Building Bridges with Blocks: Assisting digital library and Virtual Learning Environment integration through reusable middleware

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Abstract

Various studies have reported that achieving effective use of increasingly heterogeneous scholarly objects within institutional learning and teaching frameworks is becoming critical to the performance of educational institutions. The integration of digital information environments, such as a University library, within a virtual learning environment (VLE) encapsulates this challenge. This paper presents reusable middleware to achieve effective digital library (DL) and VLE integration. The aim of the study is to demonstrate that the use of open standards and service-oriented architectures (SOA) to build "light" web-services-based middleware is a suitable alternative for embedding digital library information sources in learning and teaching frameworks. We argue that by using open-source and open-standards approaches rather than software and practices developed specifically for a particular VLE product, it is possible to obtain open reusable middleware that can simplify the DL-VLE integration and bridge the functionality of both environments. We hope that our methodology can provide a common foundation on which a variety of institutions may build their own customized middleware to integrate scholarly objects in VLEs. The study has assessed the impact of the VLE-library integration on academic users of both the library and the VLE. Performance issues of the proposed digital library-VLE integration are also discussed. A secondary but important finding of our study is that much more effort is required to open and standardize the closed, restricted and proprietary approach of digital publishers to the reuse of scholarly material. This approach can be a serious obstacle to effective digital library-VLE integration and can limit the publishers' ability to allow the discovery, integration and reuse of scholarly material. Current research in this area is analyzed and discussed.

Keywords: reusable middleware; SOA; SRU/SRW; federated search; VLE; open standards.

1.   Introduction

It is becoming clear from a number of perspectives that allowing effective discovery and use of scholarly objects within learning and teaching frameworks such as VLEs and institutional portals will be critical to the performance of educational institutions [1,2,3,4,5,6,7]. However, as Low B. [8] has noticed, resource discovery has been overlooked as a function of VLEs by vendors. We believe that this deficiency needs to be addressed urgently and with an "open standard" perspective. Digital libraries (DL) and VLEs both support learning and teaching in academic institutions. Institutions use library management system or digital libraries (DLs) to gain access to the content of scholarly objects from local databases such as institutional repositories or other collections of research papers, e-theses, technical reports, OPACs, image banks, etc., as well as from subscribed external content such as scientific papers provided by journal publishers or aggregators, and remote digital libraries, directories and online databases. On the other hand, VLEs are integrated environments of components (e.g. online discussions, course materials, e-mailing communication, submission of assignments, assessment, etc.) in which learners and tutors participate in "online" interactions of various kinds, involving online learning (VLEs are also known as Learning Management Systems (LMS) outside the UK.) However, despite the fact that both DLs and VLEs are oriented to support learning and teaching, previous studies have reported that the process of integrating DL and VLE systems can raise technical issues that require in depth investigation and complex solutions [9,10,11] (non-technical but important issues are beyond the scope of this study.) For example, systems run on different operating systems, use different data formats, have different authentication requirements and different web interfaces, etc. This paper sheds some light on a cost-effective methodology for overcoming such

technical issues and confirms that a service-oriented approach combined with web services technology that makes use of standards or specifications for interoperability is a simple solution for achieving effective DL-VLE integration.

This paper first briefly describes the PerX toolkit, an open-source federated search software application produced by the *Pilot Engineering Repositories Xsearch* (PerX) Project [12]. It then presents the web services-based and open shareable SOA-compliant middleware used to embed Library functionality within the VLE. When describing the work done for encapsulating the middleware in the VLE used in this study, the paper mentions the commercial VLE *Blackboard* platform [13]. However, the work presented is not dependent on *Blackboard,* because it uses open standards and open source. Thus, our work can provide a common foundation on which a variety of institutions may build their own customized middleware to integrate their scholarly objects in their own VLEs. The only requirement is that the VLEs support XML-based retrieval via HTTP, preferably using standard web services communication. Further information and discussion on the middleware implementation and details of the "*Building Block*" encapsulation is presented in section three.

We also discuss the current status of digital publishing with respect to DL-VLE integration, finding that, within this context, most digital publishers have adopted a closed, restricted and non-standard approach. Publishers of scientific papers are one of the main sources of DL content and their lack of participation in sharing and reusing of scholarly metadata via open standard mechanisms can have a negative impact on DL-VLE integration success. Some recommendations for increasing interoperability and reuse in digital publishing are outlined at the end of section four.

The study has assessed the impact of the proposed VLE-library integration on academic users of the VLE and library services. Use case scenarios highlighting experiences gained and implications for stakeholders arising from the pilot are described in section five. The outcomes of these experiences are used as a basis for recommendations for future development of the pilot as well as for institutions planning to integrate their library with institutional VLEs.

After a discussion of the implications and some performance issues of the proposed digital library-VLE integration, the paper ends with conclusions obtained from the study.

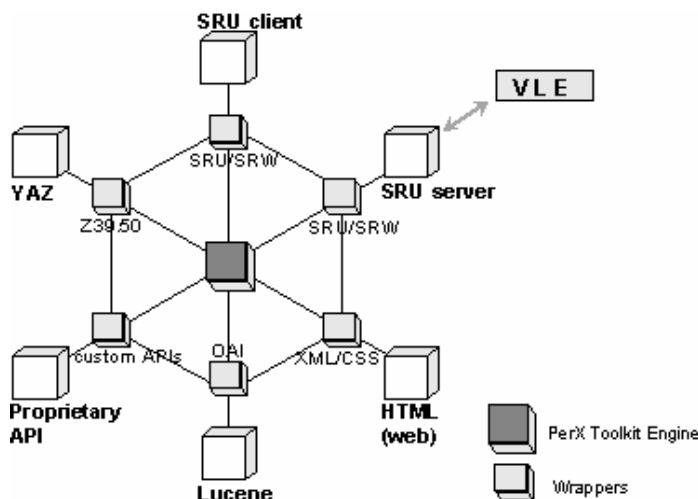## 2.   The PerX federated search toolkit

The core software component of this pilot is an open-source federated search toolkit produced by the *Pilot Engineering Repositories Xsearch* (PerX) Project, funded by the JISC Digital Repositories Programme. We chose this federated search software (referred to as the PerX toolkit) because it uses both an XML-based technology for system integration and a service-oriented architecture (SOA) [14] for achieving greater "loose" separation between its software components. In fact, the PerX toolkit is a reusable library of open source software applications integrated by a SOA model. It is a loosely coupled collection of proven, scalable and reusable software libraries and APIs (Application Program Interfaces) that have been combined via XML messages. Figure 1 represents the PerX toolkit architecture. Its main component is the *PerX Toolkit*

Figure 1 The PerX Toolkit Architecture

Engine, which communicates with the rest of the software components via *wrappers*. The *wrappers* use XML-messaging for handling requests from/to the reusable APIs, which in turn deal with the database sources. The toolkit allows remote and local heterogeneous database sources to be cross-searched from one access point. It uses open standard technology for metadata exchange such as OAI-PMH (Open Archive Initiative-Protocol for Metadata Harvesting, [15]) and the search protocols SRU (Search/Retrieve via URL, [16]) and Z39.50

(International Information Retrieval Standard ISO 23950, [17].) Chumbe et al [18] presents a full description of searching databases with the PerX Toolkit as well as the processes involved in metadata exchange with data providers (harvesting, normalization, searching and rendering.)

3. Reusable middleware approach for embedding DL functionality within a VLE

Heriot-Watt University Library has recently collaborated with the Institute for Computer Based Learning (ICBL) on a *Blackboard* VLE - e-Library integration pilot. The core software component of this pilot is the PerX toolkit described in the previous section. However the key player, or broker, of the integration itself is the reusable web-services based and SOA compliant middleware used to embed the toolkit functionality within the VLE. An important condition for the pilot was that the middleware should know nothing about the hosting VLE environment and thus can potentially be reused within any VLE framework. Its only function was to provide a "live bridge" between the toolkit functionality and the VLE system.

Traditional client/server middleware has typically been deployed in a 2-tier, point-to-point architecture [19], which in our case would involve the installation of a proprietary API Client on the VLE server, and an API server on the PerX server machines. However, this is an expensive and inflexible model, because neither of the Client and Server APIs can be reused. A step forward in flexibility is an n-tier model, where an XML-based middleware API is installed between the client (VLE) and the server (DL) systems. The n-tier model offers the benefit of avoiding the development of two different APIs and the need to access source codes on both sides to enable interoperability. The XML-based middleware API is a kind of *wrapper* that hides the complexity of the native APIs of both server and client because it uses web services technology for exposing their services. This XML-based n-tier model has been used by the LEBONED Project to integrate the *eVerlage* Digital Library product into the *Blackboard* VLE [20]. However, the cost-effective factor is still unresolved by this approach, because such a specific *wrapper* will need to be written again for any other digital library system to be integrated into *Blackboard*. We present here a further step towards achieving inexpensive, reusable and flexible DL-VLE integration. Our approach is also based on a three-tier design pattern using an XML-based middleware API that sits between the *Blackboard* VLE (front end) and the PerX toolkit (back end) systems, but we do use the open standard SRU/SRW protocol for interoperability and XML message exchanging between the systems. The use of proven open standards effectively turns our XML-based middleware into a reusable *wrapper* or message broker. This approach would allow organizations to access virtually any SRU/SRW compliant system from within any SRU/SRW compliant DL system through a scalable service-oriented architecture. While simple, the middleware constitutes the basic infrastructure behind the DL-VLE integration, becoming a versatile alternative for integration. The basic deployment architecture of the proposed approach is shown in Figure 2.
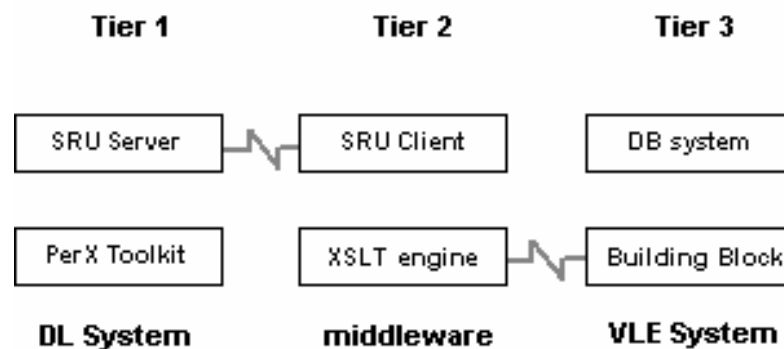

Figure 2 DL-VLE integration architecture using a three-tier design model

The approach described above offers a potentially rich system-level DL-VLE integration because it uses a standard specification for interoperability such as the Search/Retrieve via URL (SRU) protocol encapsulated in a reusable middleware. The SRU/SRW protocol is simple to implement because it is a standard REST-ful specification for providing Web Services functionality without the complexity of tightly coupled designs as found in remote procedure calls such as SOAP [21]. A REST-based protocol uses the HTTP mechanism to implement a client/server model using TCP/IP sockets [22]. The encapsulated middleware (the HTTP client) opens a connection to the PerX toolkit's SRU server (the HTTP server) and sends a request message consisting of a search query using the HTTP GET method. The HTTP server then returns a response XML message with

Figure 2 DL-VLE Integration architecture using a three-tier design pattern

the search results using the POST method and then closes the connection. The middleware then reformats the XML message and puts the search results into the VLE database system, so they can be shareable in the VLE modules. The middleware is a kind of proxy or intermediary software that handles requests on behalf of the systems that it is bridging.

In order that the middleware be recognized by the VLE as one of its components, it needs to be encapsulated in a *building block* of the *Blackboard Learning System*. This is accomplished by issuing an XML configuration file (*manifest*) to identify the middleware as a "bridge type" *Blackboard* "*building block*," and by including *Blackboard* proprietary Java class Tag libraries to abstract user interface components [23]. The middleware implementation has followed as strictly as possible the current Java Servlet specifications for Web applications [24]. The *Blackboard* system includes a portal running on a *Tomcat servlet* [25] and in fact its "*building blocks*" are just local *portlets* that can be handled as web applications individually deployed on the local *servlet*. These *building blocks* do not adhere to the web services specifications for remote *portlets* (known as Web Services for Remote Portlets WSRP specification [26]), so they are not shareable from other portals or remote systems. However, this is not an issue for our implementation as we supply the share-ability via the REST-ful model described above. At its very core, the middleware is an SRU client that provides standards-based technology to achieve integrated behavior and performance at the system-level across diverse environments such as the federated search toolkit and the VLE system.

Unlike other open standards for interoperability, such as the Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH), implementations of the SRU/SRW protocol are poorly reported in the digital library literature. Equally, while OAI-PMH has attracted much attention in providing interoperability, despite reports of a number of important issues concerning OAI-PMH in the literature [18,27,28,29], practical examples of SRU and its relevance in the digital library are seldom discussed. To the best of our knowledge the approach of combining SOA with SRU to embed DL functionality within a VLE for cross-searching remote databases and local repositories has not yet been reported fully, and practical implementations have not received much attention. An attempt to integrate VLEs and digital repository systems using the SRU protocol in the open source d+ toolkit has been reported by Low B. [8]. However, some issues with the software were uncovered when using d+ for interoperability with VLEs. Despite claims of adherence to the current service-oriented trend, it was found that, apart from the SRU functionality provided by licensed OCLC software, deployment and use of the d+ toolkit required hardcode configuration of the software components as well as of the digital repositories. Also, at the time of testing, d+ could only query one database at the time (a sequential searching approach in contrast to the desirable "simultaneous" cross-searching approach.) Performance issues were also noted. It seemed that the ability of d+ for searching Z39.50 targets was bound to the limitations of the JAFER toolkit [30], which is still not fully available for production. Other open source alternatives considered before PerX and found unsuitable for the work discussed here, were the MDC toolkit, MyLibrary and the software suite Greenstone. In the UK, the JISC – DiVLE research strand involved a number of projects looking at how library resources can be integrated into VLEs using open standards. Thus, for example, between 2002 and 2004, the OLIVE project has been focused on how the OpenURL standard can be used to link Reading lists and Learning objects from the VLE. It also explored the use of Web Services (SOAP.) However, little practical achievement was reported [31], and unfortunately most of the plug-in software developed by the project was dependent on the commercial platforms used for integration (*MetaLib*, *Blackboard*, *Aleph*, *Discover*, *SFX*, etc.) For example, the method for implementing OpenURL is tightly coupled to the search form in the *Building Block* and cannot be reused for other applications. Also, the approach of the OLIVE project of loading functionality on the *Building Block* for metadata management raised many interoperability issues, as the *Blackboard* metadata functionality proved to be unusable and inaccessible to other areas within *Blackboard*. In Australia, Richardson J. [32] also reported on a project at Griffith University to integrate library resources into the *Blackboard* system. She recognized the power of commercial products in this arena, such as Sentient *Discover*, which supports OpenURL and Z39.50, but also highlights the "cognitive disconnect" faced by users of *Blackboard* when are taken away to the *Discover* user-interface environment from the *Blackboard* user-interface environment.

On the other hand, SOA approaches in e-learning are being promoted as suitable alternatives by important organizations such as JISC (the United Kingdom's Joint Information Systems Committee), DEST (the Australian Department of Education Science and Training), ADL (the US Advanced Distributed Learning Initiatives), IMS (the Innovation Adoption Learning global learning consortium), NSDL (the US National Science Digital Library) and IC (Industry Canada). Need for stable and coherent technical frameworks or infrastructures where e-learning services can inter-operate harmoniously have been highlighted [33,34,35,36]. Our work is firmly in harmony with the above approach and recommendations, and it would be part of any standard e-learning framework where its functional components expose service behavior via loosely coupled interfaces. In this context, we follow with interest the work being carried out by related projects, such as the open source digital

library architecture Fedora [37] and the NSDL Data Repository Architecture [38], as well as any research outcome from the JISC e-Framework for Education and Research Programme [39].

4.   Issues of the digital publishing model regarding reuse of scholarly material

An additional finding of our study is that integration of digital publishing is made difficult by the fact that publishers rarely use open standards to make their metadata available to third parties. Many publishers currently rely on large external aggregators in order to expose their scholarly contents to a wider audience. Frequently, digital libraries need to deal with these external aggregators in order to gain access to subscribed scholarly material using expensive commercial software tools, which in most cases do not use open standards. The consequence is that it is often difficult for institutions to get access to publishers' metadata and databases using suitable open standards and protocols for interoperability. The reality is that progress towards integration of scholarly digital information within VLEs is slowed down by commercial publishers and aggregators by not offering machine-to-machine access to their databases using open standards. Figure 3 illustrates a simplified view of a typical digital publishing model within the digital library context. Clearly noticeable is a need for a "consolidator" point for effective inter-operation between digital library and the rest of components of the model. Integration in a component-by-component basis would be unfeasible. Figure 4 sketches an alternative model where effective integration is enable by a suitable "middleware consolidator" created using technology presented in previous section. Advocacy for open standards is not about encouraging free access to resources but simply about providing effective ways to find (discover) and reuse resources. The PerX Project has produced a relevant report on the benefits for publishers of exposing their metadata via open standards [40]. Also other works [41,42] advocate the use of best practices among data providers and argue that the business strategies of digital publishing in fact can benefit from the standards that are part of the digital library.

Figure 3 A typical digital publishing model.

Figure 4 Publishing model with "middleware consolidator"

Currently there is a large movement towards openness in almost all aspects of digital publishing. Promising initiatives for solving important interoperability issues are not only coming from organizations that advocate open standards. Thus two technologies for enabling easier scholarly resource discovery have emerged, one from the publisher's side (CrossRef) and another one, Google Scholar, from Google, the leading commercial search engine. (Microsoft Windows Live Academic Search and Scirus services could also be mentioned here.) CrossRef is being promoted by the publishing industry to make possible standard scalable linkage of scholarly material through Digital Object Identifiers (DOI) [43]. We have been investigating the feasibility of using the CrossRef OAI service to cross-search metadata for a selection of the 23 million records hosted by CrossRef as well as to provide openURL linkage via the CrossRef openURL resolver. Unfortunately access to the CrossRef OAI repository is not open to everyone, which again puts a limitation to the reuse of metadata. Also, the CrossRef OAI service uses a somewhat limited subject classification that makes subject-based implementations difficult. The usefulness of being able to only search on title, authors and citation of papers could be also challenged (CrossRef does not store abstract and keywords.) Google Scholar [44] via
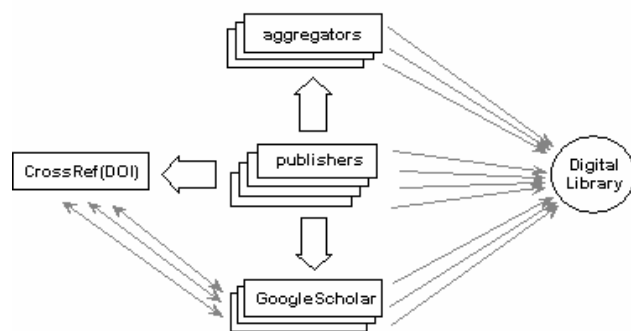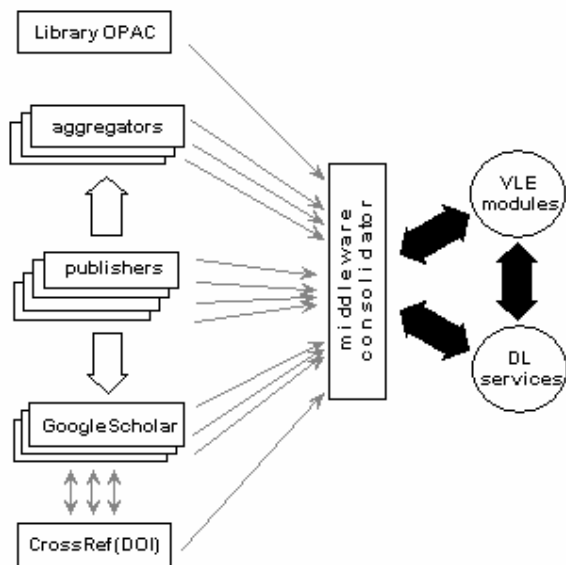
direct agreements with publishers is in fact crawling and cross-searching a very important and increasing portion of scholarly resources (e.g. peer-review articles, theses, preprints, technical reports, etc.) Google Scholar also works with CrossRef to use the DOI as the primary means to link to an article. Despite the facto that Google Scholar is still a very broad commercial oriented solution that includes any material that "looks scholarly" and that can come from unknown sources, it offers something more than other open access federated search services such as the DOAJ (Directory of Open Access Journals [45]) or Scirus [46]. It offers enhanced and fast search capabilities, cited references and links to subscribed resources through local link resolvers. On top of that, Google Scholar has the advantage of being quickly associated with the de facto ubiquitous discovery tool: Google is everywhere. As the value and usage of Google Scholar is significant, we have integrated Google Scholar in the DL-VLE prototype, via a custom API. Some researchers think that Google Scholar could be the possible solution to the cluttered access provided by traditional gateway and hosting providers used by the library. However, Google is still a commercial initiative, produced without open standards and developed in a way in which not everyone can participate, which raises concerns over obsolescence and dependency issues. For example, experience suggests that only file formats that use open standards can secure long-term preservation of scholarly material and avoid software dependencies.

In fact, the publisher with relatively cost-effective and simple solutions can produce chunk-able, reuse-able and embed-able metadata using open standards. The technical undertaking by publishers need not be large, though the potential benefits are. Publishers are already using complex and tailored mechanism to expose their data on demand basis. This approach can be ineffective and expensive. Let us consider, for example, the case of a publisher that wants its metadata to be included in CrossRef, and also be available (optionally the full-text, too) from various aggregators (MetaPress, ingentaConnect, Ovid, ProQuest, SwetsWise, etc.) and indexed by Google Scholar. Without standards, the publisher will need to set up and maintain different XML metadata files for Google, for CrossRef and for each aggregator. It will need to use an FTP-based mechanism for uploading data on the aggregators or allow them to crawl their servers hosting its data. All that could be avoided if the publishing industry agree on using a set of open standards, and better still if they work with librarians for enabling easy resource discovery, as both of them share the same goal: to make scholarly content available for the users that need it. The benefits of making online search a pleasing experience are for both the publishers and the digital libraries. We suggest that publishers start by implementing "light" open standards such as SRU/SRW, openURL, RSS feeds, and Dublin-Core (DC) metadata format. It is worth it for publishers to consider redirecting some of their IT resources to implementing open standards, automatic machine-to-machine access and simplified user interfaces. Diverse studies have already suggested that what online users want is fast and effortless access to the resources they need [47,48,49,50]. Users give little value to sophisticated user interfaces provided by publishers' web sites. Publishers should take notice of the behavior of users. On the other hand, commitment to protocols or specifications that do not adhere in full to the open standard concept [51] should be avoided if possible, in case that "cutting edge" technology that is not backed by mature open standard bodies is abandoned. For example it can be instructive to follow the discussions on the reasons for the apparent decline in the use of the CORBA protocol [52], which has been providing interoperability for more than a decade. In summary, it would make a positive impact on interoperability in general, and possibly in their revenues too, if publishers implement open standards for enabling institutional and individual users to gain quick access to the content they need with almost no effort.

5.   Study of the impact of DL-VLE integration on library users

A prototype working system demonstrating the VLE-Library system interoperability has been implemented and made available to stakeholders (students, academic and library staff) at the Heriot Watt University. It is being used to asses the impact of the VLE-library integration on academic and library users as well as a basis for gathering suggestions and recommendations for future developments to benefit institutional planning for library and institutional VLE integration. The prototype system, named as *PerX Building Block*, provides distributed searching of a sample of subscribed e-journals, the local library catalogue (OPAC) and the Google search engine. A facility for bibliographic export in RDF-based format is being added in the prototype. Testing is being carried out with a group of academic library users, and feedback is being gathered using a short questionnaire and informal interview. So far our study has confirmed the perception that in particular under-graduated students tend to ignore searching in databases subscribed by the library and prefer the ease of using Google [53]. Post-graduate researchers also feel attracted to Google capabilities. The current searchable web based interface of the library does not include links to Google or Google Scholar. If even lecturers and librarians use Google in their work, we expect that users will appreciate having Google Scholar embedded in the prototype. In fact Google Scholar can be used to drive users to the library web site and add value to the sometimes ignored library catalogues at not cost.

The reuse and sharing of DL content among the different VLE components is being explored with particular interest. We have had high interest in finding out how users rate the usefulness of cross searching from within the VLE and the convenience of onward use of search results in other VLE functions e.g. exporting, saving, emailing and posting them to discussion boards.

In parallel to our work, the University VLE Educational Support Team has been conducting consultation meetings with lecturers who are using the VLE in their courses to give them the opportunity to bring up any problems and provide feedback. In some of the meetings various issues were mentioned by lecturers that in fact would be solved by enabling machine-to-machine inter-operability between the VLE and the rest of University systems. This prompted the possibility of expanding the applicability of the reusable middleware for *bridging* systems such as the Students Registration System with the VLE.

Regarding possible performance issues of the proposed DL-VLE integration, we have noticed that SRU/SRW is not necessary relatively slow. We were expecting that the SOA-based prototype be significantly slower than fast, general purpose search engines because it uses XML-based messaging services, which typically consume more computing resources. However, after assessing the performance of the search services when searching various heterogeneous scholarly objects, users noticed that speed and performance were not issues in the prototype.

Finally, some recommendations for increasing the usability and the effectiveness of the prototype have been identified. In addition to more sophisticated retrieval and searching algorithms (e.g. full common Boolean support across heterogeneous databases), there are key operational enhancements that have been acknowledged as desirables. Enhancements include:
* Combining search results from multiple databases, which involves unified ranking.
* Comparing and consolidating search results (simplest case: removing duplicate search results; more complex case: fussy techniques for combining several databases´ results).
* Discovering inconsistencies and removing them in the search results (for example search results that seems to be different but in fact point to same resources).

6.   Conclusions

By using open-source and open-standards approaches rather than products and practices developed specifically for an individual VLE product, we have obtained a reusable middleware that can provide a common foundation on which a variety of institutions may build their own customized middleware to integrate their scholarly objects in VLEs. Our study hopes to demonstrate that the use of service-oriented architectures (SOA) and REST-ful based (SRU) open source middleware is a cost effective, simple and open alternative for embedding digital library services within learning and teaching frameworks.

We have described relevant related works and software solutions. We have highlighted shortcomings and pros of those studies. Most of these studies have tended to produce solutions tied to commercial platforms or have given priority to questionable standard such as OAI-PMH, for achieving interoperability, as it was in the case of the BRICKS Project [54], which it seemed promising when presented web services based concepts for achieving integration. However the SOA factor and the ease of alternatives such as SRU/SRW were unnoticed by these projects.

Although SOA middleware reduces the need for system development and also management and maintenance burdens, the performance of SOA-based search services need to be monitored for large production services, because XML-based messaging services typically consume more computing resources and are slower than fast general purpose search engines. Early testes suggested that users have not found performance issues using the DL-VLE integration prototype system.

A key requirement for VLEs should be integration, and the tendency of using VLEs that do not support SOA, open standards and Web Services should be reversed. Main global and national organizations are working towards SOA e-Frameworks, where monolithic and centralized architectures are no longer taken into account for effective delivery of services. The ultimate aim of a VLE should be to provide a framework where service applications are embedded and integrated through agreed behaviors and interfaces using open web services technology to achieve interoperability.

The combination of open standards, "light" web services and SOA can produce powerful platforms that can help to develop information environments that are responsive to new generation of library users (the Net generation) that expect to find ubiquitous discovery tools, such as Google Scholar, in their learning environment systems.

Publishers and libraries share the ultimate goal of making scholarly content available for the users that need it. Both of them also face the same challenge produced by the movement towards openness in almost all aspects of e-learning. Clearly it has been demonstrated that both can benefit from open standards. Libraries and publishers no longer can expect that their users adapt to and learn about their existing closed, restricted and non-standard systems. It is them who need to provide open access to their assets for interoperability purposes.

Our study concludes that without open standards, any middleware used to integrated different systems is likely to become rather cumbersome and infeasible. The use of open standards reduces dependency and heterogeneity and it is a key facilitator for systems integration and for making reality service-oriented systems.

Acknowledgements

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