The Future of Technology Enhanced Active Learning – a Roadmap[1]

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ABSTRACT

The notion of active learning refers to the active involvement of learner in the learning process, capturing ideas of learning-by-doing and the fact that active participation and knowledge construction leads to deeper and more sustained learning. Interactivity, in particular learner-content interaction, is a central aspect of technology-enhanced active learning. In this roadmap, the pedagogical background is discussed, the essential dimensions of technology-enhanced active learning systems are outlined and the factors that are expected to influence these systems currently and in the future are identified. A central aim is to address this promising field from a best practices perspective, clarifying central issues and formulating an agenda for future developments in the form of a roadmap.

KEYWORDS:
Computer-based Learning and Training, Technology-Enhanced Learning, Active Learning, Emerging Technologies, Research Issues.

INTRODUCTION

Activity and interaction are central in learning processes. Technology-enhanced learning (TEL) software can act as a mediator between the learner and her/his environment, i.e. content, peers, and instructors. Engaging the learner to actively learn is a central objective towards deeper and lasting learning experiences. With recent technology advances, for example in multimedia and Web technologies, a shift from purely knowledge-based learning towards activity-based learning and training can be observed. Interactive Web and multimedia technologies are enablers of skills-oriented training in technology-enhanced learning environments. In a wide range of areas from technical and scientific applications to language learning, training of activities and skills is of paramount importance.

The overall aim of this chapter is to address emerging technologies for new-generation TEL and challenges for the future. This investigation targets a specific form of learning – active learning and training – and its technology support. A reflective analysis of existing technology-enhanced active learning (TEAL) environments shall establish the state-of-the-art and best practice. Based

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on major dimensions of these environments, external factors are identified that are likely to have an impact on their development and deployment in the future. Their impact on active learning support is examined and emerging trends, challenges and possible solutions are discussed. The aim is to identify a realistic roadmap scenario for future technology-enhanced active learning.

Based on an analysis of the state-of-the-art, dimensions of technology-enhanced active learning environments and external factors that influence these are identified (Figure 1). The factors can be categorised along the dimensions as follows: a) modelling, architecture, and development, b) interoperability, delivery, and standards, c) learning and systems evaluation, and d) evolution. A discussion of the pedagogical context of activity-based learning and training and an analysis of some sample systems complements the discussion of the four dimensions. The dimensions are relevant in terms of best practices considerations:

- Pedagogy addresses the skills training perspective necessary for a wide range of subjects.
- Development addresses the effective and efficient development of TEAL environments.
- Change and evolution capture the mid- to long-term perspective on TEAL deployment.
- Examples for analysis are relevant for both development and deployment.
- Implementation addresses exchanges and reuse through interoperability.
- Evaluation focuses on the effectiveness of approach and environment.

Affected practically by these factors and dimensions are both learners and instructors, through content and instruction, and the administrators, through infrastructure aspects. Our discussion shall provide answers to some questions:

- how to support activity-oriented topics that require the learner to acquire skills and experience,
- how to provide such an environment in terms of developing new material and infrastructure and also in terms of reusing and integrating existing artefacts,
- how to manage such an environment on a long-term basis based on regular evaluation and continuous evolution.

A number of technologies enable the support of active learning and training, including devices, media, architecture, and semantics. These enablers are discussed in the context of the factors to highlight characteristics of current and future technology-enhanced active learning environments.

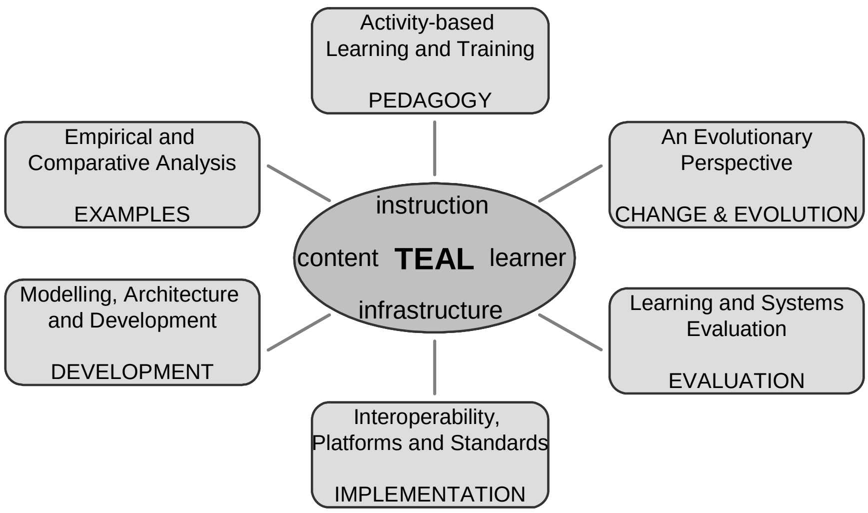

Figure 1. Dimensions of Technology-Enhanced Active Learning (TEAL)

In terms of best practices, this chapter serves two purposes. Firstly, TEAL is promoted in terms of best practices in the TEL context by illustrating its benefits through a case study. Secondly, a roadmap in form of an agenda for the future of this still underdeveloped field is discussed in order to enhance current best practice.

A case study – the Interactive Database Learning Environment IDLE, which is a Web-based learning and training system for database modelling and programming – is used to illustrate concepts and to discuss current state-of-the-art and challenges. IDLE has been used since 1996 in a blended learning context for an undergraduate computing degree (Kenny & Pahl, 2005). IDLE is based on the virtual apprenticeship model, which emphasises skills-oriented learning activities. The system acts as a mediator between a learner and interactive content in a realistic training environment.

ACTIVITY-BASED LEARNING AND TRAINING

This section introduces active learning and training as a pedagogical framework:

- Active learning and training is a conceptual framework that captures the current trend towards skills and training as opposed to classical knowledge learning.
- Pedagogical frameworks such as activity theory and scaffolding, which explain the role of technology in technology-enhanced learning, are introduced.
- Specific forms such as the virtual apprenticeship framework, which has been developed to address active learning and training, are also looked at.

This section aims to clarify the role of activity for a deeper understanding and more successful learning experience.

Interactivity and Learning Activities

Northrup (2001) emphasises learning as an active process in which interactivity is central. Moore (1992) distinguishes three learning interactivity types – learner-learner, learner-instructor, and learner-content interactions. Among these types, content has a more central function in TEL than interaction with peers or instructors (Sims, 1997; Ohl, 2001). Ohl's definition of interaction as an internal dialogue of reflective thought that occurs between learner and the content supports this perspective. As part of the interactions between learner and content, the following learning and training activities can be facilitated by TEL systems:

- The aim of declarative knowledge acquisition activities is the acquisition of declarative knowledge in order to reason about it.
- The aim of procedural knowledge acquisition activities is the acquisition of procedural knowledge in order to reason about it.
- Skills acquisition activities aim at the acquisition of procedural knowledge and experience in order to perform the instructions.

The style of the interaction and activity execution is constrained by the degree of involvement and influence of the learner. Different types of interaction ranging from system-controlled to learner-controlled environments can be distinguished:

- Observation is a form of knowledge acquisition with no influence on the environment activities by a passive learner.
- Controlling is a form of knowledge acquisition mixed with knowledge production, based on observational elements, but allowing the learner to influence the environment activities to control their ordering.
- Creation is a form of activity where knowledge or skills are created by producing some form of artefact that can be processed by the learning environment.

Declarative knowledge is often acquired through observation, procedural knowledge for reasoning purposes through controllable animations, and skills through knowledge or artefact creation and processing. The targets of this investigation are TEL environments more geared towards skills acquisition and creation.

Active Learning and Training

The learning-by-doing idea is part of the active learning and training approach focussing on procedural knowledge and skills acquisition. It captures the interplay of knowledge acquisition and knowledge creation in an interactive process with the learning environment.

This focus is for instance displayed in IDLE by considering knowledge acquisition on the one hand and skills and experience acquisition on the other hand as dual sides of learning and training. One of the skills acquisition activities in the IDLE system is SQL (i.e. database) programming. A student works through guided material covering a range of individual problems, while being directly connected to a database system. Each problem is based on a submission- and execution-cycle with a high degree of involvement of the learner through knowledge creation. Each solution – content-specific knowledge that is created by the learner – is analysed and, based on an individual activity history and integrated assessments, personalised feedback is given by the system. An important aspect of the design of a system like IDLE is the design of the learner activities within the framework of an underlying pedagogical model.

Pedagogical Models

Various models and theories have been proposed to capture and explain the ideas of active learning.

- Activity theory is a conceptual framework that can describe the structure, development, and context of computer-supported activities (Nardi, 1997). Activity theory explains the principle of tool mediation in an online environment – here multimedia tools handle the student's interaction with the learning content. The emphasis on the interaction between learners and their environment explains the principle of tool mediation. Tools shape the way humans interact with reality. Educational tools reflect experiences learners and instructors have made in trying to solve particular problems.
- The cognitive apprenticeship model captures the relationship between an apprentice and a master (Collins et al., 1991). An apprentice is a learner who is coached by a master (an instructor) to self-reliantly perform a specific task. The model applies this relationship notion and adopts it to the cognitive processes of knowledge learning.
- Scaffolding is a support technique that can substitute the master in the apprenticeship model in the virtual world (McLoughlin et al., 2000). Scaffolding uses an analogy to construction

where a temporary framework supports the learner in becoming self-reliant and in obtaining skills and competency. Scaffolding features in practice offer the learner support only as long as necessary, withdrawing this support as the learner becomes more and more self-reliant.

An overall constructivist style of education should be facilitated, allowing the learner to construct knowledge and obtain experience through active participation in a course. The learner should be engaged in solving meaningful problems in an activity-based, realistic setting.

Another, more targeted example of a pedagogical model is the virtual apprenticeship model (Murray et al., 2003), which is a pedagogical theory based on the cognitive apprenticeship model that defines an activity-based and skills-oriented learning and training framework. In a TEL environment, the master's role is often replaced by an intelligent software tool. Tools reflect the experience people, such as the apprentice's master or the instructor, have made in trying to solve a particular problem. The apprenticeship model determines a number of aspects including the activity purpose and the degree of involvement, interaction styles (e.g. the organisation of learning into sessions and cycles), and the interconnectedness of activities and features. The virtual apprenticeship model puts an emphasis on skills-oriented activities with a high degree of involvement of the learner.

Discussion

Active learning and training plays an important role in recent instructional design approaches. Learning is seen as a process in which learners actively construct knowledge and acquire skills. In the context of technology-enhanced active learning and training environments, the role of the computer environment needs to be defined through pedagogical models. The TEAL environment is a tool that mediates the interaction between learner and content at the centre, but also between learners and their instructors and peers. While appropriate theories exist, they have mainly, with the exception of the virtual apprenticeship, been applied to knowledge learning.

EMPIRICAL AND COMPARATIVE ANALYSIS

Active learning is central in recent approaches to instructional design, where learners actively construct knowledge and acquire skills.

- An empirical analysis of IDLE as a situated, authentic active learning and training environment forms the core of this section.
- A range of other learning tools and environments including intelligent tutoring systems and virtual instruments used in science, engineering, and medicine and simulators are also considered.

The section aims to reflect examples of best practice in active learning and looks at current state-of-the-art and recent challenges.

Evaluation Criteria

Based on the key characteristics of pedagogical theories that support active learning and training, the instructional aspects that TEAL systems need to support can be summarised as follows:

- The active participation of the learner through knowledge and artefact creation is highly beneficial.
- Active construction of knowledge and skills results in an increased ownership of the learner in the learning process.
- Meaningful projects allow learners to acquire skills and, importantly, also experience.
- A realistic setting improves the learning experience and demonstrates the applicability of knowledge and skills.
- Guidance and feedback provide instructional support in the environment.

These aspects can service as an evaluation guideline for TEAL systems.

Activities for the learner, such as programming in IDLE, are at the centre of technology-enhanced active learning and training environments. However, supporting the learner through scaffolding is also essential from the instructional perspective (Guzdial & Kehoe, 1998). In addition to just mediating between student and tools, the environment must fulfil functions of the instructor. The environment replaces the instructor in form of a virtual master that guides a learner through exercises and that provides immediate feedback on activities. Each activity needs to be complemented by conceptual and procedural knowledge in form of, for instance, virtual lectures and animated tutorials that are relevant and problem-related for the activity in question.

IDLE Analysis

An interactive SQL learning and training environment is embedded into IDLE (Pahl, Barrett, & Kenny, 2004). The SQL part forms a central part of IDLE as database programming is one of its core learning objectives. Programming (i.e. defining, updating, and querying database tables) is a skill. Programming skills need to be trained. Moreover, this course is also an introduction to database engineering. Therefore, understanding and mastering the overall development process of a database application is equally important.

The system provides coherent integration of different learning and training activities relevant in the context of database development and programming:

- Conceptual knowledge is presented in a virtual lecture system.
- Procedural knowledge is presented in an animated tutorial system. SQL and parts of its underlying data model are about the execution of instructions.
- Programming skills acquisition is the core activity, supported by an interactive tutorial that guides the student through exercises to be worked on within the system. The tutorial guides a student through a sequence of exercises with increasing difficulty. Syntactic and semantic feedback is available.
- Development skills are equally central, which supported by an integrated lab environment with modelling, programming, and analysis features. The student is provided with a workspace in which s/he can create and store a data model. An integrated, realistic lab environment that resembles features of database development environments is the central feature.

The pedagogical frameworks list a number of best practice-related success criteria for TEAL environments that are addressed in IDLE:

- Realistic setting and meaningful problems. A realistic setting with meaningful problems is a crucial aspect, required by for instance activity theory, which IDLE supports through database application development. The IDLE system creates a realistic setting by integrating tools of a real database development environment into a learning and training environment. These features are enhanced by the inclusion of instructional functionality such as guidance and feedback.
- Tool mediation. In particular the tutorial and lab support features are mediating tools in the activity theory sense, sharing the experience of developers and instructors with learners. They support modelling and programming problems, i.e. the developer's perspective, but they also incorporate the instructor's experience in teaching the topic over several years.

Active Learning Environments

Intelligent tutoring systems (ITS) are examples of systems where knowledge-level input is processed by the system. Like IDLE, the SQL Tutor (Mitrovic & Ohlsen, 1999) is an example of this category in the same subject domain. The aims are to allow students to practice and to get feedback. An emphasis has been on providing students with feedback as it would be given by an expert in the domain. The constraint-based reasoning that is applied to analyse student input had to provide only pedagogically useful and constructive responses, i.e. should only respond if the response can actually be understood by the learner and used to improve the previous input. This system highlights the difficulty that a correction feature itself is not sufficient. The virtual master or mediating tool in the environment needs to understand the student, which in some form has to be captured in terms of learner model.

A virtual instrument (VI) is a multimedia tool that can be used to present information on an experiment prior and during to students performing it (Brabazon et al, 2006). Evaluation of student performance has shown improved and indicates a greater degree of student interaction with the instrumented experiments. For example, a VI might present an animation of how the experiment should be performed, a real time graph of the experimental data, or interactive equations to be used to calculate the experimental results. Animations, images and video clips can virtualise the experiment. This engages students and allows them to relate theoretical concepts to real world examples. This allows students to obtain the hands-on benefit of the laboratory whilst gaining a greater understanding of the concepts being presented to them. Simulators that allow learners to train specific activites that might otherwise be difficult to provide or dangerous.

Authentic and situated learning environments require learners to actively engage in real-world problem solving that reflects both the context and complexity of the practical situations in which the need for learning was created (Herrington & Oliver, 2000). Language learning is a classical example where the immersion in the cultural context is more effective than textbook-based learning. TEL systems can provide virtual environments in which learning can take place, where for instance learners can move through and communicate in virtual organisations to achieve a particular learning goal. The importance of the context or environment in which an activity takes place is emphasised in this approach to learning and training.

Problem-based learning is another direction that is captured by the term active learning (Barrows, 2000). Specific, meaningful problems that usually require the interaction between learner and content, but also between the learner and both instructors and peers, form the basis of the learning experience. While in this context the construction and processing of knowledge is not always an issue, the collaboration of groups of learners is.

Discussion

The analyses have emphasised the practice-oriented success factors for current TEAL environments. What can be clearly seen from this evaluation are the challenges that TEAL brings.

- The use of interactive educational multimedia needs to go beyond the use of for instance Web technologies today, which are mainly text and image oriented. An interaction in terms of the concepts and objects of the subject domain (such as programs or graphical models for databases) is a challenge.
- Integration and interoperability of tools and components is a necessity to complement each individual learning activity, such as skills training activities with declarative and procedural learning activities. Education-specific standards and agreed interfaces are here required.
- Collaboration emerges as a central of interaction. Real problems can often only be solved in groups, possibly involving different roles. A TEL system for this context needs to facilitate collaboration in terms of interaction/communication and shared workspaces.

Beyond these individual aspects, one general observation summarises an essential requirement. Ravenscroft, Tait, & Hughes (1998) highlight the importance of the appropriate level of student interaction with learning content. Often, a distinction is made between content aimed at developing conceptual knowledge on one hand and content aiming at skills development on the other (Weston & Barker, 2001). The learner motivation in TEAL environments is the acquisition of skills and good performance in practical coursework and examinations. Consequently, the form of interaction with content supporting active learning of skills is different from knowledge-based learning. IDLE is an example for the importance of the appropriateness of content interaction, in the IDLE case the implementation of skills-level interactions such as interactive programming and modelling.

MODELLING, ARCHITECTURE, AND DEVELOPMENT

The previous section has looked at full TEAL systems, now the content at their core shall be investigated. The learning object notion as a reusable and sharable unit is becoming more and more important. This section

- introduces learning objects for active learning, their modelling, and their reuse,
- focuses specifically on modelling the assembly of these learning objects,
- discusses the automated generation of content objects from models, possibly enriched to semantical, knowledge-based models.

Modelling, architecture, and semantics emerge as technical notions that will impact the practical aspects of content authoring. These have the potential to bring together the requirements from technology enablers with the requirements from the active learning perspective.

Learning Objects

Learning objects are reusable, digital representations of learning content. Learning content is expensive to develop, in particular if advanced features such as IDLE's interactive programming feedback system or graphical modelling tools are considered. In order to facilitate the content development process and to allow content to be reused, the representation of content in the form of individual, identifiable and sharable learning objects is a solution. Two reasons motivate a notion of learning objects:

- Firstly, the clear separation of content and the infrastructure that controls its storage, delivery, and presentation. A learning object is a notion that reflects this separation and allows content units to be clearly identified in these infrastructure environments.
- Secondly, learning objects are content units of a small to medium size, which allows their reuse and flexible combination in different instructional contexts.

Content in the form of learning objects does not exist on its own. Learning objects need to be supported by a software infrastructure – which makes the joint discussion of learning objects and the architecture that process them necessary. Some IDLE learning objects are software components in their own right, which interact with other infrastructure components

Architectures

The architecture of a technology-enhanced learning system is the description of its structural and abstract behavioural characteristics. It describes the learning object storage, processing, and delivery. The different stages of the content lifecycle provide the starting point to understand the functional architecture of a TEL system. Three learning object development stages are:

- creation and maintenance of learning objects based on ontologies and models,
- making learning objects accessible through navigation infrastructures and adaptive delivery, including assets such as multimedia objects, references, and links,
- packaging and assembling content to form interoperable ready-to-use units of study.

An essential aspect of architectures is their role in facilitating learning object design and deployment. Each of the above stages requires specific infrastructure support. If for instance existing active learning objects are imported to compose larger units of study, their interaction interfaces need to be supported by the infrastructure.

The Web Services architecture aims to enable interoperability for software using the Web platform. The principle of software services, provided at certain locations on the Web that can be used by other software applications, is the basis. Service-oriented TEL systems are the application of this principle in the educational context (Devedžić, 2004). This architecture platform blurs the distinction between content and infrastructure system. Content will be provided through services, as will standard functions of a learning technology system such as user management or evaluation support. From the perspective of instructors and learners, it requires to see learning content as dynamic, interactive objects encapsulated as services that can support active learning.

Semantics, Ontologies, and Modelling

Learning objects and supporting architectures also need to be looked at in the context of another development in learning technology – the use of explicit knowledge representation and semantics through ontologies and models (Mizoguchi & Bourdeau, 2000; Aroyo, Dicheva & Cristea, 2004; Wilson, 2004). Knowledge plays a central, though often implicit role in the creation, management, and delivery of learning content. Ontologies are explicit representations of knowledge structures of a particular domain. Ontologies can support the modelling and creation of learning objects, add flexibility to the abstract model-based management and organisation of learning objects, and improve the guided delivery of learning objects (Pahl & Holohan, 2004; Devedžić, 2006).

Ontologies and learning objects can act as the central information objects of an information model for the creation and maintenance subsystem of an architecture. Ontologies consist of concepts, relationships, and instances. Learning objects can, for example, be lessons or tests. The content of a lesson usually consists of text and images, which can both be related to concepts or instances of the ontology. Similarly, tests consist of a question, possible answers, and the correct solution, where the answers and solutions are again directly based on concepts and instances.

Support for ontology-based authoring and delivery is still in its infancy and currently limited to static content. Providing this support for active learning objects requires specific ontologies and models for their description and generation that go beyond standard domain ontologies, which focus on static concepts rather than procedures and activities. In order to enable an explicit and more effective use of knowledge in learning object development and deployment, an adequate architecture of learning content management systems (LCMS) for authoring and storage and learner management systems (LMS) for delivery to support these activities is then also needed.

Discussion

Reusable active learning objects cause problems across all aspects discussed in this section – such as available and sharable ontologies and models and also architecture standards and interfaces (which are addressed in more detail in the next section). In addition, the practical aspects of the development of reusable active learning objects is not well understood either. The development of learning objects and infrastructure architecture for knowledge-based learning objects need to be looked at from two perspectives:

- The functional (or structural) view on architectures is the classical view on software architectures, focusing on the system components and their assembly.
- The development (or process-oriented) view focuses on the development and authoring activities of learning objects in these architectures.

The process model underlying the development view captures the learning object authoring process and, therefore, determines central aspects of the functional architecture.

INTEROPERABILITY, PLATFORMS, AND STANDARDS

Learning technology enablers – such as devices, media, architectures, or semantics – are central for the delivery. In this section, the previous focus on content shall be moved to infrastructure, discussing the potential of arising new platforms (e.g. iPod or mobile phones) and their impact on new forms of active learning and training, and the standards – current and in progress – in relation to the delivery of active learning and their shortcomings. The challenges arising from the limitations of the new platforms for active learning are discussed.

Interoperability and Platform Requirements

Technology-enhanced learning is a central aspect of education today. In particular, the Web as the platform for development and delivery has impacted TEL. While initially mainly static resources were provided, the focus has shifted to more effective learning through engaging learning content objects. Active learning objects (ALOs) that support active and engaging learning and architectural frameworks for ALO development and deployment to enable reuse and interoperability of ALOs are currently being investigated.

- Their development can be supported by a description and discovery technique that allows learners to find and select suitable ALOs. The infrastructure aim is to support abstract description in particular in terms of interactions and activities and to facilitate discovery.
- Their deployment can be supported by container-based component or service architectures. The core problem is interaction – between learning objects and learner and also infrastructure services. Questions concern the level of interaction in terms of concepts and activities of the subject and the support of standard learning services.

Another central aspect is learner-centricity, i.e. pursuing an infrastructure that enables a learner to control the selection, integration, and consumption of content, motivated by current trends in mobile gaming and music; an issue that can be expected to become more important in the near future with changes in learner behaviour and expectations. The emerging support for portable devices such as mobile phones and iPods has already greatly impacted music and entertainment.

What these observations show is the need for standards and platforms supporting the interoperability of active learning objects and architecture components and services. The proliferation of TEAL is currently hampered by high development costs and the lack of reusability and interoperability technology. Two facets characterise the current developments in this area:

- ALO Engineering. ALOs are currently investigated from an instructional design perspective, but the systematic engineering of these objects as reusable entities has not been considered. A systematic approach is, however, necessary to develop the quality for reusable and interoperable, well-documented and annotated learning objects.
- Interoperability and Architecture. Currently, standardisation efforts and learner management systems focus on static learning objects, providing only a minimal interaction interface for learning objects. There is a need to advance interoperability to include a higher degree of knowledge/skills-level interaction, but also to consider a wider range of technology platforms.

A number of technologies affect these developments, both in terms of active learning and also proliferation of technology platforms and devices. Current standards provide a minimalist standard for learning objects integration. Java applets provide mobile code technology. Enterprise Java Beans, the Java component technology, for instance, is based on containers that provide a standardised set of common functions and in which reusable components are executed. Web services provide a higher degree of interoperability and a possibility to package learning objects in a uniform way. Learning object integration needs to be progressed further for ALOs using mobile component and container technologies to provide a platform for learner-centric active learning on the Web platform comprising an engineering solution and infrastructure support.

Standards Overview

A number of standards relating to learning objects and supporting infrastructure and architectures shall briefly be discussed:

- The SCORM suite of standards is implemented by most LMS and LCMS for the exporting and importing of learning content and sequencing instructions (ADL, 2004). The standards that come together can be grouped into three groups. They are the Content Aggregation Model (CAM), the Sequencing and Navigation (SN) and the Run-Time Environment (RTE). CAM is used for the packaging and description of learning content. RTE describes how a package is to be managed and utilised at runtime. The RTE allows the learning resources within packages to be platform- and LMS-independent. SN describes how learning content contained within a package can be sequenced according to learner actions and preferences.
- IMS Learning Design (LD) is a standard addressing the development of composite learning activities (IMS, 2003). Instructional knowledge is needed to give structure to educational resources. Education-specific markup languages, such as Learning Design LD, can form a notational system for content development and representation.
- The IEEE Learning Object Metadata standard (LOM) provides a basic metadata framework for the facetted description and classification of learning objects (IEEE, 2002). LOM defines the attributes required to fully describe a learning object. It classifies attributes into nine categories addressing for example general, technical, educational, and lifecycle aspects.
- The IEEE Learning Technology System Architecture (LTSA) is a functional architecture based on the software components of a learning technology system (IEEE, 2002). This architecture is geared towards a software developer.

Discussion

Although standardisation is in progress, these have been addressing static learning objects and approaches to learning and training. These standards are currently lowest common denominators of available technology and consequently do not support best practice concerns adequately. Their extension to embrace active learning and training is therefore of paramount importance. Without reusability and standardisation, the high costs of development of TEAL might turn out to be prohibitive. The focus has so far also been on PC-based environments, leaving mobile devices until very recently largely unexplored.

LEARNING AND SYSTEMS EVALUATION

Novel platforms as just discussed and new types of technology utilisation for any learning type raise questions about the acceptance and usage of technology by learners. Evaluation of their behaviour in these systems is therefore paramount. This section looks at:

- how to capture changing learner attitudes and behaviour,
- how to implement constant monitoring and formative evaluation

under consideration of the higher level and complexity of interactions for the targeted active learning context, using for instance data mining techniques.

Evaluation of Interaction and Learning Activities

So far, the development and deployment of active learning content and infrastructure has been discussed. This lifecycle is not complete without an evaluation stage. Novel methods that combine classical survey methods with computational techniques for data mining and analysis are needed to address the evaluation needs for interaction and activity in TEAL environments. On the technical level, interaction is a reflection of learning activities and strategies. The evaluation of learning and training behaviour needs to be based on the analysis of content interaction in TEAL environments. Learning behaviour in learning and training environments particularly with a high degree of activity ad knowledge-level interaction, however, is currently not well understood. In contrast to traditional classroom-based learning and training, the learning strategies and behaviour are more determined by the learner's own decisions how to organise learning and training (Northrup, 2001). Additionally, often several educational features are available at the same time, allowing competent learners to choose their own approach of combining resources and features. Consequently, the analysis and evaluation of learning and training behaviour is of central importance (Oliver, 2000). A general understanding of effective and preferred learning styles and behaviour is required for authors and instructional designers to improve the design of learning content. Instructors require feedback on usage to improve the delivery of educational resources.

Learner Behaviour

The behaviour of learners in computer-based teaching and learning environments is influenced by the motivation to use the system and the acceptance of the approach. These two more abstract aspects relate concrete learning behaviour with the objectives and state-of-mind that have led to that behaviour. A learning activity is an engagement towards a learning objective. Two aspects of the student's concrete behaviour can be distinguished, which defines the learning activity. Firstly, the learning organisation addresses the study habits and captures how students organise their studies over a longer period of time. This includes how they plan to learn and work on coursework, and how they prepare for exams. Secondly, the usage of the system captures single learning activities and embraces how the student works with and behaves in the system in a single study session. Overall, four aspects of learning behaviour can be identified:

- Motivation – the reason to do something – causes the learner to act in some planned and organised way, giving the activities a purpose.
- Acceptance – to follow the learning approach and use the system willingly – is crucial for the introduction of new educational technology.
- Organisation – the way the learning activities are planned and put into logical order – reflects the study habits and is guided by the purpose.
- Usage – the way the tool is actually used – reflects the actual learning activities.

Both the pedagogical framework and the TEAL system need to support the objectives that form the students' motivation in order to be accepted. The organisation is determined by the motivation – the objectives determine how activities are organised and executed. The usage follows the organisational plan to achieve the objectives. Motivation and acceptance are necessary to interpret organisation and usage.

Instruments for Behaviour Evaluation

Traditionally, direct observation and surveys are used to determine the learning behaviour in classroom-based learning and training, but with the emergence of computer-supported, and in particular Web-supported learning and training environments, there is now another option. Learners leave traces of their activities and behaviour in TEAL systems. In Web-based systems, access logs are automatically generated by Web servers that handle user requests.

Behaviour in learner-controlled environments is determined by the four aspects identified above. Consequently, the instruments for the behaviour analysis include two instrument types: survey methods to address motivation and acceptance and data mining techniques (Pahl, 2006a) to capture organisation and usage directly from records of learner activity in the environment. This combination provides a more complete and accurate picture than surveys and student observation alone or student tracking features available in various learning technology systems. Formative evaluations of behaviour are vital for identifying key design issues and for improving the understanding of pedagogical issues and the design of effective types of learning environments (Kinshuk, Patel, & Russell, 2000). A framework for the analysis and evaluation of active learning and training behaviour and interaction needs to support a variety of techniques:

- the detection and discovery of learning and training interaction from sources such as access logs,
- the explicit capture and representation of interaction behaviour abstracted from the interaction and access requests recorded in the logs,
- the analysis and interpretation of behaviour within the educational context using an analytic model of activities.

Current standardisation efforts, for example in the SCORM context, address functionality to track and store learner behaviour in LMS.

Behaviour and Usage Mining

Data mining (Chang et al., 2001; Scime, 2004), in the application to behaviour in Web-based environments called Web usage mining, can be used to make implicit, latent knowledge in activity logs explicit. Data mining is about the discovery, extraction, and analysis of data from large databases. Web usage mining aims to extract behaviour in Web sites from access logs. To derive learning activities from navigation and interaction in Web-based systems is not always straightforward. Web log data can give a precise and objective account of low-level activities. Web logs record accesses to resources, which then have to be associated to learning activities. Web usage mining is an observation-oriented evaluation technique suitable for learning behaviour analysis (Ventura & Romero, 2006). Despite some limitations, it offers a non-intrusive form of observation that is useable at all times and that can contribute substantially to reliable and accurate evaluation results for TEL.

In addition to classical Web usage statistics such as number of hits in a period of time, usage mining allows a more targeted analysis of Web log data for educational purposes, (Ventura &

Romero, 2001). TEL-specific analyses can be supported based on two mining techniques developed for the educational context (Pahl, 2006b):

- Session classification. An access log is a chronologically ordered list of resource requests. The first task is to identify learning sessions, which are defined as periods of uninterrupted usage of an individual user. The classification tries to identify purposes or activities of a session, for example interactive learning, attending a virtual lecture, or downloading resources.
- Behavioural pattern discovery. The access log provides a sequential list of learner requests representing the learner activities in the system. The first task is to find sequential patterns (i.e. recurring sequences of requests). The second step is the identification of behavioural patterns such as repetition or the parallel use of features in these sequences and sequential patterns.

These two techniques allow the interpretation of low-level activities and interactions in terms of the broader learning activities.

Discussion

In practice, evaluation is a key instrument to address the effectiveness of teaching and learning. Overall, complementary evaluation instruments – student surveys and observation-based Web usage mining – can be combined in evaluations to address the different aspects of behaviour. Adding Web usage mining gives instructors an improved interpretative strength over classical methods for behaviour analysis. A benefit of the combination is the validation of behaviour-specific survey results and addition of preciseness through usage mining.

While for static content, navigation behaviour is already indicative of the learner's activities, the evaluation of active learning and training behaviour requires also the identification and interpretation of knowledge-level interactions. The reliability of these interpretations is crucial, since design decisions are meant to be based on them, but have proven so far to be difficult to capture in a generic tool.

AN EVOLUTIONARY PERSPECTIVE

Technology-enhanced learning is subject to constant evolution. Change needs to be embraced from the outset.

- Factors of change – like infrastructure, content, organisation, and pedagogy – are identified and their impact discussed.
- Solutions for the active learning context such as specific approaches modularity and standards are outlined.

This section brings some of the earlier aspects into a more long-term perspective.

The Impact of Change and Evolution

The IDLE system is a good example for the impact of evolution and change. IDLE has grown substantially since its first deployment in 1996 (Pahl, Barrett, & Kenny, 2004). In addition to the continuing development and extension, the maintenance of the existing content and functionality has become a problem. Changes that were made to the content and the system can be captured in a model, which reflects the different change facets of a TEL system and also the different stakeholders involved.

- Content – the subject-oriented perspective. The learner works with the content for a subject, which is, however, created by the instructor.
- Format – the organisational perspective. The organisation determines aspects such as syllabus, stakeholders, or aspects of the environment.
- Infrastructure – the technical perspective. Both organisation and developer are responsible for determining the infrastructure technology.
- Pedagogy – the educational perspective. The instructor is the key factor in determining the pedagogy.

While properly designed learning objects themselves should not be affected by for instance change in a course format, in reality these aspects are often not clearly separated and changes in format, infrastructure, or pedagogy will impact content. IDLE has been subject to changes in all facets, resulting in simple and cost-effective changes to the sometimes necessary discontinuation of features.

Design for Change

The IDLE experience calls for a more systematic approach to active learning objects and infrastructure development that embraces change from the outset. Change and evolution are factors that accompany content in any form and require appropriate management support (Pahl, 2003). A number of factors need to be kept in mind when learning objects – on which shall be focused here – are designed.

- Reusability. Reuse is a necessity to keep development and maintenance costs under control. Reuse requires learning objects to be developed for this purpose. Reusable learning objects need to be internally coherent. Reusable objects tend to be small in scale in order to enable their modular composition to courses in different contexts. Reusable objects need to be described to allow potential users to determine for instance the infrastructure requirements the object might have. This type of knowledge about dependencies helps to determine the change impact and carry out modifications.
- Standards. Standards enable interoperability. For static learning objects this refers to the format in which the objects are represented. For dynamic, interactive learning objects, their integration into a delivery environment is more challenging. These objects are executable software artefacts that have to be invoked by the delivery systems they are integrated in. This invocation interface needs to be standardised. The composition of learning objects – often referred to as sequencing – is equally important. Standards-compliant representation of content and interfaces guarantee a certain degree of stability and also control over the impact of changes.
- Maintainability. Similar to reusability, maintainability requires an adequate design. Internal coherence and small scale are factors that tend to reduce change impacts. Changes cause by the environment will occur. The main issue is to predict the impact of changes and the costs to deal with them and to limit them. The four facets can act as a TEL-specific guideline to assess the implications of change.

Discussion

Overall, the separation of concerns is one the central rules for the design of maintainable learning objects and TEL systems. In practice, maintainability is a crucial, but often neglected aspect. Content needs to be separated from its configuration into courses, from adaptivity and personalisation in the delivery, and from any scaffolding added to support the learner. Change and evolution are, however, inevitable and need to be catered for from the beginning by limiting the change impact and allowing this impact to be determined easily. The novelty of TEAL means that major evolutions in pedagogy and technology that have been outlined will take place.

CONCLUSIONS

The use of technology-enhanced learning and training environments to enhance or replace traditional forms of learning and training has increased over the past years. In particular the World-Wide Web has gained the status as the predominant platform for these environments. First generation Web-based educational environments succeeded due to their advantage of easy access to educational resources. Recently, the focus has been on supporting a wider range of educational activities, thus enhancing the learning experience for the learner through improved interactivity and engagement. Traditional knowledge-based learning is complemented by skills-oriented active learning and training. The combined facilitation of interaction between learners and content supporting knowledge acquisition and skills training is central.

While the benefits of active learning are widely recognised, a range of problems remain concerning best practices. Pedagogical frameworks exist and some successful prototypes have been developed. These have highlighted the limitations in terms of standards and interoperability, in actually making implicit knowledge of different types explicit, and, last but not least, understanding the learner's behaviour in these environments. Practical aspects such as development and maintenance problems limit the full exploitation of the potential. The development, or rather the overall lifecycle of active learning content and infrastructure, needs to be supported by a comprehensive engineering framework. The development of TEL environments is a participative effort of instructors, learners, and software specialists that requires an adequate methodological framework. In particular the maintenance and evolution of these systems as a consequence of formative evaluations and technological changes in the deployment context need to be embraced from the outset. These aspects are hampered by the fact that active learning and training on the one hand and current technology development (e.g. devices) and pedagogy trends (e.g. collaborative learning) on the other hand, however, often have opposing requirements. Pedagogy, examples, development, implementation, evaluation, and change and evolution are the aspects of the presented roadmap that summarise the main technical, pedagogical and administrative challenges of TEAL as an approach.

As technology-enhanced active learning is still in its infancy, a two-stage evolutionary process is likely to address the issues arising from this roadmap discussion.

- In a first phase, active learning and training with current media and architecture technology still needs more best practice results for authoring and delivery, to try to understand how learners work best in these environments.

- In a second phase, these results can be adapted to new contexts such as emerging delivery platforms and devices, integrating some of the advanced aspects such as ontologies that have been discussed here.

Ultimately, due to the recognition of constructive and active learning as beneficial, these will be implemented in technology-enhanced learning environments, but require a period of further learning for developers and instructors and also technology development before this can take place.

REFERENCES

ADL. (2004). *Sharable Content Object Reference Model (SCORM)* – Content Aggregation Model (CAM), Run-Time Environment (RTE), Sequencing and Navigation (SN). http://www.adlnet.org/index.cfm?fuseaction=scormabt.

Aroyo, L., Dicheva, D., & Cristea, A. (2002). Ontological Support for Web Courseware Authoring. *Proceedings Conference on Intelligent Tutoring Systems ITS'02*. 270-280. Springer-Verlag.

Barrows, H. (2000). Foreword. In D. Evenson and C. Hmelo (eds.) *Problem-based Learning: A Research Perspective on Learning Interaction*. *vii-ix*. New Jersey: Lawrence Erlbaum Associates.

Brabazon, D., McLoughlin, E. & Smyth, P. (2006). Virtual Instruments - Visualising and Logging Science and Engineering experiments. *Assocation for Learning Technology Online Newsletter*, 5.

Chang, G., Healey, M.J., McHugh, J.A.M., & Wang, J.T.L. (2001). *Mining the World Wide Web - An Information Search Approach*. Kluwer Academic Publishers: Boston, 2001.

Collins, A., Brown, J.S. & Holum, A. (1991). Cognitive Apprenticeship: Making thinking visible. *American Educator*, Winter edition.

Devedžić, V. (2004). Web Intelligence and Artificial Intelligence in Education. *Educational Technology & Society*, 7 (4), 29-39.

Devedžić, V. (2006). *Semantic Web and Education*. Springer-Verlag.

Guzdial, M. & Kehoe, C. (1998) Apprenticeship-based learning environments: A principled approach to providing software-realized scaffolding through hypermedia. *Journal of Interactive Learning Research*, 9(3/4), 289-336.

Herrington, J. & Oliver, R. (2000). An instructional design framework for authentic learning environments. *Educational Technology Research and Development*, 48(3), 23-48.

IEEE Learning Technology Standards Committee LTSC (2002). IEEE P1484.12/D4.0 *Draft Standard for Learning Object Metadata (LOM)*. IEEE Computer Society.

IEEE Learning Technology Standards Committee LTSC (2003). IEEE P1484.1/D11 *Draft Standard for Learning Technology Systems Architecture (LTSA)*. IEEE Computer Society.

IMS Global Learning Consortium (2003). *IMS Learning Design (LD) Standard*. http://www.imsglobal.org/learningdesign/.

Kenny, C. & Pahl, C. (2005). Automated tutoring for a database skills training environment. A*CM SIGCSE Computer Science Education Symposium 2005*. 58-64. ACM Press.

Kinshuk, Patel, A. & Russell, D. (2000). A Multi-institutional Evaluation of Intelligent Tutoring Tools in Numeric Disciplines. *Educational Technology & Society* 3(4).

McLoughlin, C., Winnips, J.C. & Oliver, R. (2000). Supporting Constructivist Learning through Learner Support On-line, *World Conference on Educational Multimedia, Hypermedia and Telecommunications EDMEDIA'2000*, 674-680.

Mitrovic, A. & Ohlsen, S (1999). Evaluation of a Constraint-Based Tutor for a Database Language. *International Journal of Artificial Intelligence in Education* 10, 238-256.

Mizoguchi, R. & Bourdeau, J. (2000). Using ontological engineering to overcome common AI-ED problems. *International Journal of Artificial Intelligence in Education* 11, 107-121.

Moore, M.G. (1992). Three types of interaction. *The American Journal of Distance Education*, 3(2), 1-6.

Murray, S., Ryan, J. & Pahl, C. (2003). A tool-mediated cognitive apprenticeship approach for a computer engineering course. *IEEE International Conference on Advanced Learning Technologies ICALT'03*, 2-6.

Nardi, B. (ed.) (1997). *Educational Context and Consciousness: Activity Theory and Human-Computer Interaction*. MIT Press.

Northrup, P. (2001). A framework for designing interactivity into Web-based instruction. *Educational Technology*, 41(2), 31-39.

Ohl, T.M. (2001). An interaction-centric learning model. *Journal of Educational Multimedia and Hypermedia*, 10(4), 311-332.

Oliver, M. (ed.) (2000). Special Issue on Evaluation of Learning Technology. *Educational Technology & Society*, 3(4).

Pahl, C. (2003). Evolution and Change in Web-based Teaching and Learning Environments. *Computers & Education*. 40(1), 99-114.

Pahl, C. (2006a). Behaviour analysis for Web-mediated active learning. International *Journal of Web-Based Learning and Teaching Technologies.* 1(3), 45-55. Idea Group Publishers. 2006.

Pahl, C. (2006b). Data Mining for the Analysis of Content Interaction in Web-based Learning and Training Systems. In S. Ventura und C. Romero (Editors). *Data Mining in E-Learning*. 41-56. WIT Press.

Pahl, C., Barrett, R. &. Kenny, C. (2004). Supporting Active Database Learning and Training through Interactive Multimedia. *International Conference on Innovation and Technology in Computer Science Education ITiCSE'04*. 58-62. ACM.

Pahl, C., & Holohan, E. (2004). Ontology technology for the development and deployment of learning technology systems – a survey. *International Conference on Educational Hyper- and Multimedia EdMedia'04*. 2077-2084. AACE.

Ravenscroft, A., Tait, K. & Hughes, I. (1998). Beyond the Media: Knowledge Level Interaction and Guided Integration for CBL Systems. *Computers & Education*, 30(1/2), 49-56.

Scime, A. (2004). *Web Mining: Applications and Techniques*. Idea Group Inc.: Hershey.

Sims, R. (1997). Interactive learning as "emerging" technology: a reassessment of interactive and instructional design strategies. *Australian Journal of Educational Technology*, 13(1), 68-84.

Ventura, S. & Romero, C. (eds.) (2006). *Data Mining in E-Learning*. WIT Press.

Weston, T.J. & Barker, L. (2001). Designing, Implementing, and Evaluating Web-Based Learning Modules for University Students. *Educational Technology*, 41(4), 15-22.

Wilson, R. (2004). The role of ontologies in teaching and learning. *JISC Joint Information Systems Committee – Technology and Standards Watch Report TSW0402*. http://www.jisc.ac.uk/uploaded_documents/tsw_04_02.pdf

Xu, L., Pahl, C. and Donnellan, D. (2003). An Evaluation Technique for Content Interaction in Web-based Teaching and Learning Environments. *International Conference on Advanced Learning Technologies ICALT'2003*. IEEE Press. pp. 294-285.