Combining ITS and eLearning Technologies: Opportunities and Challenges

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Abstract. The development of Intelligent Tutoring Systems (ITS) and eLearning systems has been progressing largely independently over the past several years. Both types of systems have strengths and weaknesses – ITSs are typically domain specific and rely on concise knowledge modeling and learner modeling, while eLearning systems are deployable in a wide range of circumstances and focus on connecting learners both to content and to one another. This paper provides possibilities for convergence of these two areas, and describes two of our experiences in providing an ITS-style approach to eLearning systems.

1 Introduction

The term eLearning brings to mind several core concepts; learning activities supported by Web-technologies including learning management systems (LMS) such as WebCT, Moodle, etc., conferencing and discussion systems, and rich multi-media content. ELearning applications fall into a broad qualitative spectrum, and critics have attacked these products for having a lack of pedagogical and psychological validity, as well as an absence of controlled evaluations.

By comparison, Intelligent Tutoring Systems (ITS) have mostly been focusing on supporting and scaffolding of problem solving in learning. Typically they have been built on specialized, rich knowledge representations, and use cognitive diagnosis and user modeling techniques to respond to the needs of the learners. Until quite recently, employing Web-technologies has not been a major focus of ITS. Only a few ITSs use technologies such as adaptive hypermedia [1] or metadata and knowledge management [2, 3].

This suggests that there should be gains from integration and collaboration between the two communities. Despite this, the cultural differences between the two communities has led to little cross-fertilization of ideas and technologies. This paper discusses this topic as follows: Section 2 examines the differences between common ITS and eLearning environments. This is followed in Section 3 by a discussion of our experiences with two different systems that aim to fill the gap between these communities, ActiveMath [4] and iHelp Courses [5]. Section

4 concludes the work by identifying specific challenges that exist, and potential ways to address these challenges.

2 Differences

ITS has grown out of artificial intelligence, cognitive psychology, and education and has typically focused on the creation of specialized research systems which are domain dependant and mostly aimed at school education. As the area has been mostly one driven by research, implementations tend to be unique in the features they provide, contain hand-crafted ontologies developed by a small group of developers, and lack interoperability between one another. ELearning systems, on the other hand, are a mostly technology-driven enterprise so far mostly worked on by institutions aimed at higher education and workplace training. This community tends to be more risk-adverse, and its motivating factors are interoperability through standardization (for instance, the IMS specifications, see below) and wide-scale deployment. Thus the thrust of traditional eLearning research is the issue of reuse, interoperability of components, integration with organizational software, and authoring of content. Table 1 provides a coarse distinction of the main features of ITS and eLearning systems. It must be noted that many instances of exceptions to this classification are beginning to emerge as efforts (such as ours) are initiated to reduce the boundaries between ITS and eLearning.

Table 1. Features of typical ITS and eLearning applications

ITS	eLearning
aiming at improved learning	organizing learning & presenting material
restricted content	massive content
carefully crafted content	content crafted by normal authors
single author/designer	potentially collaborative authoring
fix abstract domain ontology	several ontologies, content-based
elaborate feedback	simple feedback
some feedback generated	pre-scripted feedback
tightly integrated components	service approach
few generalizable solutions	scalability and reuse important

2.1 Technologies in eLearning

LMSs contain functions for managing authors, instructors, administrators, and learners in courses (e.g., roles, passwords, etc.), connecting learners together (e.g., by discussion forums and chat systems), and providing and managing access to content (e.g., access rules, quizzes, etc.). These systems generally offer a very simple level of monitoring and feedback mechanisms – instructors can usually see only a coarse-grained view of what content students have accessed (or discussions students have engaged in) and students typically can obtain pre-scripted simple feedback or limited branching to alternate content resulting from instructor-created quizzes.

These systems use the Web and browsers for delivery and allow for learning which is independent of time, place, and pace. Both hypermedia and multimedia are used to help motivate learners, though it has been suggested that this may neither last nor result in deep learning as the grip of the new media evaporates. Still, psychological research suggests some value of multimedia for attracting attention and for grasping complex information through multiple sensory channels. In addition to the rich content provided by these systems, there is a strong potential to leverage Web-technologies for personalization and adaptation, and there is a growing awareness for its importance to eLearning (see, e.g., [6]).

Standardization of learning objects hold the promise to make reusability of learning material easier. The standards are aimed at solving a number of problems including the description of technical, administrative, and pedagogical aspects of content (e.g., IEEE LOM [7]), the interconnections between content and learning actors (e.g., IMS Learning Design [8]), the aggregation and ordering of content for deployment (e.g., IMS Content Packaging [9]), and how content should be sequenced for the the learner (e.g., IMS Simple Sequencing [10]).

The standardization process has been largely influenced and governed by commercial interests and tries to be completely comprehensive, which makes the standards simultaneously large and cumbersome yet failing to include specific needs. In particular, the metadata as well as much of the technology usage have not yet been targeting deep learning and are not much informed by empirical psychological results [11].

In addition to standards-compliant learning materials, a number of other Web technologies hold great promise. For instance, the use of XML, XSL, and the Resource Description Framework (RDF) serve the separation of structure, presentation, and semantics and they provide a rich and extensible layer.

Web services are clearly becoming the choice for system-to-system integration and could help specialized ITS components attain a higher level of interoperability. Web services typically require developers to provide strict definitions of the functionalities that can be requested from a stand-alone application living on its server. This is typically done in a blackbox manner, where a wrapper around domain tools (e.g., an equation solver or a computer algebra system) is generated and exposed to the world. Unlike the typical glassbox ITS system (such as the physics problem solver in Andes [12]), blackboxes are often more difficult to use when the goal is to generate feedback based on human problem solving spaces. For instance, computer algebra systems compute solutions in steps and by algorithms that typically are different from human problem solving behavior.

The lack of adaptivity to individual learners is the main shortcoming of traditional eLearning approaches. Customizing feedback or limiting learner options is based on fairly superficial knowledge, typically the answer given to a question in a quiz. Guidance for learners must be completely scripted by authors with no run-time inference or subtle adaptation based on individuals' actions. The task of selecting content for presentation to the learner is left to authors (or to the learners themselves). More successful forms of adaptivity have been in adjusting presentation style to specific devices or to dichotomic learning styles (e.g. verbal vs. visual learners such as in the INSPIRE and 3DE projects.

Despite strong adoption of eLearning in the marketplace (including the open source world), some eLearning developers have become aware of the downfalls of current technologies. However, the idea of 'diagnosis' does not belong yet to the common ground.

2.2 Intelligent Tutoring Systems

Typically the "intelligent" in ITS refers to (1) a problem solving system that can assist and help to produce feedback and hints to learners; (2) model tracing that predicts the learner's current mastery and likely next step in order to scaffold problem solving; (3) knowledge tracing that assesses the learner's abilities and concept-mastery in order to release new exercises or topics to learn; and (4) tutorial dialogues for scaffolding problem solving. Certainly, the literature reveals many more ideas that have been proposed in ITS-research such as tools for inquiry learning and for collaborative learning.

ITS-research has a long record of student modeling, of appropriate responses to students' problem solving activities, of collaborative learning techniques. It offers a range of techniques for macro- and micro-adaptation [13] which adapt both *what* is presented to the learner and *how* it is presented. Many ITSs realize (pedagogical) ideas and technologies that are informed by empirical results from cognitive and pedagogical psychology, e.g. on cognitive models, self-explanation, or the zone of proximal development. Moreover, controlled experiments belong to the arsenal of methods practiced in the ITS-community.

3 Filling the Gap

It is our claim that eLearning can be made more intelligent and ITS more open and reusable while preserving their useful existing features. In particular, Web-technologies can be employed to enhance adaptivity technologically, to reuse interoperable components, and to make systems more widely available and maintainable. ITS-techniques can be used to make adaptation truly beneficial for learning, to provide student modeling, tutorial dialogues and other useful ideas and tools developed over years.

As eLearning goes through an explosion of adoption, more and more systems are integrating ITS research into traditional eLearning environments. This section describes two deployed systems which seek to integrate some level of adaptation and personalization while recognizing the specifications and standards of the broader eLearning community.

3.1 iHelp Courses

The LORNET network investigates ontologies, artificial intelligence, data mining, and multi-media in an eLearning project. We are investigating how adaptive systems can embed intelligence into standardized learning objects, as well as connect users in real time and asynchronous virtual communities. iHelp Courses [5] is one project within LORNET in which a web-based and learning object-based content management system provides some learner personalization while maintaining standards compliance. It requires instructors to provide aggregations of content using the IMS Content Packages. Content can be in any format renderable by a browser (including Flash, Java Applets, etc.). The flexibility of the format allows an instructor to take existing learning materials and readily integrate them into a new course. Further, by supporting eLearning standards for content aggregation, instructors gain the benefits of traditional content management systems (i.e. portability of content).

Personalization is achieved through the use of a fine grained role structure. Learners are assigned to an arbitrary number of hierarchically arranged roles which govern the path(s) that they can take through the learning material. Instructors associate rules that determine the availability of a piece of content with content/role tuples. These rules follow the spirit of the IMS Simple Sequencing specification and can access both the structure of content, the knowledge-tracing model of the user, and various system functions. As a user can be put into an arbitrary number of roles, rules are compiled into Java Bytecode, loaded on-demand, and executed to provide high performance.

Rule functions outside of the scope of simple sequencing can be easily added to iHelp Courses, and provide increased user modeling functionality. Data we collect includes dwell time on each learning object, the path taken to get to a particular point, and a history of the responses the learner has provided. This modeling is deeper than the user tracing laid out by eLearning specifications, and integrates with knowledge representation and reasoning efforts in ITS and Semantic Web research.

iHelp Courses has been deployed at the University of Saskatchewan, and has been used with over 200 students in distance eLearning courses and over 2000 students in blended learning environments.

3.2 ActiveMath

The EU-project Language-Enhanced, User-Adaptive, Interactive eLearning for Mathematics (LeActiveMath) is carried out by 8 European partners from research institutes, universities and an educational publisher. It combines expertise in Web technologies, knowledge representation and services, in ITS including user modeling, in mathematics teaching and competency-based pedagogy, and in computational linguistics. LeActiveMath builds upon ActiveMath, a multi-lingual, Web-based, adaptive learning environment for mathematics. It combines several components and services in one application using a distributed architecture based on XML-RPC as well as an asynchronous event framework [14]. It employs computer algebra services and domain reasoner for generating feedback and assessment for exercises and develops tutorial dialogues. LeActiveMath provides advanced tools such as an open learner model, semantic search, interactive concept mapping, and assembling tool. LeActiveMath employs a semantic XML-representation for mathematics, OMDoc [2], compliant with LOM. A presentation engine transforms the content into a variety of output formats (e.g., HTML, MathML, and PDF). ActiveMath realizes personalization through instructional planning [15]. For instance, the content may vary for different learning contexts and in detail and difficulty. ActiveMath adapts and personalizes content by assembling learning objects according to prerequisite and other relations and by modifying this according to preferences, learning scenario, goal-level and ability.

On the one hand, LeActiveMath relies on Web-fueled knowledge representation and Web-technologies such as XSLT, Web-server, brokerage of services, servlets, JSP, and Velocity templates. On the other hand, it also realizes typical AI-techniques such as student modeling, adaptive hypermedia, adaptive course generation, blackboard suggestion mechanism, feedback in problem solving based on back-engine computation and reasoning.

LeActiveMath is tested at different European universities and in German high schools in several small- and large scale evaluations.

4 Challenges and Opportunities

Opportunities are opened up by the growing quantity of learning material that has been tagged and annotated using standards and that is available via the Web. Intelligent tutoring systems can benefit from employing an extensible and reusable knowledge representation scheme that is accessible for other systems as well. This includes the formats but also the concrete metadata that characterize an instructional item or learning object. The Web as a knowledge base could and should be employed in inquiry learning, especially if strong (semantic) search facilities can be provided. This is how many students now learn anyway.

Although our work aims at filling the gap between ITSs and eLearning systems, it is clear that a number of challenges still exist.

Extensibility: The majority of (if not all) eLearning specifications use XML to aid interoperability. In theory, this allows vendors to extend specifications in a conforming fashion by introducing new elements and attributes within their own namespaces. In practice however, vendor extensions to XML documents tend to break when imported into other eLearning applications. This is actually a side effect of using XML in a structural fashion – the relationship of one element to another is based on a hierarchy called the Document Object Model (DOM). Introducing new elements to "wrap" existing elements reorders the hierarchy exposed by the DOM, and thus typical structural querying languages (such as XPath) tend to have problems. While this can be avoided (both in the design of the XML Schema, and in the implementation of XPath queries), the fact remains that vendor-based extensibility is quite low. The shift to more semantic-based representations (in particular semantic web technologies, such as RDF and OpenMath) increases extensibility without hampering the gains by interoperability. ActiveMath, for instance, uses an extensible implementation of OpenMath.

A further development of the XML-structures and of the metadata for instructional items (such as worked examples and exercises) is needed with the objective to include feedback-relevant data for problem solving activities as well as structures and metadata for the generation of tailored exercises as described in more detail in e.g. [16]. For instance, substructures in examples and exercises have to be identified and annotated with metadata in order to make them first-class citizens which can be diagnosed, faded and replaced adaptively, etc. In ActiveMath, we created such structures which carry more knowledge [16] and submitted them to standardization by IMS Math QTI.

Domain Ontologies: Domain ontologies have to be constructed and maintained. In a realistic setting which is that of collaborative authoring, this may be difficult: several ontologies may exist and these ontologies are in constant evolution and are gradually refined in collaboration with the domain experts and through experimentation with learners. Mapping is important in order to enable the reuse of domain-specific material that will be more and more available on the Web. In our experience (see [17]) and that of other ontology-builders, too, large content ontologies (e.g. 1,000 concept+) are extremely difficult to keep up to date and to maintain manually, hence automatic tools have to be developed and used. One avenue we follow in ActiveMath is the creation of domain maps from content and feeding the domain map back to the content authors for quality control and consistency checking. This way, we can keep relevant ontology information from the content (similar to T-Box and A-Box approach in description logics).

The management of ontologies and detection of inconsistencies is critical. ITS might contribute experiences from the development of ontologies from an instructional point of view, as well as from a technical point of view. The automatic creation and management of those - maybe multiple - domain ontologies poses even bigger challenges. Visualization alone is not sufficient here but quality management is needed that includes consistency checks and version control that builds on dependencies and semantics. Formal methods can contribute to discovering inconsistencies and version maintenance.

Contextualized Metadata: With the goal of reusing Learning Objects it is sometimes impossible to assign a single one-dimensional value for metadata. Consider, for example, the *difficulty* value of a learning object. Any exercise or example will be more difficult for an elementary school student than for a university student. Yet such simple contextual inferences may not be possible with current standards, where difficulty has a single qualitative value. One possible solution is the contextualization of metadata (providing multi-dimensional metadata) as currently done in ActiveMath. Such a need did not occur previously in ITSs adapting the difficulty of exercises or examples to the capability of the student because these ITSs are normally narrowly focused for a particular audience only.

Using the previous example, one can also imagine definitions relative to various kinds of assessment contexts (e.g., an author assesses the difficulty, a teacher, a student, statistical assessment of difficulty, etc.). While some work has gone into solving these problems within iHelp Courses (see [18]), validation of this approach is required. It is important to note that informal human-readable metadata, such as instructional designer reviews and opinions about a learning object and are rarely available in standardized form and therefore, they are essentially useless to the content management systems.

Creating more diverse sets of metadata for different purposes leads to another problem - who owns the metadata? Where should it be stored? Traditional eLearning standards store metadata along with a learning object, e.g., in a Content Package. Once multiple pieces of metadata can be created for a single piece of content one can envision distributed systems being employed to store data close to the creators. This opens another Pandora's box: collaborative authoring. With distributed databases the search becomes more expensive (which is bad for dynamic generation) and even worse, the maintenance of those knowledge bases becomes much more difficult. Here, again, quality maintenance must include semantic consistency checks.

Validation of Metadata: Misleading and incomplete metadata are rampant in actual deployed learning object systems, in particular learning object repositories [19]. ITSs typically specify explicitly how accurate a given piece of knowledge is (often through probabilistic models, such as Bayes nets). Hybridizing these approaches and providing a probabilistic overlay on contextualized metadata (both author generated and observed within the learning environment) is the next milestone for iHelp Courses.

Dynamic Content and Sequences: While IMS Simple Sequencing (IMS-SS) is appropriate for representing a completely generated course, it is still insufficient for true interactivity and reactivity that goes beyond the programmed instruction. In IMS-SS reactivity is defined only in terms of interaction of learner with content rather than including other dynamic aspects of the learner such as 'field of study'. Moreover, currently IMS-SS is not suited for adding or deleting content dynamically. Therefore, IMS Simple Sequencing should be extended to allow for more informed instructional planning. Ideally this should include the ability to re-plan in an ad-hoc manner based on changes in the learner model or learning environment, as well as be usable within different kinds of planning environments (classic, constraint-based, probabilistic, etc.) [20].

Distribution of Services: Currently most eLearning and ITS systems follow a centralized architecture. With the inclusion of ITS technologies, such as domain-specific reasoning engines (e.g. an algebraic problem solver) or specialized user modeling components, a distributed architecture must be considered.

Web-services seem to provide the correct amount of flexibility and generality to fit this architectural need. Brusilovsky [21] for instance, provides a description of how Web-services can be used to create a centralized user modeling server. Brooks et al. [22] provide a semantic Web-based architecture that can be used to collect and distribute user modeling information in eLearning environments. In ActiveMath with its central student model and action history, events are passed asynchronously and requests to/from services exchanged [14].

New Models of (Life-Long) Learning: Both, ITS and eLearning could develop learning scenarios that rely on self-organization models with little control for certain phases in learning. Such models are typical for the Web and have the potential to engage and motivate certain learners. Feedback and encouragement is useful but too much control can hinder self-guidance and construction of knowledge particularly for adult learners.

5 Conclusion

The aim of our research is to provide working systems that increase the efficiency of teaching and at the same time are effective for learning and pedagogically as well as cognitively sound. Therefore, they have to take advantage of ITS and Web-technologies. We – very briefly – described how this integration is pursued in ActiveMath and iHelp Courses.

Acknowledgement

This publication is partly a result of work in the context of the LeActiveMath project, funded under the 6th Framework Program of the European Community – (Contract IST-2003-507826). The authors are solely responsible for its content. The iHelp Courses project was funded in part by the University of Saskatchewan and the Government of Saskatchewan through the Technology Enhanced Learning program, as well as the Government of Canada through the LORNET NSERC research network.

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