Service Oriented eLearning Platforms: From Monolithic Systems to Flexible Services

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Abstract—The Learning Management System (LMS) has dominated internet-based education for the last two decades. However, the monolith of the traditional LMS is failing to keep pace with advances in internet technologies and social interactions online. As eLearning shifts from passive to active, the learner becomes more dynamically involved and engaged with the learning experiences. Technologies emerging from the adaptive hypermedia, semantic web, mobility and distributed computing communities are being widely employed in online learning. To support the diversity in technologies, steps towards Service-Oriented eLearning platforms have been defined by eLearning Framework (ELF), IMS Abstract Framework and Open Knowledge Initiative (OKI). The nature of next generation eLearning platforms will be based on these service-oriented visions. This paper illustrates and discusses the evolution of LMSs and focuses on a set of core challenges to be addressed in order to achieve information interoperability in next-generation eLearning platforms.

Index Terms— eLearning Platforms, Service-Oriented Architectures, Interoperability, Internet Technologies

I. INTRODUCTION

As the technologies of the internet proliferate into our daily lives, new and exciting opportunities draw closer to realization. From e-commerce to eLearning, the advancement of technology can be felt. This holds true for existing and emergent eLearning platforms. Traditional passive eLearning is being replaced by more dynamic and active eLearning. Active eLearning applies the broad range of technologies of the internet to achieve pedagogic scenarios otherwise inaccessible to traditional forms of learning, such as mobility, personalization and simulation [1]. This places an increasing set of requirements on the eLearning platforms of today.

The demand for modularized and personalizable eLearning platforms is growing [2]. Traditional eLearning platforms cannot support this requirement for architectural flexibility due to their monolithic designs. Current vendors of eLearning platforms are addressing this demand by providing toolkits which support customization or by making their source code available for modification under the various guises of open source license. This indicates an emerging shift from generic solution to specific application. The eLearning platforms of tomorrow will support a wider range of needs by providing interoperability architectures for the various existing and emergent eLearning services.

Future eLearning platforms will support federated exchange between services (information and control), various levels of interoperability (intra-domain and inter-domain) and service composition (orchestration and choreography). However, these next-generation eLearning platforms introduce a range of issues from a number of research areas including the semantic web, adaptive hypermedia, dynamic services and federated modeling.

The paper first describes the evolution of eLearning platforms and their progression towards next generation eLearning. The paper then illustrates some key challenges of information interoperability in next generation eLearning platforms. The paper identifies information and knowledge (semantic) interoperability as a key aspect of flexible service-oriented interoperability. Section III discusses the standards and technologies which support this platform evolution. The final section describes a knowledge-driven approach to service and information interoperability for future eLearning platforms.

II. eLEARNING PLATFORMS

Traditional eLearning platforms, Learning Management Systems (LMSs), provide a holistic environment to deliver and manage educational experiences. They provide a suite of tools which support the creation of, the maintenance of and the delivery of online courses, the enrolment and management of students, the administration of education and the reporting of student performance. LMSs can be grouped into two main categories; 1) open source initiatives such as Moodle (http://www.moodle.org), SAKAI (http://sakaiproject.org), ATutor (http://www.atutor.ca) and Whiteboard (http://whiteboard.sourceforge.net) and 2) proprietary solutions such as WebCT/Blackboard (http://www.blackboard.com), Gradepoint(http://www.gradepoint.net/), Desire2Learn (http://www.desire2learn.com) and Learn.com (http://learn.com). Open source LMSs are typically built upon extendable frameworks allowing implementers to adjust and modify the LMS to suit

Manuscript received October 19th, 2007. This work was supported in part by IRCSET. The support of the Informatics Commercialisation initiative of Enterprise Ireland is gratefully acknowledged.

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their specific needs. This approach, although traditionally not adopted by the proprietary sector, is emerging through such initiatives as WebCT’s PowerLinks kit and Blackboard’s Building Blocks. These provide software developers with “hooks” to tie third-party software into the LMS.

A. First Generation

The first generation of eLearning platform (c. 1993 onwards) provided, in essence, black box eLearning solutions. For the most part, these systems used proprietary formats to manage courses directly. It was common to find a 1:1 mapping between systems and courses, with very limited user tracking, if any. They focused on the delivery and interoperability of content designed for a specific purpose. During this time a range of standards emerged, such as Dublin Core (http://dublincore.org/), IMS Learning Resource Metadata [3] and IEEE Learning Object Metadata (http://ltsc.ieee.org/wg12/) which are still in use today. Content described by these standards could be shared at the asset level between standards-compliant LMSs, however this practice was not widespread.

Interoperability between different systems was provisioned for at the content level through communication channels such as AICC Computer Managed Instruction (CMI) (http://www.aicc.org/pages/aicc_ts.htm). This described a common communication API, to be included in all content, which supported such functionalities as launching and stopping learning content. The main evolutionary points of first generation eLearning platforms were their support for sharing content in an interoperable way. Examples of these early eLearning platforms include the first versions of WebCT and Blackboard.

B. Second Generation

The second or current generation of eLearning platform (c. 1999 onwards) expanded upon the successes and failures of their predecessors. They began to focus not only on the sharing of content but also the sharing of learning objects, sequences of learning objects and learner information. This support is achieved through an import/export paradigm allowing courses and parts of courses to be shared between standards-compliant eLearning platforms. Standards emerging during this time such as SCORM (http://www.adlnet.gov/), IMS Content Packaging [3] and IMS Learning Design [3] supported this level of interoperability. Another significant change developing was the embracing of “services” in principle. The design of these eLearning platforms was becoming more modularized making it easier to integrate new functionality as it arose. In some cases, such as SAKAI, web services were designed to expose a limited set of functionality supported within. There was an increased move toward separating content from tools and the learner information became more distinguished. However, these systems are not entirely learner-centric. There is a strong focus on learning administration (course management) rather than a focus on the learner. Examples of these second generation eLearning platforms include WebCT/Blackboard, Moodle and SAKAI.

Their main evolutionary points were the shift towards modular architectural designs and the recognition of the need for exchange.

C. Evolution

As these changes continue, the path towards next generation eLearning platforms is being laid. This in essence, involves the application of “service” frameworks to the modular design of eLearning platforms. The separation of LMS and Learning Content Management System (LCMS) functionality provisions support for much higher levels of interoperability, where not only content and learning scenarios can be shared but where tools, functionalities, semantics and control can be exchanged in a seamless and dynamic fashion. This also involves a much wider range of information which can be used and reasoned across in eLearning platforms such as, user information, context, sequencing, workflow, control, etc. This will allow the user to build custom eLearning platforms for their specific needs at a specific time from a vast range of eLearning services in a dynamic way. The LMSs vendor of old will no longer sell monolithic, one size fits all, eLearning solutions but interoperable eLearning platforms and a range of eLearning services, allowing the consumer to choose the right combination of eLearning services for their requirements. The evolutionary path of eLearning platforms has led from the monolithic (first generation) to the customizable (current generation). This continued advancement leading towards the service-oriented (next generation).

D. Challenges for Flexibility and Interoperability

Next generation eLearning platforms introduce a number of key challenges for interoperability of information that must be addressed going forward. The shift towards semantic exchange creates a range of new challenges. Information will not only be exportable and importable across different environments but will be exchangeable between heterogeneous environments. For example, with current eLearning platforms, user information (knowledge state, skills level, preferences, etc) can be sent between environments. However, there is no support for understanding the semantics of this information, how this information can be reasoned across or how it can be used by the different environments. For this level of interoperability, both the syntax and the semantics of the information must be exchanged. This cannot be envisioned through what some call “shared” semantics, i.e. single global semantic models. In reality, people (the core ingredient of information systems) are adversely different in, for example, how they describe objects [4]. Therefore, flexible solutions must identify and support dynamic semantic mappings to support true semantic interoperability [5]. Another key aspect to exchange relates to control. eLearning services cannot be assumed to be simply dumb content. They have and will continue to have their own internal representations, their own control flow and in some case their own tracking mechanisms. Therefore future eLearning
platforms must support the exchange of control between interoperating eLearning services.

A further challenge is to support higher levels of interoperability. One aspect of Intra-domain interoperability involves the creation of frameworks and standards to support plug-ability, which numerous initiatives and standards bodies have already begun. Inter-domain interoperability however is a much newer field of research. This involves the interoperability of context, a topic which is future detailed in section IV of this paper.

Service composition will allow these eLearning platforms to dynamically discover and assemble eLearning services to achieve the desired specific purpose of the user. This includes the realization of service orchestration and service choreography [6], topics which merit lengthy discussion outside the scope of this paper.

Research initiatives in this area are beginning to address these challenges but most work is in the early stages. The following section discusses the range of technologies, standards and methodologies which support the interoperability of eLearning platforms.

III. STANDARDS AND TECHNOLOGIES WHICH SUPPORT INTEROPERABILITY OF ELEARNING PLATFORMS

There exist a range of standards and technologies which support the interoperability requirements for next generation eLearning platforms, as illustrated in Figure 1. Existing and emerging methodologies evolve around the idea of modularization and separation of concerns. This, in essence, sees the division of functionality into modules. The modules can then be combined to provide an integrated eLearning platform. Service-Oriented Architectures (SOA) describe an architectural concept which defines the expression of processes and logic as individual services which in turn publish or expose facets of their functionality in a standardized way allowing other services to access and use their functionality in a flexible manor.

Component-Oriented Architectures (COA) are more finely grained and tightly coupled than SOAs. Changes to individual components typically impact software accessed by that component, making COAs less flexible and extensible than SOAs. COAs are primarily concerned with a local component, its properties and methods.

In Middleware Architectures a software layer is inserted between applications or services to facilitate interoperability. This layer of software can be used to provide services such as identification, authentication, authorization, information exchange and security. Middleware is especially applicable to modern knowledge based systems developed upon XML, SOAP and SOAs. Middleware is often described as the “plumbing” between web services.

The standards community has been pioneering frameworks, specifications and guidelines for service oriented eLearning platforms for some time now. IMS Abstract Framework [3] loosely identifies and represents the core components and interfaces of an eLearning system. ELF (http://www.elframework.org/) illustrates the common functionalities of eLearning systems. Similarly, the Open Knowledge Initiative (OKI) (http://www.okiproject.org/) defines service layers for the development of eLearning platforms. The common approach here is the modularization of functionality. The division usually defines the following: 1) sets of applications (e.g. LMSs); 2) application services (finer grained services that the user directly interacts with such as quizzes, simulations, etc.); 3) educational services (usually revolving around education administration such as course management, scheduling, etc.); 4) common services (functionality that the user is not directly exposed to but is essential such as authentication, file sharing, logging, database management, etc.) and 5) infrastructure (the backbone of the services including HTTP, SOAP, XML, etc.). The frameworks, specifications and guidelines then define layered approaches to constructing eLearning systems from the collections of services previously defined. At a more fine grained level, there are standards and specifications describing the syntax with which to represent information, a crucial component of interoperability is missing; the ability to dynamically use the information in a meaningful way. This is where the semantic web community makes a vital contribution.
A key assumption in having machine-readable information and services is that they can interoperate and negotiate on the fly. Semantic Web began with RDF and DAML+OIL and has since progressed towards the Web Ontology Language (OWL) (http://www.w3.org/TR/owl-features/), recently becoming a W3C Standard. OWL expresses an ontology: a knowledge base of concepts which can be queried to retrieve information. Of particular importance to ontologies is the fact that they can be used to produce new knowledge. This means that reasoning can occur within the knowledge base in order to achieve a goal, and that this information need not be specifically input by the creator of the ontology. This has been extended to the realm of web services with OWL for services (OWL-S).

At a finer grained level W3C Web Service Description Language (WSDL) (http://www.w3.org/TR/wsdl) is a specification used to describe the functionality of a web service in terms of its IOPE (Inputs, Outputs, Preconditions and Effects). It provides a syntax through which a calling system or service can access exposed functionality without concerning itself with its inner workings.

At a higher level of granularity, the semantic web community is developing specifications for the organization and workflow of services. WSBPELS (http://docs.oasis-open.org/wsbpel/2.0/wsbpel-specification-draft.html) can be used to support the organization and flow of services within service-oriented architectures. This is also a goal of Enterprise Service Bus (ESB) [7] which illustrates the organization and orchestration of services.

Adaptive Hypermedia [8] systems form the second tranche of technology for interoperation. Adaptive systems benefit from a different approach, as they tend to be open-ended information systems with a highly developed sense of their domain. This means that new information can be added relatively easily, and that a small amount of additional information will result in a considerable improvement in performance.

The main link between the Semantic Web and Adaptive Hypermedia is Web Service technology and composition. The SOAP xml language allows for remote systems to make use of web-based communication to create complex systems built from atomic services.

Adaptive Services, taking advantage of the OWL-S service ontology, in addition to core OWL, provide an extremely rich, highly expressive framework for interoperating services. The following section describes an approach to service and information interoperability in the context of eLearning.

IV. eLEARNING SERVICES

eLearning Services can represent and manage any functional aspect of an eLearning scenario. A wide variety of coarse grained functionalities of eLearning Services have been defined as part of initiatives such as eLearning Framework (ELF), IMS Abstract Framework and OKI. eLearning services include traditional functionalities such as: authentication, portal, tracking, course management, scheduling, activities, tools, assessment; and emerging functionalities such as: personalization, resource harvesting, context management, federated exchange, simulation, games, wiki, blogging, podcasting, etc.. Therefore an eLearning platform must support this expanding range of coarse grained and emerging finer grained services to provide real flexibility to their users. In comparison to the adoption of content related standards, the complexities and variations in these standards will lead to many diverse implementations. It will be essential for eLearning platforms to support “loose coupling” allowing the semantics of the services to be interoperable. One the key challenges to supporting autonomous eLearning Services is in achieving service interoperability.

A. Service Interoperability

Service interoperability concerns the seamless creation, deployment, consumption and orchestration of web-based services. Most of the research in this field focuses on the interoperation of service syntax, i.e. the ability to create a service on any platform in any environment and interact with it from a different platform and environment. Through specifications like OKI, common framework-based APIs are being specified for certain application areas (eLearning). However, these APIs provide support for tightly knit collections of services, grouped based on functionality. Going forward, it is envisioned that looser connections will provide the greater potential for interoperability and flexibility. Instead of specifying APIs for communications in a common syntax, we begin to focus on semantic-exchange and control flow management between services. The semantic-exchange supports a more detailed view of what the service can do, what it produces, how it can be managed and what are its uses. It also paves the way for generating and interpreting a range of other information such as context, trust and security. The following describes an approach to interoperability based on context informed services.

B. Supporting Service Interoperability in Context Informed Services

Pure ubiquitous computing research is based on two key concepts: pervasive computing and calm computing [9]. The objective of context-informed eLearning is to lower the information burden on the user in order to allow them to concentrate on their task, in this case learning. There are numerous projects, such as [10] that demonstrate how a variety of co-operating systems can enhance the user’s experience by placing a much wider variety of information at their immediate disposal.

Educational applications represent a natural application domain for this type of work, in part due to the immediate familiarity to academic researchers, but more importantly due to the rich information needs of students. Projects such as ActiveClass [11] address domain-specific concerns, while maintaining the generalized ubiquitous computing approach.

Typically, in current systems (e.g. [12]) context is represented by physical properties such as location. Next
generation systems will be able to leverage rich information sources made available by a service-oriented approach. There will be services which provide a great deal of information about the Learner and their activities. The information will be offered with metadata describing it. This richer information space will allow systems to incorporate a much wider amount of information, much of it located and integrated at run-time.

One approach, currently being investigated by the authors, involves integrating adaptive systems with semantically described services [13]. This approach makes use of a semantic overlay network to create links between the knowledge residing in external services and the eLearning application. These links can then be used to transfer information known by external services to the eLearning application, based on the user’s situation and needs (i.e. their context).

By generating a Shared Semantic View of the user’s context, it is possible to include a wide variety of extra information relevant to the user’s task, without having to model the types of useful information a-priori. The semantic approach provides a method for tailoring the knowledge and behavior of adaptive systems to take advantage of extra available knowledge in a dynamic fashion. The type of information is not specified in advance, but rather services are discovered and links are found based on the descriptions that accompany those services. Initiatives designed to add rich descriptions to services and their information (such as the Semantic Web) present a clear opportunity to greatly enhance the eLearning process. The next-generation service-oriented approach to eLearning is particularly focused on such interoperation. The intention of this approach is to leave the user with fewer administrative tasks to undertake in order to specify their needs and preferences in achieving a goal.

C. Example of Flexible Service Interoperability in Personalised eLearning

David is a site engineer working for the Tech Corporation, a large software services and hardware vendor. As part of his work, David travels to client premises to perform upgrades and perform maintenance on a wide variety of software and servers provided by Tech Corp.

In this particular Scenario, David is on-site with Widgets, Inc. and needs to perform an upgrade to the client's servers. The task involves some new technologies which David is not familiar with, so he needs to make use of the Tech Corp. Learning Resources for assistance.

Tech Corp maintains a Technical Knowledge Base (TKB), as illustrated in figure 2, to assist employees of different levels and areas in learning new skills and performing specific tasks. In addition to the TKB, Tech Corp maintains a Human Resources Database with details of individuals and their positions. This is complimented by a Customer Relationship Management Database, containing the deployment details of each customer. Finally, the site maintained by Widgets, Inc. includes a security management service, and a server-management service.

1) As part of learning for the upgrade, David connects to the Tech Corp. TKB. The TKB authenticates and manages the user’s session and forwards this information as required to the ancillary services.

2) David’s learning preferences are retrieved through a Federated User Modeling Exchange Service (FUMES) which extracts David’s preferences from LMS services (LMS1 and LMS2) that he has previously used. This provides a semantically rich description of David’s past eLearning experiences.

3) The TKB is a context-informed adaptive service suite. The Adaptive Contextual Portal (ACP) [13] that manages the TKB is aware of the services situated both on-site and in David’s office. The ACP maintains a shared semantic view of David’s Context. The ACP is able to tailor David’s Learning experience, based on information held in the CRM and HR services. The System is able to guide David in his choice of learning resources, and specifies additional parameters for the personalization of David’s learning experience. The system chooses to select technical, descriptive learning resources, because David is an on-site engineer who needs practical advice on task completion.

4) The TKB maintains an archive of content that Tech Corp. believes is both necessary and beneficial to the training and professional development of its staff. However, on occasion a task assigned to a Tech Corp. employee may involve technologies that are currently unsupported by the TKB. In this instance the TKB can utilize a complimentary content harvesting service called the Open Corpus Content Service (OCCS) [14].

The OCCS employs a focused web crawler to traverse the WWW and many digital repositories, creating an archive of all the relevant content encountered. This archive is indexed and can receive content requests from the TKB. Content requirements are extracted from the semantic interpretation of David’s task, derived by the ACP, from his current learning preferences and from his past learning experiences (FUMES).

The OCCS has to address some interoperability issues to be able to leverage the content available on the www. There are issues with content that has insufficient, or in some cases no associated metadata descriptions. There are also problems with incompatible metadata standards being implemented on various pieces of content. Semantic mappings to a canonical metadata model using a fixed taxonomy of terms is employed to overcome these issues. Semi/Automatic annotation of content also occurs to generate descriptions of content that have no associated metadata.

The process of this context-informed approach is as follows: each service, having been located for the ACP, registers an ontology of the information that service can share. A reasoner suite examines the concepts known to each service, and builds a shared semantic view as a topic map within the system. As the TKB performs the operations needed to build the course for David, hooks within the TKB's share the current knowledge of the service with the ACP. This current knowledge is enhanced with knowledge from the
ACP's shared semantic view, and 'pushed' back to the TKB. David then engages the offering from the TKB (step 5 of figure 2) and successfully completes the current task. The context-informed approach means that the TKB's designers needed only define the points where context could be used, and allow the aware environment to push context-enhanced models to the system.

V. CONCLUSION

The high development cost of learning resources and pedagogical strategies is a key motivating factor in the evolution of LMSs. As functionality is decoupled from monolithic systems, these resources become exchangeable and reusable.

With the growth of innovative internet technologies and applications, people are placing more aspects of their lives online. Passive consumer models are rapidly being outpaced by more active producer models. Defining rigid frameworks and boundaries for eLearning platforms does not fit with the free model of internet. Wrapping eLearning as a bundle to be delivered is a failed approach. In reality, every contribution to the web has a learning-related value associated with it. eLearning platforms of tomorrow will deliver knowledge when, where and how you want it.

Much of the work currently being undertaken is concerned with interoperation and exchange. However, there are only a small number of services generally available for consumption. Without a critical mass of such services, there is a risk that the evaluation of next generation LMSs will be hindered.

REFERENCES

FIGURES

Figure 2, Dynamic Personalized eLearning Scenario