used to get and set data from and to a learning system.
- *Sequencing and Navigation (SN).* The SCORM SN covers the essential learning system responsibilities for sequencing content objects during run-time and allowing SCOs to indicate navigation requests. The SCORM SN is based on the IMS Simple Sequencing (SS) Specification v1.0 (IMS, 2003), which defines a method for representing the intended behavior of an authored learning activity such that any conformant learning system will be able to sequence discrete content components in a consistent way. It defines the required behaviors and functionalities that SCORM-conformant learning systems must implement to process sequencing information at runtime. More specifically, it describes the branching and flow of learning content in terms of an Activity Tree, based on the results of a learner's interactions with launched content objects and an authored sequencing strategy. The SCORM SN describes how learner-initiated and system-initiated navigation events can be triggered and processed, resulting in the identification of learning content for delivery.

Based on the definition of learning activities as triples, the IEEE LTSA reference model with the refinements introduced by SCORM can provide learning systems that are capable of representing learning activities that engage learner and tutor and define interactions between them and interactions with the content. The open issues in modeling of a learning activity include the description of interactions between the participating roles and the environment, as well as, the definition of multiple participating roles (e.g., multiple learners working together) and the interactions between them.

Current State-of-the-Art Authoring Tools

Nowadays, there are several vendors that provide Learning Management Systems incorporating authoring tools that are based on the SCORM reference model.

The main limitation of the SCORM-based courseware authoring tools is that they are based on a single learner model. This model assumes that a learner interacts only with content objects and that the learning activities are content-based activities engaging the learner in the learning process. Thus, the support provided by SCORM-based courseware authoring tools in the authoring process is limited in supporting the creation and sequencing of single learner, content-based learning activities. To this end, such authoring tools exclude the design of activities based on state-of-the-art pedagogical approaches such as constructive learning, collaborative learning etc. Moreover, since interactions between individual learners and/or between a learner and a tutor are abstracted in the SCORM reference model with no reference on how a learning system could support those interactions, SCORM-based authoring tools limit the interoperability between systems to only content interoperability. These tools do not allow the description of such interactions leading to possibly different interpretation of learning activities between different systems.

On the other hand, a wide variety of non-SCORM conformant systems exist providing specific pedagogical approaches including active learning, constructive learning, collaborative learning, intentional learning, conversational learning, contextualized learning, reflective learning, such as ActiveMath (Melis et al., 2001; Libbrecht, 2004), MetaLinks (Murray, 2002), NetCoach (Weber, Kuhl, & Weibelzahl, 2001), DCG (Vassileva & Deters, 1998), Interbook (Brusilovsky, Eklund & Schwarz, 1998). The main drawback of those systems is that they are closed, self-contained systems that cannot be used as service components (*lack of reuse support*) (Brusilovsky, 2004). Additionally, due to their close architecture they cannot support all the required functionalities in a learning process since they cannot use external services (*lack of integration*). On the other hand, even if an open and scalable environment has been implemented, the supported content and learning scenarios are a-priori designed to serve and support a specific pedagogical approach. As a result they are non-flexible in supporting different pedagogical approaches and they require extensive redesign effort in order to be used in different domains.

Modeling Learning Activities

The Need for Standardization

Reusing learning activities across different learning systems requires that all components of a learning activity can be modeled in a commonly understandable form (Rawlings, Van Rosmalen, Koper, Rodriguez-Artacho, & Lefrere, 2002; Koper, 2001; Koper & Manderveld, 2004) and that those platforms include the structural components required for the support of learning activities (Koper & Olivier, 2004). A first step is to agree on common ways for representing learning scenarios and describing the interactions between participating roles (learners, tutors, etc.) and educational systems' services. The ultimate goal is to structure the learning scenarios in such a way that separates them from the learning resources. Thus, learning resources can be reused within different scenarios and scenarios can be also reused when populated with different resources. Moreover, repurposing of learning activities in a consistent manner requires authoring tools that are capable of handling the machine understandable representation form of learning activities (Koper & Tattersall, 2005).

To this end, standardization efforts on learning technologies have led to the IMS Learning Design specification (IMS GLC, 2003) which provides a standard notation language for the description of learning scenarios. This specification promises the capability of describing a wide variety of learning activities based on different pedagogies. IMS Learning Design has the ability to define the role of different actors in the learning process, enabling the definition of both teacher-led and student-led scenarios. This specification builds upon the IMS Content Packaging specification, thus can integrate single learner (SCORM-compatible) activities in more complex activity-based learning scenarios.

The Learning Design Framework

The core concept of the Learning Design framework is that regardless of the pedagogical strategy, learners attain learning objectives by performing a specific order of learning activities. Multiple roles can participate in learning and/or support activities of the training process. This formalization has the potential to describe a wide variety of learning activities based on different pedagogies.

The core components of the Learning Design Framework are shown in Figure 3 and summarized below:

- *Role* component specifies the participating roles in learning activity. There are two basic Role types: the *Learner* and the *Staff*. These roles can be sub-typed to allow learners to play different roles in certain types of learning activity such as task-based, role-play and simulations. Sim-

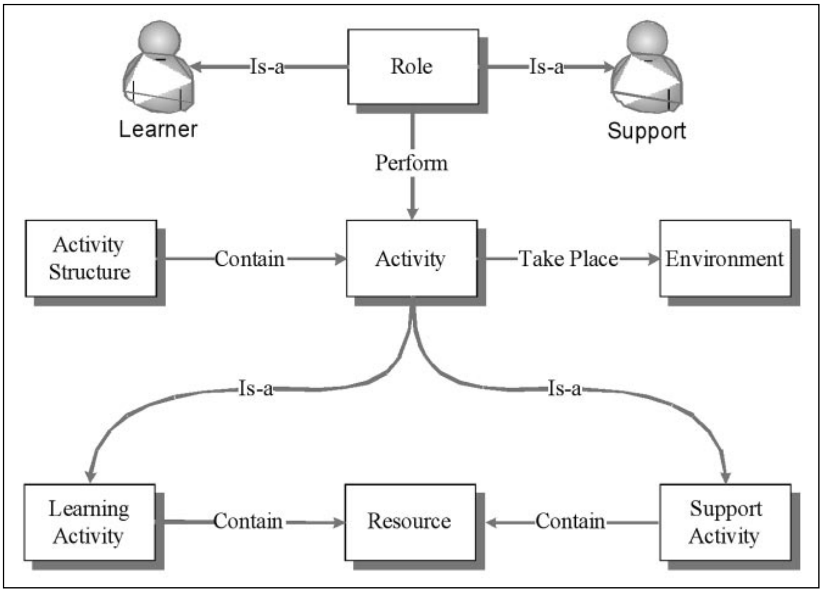

Figure 3. Learning Design rationale

ilarly, support staff can be sub-typed and given more specialized roles, such as Tutor, Teaching Assistant, and Mentor. Thus, Roles set the basis for multi-user models of learning. The name that a certain role is given depends on the underline pedagogy and the setting in use. In some instances a learner is called a *student*, whereas in others a *participant*. The names of staff roles can be even more diverse (e.g., teacher, trainer, tutor, facilitator, mentor, assessor).

- *Activities* are one of the core structural elements of the learning workflow model for Learning Design. They form the link between the roles and the services in the learning environment. They describe the activities that a certain role can undertake within a specified environment. They also specify their termination conditions and the actions to be taken upon termination. There are two basic types of activities: *Learning Activities* and *Support Activities*. A Learning Activity is directed at attaining a learning objective per individual actor. A support activity is meant to facilitate a role performing one or more learning activities.

The Learning Design framework is implemented in the IMS LD specification at three levels. Learning Design Level A includes the following elements: a series of activities (assessment, discussion, simulation), performed by one or more actors (learners, teachers, etc.) - roles, in an environment consisting of learning objects or services. Level B adds properties (storing information about a person or group), and conditions (placing constraints upon flow). Level C adds notifications (triggered events - e.g., if a student asks a question, the teacher needs to be notified that a response is needed).

Towards Next Generation Activity-Based Learning Systems Architecture

The Authoring System

In this section, we present the high-level architecture for authoring of learning activities that combines the components of a SCORM-compatible authoring system with the Learning Design framework. The key design principle in this architecture is the separation of the learning design process from the content packaging process. This separation enables the design of learning scenarios by defining the participating actors, the response of a learning system to their interaction with the learning content and the services provided by the learning system in such a way that is independent from the learning content. Thus, it enables the same learning scenario to be used with different content, as well as, different learning scenarios to use the same content objects.

Figure 4 presents the proposed authoring architecture based on the Learning Design framework described in the previous section of the article. This figure shows the structural components of the authoring system and their interconnection paths. Interconnection between components is modeled by associations (directed arrows). These associations represent direct connections or they abstract away details of more complex connection and communication patterns (e.g., indirect communication based on events).

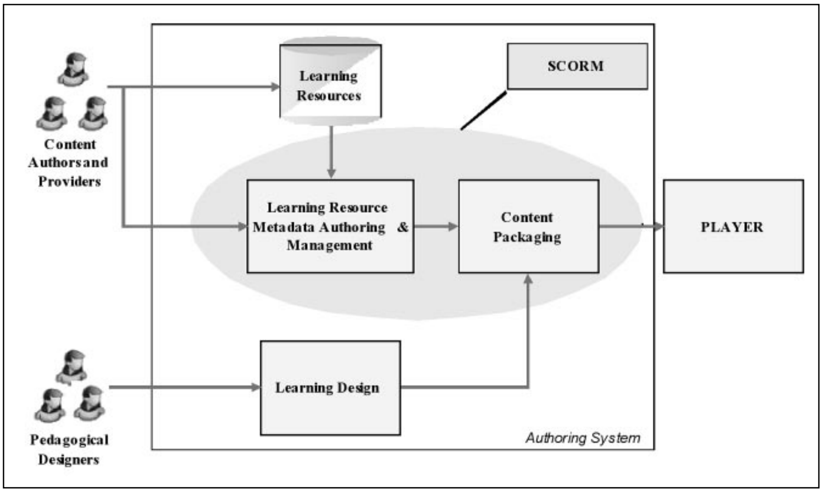

Figure 4. Authoring System Architecture incorporating Learning Design

The main components of the proposed architecture are the following:

- *Learning Design subsystem.* This part of the authoring system is based on the use of IMS Learning Design specification in order to provide the pedagogical designer with the environment for defining learning scenarios. The main scope is to enable the definition of generic, domain independent learning scenarios that can be used by the content packaging system in order to create learning activities based on the use of the learning objects stored in the content repository.
- *Content Packaging subsystem.* This part of the authoring system enables the population and packaging of learning scenarios with the learning content. In our system implementation, the development of such packaging tool is based on the commonly used IMS Content Packaging v1.1.3 specification and the supported metadata for indexing the content components of learning activity is based on the IEEE Learning Object Metadata standard.
- *Learning Resources Metadata Authoring & Management subsystem.* This part of the authoring system supports the metadata authoring and repository management. The main goal of this component is to provide an easy-to-use and accessible from anywhere platform capable of authoring, storing, managing and deliver the educational metadata produced for supporting searching and retrieval of learning resources.

The Runtime System

In this section, we present a high-level architecture for the Learning Design runtime system. The key design principle of the runtime system architecture is the capability of invoking distributed services defined in the design of learning activities. The distributed services can be activity-based services, that is, services that have embedded a learning scenario (e.g., a simulation game with specific learning objectives and guidelines on how to achieve the learning goal), or content-based services, that is, services providing educational content without specific learning objectives.

Figure 5 presents a service-based architecture for LD runtime system that supports the integration of distributed services in the design of learning activities. The main components of the proposed architecture are the following:

- *Roles Activity Handler.* This part of the runtime system is responsible for setting up the different runtime instances (runs) based on the role part definitions in the Learning Design manifest. This handler controls the different activity scripts for the different participating roles in the learning process.
- *Sequencing Rules Handler.* This part of the runtime system controls the sequencing information (flow of activities) defined in a runtime

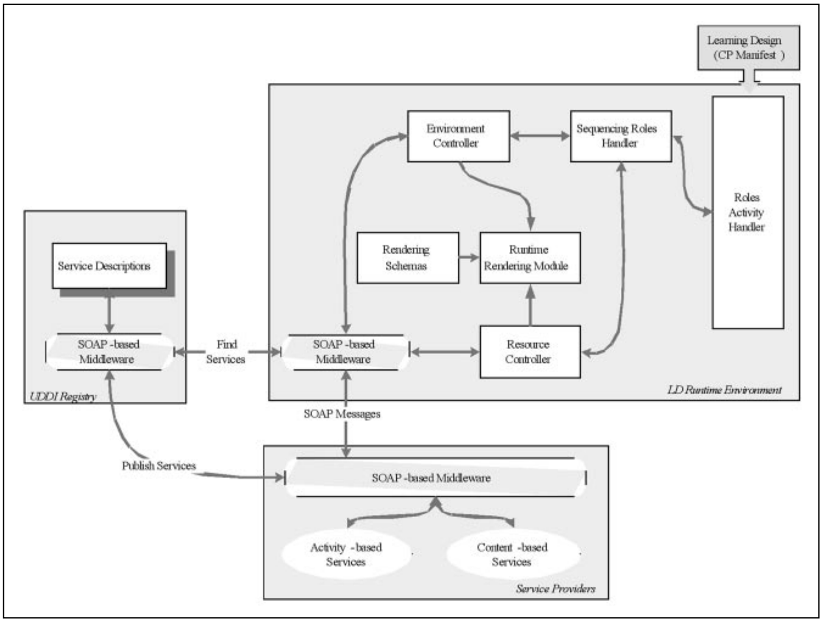

Figure 5. Learning Design runtime architecture

instance based on sequencing rules (conditions) defined over learning and support activity properties. These rules represent the method which will be used for navigating over the flow of activities defined in the Learning Design manifest.

- *Environment Controller.* This part of the runtime system is responsible for controlling the required environments for each activity defined in the activity sequence. At design time (authoring phase) the software environments, which an activity utilizes are defined. The environment controller will initiate a search request for the corresponding services (e.g., forum, chat, etc.) and will initialize them using the corresponding parameters defined at design time.
- *Resource Controller.* Similarly to the environment controller the resource controller is responsible for requesting the resources associated with a specific learning activity at design time.
- *Runtime Rendering Module.* This part of the runtime system invokes the services retrieved by the environment and the resource controller in order to provide the actual services. The rendering process uses the corresponding rendering schemas retrieved from the *Rendering Schemas Pool.*

ASK-LDT: An Authoring Tool for Learning Activities Based on IMS Learning Design

Description of the ASK-LDT

The ASK Learning Designer Toolkit (ASK-LDT) (Sampson, Karampiperis, & Zervas, 2005) is a tool supporting the proposed architectural approach for learning activities authoring (see Figure 6).

The ASK-LDT is based on the use of IMS Learning Design specification in order to provide to a pedagogical designer the environment for defining complex learning scenarios. The produced learning scenarios conform to the IMS Learning Design v1.0 Level B specification. The ASK-LDT also supports metadata for learning resources that conform to the IEEE Learning Object Metadata 1484.12.1-2002 standard.

Based on the Learning Design framework principles, the authoring process that the ASK-LDT supports consists of the following steps (Figure 7):

- *Definition of Pedagogical Elements.* At this step the ASK-LDT supports the pedagogical designer in defining the activity types he/she wants to support in a learning scenario, as well as, in defining a notation schema for each activity type specified. During this step the designer has the ability to characterize each activity type as *learning* or *support* activity.
- *Definition of the Environment.* At this step a designer defines the participating roles in the desired learning scenario, as well as, the environments in which the activities are taking place. An environment can be a virtual environment (such as a virtual laboratory, an online chat, a dis-

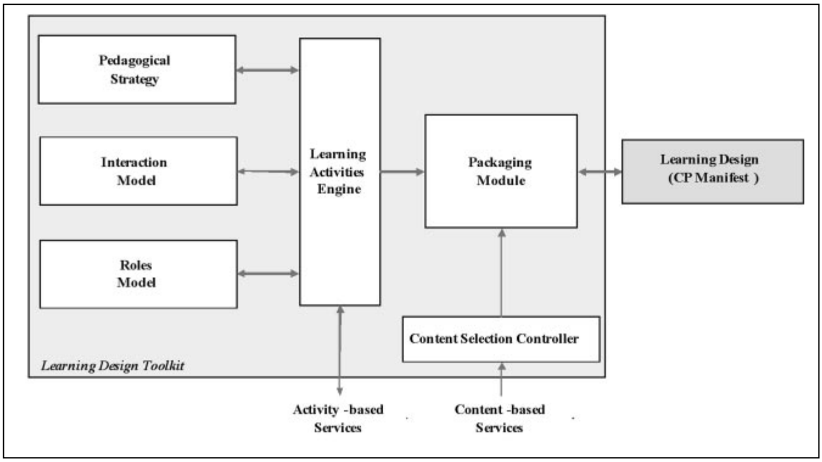

Figure 6. Internal architecture of ASK-LDT

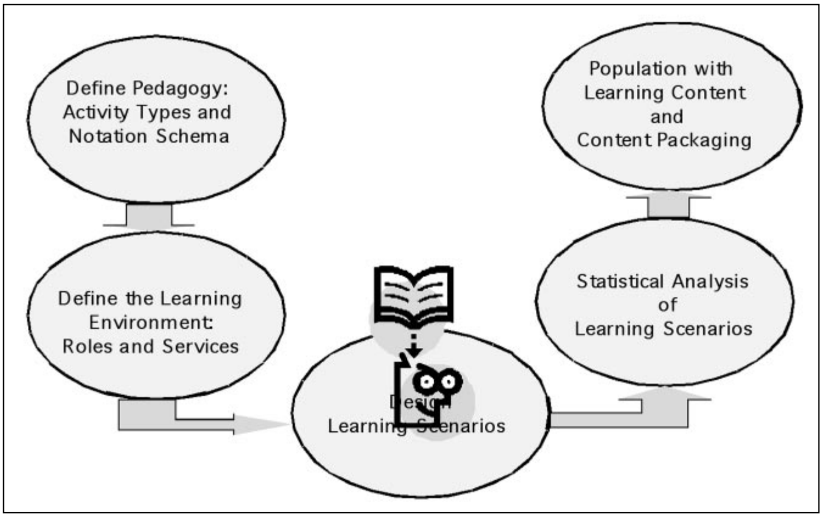

Figure 7. ASK-LDT authoring process

cussion forum, etc.), or a software tool exposed as a service (such as an annotation tool, a search engine, etc.).

- *Learning Scenario Design.* During this step the designer specifies the activity sequence of a learning scenario using a graphical user interface. For each activity the designer defines the participating roles, the environment in which the specific activity is taken place, as well as, the method by which this activity will be completed and/or terminated (user choice or time limit).
- *Statistical Analysis.* At this step the ASK-LDT provides statistics of the use of each activity type and environment in the learning design specified, in order to visualize the designer's decisions.
- *Content Packaging.* This is the final step in the authoring process, in which the content components required to support the designed activities are specified. The output of this step is content packages conforming to the IMS Content Packaging v1.1.3 specification.

The core design concept of the ASK-LDT is to provide a graphical user interface for the design and sequencing of learning activities, which, on one hand uses a standard low-level notation language for the description of learning scenarios (so as to be able to inter-exchange learning activities between different systems), and on the other hand enables pedagogical designers to use their own design notation (high-level notation) for the definition of learning scenarios (see Figure 8).

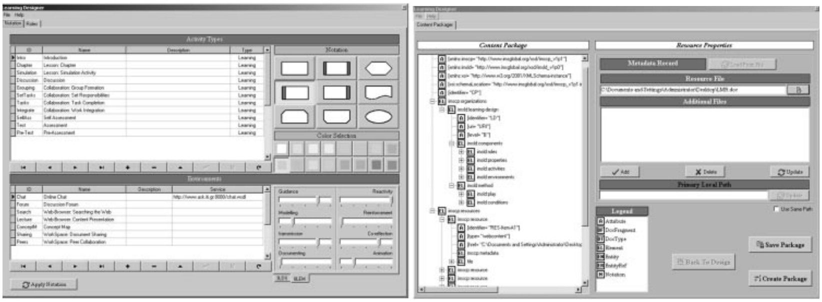

Figure 8. Supporting high and low level notation with the ASK-LDT

The ASK-LDT supports the learning design process by allowing the design of sequences of learning activities, as well as, the definition of the participating roles and the corresponding environments for each part of these activities. It provides several advanced features (Figure 9) including the capability to define participating roles based on specific attributes of a user model and offers advanced control of learning activities sequencing based on the definition of properties and conditions upon learning flow.

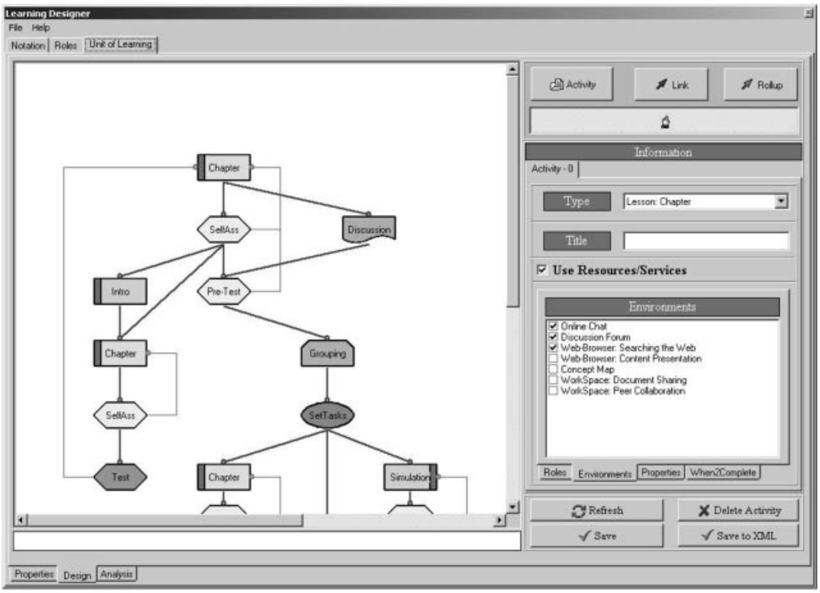

Figure 9. Supporting learning scenarios design and role definition through a graphical design interface

The following section presents the use of the ASK Learning Designer Toolkit in the definition of learning activities following the principles of the Learning Design framework.

Collaborative Creation of Concept Map Scenario Using ASK-LDT

An example of a learning scenario which can be defined with the use of the ASK-LDT is a scenario for collaborative creation of a concept map. In this scenario several participants are trying to collaboratively create a concept map based on their experiences on a specific subject. For each concept or relation defined on the concept map they are asked to explain (by annotating the corresponding concept or relation) the reasons for adding this information.

Following the authoring process supported by the ASK-LDT the pedagogical designer has to follow the following steps:

- *Definition of Pedagogical Elements.* In this learning scenario the activity types in use are brainstorming, annotation, discussion and knowledge expression.
- *Definition of the Environment.* In these activity types two roles are participating: the moderator and the users. The environments in which these activity types are taking place are discussion forum, online chat, annotation tool and concept representation tool.
- *Learning Scenario Design.* During this step the designer specifies the activity sequence presented in Figure 9, representing the desired learning scenario. For each activity specified the designer defines the participating roles and the corresponding environments.
- *Content Packaging.* In this step of the authoring process, the content components required to support the designed activities are specified (e.g., an introductory text-based component presenting the objectives of the whole activity).

The output of this process is a content package conforming to the IMS Content Packaging v1.1.3 specification that can be delivered through an IMS Learning Design conformant learning platform.

In the literature, a number of systems implementing this scenario exist (Kay & Miller, 2003; Mirlad, Spector, & Davidsen, 2004). The main limitation of those systems is that they are closed systems. Thus, they support only the specific learning scenario and that those systems due to their architecture cannot be used externally from other platforms to support the learning process. By using the ASK-LDT, pedagogical designers can specify their desired learning scenarios in an abstract way that enables system designers to implement required software components as services. As a result, software components can be reused to support different learning activities (e.g.,

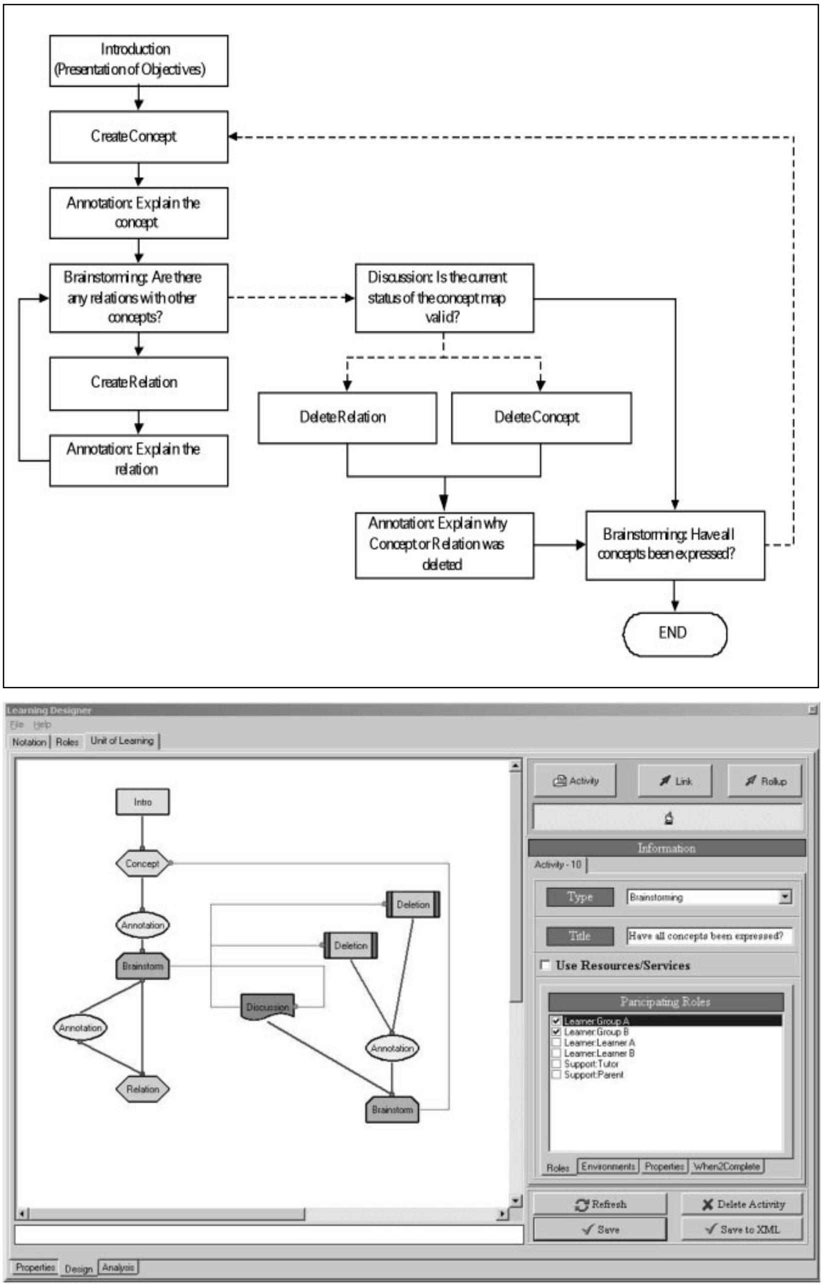

Figure 10. Example of scenario for collaborative concept-map creation

the same annotation tool used in the above mentioned scenario for concept map creation can also be used in a collaborative peer reviewing scenario).

Moreover, since the learning scenario is not hard-wired in the specific learning platform, but acts as a script delivered by the learning platform, learning platforms can support several pedagogical scenarios enabling at the same time reusability of learning activities across different platforms

CONCLUSIONS

In this article we discussed the limitations of the state-of-the-art of learning systems and authoring tools and discussed open issues and problems concerning the support of learning activities. Based on this discussion, we investigated how the Learning Design framework can be incorporated in the architecture of a SCORM-compatible authoring and runtime system so as to address those issues. Then, we presented a high-level system architecture that utilizes the Learning Design principles to provide the means for designing activity-based learning systems. Finally, we examined the use of ASK-Learning Designer Toolkit, which implements the presented architectural approach, in the definition of a complex learning scenario, namely, the collaborative creation of a concept map.

References

Advanced Distributed Learning Initiative. (2004). ADL Sharable Content Object Reference Model (SCORM) Version 1.2. Available at http://www.adlnet.org (Retrieved 28 August 2005).

Blackboard Inc. (2005). Blackboard Course Management System, Blackboard Inc., Available at http://www.blackboard.com/ (Retrieved 28 August 2005).

Brusilovsky, P., Eklund, J., & Schwarz, E. (1998). Web-based education for all: A tool for developing adaptive courseware. *Computer Networks and ISDN Systems, 30*, pp.291–300.

Brusilovsky, P., & Nijhawan, H. (2002). A framework for adaptive e-learning based on distributed re-usable learning activities, In *Proc. of the World Conference on E-Learning*, pp. 154-161.

Brusilovsky, P. (2004). KnowledgeTree: A distributed architecture for adaptive e-learning. In *Proceedings. of The Thirteenth International World Wide Web Conference*, pp. 104-113.

Carr, C. S. (2001). Computer-supported collaborative argumentation: Supporting problem-based learning in legal education. In *Proc. of the Computer support for Collaborative Learning Conference* (CSCL), Maastricht University, Holland.

Duval, E., Forte, E., Cardinaels, K., Verhoeven, B., Van Durm, R., Hendrix, K., Wentland Forte, M., Ebel, N., Macowicz, M., Warkentyne, K., & Haenny, F. (2001). The Ariadne knowledge pool system. *Communications of ACM 44*(4), pp. 73-78.

Friesen, N., Roberts, A., & Fisher S. (2002). CanCore: Metadata for learning objects. *Canadian Journal of Learning and Technology 28*(3), pp. 43-53

Gonzalez, M. A. C., Suthers, D., & Escamilla De Los Santos, J. G. (2003). Coaching web-based collaborative learning based on problem solution differences and participation. *International Journal of Artificial Intelligence in Education 13*(1)

Guth, S., Neumann, G., & Simon, B. (2001). UNIVERSAL design spaces for learning media. In Sprague R. H. (Ed) *Proceedings of the 34th Hawaii International Conference on Sytem Sciences.* Maui, USA.

IBM Lotus, Lotus Learning Space (2005). Available at http://www.lotus.com/products/learnspace.nsf/wdocs/homepage (Retrieved 28 August 2005).

IEEE Learning Technology Standards Committee, IEEE Computer Society (2001). Draft standard for learning technology - Learning Technology Systems Architecture (LTSA). IEEE P1484.1/D9,2001-11-30. (Retrieved 28 August 2005).

IEEE (2002). IEEE standard for learning object metadata. IEEE P1484.12.1/d6.4. Available at http://ltsc.ieee.org/wg12/files/LOM_1484_12_1_v1_Final_Draft.pdf (Retrieved 28 August 2005).

IMS (2003). Simple Sequencing Specification Version 1.0. [Online]. Available: http://www.imsglobal.org/simplesequencing/index.cfm (Retrieved 28 August 2005).

IMS Global Learning Consortium Inc. (2003) *IMS Learning Design Specification Version 1.0.* Available at http://www.imsglobal.org/learningdesign/index.cfm (Retrieved 28 August 2005).

Jonassen, D. H., Hernandez-Serrano, J., & Choi, I. (2000). Integrating constructivism and earning technologies. In Spector, J. M. and Anderson, T. M. (ed), *Integrated and holistic perspectives on learning, instruction and technology: Understanding complexity*, Dordrecht: Kluwer, pp. 103-128.

Kay, C. J., & Miller A. (2003). Incremental student modelling and reflection by verified concept-mapping, in *Proc. of the AIED2003*. Learner Modelling for Reflection Workshop. vol. V pp. 219-227.

Koper, E. J. R. (2001). Modelling units of study from a pedagogical perspective: The pedagogical metamodel behind EML. [Online]. Available: http://eml.ou.nl/introduction/docs/ped-metamodel.pdf (Retrieved 28 August 2005).

Koper, E. J. R., & Manderveld, J. M. (2004). Educational modelling language: Modelling reusable, interoperable, rich and personalised units of learning, *British Journal of Educational Technology, 35*(5), pp. 537-551.

Koper, R., & Olivier, B. (2004) Representing the learning design of units of learning. *Educational Technology and Society, 7*(3), pp. 97-111.

Koper, R., & Tattersall, C. (2005), *Learning design: A handbook on modelling and delivering networked education and training*, Springer-Verlag.

Learn eXact, Giunti Interactive Labs. (2005). Available at http://www.learnexact.com (Retrieved 28 August 2005).

Libbrecht, P. (2004). Authoring Web Content in ActiveMath: From Developer Tools and Further. In *Proc. of the 3rd International Conference on Adaptive Hypermedia and Adaptive Web-based Systems* (AH2004), Workshop on Authoring of Adaptive and Adaptable Educational Hypermedia, Eidhoven, Netherlands.

Littlejohn, A. (Ed) (2003). *Reusing online resources: A sustainable approach to e-learning*, Kogen Page, London.

Marra, R. M., & Jonassen, D. H. (2001). Limitations of online courses for supporting constructive learning. *Quarterly Review of Distance Education, 2*(4), pp. 303-317.

McGreal, R. (Ed.) (2004). *Online education using learning objects*, Taylor & Francis Books Ltd.

Melis, E., Andrus, E., Bodenbender, J., Frishauf, A., Goguadse, G., Libbrecht, P., Pollet, M., & Ullrich, C. (2001). ActiveMath: A web-based learning environment. *International Journal of Artificial Intelligence in Education, 12*(4), pp. 385-407.

Milrad, M., Spector, J. M., & Davidsen, P. I. (2004). Model facilitate learning. in S. Naidu (Ed.), Investigating the effects of information and communications technology: What is working, where and how. London: Kogan Page.

Mohan, P., Greer, J., & McGalla, G. (2003). Instructional planning with learning objects. In *Proc. of the 18th International Joint Conference on Artificial Intelligence*, Workshop on Knowledge Representation and Automated Reasoning for E-Learning Systems.

Murray, T. (2002). MetaLinks: Authoring and affordances for conceptual and narrative flow in adaptive hyperbooks. *International Journal of Artificial Intelligence in Education.* Special Issue on Adaptive and Intelligent Web-Based Systems, vol. 13.

Nejdl, W., Wolf, B., Qu, C., Decker, S., Sintek, M., Ambjorn, N., Nilsson, M., Palmer, M., & Risch, T. (2002). Edutella: A P2P networking infrastructure based on RDF. In *Proceedings of the 11th International World Wide Web Conference*. Hawaii, USA.

O'Droma, S. M., Ganchev, I., & McDonnell, F. (2003). Architectural and functional design and evaluation of e-learning VUIS based on the proposed IEEE LTSA reference model. *Internet and Higher Education, 6*, pp. 263-276.

Olivier, B., & Liber, O. (2003). Learning content and interoperability standards. In Littlejohn, A. (Ed), *Reusing online resources: A sustainable approach to e-learning*, Kogen Page, London, pp. 146-155.

Quemada, J., & Simon, B. (2003). A use-case based model for learning resources in educational mediators. *Educational Technology and Society, 6*(4), pp. 149-163.

Rawlings, A., Van Rosmalen, P., Koper, R., Rodriguez-Artacho, M., & Lefrere, P. (2002). Survey of Educational Modeling Languages (EMLs) Version 1.0, *CEN/ISSS Learning Technologies Workshop*,.Available at: http://www.cenorm.be/cenorm/businessdomains/businessdomains/isss/activity/emlsurveyv1.pdf (Retrieved 28 August 2005).

Richards, G. (2002). Editorial: The challenges of the learning object paradigm. *Canadian Journal of Learning and Technology, 28*(3), pp 3-9.

Sampson, D., Papaioannou, V., & Karadimitriou, P. (2002). EM2: An environment for editing and management of educational metadata. *Educational Technology & Society Journal, 5*(4), pp. 98-115.

Sampson, D., & Karampiperis, P. (2004). Reusable learning resources: Building a metadata management system supporting interoperable learning object repositories. In McGreal R. (ed), *Online Education Using Learning Objects*, Taylor & Francis Books Ltd.

Sampson, D. (2004). The evolution of educational metadata: From standards to application profiles. In *Proceedings. of the 4th IEEE International Conference on Advanced Learning Technologies* (ICALT 2004), Finland.

Sampson, D., Karampiperis, P., & Zervas, P. (2005). ASK-LDT: A web-based learning scenarios authoring environment based on IMS learning design. *Advanced Learning Technologies Journal, 2*(5).

Simon, B., Dolog, P., Miklos, Z., Sintek, M., & Olmedilla, D. (2004). Conceptualising smart spaces for learning. *Journal of Interactive Media in Education,* Special Issue on the Educational Semantic Web, vol. 9.

Vassileva, J., & Deters, R. (1998). Dynamic courseware generation on the WWW. *British Journal of Educational Technology, 29*(1), pp. 5–14.

WebCT (2005). WebCT Course Management System, Lynnfield, MA, WebCT, Inc., Available at http://www.webct.com (Retrieved 28 August 2005).

Weber, G., Kuhl, H.-C., & Weibelzahl, S. (2001). Developing adaptive Internet based courses with the authoring system NetCoach. In *Proc. of the 8th International Conference on User Modeling* (UM2001), Workshop on Adaptive Hypertext and Hypermedia, Sonthofen, Germany, pp. 35-48.

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A "Simple Query Interface" Adapter for the Discovery and Exchange of Learning Resources

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Developed as part of CEN/ISSS Workshop on Learning Technology efforts to improve interoperability between learning resource repositories, the Simple Query Interface (SQI) is an Application Program Interface (API) for querying heterogeneous repositories of learning resource metadata. In the context of the ProLearn Network of Excellence, SQI is used to interconnect heterogeneous networks of metadata repositories such as Elena, Celebrate, Ariadne or Edutella (Simon, Massart, Van Assche, Ternier, Duval, & Brantner, et al., 2005).This article proposes to use SQI not only as an interface for searching metadata as it is primarily intended by the CEN/ISSS workshop, but also to obtain the learning resources themselves. It describes how, taking advantage of its asynchronous mode, SQI constitutes a simple and robust entry point to the networks of metadata and learning object repositories that compose an iClass server.

Learning objects are definable, reusable chunks of digital content and process elements used for learning, training, and instruction (Richards, 2002). Actually, learning objects can be anything digital used in learning (e.g., texts, illustrations, digital videos, interactive multimedia, tests, lessons, or courses). The potentially dynamic and multimedia nature of learning objects makes most of them unlocatable using text-based search engines such as Google which, in addition, returns results that are difficult to assess by teachers and pupils. This problem is usually solved by creating metadata to adequately describe learning objects (Richards & Hatala, 2003). The IEEE Learning Object Metadata standard (IEEE Standards Department, 2002) was created to unify the way learning objects are described and to ease their retrieval. Although they can be stored on a web server, learning objects and metadata are often stored in specialized repositories referred to as learning object repositories.

Usually, obtaining a learning object is a three-step process consisting of (a) searching and evaluating metadata, (b) resolving the location of the chosen learning object, and (c) consuming the learning object. This process is depicted on the activity diagram of Figure 1.

1. *Searching and evaluating metadata:* Selecting a learning object that satisfies user needs on the basis of the description provided in the metadata. It may be necessary to repeat this step in order to refine the search criteria and find the appropriate learning objects.
2. *Resolving the learning object location:* Under some circumstances, metadata provides references to learning objects rather than their locations and an additional step is necessary to resolve the location of an object on the basis of its reference[1] . This situation occurs, for example, in the Celebrate federation (Van Assche & Massart, 2004; Simon & Colin, 2004) where the additional step, which consists of requesting a learning object location, is used to enforce the digital rights associated with the learning object. The actual location of a learning object is delivered only if the requester is authorized to access the learning object. Another reason (for not storing the location of a learning object in the metadata describing it) is illustrated by the iClass project (iClass Consortium, 2004) where the adaptive and multimedia nature of the learning objects combined with the peer-to-peer nature of the underlying network of learning object repositories makes it difficult to access learning objects directly. This is why, in iClass, the "resolve-location" step is used to retrieve the requested learning object in a peer-to-peer network of repositories and move it to a streaming server which, combined with a "presenter," gives access to the learning object using a web browser.
3. *Consuming the learning object:* Getting the selected learning object at the location – usually a universal resource locator (URL) – obtained during the second step.

Obtaining a learning object from a peer-to-peer network of learning object repositories, such as the one developed by the iClass project, requires

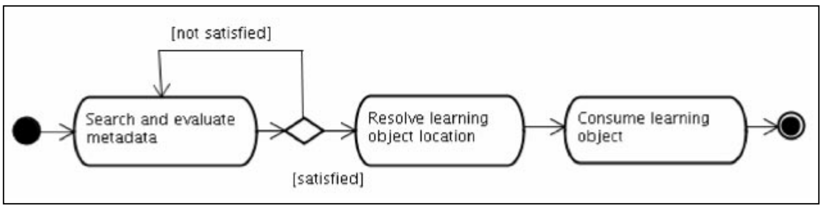

Figure 1. Activities involved in obtaining a learning object

an interface that not only supports all of the three steps but is also able to perform those steps in an asynchronous mode. Currently none of the interfaces that have been proposed to enable open learning object repositories to search each other[2] fulfills all those requirements.

Among these interfaces, the Simple Query Interface (SQI) is the only one that supports asynchronous queries. This article shows how the adapter developed by the iClass project (iClass Consortium, 2004) takes advantages of SQI independence in terms of query language and resulting formats to resolve learning object locations (i.e., step 2) in an asynchronous way.

The rest of this article is structured as follows: the section “Overview of the Simple Query Interface (SQI)” gives an overview of the main characteristics of the Simple Query Interface. “The iClass Adapter in Context” section presents the main components of the iClass project used for searching metadata and obtaining learning objects. Finally, the section “Obtaining Learning Objects with SQI” describes how SQI can be enriched by a new query language and a new result format to request learning object location without modifying the interface itself.

OVERVIEW OF THE SIMPLE QUERY INTERFACE (SQI)

The Simple Query Interface (SQI) is a standard[3] Application Program Interface (API) for querying heterogeneous learning resource repositories (Simon, Massart, Van Assche, Ternier, & Duval, 2005) (i.e., it covers the first step of the process of obtaining a learning object, previously described). Its main characteristics are:

- simplicity and ease of implementation,
- neutrality in terms of query languages and result formats, and
- support for both a synchronous and an asynchronous query mode.

Considering two repositories sharing at least a common query language and a common metadata format, the following steps are necessary to enable one repository (referred as the source of the query) to query the other (referred as the target of the query) using SQI:

- the source selects one of the query languages available at the target (e.g., XQUERY - It is possible to skip this step when a default query language is proposed by the target),
- the source selects one of the result formats available at the target (e.g., the IEEE Learning Object Metadata binding - Here also it is possible to skip this step when a default result format is proposed by the target),
- the source sends a query in the selected query language,
- depending on the query mode selected, the target provides the result of the query in the selected format either as the return value of the call used

to send the query (synchronous mode) or by calling one or more times a query result listener implemented by the source (asynchronous mode). The latter mode is much more robust and enables SQI to be used as the front-end interface of a federated search since it is not necessary to wait for the end of the initial query before returning the first results.

The API itself is depicted on the class diagram of Figure 2. It consists of 13 methods that can be grouped into four categories: session management, query management, synchronous query management, and asynchronous query management.

Actually, session management methods are not part of the SQI specification itself and can potentially be replaced by any other session management mechanism that would be considered more appropriate. Current methods permit opening anonymously (*createAnonymousSession*) or not (*createSession*) and to close (*destroySession*) a session with the target repository.

The query management methods permit the configuration of query parameters such as the query language (*setQueryLanguage*), the format of the results (*setResultsFormat*), the maximum number of results returned (*setMaxQueryResults)*, and the duration of a query (*setMaxDuration*).

In a synchronous query, query results are returned as the result of a query call (*synchronousQuery*). Additional methods permit the choice of the number of results returned by a call (*setResultsSetSize*) and to know the total number of results of a query (*getTotalResultsCount*).

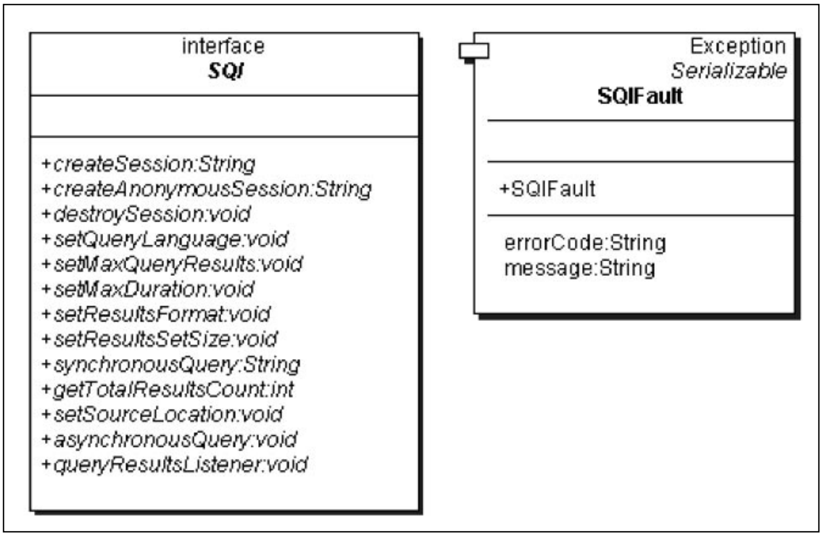

Figure 2. Class Diagram of the Simple Query Interface

In an asynchronous query, query results are sent by the target to the source of the query by calling a listener implemented by the source (*queryResultsListener*). This implies that the source has to indicate the location of the listener to the target (*setSourceLocation*) before sending an asynchronous query (*asynchronousQuery*).

The fault mechanism provided by SQI is intentionally unsophisticated. It aims at simplicity rather than richness in order to offer the greatest opportunity for consumption by a variety of applications. When a failure occurs, each SQI method is able to report it by throwing a fault (*SQIFault*) that specifies a predefined error code[4] and a free-text message.

THE ICLASS ADAPTER IN CONTEXT

The iClass adapter is a component of the Intelligent distributed Cognitive-based Learning System for Schools (iClass, [iClass Consortium, 2004]). It enables the end-users of so-called "legacy systems,"[5] such as the learning management systems and learning content management systems that are members of the Celebrate federation, to search and access iClass contents (or learning objects).

The iClass components interacting with the iClass adapter are specified on the component diagram of Figure 3. A legacy system communicates with an adapter using the simple query interface. In turn, the adapter communicates with two elements of the iClass server to which it is connected: the content server and the content distribution system using their respective interfaces.

The content server is a peer-to-peer network of metadata repositories (Blyuss, 2004b). It propagates each query received from node to node. Each node processes the queries and returns the results to the content server which forwards them asynchronously to the source of the query.

The content distribution system is a peer-to-peer network of learning object repositories (Blyuss, 2004a). When the location of an iClass learning object is requested (on the basis of an iClass learning object identifier found

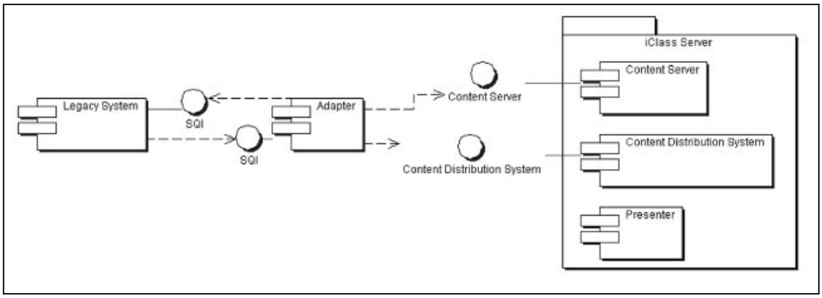

Figure 3. Component diagram of an iClass adapter

in the metadata), the request is propagated from node to node until an instance of the iClass learning object is found. The iClass learning object is then moved to a streaming server close to the requester location and a URL from which the iClass learning object can be consumed is returned by the content distribution system. Since potentially this process has a "certain duration," the content distribution system answers to these requests asynchronously. The presenter is a web server from which the iClass learning object can be consumed.

OBTAINING LEARNING OBJECTS WITH SQI

The use of a standard and open interface is a strong requirement to enable as many learning systems as possible to search and access the iClass collections of learning objects. The simplicity of SQI, its ability to be used in combination with any query language and result format, and its asynchronous query mode make it a good candidate interface for searching metadata in a peer-to-peer network of metadata repositories such as the iClass content server[6].

In iClass, metadata indicates the identifier of the learning object and not its location. A second step is thus necessary to resolve the location of a learning object identified in the metadata. Since an open interface for performing this step asynchronously does not exist, and rather than create an ad hoc interface, it was decided to use SQI for this task as well by adding a new "query language" for requesting a location and a new "result format" for returning a location to the list of languages and formats supported by the iClass adapter. It is easier for those with legacy systems and the adapter to implement this solution rather than a new interface.

The sequence diagram of Figure 4 describes the sequence of method calls necessary for obtaining the location of a learning object using the SQI interface of an iClass adapter. It covers both the step of searching the metadata and the one of resolving a learning object location. For simplicity, the method calls required to manage a session between the legacy system and the iClass adapter have been omitted.

Searching Metadata

- The legacy system starts by sending to the adapter the address of an SQI listener that can be used by the adapter to return query results (*setSourceLocation*).
- This being done, the legacy system sends an asynchronous query to the adapter (*asynchronousQuery*).
- The adapter forwards the query to the iClass content server (*queryMetadata*).
- The content server processes the query and sends the results (i.e., a set of metadata) back to the adapter (*queryResultsListener*).

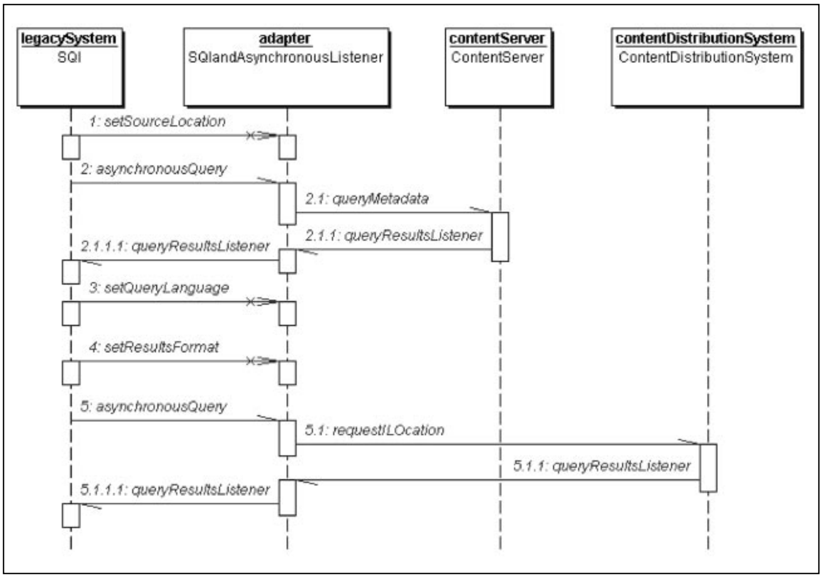

Figure 4. Sequence diagram describing the metadata search and the resolution of a learning object location by a "legacy system" using an iClass adapter

- In turn, the adapter propagates the results by calling the SQI listener implemented by the legacy system (*queryResultsListener*).

Resolving Location

At this stage, the legacy system is able to request the location of a learning object on the basis of the information found in the result of the query (i.e., metadata containing a learning object identifier),

- The legacy system calls the adapter to indicate that it will use a new query language (*setQueryLanguage*) and a new result format (*setResultsFormat*) to request a learning object location.
- In this particular case, the query language is named "ICLASS-LO-ID." A query in this ad hoc language consists of the requested learning object's identifier. The result's format is named "URL." A result in this format consists of a URL pointing to the requested learning object.
- Then, the legacy system sends the request (i.e., the identifier of the requested learning object) as an asynchronous query (*asynchronousQuery*).
- The request is forwarded by the adapter to the iClass content distribution system (*requestILOcation*).

- The content distribution system processes the request and returns to the adapter the URL from which the learning object can be consumed (*queryResultsListener)*.
- The adapter, in turn, forwards the URL by calling the SQI listener implemented by the legacy system (*queryResultsListener*).

At this stage, the URL can be used by a legacy system end-user to consume the learning object in a web browser.

CONCLUSION

Taking advantage of SQI independence in terms of query languages and result formats, this article proposes to use SQI not only for querying metadata as it is primarily intended in the context of the CEN/ISSS workshop on learning technology, but also for resolving the locations of learning objects. In the latter, requests for location are viewed as a query in an additional query language and locations are returned in what is considered as a new result format. This permits the minimization of the cost of implementing a "resolve-learning-object-location" step for learning object repositories that already use SQI for searching metadata.

References

Blyuss, I. (2004a). iClass content distribution system: High-level design specification. Version 0.6.

Blyuss, I. (2004b). iClass content server and database: High-level design specification. Version 0.2.

IMS Global Consortium (2003). *IMS digital repositories interoperability - core functions best practice guide.* Retrieved September 29, 2005 from http://www.imsglobal.org/digitalrepositories/driv1p0/imsdri_bestv1p0.html

iClass Consortium (2004). *Intelligent distributed cognitive-based learning system for schools.* Retrieved September 29, 2005, from http://www.iclass.info/iclass01.asp

IEEE Standards Department (2002). IEEE 1484.12.1-2002, *Learning object metadata standard.* Retrieved September 29, 2005, from http://ltsc.ieee.org/wg12/files/LOM_1484_12_1_v1_Final_Draft.pdf

Open Knowledge Initiative (OKI). Retrieved September 29, 2005, from http://www.okiproject.org/

Richards, G., & Hatala, M. (2003). Semantic cobblestones: An interoperability mechanism for learning object repositories. In R. McGreal (Ed.), *Online education using learning objects*, (pp. 301-313). London: Routledge Falmer.

Richards, G. (2002). The challenges of the learning objects paradigm. *Canadian Journal of Learning and Technology, 28*(3), 3-10.

Simon, J., & Colin, J.N. (2004). Celebrate: A federated model for exchange of learning objects. In *Proceedings of the World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education (ELEARN)*, (pp. 886–891), Washington, DC. Norfolk, VA: Association for the Advancement of Computing in Education.

Simon, B., Massart, D., Van Assche, F., Ternier, S., & Duval, E. (2005). *Simple query interface specification. Draft CEN Workshop Agreement (CWA).* Version 1.0 beta, Public Draft. Retrieved September 29, 2005, from http://nm.wu-wien.ac.at/e-learning/interoperability/SQI_V1.0beta_2005_04_13.pdf

Simon, B., Massart, D., Van Assche, F., Ternier, S., Duval, E., Brantner, S., et al. (2005, May). A simple query interface for interoperable learning repositories. In D. Olmedilla, N. Saito, & B. Simon, (Eds.), *Proceedings of the WWW*05 Workshop on Interoperability of Web-Based Educational Systems, 143,* 11-18, Chiba, Japan. Retrieved September 29, 2005, from http://sunsite.informatik.rwth-aachen.de/Publications/CEUR-WS/ Vol-143/paper02.pdf

Van Assche, F., & Massart, D. (2004, September). Federation and brokerage of learning objects and their metadata. In Kinshuk, C.K. Looi, E. Sultinen, D. Sampson, I. Aedo, L. Uden, & E. Kähkönen, (Eds.), *Proceedings of The Fourth IEEE International Conference on Advanced Learning Technologies, ICALT'04*, (pp. 316–320), Joensuu, Finland. Los Alamitos, CA: IEEE Computer Society.

ZING (2004). Search/retrieve web service (SRW). Retrieved September 29, 2005, from http://lcweb.loc.gov/z3950/agency/zing/srw/

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Notes

[1] Note that in some simple cases, when the location of a learning object is directly provided in its metadata, the second step is not necessary.

[2] Such as, for example, the IMS Digital Repository Interoperability (DRI) Specification (IMS Global Consortium, 2004), the Simple Query Interface (Simon, Massart, Van Assche, Ternier, & Duval, 2005), the Zing Search/Retrieve Web Service (SRW, [Zing, 2004]), or the Open Knowledge Initiative (OKI) Open Service Definition Interface (OSID, [Open Knowledge Initiative, 2004]).

[3] SQI was accepted by the CEN/ISSS workshop on Learning Technologies in June 2005 and is expected to become an official CEN Workshop Agreement in Fall 2005.

[4] Error codes are part of the SQI specification.

[5] One might regret the choice of the term "legacy system" which, in the context of the iClass project, refers to any non-iClass system.

[6] Not only the iClass content server works asynchronously but, when the adapter development started, the content server query language and result format were not chosen yet.

Interoperability of Repositories: The Simple Query Interface in ARIADNE

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This article reports on our experiences in providing interoperability between the ARIADNE knowledge pool system (KPS) (Duval, Forte, Cardinaels, Verhoeven, Van Durm, Hendrickx et al., 2001) and several other heterogeneous learning object repositories and referatories.

Introduction

This article gives an overview on the role of the Simple Query Interface (SQI) (Simon, Massart, Van Assche, Ternier, Duval, Brantner et al., 2005) in providing interoperability between metadata repositories. It reports on work that has been done bridging different Learning Object Infrastructures and tries to give an overall picture of the current status. Interoperability has been achieved with two types of systems: learning object referatories and learning object repositories.

A learning object referatory (e.g., EdNA online, MERLOT) maintains metadata about resources that are not managed by the system. It describes content and provides references to learning objects or learning resources. As these systems do not host the content, they are challenged with managing references that are often not persistent. A referatory usually also offers mechanisms to detect changes and trigger updates on metadata, as content on the Web evolves over time without notification.

A learning object repository (LOR) (e.g., the ARIADNE KPS, http://www.ariadne-eu.org) offers besides a metadata repository also a content repository. For this type of system, there is no need to deal with the issues described above, as the system manages the content itself. Administering the content comes with the obligation to provide other content management services like digital rights management, version tracking, making the content accessible, etc.

As our SQI applications only deal with querying metadata, this article will not cover content management and hence, we limit ourselves to metadata repositories only. These are offered by both learning object repositories and learning object referatories. We assume however that all metadata repositories are able to provide a reference. This reference can either resolve directly to the content, or can lead a user to a page, describing how to proceed further if he/she wants to obtain the content.

In this article, our understanding of metadata repository will cover an individual storage layer (relational database, XML store) which can be part of a peer-to-peer network (Nejdl, Wolf, Changtao, Decker, Sintek, Naeve et al., 2002), federated search network, etc. An ARIADNE knowledge pool system is considered as one storage layer, while the federated search layer that will be described below is not. This federated search layer is not part of the ARIADNE Knowledge Pool System, although it is used by some ARIADNE tools.

SQI API

SQI is a specification created under the auspices of the CEN/ISSS Learning Technologies Workshop. The partners involved in this process all represent very different kinds of metadata repositories. This has led to a query transport specification that is applicable in different contexts and that meets very different architectural requirements. For ARIADNE, the SQI API enables two kinds of interoperability.

- *Tool interoperability.* Users have more freedom in picking a search engine, to search into the ARIADNE knowledge pool system. From the moment that the API is implemented on a system, its searching functionality becomes available in a whole range of applications that know how to send queries to an SQI enabled search engine. These applications that were formerly very strongly coupled to the ARIADNE knowledge pool, are now reusable on non ARIADNE repositories. Providing such an interface between search components, leaves organisations with more freedom in providing search functionality in their e-learning framework.
- *Interoperability between metadata repositories.* The SQI API is beneficial for both foreign repositories targeting interoperability with ARIADNE and ARIADNE aiming interoperability with other repositories.
  - At the time of writing, the ARIADNE SQI interface is integrated in Edusource (Splash Federated Search, 2004) through an ECL gateway, MERLOT (1997) and Celebrate (Celebrate, n.d). Other implementations in EdNA (2005), Lionshare (2005) and EducaNext (ELENA, n.d.) are ongoing. These repositories benefit from SQI by future integrations of other SQI-enabled repositories becoming available for free.
  - Inversely, the ARIADNE search tool can benefit from other repositories that implement SQI because the federated search layer it uses

can be extended with other SQI targets. As more metadata repositories provide SQI targets, integrating them is only an issue of configuration provided that they offer queries in the same query language and return results in the same metadata binding. Currently, the ARIADNE community can search through SQI in MERLOT, EdNA, EducaNext, RDN, Pond and Celebrate.

SQI comes in two communication scenarios: an asynchronous scenario and a synchronous scenario. One must implement at least one scenario. In the synchronous scenario, a client (source) sends a query to a repository (target) and actively waits for the target to return results. Note that in this scenario, a program (thread) halts until it receives results. In the asynchronous scenario, clear distinction is made between two actions. After the source has sent a query to a target, it proceeds execution and does not wait for the target. Using a result listener service (implemented on the source), a target can later register its results. This scenario assumes that the target is able to contact the source.

Federated Search Through SQI

Searching beyond the borders of ARIADNE is of great value to the end users. Before, SILO - ARIADNE's search and indexation tool - only delivered results that were indexed by ARIADNE members. With each new repository that is added through SQI, more heterogeneous content becomes available to the ARIADNE community. Both the synchronous and asynchronous interface are useful here. On one hand, a front-end tool requires an easy way to integrate API. On the other hand, the back-end architecture needs to be able to send queries and retrieve searches in a flexible way. SQI has proven to be very useful here.

A programmer or web-designer that wants to integrate a search API into a front-end tool, does not want to deal with the complexities of asynchronous querying, ranking and merging results. Asynchronous requests suffer an additional complexity when dealing with software that runs on desktops. As these are often hidden behind a network address translation (NAT) or firewall, it might not always be possible for a target to initiate contact with the hidden source and hence receiving the results asynchronously. Therefore, both SILO and a search prototype tool only use the synchronous SQI API.

In the back-end, a federated search component acts as a gateway to different SQI enabled repositories. This component offers a synchronous SQI interface to the front-end and is able to issue both synchronous and asynchronous queries in the back-end. The federated search component is able to forward queries to both API's. The asynchronous API has proven to be helpful here, as it can forward a query asynchronously to a number of repositories and use one listener to collect all results. The component can also federate queries to synchronous SQI targets, as we don't want to exclude targets that do not implement the asynchronous interface. In the latter scenario, we need a separate thread for each synchronous target to which the federated search layer connects. This thread first sends the query to the foreign target and next synchronously waits for results.

SQI makes it possible to implement a query service that is either stateful or stateless. In the stateless scenario, an implementation usually re-executes a query when a source polls for additional results. This is not the behaviour we target when providing SQI on top of a federated search target. As re-executing a query might not only be time consuming, but will likely return results in another order. Because of that, a stateful federated search layer was designed, where the query string identifies the state of an ongoing query. The ARIADNE knowledge pool offers a stateless SQI service, as the time necessary to execute a query on this target is negligible.

In this section, we briefly outlined how searches are federated to other repositories. Note that SQI is agnostic about the architecture for interoperability and that we only explained one possible solution for this architecture. In the Edusource network, it is up to the client to decide in which repositories to conduct a search. Using the Edusource Communication Layer (ECL), a layer which can be implemented on top of a repository, a client can query a repository. The client, however, doesn't send its query to an intermediate layer, but to each repository separately which the client can discover through a Universal Description, Discovery and Integration (UDDI) service. As the UDDI registry contains information about the query templates a repository supports, the client itself is able to do the mapping from one query language to another query language. Note that in this context some ECL to SQI gateways are already operational (Splash Federated Search, 2004).

Query Languages

All partners involved in this network, offer different search methods on their repository. At a technical level, searches differ in semantics, encoding and underlying metadata standard.

- The ARIADNE KPS implements two query languages. Users can express advanced queries that are transported between applications serialized as XML messages. The following excerpt exemplifies such an XML document.

```
<advancedQuery>
<And>
 <queryItem comparison="contains"
  path="ariadneDocument/title" value="Java" />
 <queryItem comparison="lower"
  path="ariadneDocument/publicationDate" value="10/11/1993" />
</And>
</advancedQuery>
```

As most end users only want to provide search terms to the query application without the need know what the exact semantics of the query is, ARIADNE also defines a metadata independent query languages. Using the latter query language applications can send a list of search terms to the KPS:

```
<simpleQuery>
 <item>LOMster</item>
 <item>Ternier</item>
</simpleQuery>
```

Note, that it is our intention to enrich these queries with the profile of a user so that better ranking or results can be presented.

- Edusource offers different templates. The most limited template enables clients to only search using search terms. In the most general case an ECL enabled repository can offer full XQuery capabilities.
- The EdNA Online Distributed Search enables Google-like searches. If one uses the HTML API, searches are encoded as a parameter in the URL. The following example illustrates this: a parameter q has as a value several search terms delimited by a '+.'
  http://api.edna.edu.au/search.xml?q=relativity+special
  Although the EdNA API only offers limited query possibilities, some of the backhand repositories that implement this EdNA API, offer more expressive search functionality.
- Similarly to ARIADNE, MERLOT offers two search syntaxes:
  - MERLOT's simple search syntax makes it possible to glue search terms together with boolean operators:

  "learning object" OR "learning resource" AND "lor"

  - An advanced query syntax defines a proper way of expressing searches that offer richer expressiveness. As illustrated by the following example, one can search into individual metadata fields using this syntax:

```
<search>
 <title>LOMster</title>
 <creatorname>Ternier</creatorname>
</search>
```

In our first interoperability step, a greatest common denominator for all query languages was offered at the level of the federated search service that forwards queries into the network. As all participating repositories offer a possibility to issue search term based queries, this is the only search functionality that is offered for now.

CONCLUSION AND FURTHER WORK

In this article, we briefly outlined how ARIADNE is connected to and connects to different metadata repositories through SQI. These repositories currently only agree on exchanging search terms. Future interoperability steps will focus on exchanging semantically more expressive searches. This will enable tools and software agents to formulate requests (e.g., based on a user profile) that will better match the needs of an end user.

Nothing has been decided yet at the level of ranking the individual results. Although all metadata repositories already leverage some kind of ranking, the aggregation layer is left with the problem of merging different arbitrarily ranked results. In a next phase, all partners could either agree on the same ranking algorithms or implement different algorithms that can then be selected by the clients.

Currently, in the synchronous scenario, a target decides how long to wait until the first results are sent back. For some clients it is however necessary to provide results just fast (e.g., Google) while in other usage scenario's, time doesn't matter as long as the application provides good results. (e.g., searches into a peer-to-peer network). Note that no changes at the level of the SQI API are necessary to provide this functionality.

References

Celebrate (n.d.). Celebrate. Retreived August 31, 2005 from http://celebrate.eun.org/

Duval, E., Forte, E., Cardinaels, K., Verhoeven, B., Van Durm, R., Hendrickx, K., et al. (2001). *The ARIADNE knowledge pool system*. Communications of the ACM, 44(5), 73-78.

EdNA Search Centre (2005). Education network Australia search centre. Retreived August 31, 2005 from http://www.edna.edu.au/edna/search

ELENA (n.d.) The ELENA smart space for learning. Retreived August 31, 2005 from http://www.hcd-online.com/ubp

LionShare (2005). Lionshare. Retreived August 31, 2005 from http://lionshare.its.psu.edu/

MERLOT (1997). Multimedia Educational Resource for Learning and Online Teaching federated search. Retreived August 31, 2005 from http://fedsearch.merlot.org/

Nejdl, W., Wolf, B., Changtao, Q., Decker, S., Sintek, M., Naeve, A., et al. (2002). *EDUTELLA: A P2P networking infrastructure based on RDF*. In Proccedings of The 12th International World Wide Web Conference. Budapest, Hungary.

Simon, B., Massart, D., Van Assche, F., Ternier, S., Duval, E., Brantner, S., et al. (2005). *A simple query interface for interoperable learning repositories.* In Proceedings of The 14th International World Wide Web Conference. Chiba, Japan.

Splash Federated Search (2004). Splash federated search. Retreived August 31, 2005 from http://pool.iat.sfu.ca/fedsearch/

Learning Objects and Process Interoperability

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CURRENT SITUATION

There has been considerable emphasis on the availability and reuse of learning content in recent years. Since 2000, the ADL initiative has refined the recommendations contained in the SCORM documents through progressive stages represented in the SCORM 1.0, 1.1, 1.2 and 1.3 documents. Fundamental to SCORM is the notion of the Shareable Content Object (SCO) and the Learning Object Metadata (LOM). There is an expectation that the Learning Experience can be designed using a set of Learning Objects or SCOs drawn from repositories of learning materials.

The use of eLearning technology has been hampered by the lack of appropriate tools to support the many processes of learning. There is also an incomplete understanding of the knowledge acquisition processes in learning and as a consequence there is an inadequate representational framework to support tool design. The standards incorporated in SCORM include the definition and structure of learning material expressed as SCOs, the metadata used to describe SCOs, the interface between the SCO and the Learning Management System as represented by a Data Model and an Application Programme Interface (API), the Packaging of SCOs, and the sequencing of SCOs to the learner to achieve a specified learning objectives. From the user standpoint, deciding on how to design SCOs in the first place is not a consideration for SCORM. Design of SCOs is an instructional design task which is carried out prior to the consideration of how they are sequenced to the learner. There are LCMS products to assist with the design of learning content but few attempt to provide support beyond the management of media assets in the formation of learning objects.

Equally, providing assistance to the user in selecting appropriately defined SCOs from a repository is not explicitly part of the process. SCORM assumes the SCOs exist, they are described by IEEE LOM metadata and they can be packaged according to the IMS Packaging Specification and the are accessed by the learner in an order defined by the IMS Simple Sequencing Specification. If all this is in place the packaged SCOs can be run on any SCORM compliant LMS thus achieving the essential content interoperability requirement. However, much of the process of putting together the learning experience remains a manual one or, if the user has an LCMS some proprietary functionality is available to "design" and organise the SCOs.

Obstacles to Progress

While SCORM has made significant progress in providing a framework for interoperability of learning content among LMS brands it does not address the issues of creating and using rich learning experiences. There are deficiencies in SCORM in that it does not have a way of describing the processes associated with learning other than Simple Sequencing. Processes relate to all aspects of learning from the design of the experience to the participation in the processes of learning, which must involve discourse among individuals.

Whatever aspect of learning we consider it is possible to distinguish user processes associated with all classes of users. Teachers go through processes to design learning experiences for a given set of learners. Learners go through a set of processes when interacting with the teacher and the learning materials as part of a learning experience. Teachers use scholarship to draw together materials on a set of topics, interpret the materials, and add their own interpretations in the context of the learning experience they are designing. In the actual design of learning materials the teacher may interact with the instructional designer, the media technologist, and the programmer in preparing a learning experience. A full analysis of these processes would reveal the nature of the support required for each stakeholder.

In addition, we require a more effective way to describe learning materials if we are to successfully combine learning components in a conceptually coherent way. Acquiring knowledge requires a framework into which concepts can be placed relative to each other and which are linked with relationships involving descriptions of order, type, part, and so forth. Knowledge derives not simply from the syntactic structure of the relationship between learning objects but must involve some form of higher level semantic description of the relative position and usage of the learning objects in the structure of knowledge of the domain. The current expectation is that learning materials can be obtained from local and remote repositories according to the specification of the learning experience being designed. But to achieve this the process of specifying the types of learning that will, at the same time, enable coherent matches to be made to existing content held in repositories will also require metadata that goes far beyond that available today as specified in the IEEE LOM.

What Needs to Be Done

To realize the full potential of ICT support of learning and knowledge acquisition we need to have two to achieve two objectives. First, we require a richer description of learning content and second, we require a framework in which to structure the description of supporting processes for all stakeholders. Achieving the first will help us to relate the learning content to the knowledge structure of the domain of discourse. Achieving the second will provide the opportunity for vendors to create new tools and services to stimulate innovation in all aspects of the learning lifecycle.

Semantic description of learning resources. The concept of ontology has previously been used to represent domain knowledge. In its basic form, ontology defines the common words, concepts, or meanings used to describe a domain of knowledge. Ontology is usually agreed among the members of a community as an acceptable way of describing the conceptual understanding of the domain. Taxonomy is part of ontology in that it represents the classifying description of the entities in the domain. Taxonomy therefore provides part of the "knowledge" of the domain by classifying the entities. Taxonomies carry with them a weak form of semantics of the domain in that they imply a structural relationship between the entities classified in the hierarchy.

Ontology contains far richer information on the meaning of a domain. An ontology not only contains information about the structure of the domain but also relationships between entities, properties of entities, processes involving the entities, and constraints and rules about how the entities relate and exist in the domain. Building ontology of a domain is about capturing in a representation the structure, meaning, rules, constraints, and relationship between the entities in the domain. Capturing and representing all this in a processable form is the reason for the excitement currently surrounding the developments associated with the Semantic Web. We believe the same requirement exists for the semantic description of learning content. We need to relate the description of learning content to the structure of the knowledge of the domain to which it applies.

There are now ontology building and management tools emerging in the market. With these tools it will be possible to express the semantic meaning of data, documents, processes, and systems in a machine processable form. In which case it will be possible to have software processes reason about entities in the domain and make meaningful decisions about them. For information on the Web this means the difference between a search resulting in tens of thousands of items, most of which are not relevant to the reader, and a result providing four or five highly relevant items. But this is only the most basic use of an ontology when considering the future of web services the availability of ontology's will provide opportunities to reason about the domain and the resources it contains. This opens up the whole area of ontology driven applications, which will move us to the next level of smart working with Internet technologies.

Description of processes and interoperability. An emerging approach to the design and structuring of computing systems today is the Service Oriented Architecture (SOA). The basis of the SOA is web services. Web services are built on the technologies associated with the Extensible Markup Language (XML) according to the standard technology stack. The various layers in the technology stack can be considered to represent levels of abstraction built upon the Core Layers. The three basic layers of interest to this discussion are respectively, the Infrastructure layer, the Services Layer, and the Application Layer. For learning technology systems there are several early approaches based on this architecture notably, the IMS Abstract Framework, the MIT Open Knowledge Initiative, and the work from the Learning Systems Architecture lab at CMU. In addition several of the major eLIG companies have adopted the SOA approach.

The SOA is specifically concerned with the definitions of processes, their coordination, and the information that flows between them. In terms of the technology stack mentioned earlier, the technologies WSDL and WSFL are part of the Services Layer, and these are used to define the abstract representations of processes and their interactions. For learning technology systems our starting point is the analysis of processes to support all aspects of the learning lifecycle. Some of these processes will be candidates for automated support tools and services while others will remain as manual tasks carried out by the stakeholder. The significant advantage of the SOA approach means that the behaviours of and interfaces to processes can be defined abstractly, independent of language and platform. This fact provides the opportunity for vendor implementations to innovate in the design of tools and services and yet remain interoperable with tools and services from others.

A full analysis of the processes to support all stages in the learning lifecycle will reveal where ICT can best be used to support each stakeholder. The ISO SC36 LTA Group identified more than 120 stakeholders in their approach to define a framework for learning technology architectures. An analysis is therefore likely to reveal a multitude of processes some of which would be usefully automated and others remain as manual tasks. A useful outcome of such an analysis would contribute to the definition of process behaviours and interfaces. Only when these definitions are available, in the abstract form provided by WSDL technologies, will it be possible to have a full stimulation of the market opportunities for innovation in tools design and implementation.

Analysis of Processes

To provide an example of the main principles of process interoperability we can consider a simplified situation involving several actors associated with the early stages of the development of a learning experience. Our basic premise is that we should first consider the set of lower level processes that form the activities associated with the basic workflows involved in designing the learning experience. Some of these processes will be human centered, for others it will be possible to map the required activities onto software specifications that can later be designed as products to be provided by tool and service vendors. For those processes or sub-processes that can be considered as candidates for tools and services we believe it would be an advantage to find abstract descriptions of the processes to allow the interfaces and the behaviours to be specified independently of the implementation of the tool. With such an arrangement it will be possible for multiple vendors to each provide their own interpretation and implementation of the tool or service. Vendors will be in a position to provide useful support tools and services and yet competitiveness in the markets will be maintained. A significant advantage to the customer will be the choice of multiple vendors implementations of the tools to meet the support of the given process stages. We maintain there will be advantages to users in being in a position to have interoperable tools in this sense.

Investigation Objectives

The overall objectives are fourfold.

1. to remove the ambiguity and fragmentation that exists in the current work on e-Learning Standards for Content Description Interoperability;
2. to provide a framework for the development of new tools and services using the SOA;
3. to develop a rich semantic description of learning content within a knowledge framework supported by ontology; and
4. to promote the design of new tools and services within selected knowledge domains to demonstrate innovation in supporting all stakeholder processes.

Phased Programme

A survey of current eLearning projects would provide an assessment of the current work relating to these objectives and avoid unnecessary duplication. There are other process oriented approaches to learning design incorporated in the EML framework (Koper, 2001) and the IMS Learning Design Specification.

New tools and services should be designed within the proposed service framework and these could usefully be focused on selected domains. Involving users of the tools and services in the definition of processes would be beneficial. A consultation process would reveal useful common approaches that would benefit the community if new tools and services resulted.

The work on eLearning standards and interoperability is in need of being extended to match the requirements of the new service enabled architectures being considered by several major vendors. Process interfaces and behaviours need to be defined so that vendors can demonstrate interoperability of supporting tools and services.

Ontology looks like a promising approach to provide the knowledge framework within which to develop the new semantic descriptions of learning content and learning sequences.

Pilot projects in chosen knowledge domains will provide the opportunity to demonstrate the effectiveness of the new approach especially if vendors are asked to provide tools for abstractly defined processes.

References

Koper, R. (2001). *Modelling units of study from a pedagogical perspective – the pedagogical meta-model behind EML*. Report, June 2001, Retrieved September 29, 2005 from http://eml.ou.nl/introduction/articles.htm