Interoperability in eLearning Contexts. Interaction between LMS and PLE *

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Abstract

The emergence of the Information and Communication Technologies and its application in several areas with varying success, implies the definition of a great number of software systems. Such systems are implemented in very different programming languages, using distinct types of resources, etc. Learning and Teaching is one of those application areas, where there are different learning platforms, repositories, tools, types of content, etc. These systems should interoperate among them to provide better and more useful learning services to students and teachers, and to do so web services and interoperability specifications are needed. This paper presents a service-based framework approach to facilitate the interoperability between Learning Management Systems and Personal Learning Environments, which has been implemented as a proof of concept and evaluated through several pilot experiences. From such experiences it is possible to see that interoperability among the personal and institutional environments it is possible and, in this way, learners can learn independently without accessing to the institutional site and teachers have information about learning that happens in informal activities.

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1 Introduction

Since its appearance, the Information and Communication Technologies (ICT) and their application in different areas have evolved very quickly. This application is more or less useful depending on the target area but in any case implies the definition of new tools, new contexts, new communication ways, etc., something that is especially remarkable with the spread of 2.0 tools. Such diversity of systems facilitates to address the necessities of institutions, users, etc.; but it also means a great deal of systems (based on different technologies) and

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stakeholders that should be able to communicate with each other. In order to make this possible it is necessary to follow interoperability strategies. But, what can be understood by interoperability? European union defines it as "the capacity of ICT systems and the business processes that they support, to exchange data and knowledge" [45]. And how to achieve such interoperability? In order to do this there are different ways. Two of the most common ways to do this are Service Oriented Architectures (SOA) and Interoperability Specifications.

Service Oriented Architectures are software architectures based on creating a set of services of different granularity, between business processes and applications [5]. These architectures main aims are 1) Model the business logic as services; 2) Provide access to functionality without knowing the underlying technology; and 3) Minimize technological dependencies between the business layer and the application layer for both ones to be able to change independently [38]. The problems of these solutions are the cost to adapt the existing systems to a specific SOA and that they will not necessarily work for other configurations or distribution of the components. Proper solutions should be implemented to allow communication between different systems and this can be achieved by using interoperability specifications and standards.

Interoperability specifications define ways to exchange information and/or interaction between systems, they can be focused on the exchange of a specific type of information or address interoperability in a global way. The drawbacks of these initiatives are their acceptation and the difficulty to implement solutions based on such kind of interoperability specifications.

In the eLearning context interoperability is also necessary. The application of ICT to teaching and learning processes has had also an important influence, as the support channel to make eLearning possible [25]. Such application leads to the development of different systems as LMS (Learning Management Systems), learning tools, contents formats, etc. However ICT application did not have so much success as it was supposed to, among other reasons because of: 1) The institutional resistance to change motivated by the policy of the institutions and difficulty to integrate new systems [29, 34]; 2) The need for provide proper support to digital immigrants and the younger pupil generations that are digital natives [9, 36]; 3) The lack of connection between the formal, non-formal and informal environments makes difficult to improve learning processes and the centralization of the activity in only one context [21]; and 4) Moreover, lot of technological applications and tools are defined without taking into account the final user, which means that adopting and using them can be difficult.

In order to address these problems, learning institutions need to change their strategies. They must provide environments more adapted to the student and open to include the new set of Web 2.0 tools that are under the student's control [17]. This implies to open the existing learning environments and the definition of Personal Learning Environments (PLE), which facilitate the user learning process by allowing them to use those tools they want to use and not joining them to a specific institutional context or learning period [1].

The openness of the existing LMS, the definition of new learning environments, and the existing technological learning tool diversity make necessary to find ways in which all those systems can interoperate between them and this is what is explored along this paper, with special attention to the interoperability between LMS and PLE.

This paper proposes an approach to do so, that is, to define a possible way to facilitate the interoperability between the LMS and other external tools that could be integrated on a PLE. The approach is based on services and interoperability specifications in order it can be flexible enough to change the involved LMS, the tools or the communication ways employed.

In order to understand properly the problem, the following section describes the current landscape of learning tools interoperability and how interoperability problems are addressed in the specific context of the LMS-PLE. After that, section 3 presents related works about how to deal with interoperability. Later (section 4) a service framework to facilitate this is posed, how it can be implemented and an example of an specific scenario a its evaluation. Finally some conclusions are provided.

2 Interoperability in eLearning Ecosystems

Since its origins eLearning implies the definition of different tools and systems, and the use of other with the aim to improve student's learning. Currently there are lot of tools employed to learn in eLearning contexts. There are different LMS i.e: Moodle (`http://www.moodle.org`), Blackboard (`http://www.blackboard.com`), Sakai (`http://sakaiproject.org`), ATutor (`http://atutor.ca/`), Desire2Learn (`http://www.desire2learn.com/`), etc.; portfolio system to gather the learning experiences i.e: Mahara (`http://www.mahara.org/`), Elgg (`http://www.elgg.com`), Desire2Learn(`http://www.desire2learn.com/`); contents and learning object repositories i.e: CAREO (`http://www.careo.org`), FREE (`http://www.free.ed.gov/`), MERLOT (`http://www.merlot.org/`); tools that can be used with learning aims i.e: Wikipedia (`http://www.wikipedia.com`), Youtube (`http://www.youtube.com`), Slideshare (`http://www.slideshare.com`), etc.

These tools are implemented with different programming languages and can be used separately or together when they are involved in learning activities.

To achieve that interoperability, learning systems and tools should be able to interoperate between them independently of the underlying technology, in order to do this previously have been described two possibilities:

- Service Oriented Architectures (SOA). They allow the interaction among different systems independently of the underlying technology. Some examples of its use in eLearning could be: 1) Use SOA to provide information from an LMS to external context, i.e: LUISA project (`http://luisa.atosorigin.es`); 2) Small adaptation of learning platforms to other applications, such as authentication services and backoffice and administrative communication tools [32]; 3) The application in interoperability specifications (such some of the described below); and 4) LMS Adaptions, that require to extract specific funcionalies from Moodle such as Moodbile (`http://www.moodbile.org`).
  The main drawbacks of these solutions in learning contexts are: the difficulty and cost of the integration of the existing systems in this kind of architectures.
- Interoperability Specifications and Standards. This implies the definition of common ways to exchange information and interaction. For example SCORM facilitates content exchange between platforms, IMS LD the Exchange of learning designs, LEAP2A to exchange user information between portfolio systems and LMS and so on. However the most difficult thing is to define standards and specifications that widen the set of possible interactions between systems. That is to say, a standard or a set of standards that facilitates interaction between systems in different senses, a simple authentication action, content transfer, information transfer, logging transfer, outcomes and so on. There are some specifications and initiatives like these and they are defined as interoperability specifications. Some of the most representative are [4, 43]:
  - Powerlinks [10]. Interoperability specification owned by WebCT and now by Blackboard. It allows discovering, launching and information provisioning of LMS services. It uses Web Services to manage users and courses, mail, calendar, tasks, notes and files. It is only available to the users of the previously mentioned platforms.

- WSRP (http://www.oasis-open.org/committees/wsrp/ – Web Services for Remote Portlets). Specification that defines an interface to represent the information provided by web services. It is not linked to a specific portlet implementation technology, such as JSR 168, but facilitates information related to how portlets can be added to portals. This specification requires a provider in the portlet container and a consumer in the portal. With these specifications the integration of applications is easier because they will be integrated into the systems not only as a service but also with a graphical representation.
- WSRP2.0 (http://www.oasis-open.org/committees/download.php/18617/wsrp-2.0-spec-pr-01.html – Web Service for Remote Portlets). Second version of the specifications that provides connections between portlets and the possibility to interact by using technologies such as AJAX or REST.
- IMS TI (http://www.imsglobal.org/ti/index.html – IMS Tools Interoperability) 1.0. Specification similar to PowerLinks. It facilitates the provisioning, launching and execution of external applications into other such as the LMS. Its implementation requires the integration of a runtime-environment into the LMS and this platform should also define deployment, configuration, execution and outcomes services for the integrated tools. On the other hand it requires the inclusion of a runtime mechanism in each of the external tools to integrate. It uses SOAP style for the implementation of Web services.
- IMS LTI (http://www.imsglobal.org/toolsinteroperability2.cfm – Learning Tools for Interoperability). It is an evolution of the previous specification, such its predecessor, provides a standard way to integrate learning tools in LMS, portals and other systems. It facilitates the launching, single-sign-on, application configuration and resources and outcomes management. In order to do this, a provider should be included in each tool and a consumer in the LMS. Its main problem is the complexity and the lack of implementations of the specification.
- IMS BLTI (http://www.imsglobal.org/lti/index.html – Basic Learning Tools for Interoperability). Reduced version of the previous specification to integrate tools in the LMS. In this case only launching and authentication services are considered. It is being extended to include outcomes. BLTI has gained greater acceptance from LMS providers. IMS Global has announced the fusion of LTI and BLTI in a new specification (http://www.imsglobal.org/lti/).
- OSIDs (Open Service Interface Definitions). Included in the Open Knowledge Initiative OKI (Open Knowledge Initiative – http://www.okiproject.org), it is a specification to define services for the integration of learning tools in SOA architectures. Such as in the other specifications a consumer and a provider are used in order to isolate the definition of services (such as authentication, course configuration, file access, etc.) from the underlying technology.

Taken into account these specifications it is necessary to think about how interoperability is addressed in the LMS/PLE context. LMS and PLE should coexist. Despite of all the benefits provided by the PLE and the shift towards the student that has happened in eLearning context, this does not mean the demise of the LMS [1]. LMS have been highly successful in stimulating online engagement of teachers and learners and, besides, they are widespread and big amounts of money have been invested on them [41]. Both systems are going to interact, tools from the LMS must be included in the PLE, and tools of the PLE can be included in the LMS; activities carried out in the PLE should be reported to the institutional environment as a way to measure the informal activity, etc.

However, it is very difficult to achieve this goal because of: 1) The problems to incorporate interoperability standards in the LMS [41]; 2) Problems of user activity traceability in the PLE and, therefore, also in the formal environment [35]; 3) Single-sign-on implementation problems [43]; and 5) Information security problems [14].

Given this situation Wilson and others proposed three possible scenarios of interoperability [52]:

- PLE and LMS exist in parallel, as informal and formal environments respectively. There are several initiatives on this sense but they are outside the scope of integration problem.
- The second scenario refers to open the LMS through the inclusion of web services and interoperability initiatives. In this scenario may be included: iGoogle based initiatives [15], social networks connected with LMS [44], the LMS that supports interoperability specifications implementation [27], PLE with specific communication protocols [47] or integration systems based on service-oriented architectures - SOA [33]. Main difficulties of these initiatives are: the institutional barriers to the opening of formal environments and the fact that those initiatives focus on information exportation and not on interaction exchange.
- The third scenario is based on the integration of external tools into the LMS. In these initiatives user might not decide which tools she is going to use and is limited to institutional decisions. Some examples of this scenario are: LMS defined for the integration of external tools [12], Google Wave Gadgets integrated into Moodle [53], PLE introducing tools based on log analysis [48], initiatives based on tools integration driven by learning design activities [19], etc. These initiatives have several problems such as: integration problems between tools, context integration difficulties, stiffness for customization by the student and so on. Those that best overcome these problems are the ones that define a learning platform starting from scratch or from a previous institutional development, however, it will greatly limit the scope of use of the solution that will be applied to very specific context.

In order to understand better the third scenario that is more focused on the use of interoperability specifications, the following section reviews the existing initiatives related with this issue in the interoperability.

3 Works related to the use of Interoperability Specifications in the LMS and PLE Contexts

The interoperability concept appears connected to the PLE since its definition in Oleg and Olivier publication [31]. In this paper the communication between institutional environments is essential and can be achieved by using specifications and standards. Despite the acceptance of the relevance of interoperability, even among authors with such different PLE perspectives as Van Harmelen [47], Wilson et al. [51], Downes [20], Schaffert y Hilzensauer [40], Wild et al. [50], this area has not been properly exploited.

This section tries to address the existing initiatives to guarantee interoperability between PLE-LMS based on specifications and standards. Before describing the interoperability specifications, some special cases should be taken in to account. In some cases interoperability among systems is achieved using specifications and standards not specifically defined with this aim; for example, in Colloquia [31] by using IMS Enterprise to add and authorize users, IMS LIP to exchange information about users, and IMS CP and SCORM to exchange content. These specifications are considering interoperability from very specific perspectives (content, user and group configuration, etc.) and in most cases take into account only information and not interaction exchange. Other examples can be found in [8, 19, 37, 50]. However, there are other specifications more focused on interaction; representative examples are described below.

The first interoperability specification to be considered is WSRP (Web Services for Remote Portlets - `http://www.oasis-open.org/committees/wsrp/`) previously described.

Examples of WSRP applications in learning contexts can be found in the WAFFLE (Wide Area Freely Federated Learning Environment) which provides a communication bus model to define a service oriented learning architecture [11] and in the integration of a set of learning tools in the LMS Sakai [54]. The main problem of this specification is the lack of adoption of the specification by LMS developers [3, 43, 54]. Moreover, in the PLE-LMS context, WSRP provides an interface to represent portlets that can be used in the PLE but not a way to communicate with the LMS.

Other specifications such as IMS TI (IMS Tools Interoperability - `http://www.imsglobal.org/ti/index.html`) facilitate the integration of external tools in the LMS by using web services and web proxies. There are some implementations of it such as those of carried out by Wang [49] or [16], that needed to integrate an LMS (MINE LMS) and a set of collaborative tools called Learning Blog (LBlog) defining a iPLE; the Campus Project [39] uses IMS TI to launch and deploy the modules based on OKI OSIDs (this specification is discussed later); and Al-Smadi and Gutl [2] propose the definition of an online activity evaluation system based on a service-oriented architecture and IMS TI.

It is evident that very few implementations of the specification have been developed which is one of its main drawbacks, and also the difficulty to implement the specification due to its complexity [22, 12]. Given the adoption issues IMS TI, in 2008 IMS Global Learning Consortium in collaboration with eLearning and editorial companies decide to evolve TI into IMS (Learning Tools for Interoperability - `http://www.imsglobal.org/toolsinteroperability2.cfm`) and a reduced version to implement so prototypes called Simple LTI (`http://simplelti.appspot.com/`). This last solution was very popular because it provided an easy way to integrate applications so it evolved into an official subset of LTI, called Basic LTI. These two kinds of implementations have had different uptake in Learning contexts. IMS LTI has been implemented in none or very few LMS, while the majority of the LMS adopt IMS BLTI (`http://www.imsglobal.org/cc/statuschart.html`). In this situation IMS has decided to unify both proposals including BLTI features with the possibility to include outcomes and to evolve to allow the inclusion of other services. The main problem with IMS LTI is again its complex implementation which means that there are very few implementations of it. On the contrary several examples could be found related with BLTI such as Google Summer of Code implementations [42]; Campus Project [39]; use and the integration of Wordpress and Mediawiki tools in the University Oberta of Catalonia [46]; integration of tools and games in learning systems based on Interactive-TV [23]; integration of educational tools such programming problem solving [28]; Google Docs integration [7].

Another specification to take into account is that proposed by the Open Knowledge Initiative (OKI) that describes how learning components can exchange information and how to integrate with others. Examples of this specification are Campus Project (`http://www.campusproject.org`) is an example of the implementation of OKI OSIDs, developed by a set of universities and companies to define an open virtual campus in which is easy to integrate functionalities from different tools (defining a iPLE in this way) [39]; implementations based on the aggregation of tools such as content repositories, wikis, blogs, etc.[24]; and Agoravirtual, an open learning platform based on teachers' experiences and flexible enough to adapt to their specific necessities to carry out an activity [6].

This specification is a very complete one for systems defined from scratch, and it can facilitate the definition of interoperable systems, but the adaptation of existing LMS and tools to it is very complex, due to the great quantity of services to consider, that is the reason for so few implementations of it. Given this context and taking into account the advantages and drawbacks of these specifications an approach to facilitate the interoperability between LMS and PLE is presented.

4 A Service-Based Framework Solution

As metioned above, there is a need of new learning environments focused on the student, and the PLE is the best representative of those environments. They should interact with the institutional learning environments in such a way that institutional functionalities can be included into the PLE, and the activity carried out in PLEs integrated in the LMS. In addition it is also needed that the existing system could be used used and not only solutions defined from scratch.

But the definition of a complete, scalable, flexible and portable approach which satisfies the students' needs and institutional requirements, while allowing to reuse the existing learning platforms, is a very difficult goal to achieve. It requires of interoperability between the LMS and the PLE. This interoperability facilitates students the definition of their own PLE in a seamless way, so that they only need to access the LMS for a minimum set of indispensable activities. Moreover, interoperability also gives teachers more information about what the students do in the external environments and give them a more broad set of tools for the proposal of learning activities. All these tools may heavily contribute to the evolution of the LMS.

To achieve this, second and third Wilson's interoperability scenarios are mixed in the approach. That is, the exportation of functionalities is considered, specially by using the web service layers that most LMS provides and the use interoperability specifications to integrate what is happening outside the institution.

4.1 Components of the Service-Based Framework Approach

When talking about the definition of a service-based framework in this proposal, it is clear that its main goal is to facilitate the communication and interaction between the institutional (represented by one or several LMS) and personal learning environments (a specific PLE). That communication will be based on the use of services and standards so as to guarantee the independence of the solution from the underlying technology (that means independence of the different LMS, PLEs or online tools), the scalability (it should be easy to add other tools or LMSs) and the portability of the approach (to other contexts such as mobile devices).

The proposal consists of three main elements: the institutional context, the personalized context and the communication channels. Besides, some other elements, such as mediator elements (to facilitate the communication between specific instances of the LMS and the online tools included into the PLE) and/or the representation of these elements in other contexts (such as mobile devices), may be used. These elements can be seen in Figure 1.

The institutional contexts can include one or several different LMS in which the student performs her academic activities. This element represents the institutional learning environments that the student uses, focused mostly in the course and not in the user. The institutional context can be represented as in Figure 1 as one or several nodes with instances of different LMS. In order to make possible the interoperability between learning tools and such learning environments it is necessary that each LMS implements: a web service interface

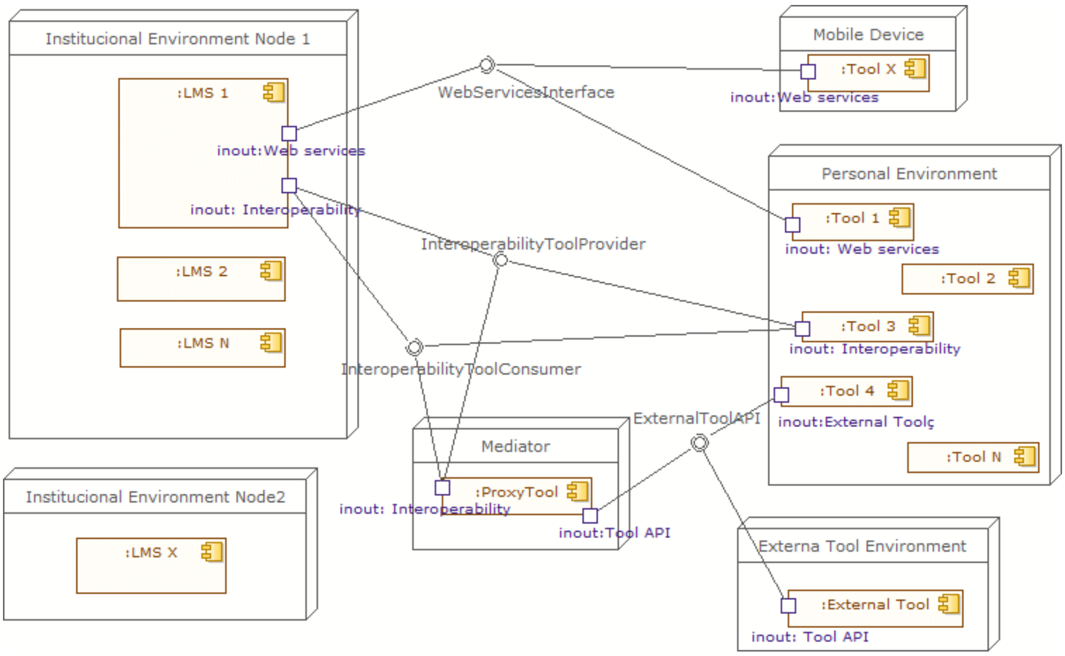

Figure 1 Deployment diagram of the reference framework approach.

to facilitate the access to the learning platform information and functionality and an interoperability interface to consume external tools (InteroperabilityToolconsumer). Moreover these learning platforms require an interoperability interface to gather information from the external tool (InteroperabilityToolProvider).

On the other hand there is a personalized environment focused on the learner which facilitates informal learning. It should allow the learner to add all kind of tools she uses to learn, including institutional tools. In order to do this, each tool should be able to work independently but into a context that acts as a container. These tools, as can be seen in the Figure 1, could have no interaction with the PLE (Tool2), use web services (Tool 1) or use interoperability specifications to communicate with the learning environment (Tool 3 and 4), sometimes they are based on external tools and require additional interfaces and intermediate components to facilitate the communication with the LMS (ExternalTool). Moreover these tools could be included in other contexts such as mobile devices (Tool X).

The other important element in the framework is the one related to communication channels. Communication channels should provide standard and independent ways to exchange in a bi-directional way (from the LMS to the PLE and from the PLE to the LMS) information and interaction. There are three kind of interfaces (Figure 1).

- Web service interface. It allows the communication between the external tools and the LMS independently of the underlying technology. These interfaces are implemented by the LMS and provide a way to access to the LMS information and functionality. They are specific for each LMS so the solutions should be adapted. Anyway some basic services should be included such as authentication, users managements, courses management, activity management and resources management.
- Interoperability interfaces. They are defined as ways to establish information and interaction channels between the LMS and the tools included into the PLE. As most of the interoperability specifications it implies the definition of a ToolConsumer (TC) in the

LMS and a ToolProvider (TP) in each Tool. The TC implements an InteroperabilityToolConsumer interface used to launch, instantiate and set up activities from the LMS based on external tools. The TP implements an InteroperabilityToolConsumer interface that is used by the LMS in order to recover information about the Tool and the activities carried out into it. In this way the teacher can define activities based on such tools in the LMS, that are going to be performed by students in the PLE, and which outcomes can be returned to the LMS to be taken into account during students' evaluation.
- External tool interfaces. In the PLE can be represented not only customized tools but also other external well-known tools which may be used in learning activities, such as GoogleDocs, Slideshare and so on. Such tools are not accessible to be installed into a PLE but they provide APIs to access to their functionality. These APIs are used by PLE Tools and also by intermediate tools.

It is also possible that the framework includes mediator elements to perform activities related to the adaptation of the transferred functionality and information. They are mainly used to facilitate the integration of proprietary and/or not educational tools. For example, the mediator may interact with a proprietary tool, which cannot be adapted to the framework and/or provide evaluation interfaces, to help to use in learning contexts.

With these components and interfaces it is possible to define solutions that not only export information from the LMS but also funcionality, and that allow monitoring the learning activities activities that are carried out by the user in the PLE. But to provide a real interoperability between these components by using the interfaces some scenarios can be considered. They are described in the following section.

4.2 Interoperability Scenarios

Given the previous architectural approach a set of interoperability scenarios can be defined. They present possible ways to facilitate the exportation of functionalities outside the LMS and the integration into the LMS of students' activities performed in other tools. The idea of these scenarios is to enable the student to learn not only in the LMS but also in her personalized environment and to enable the teacher to work in the institutional one. Both contexts should communicate between them. This communication is distributed in four possible scenarios:

- Scenario 1 - Exportation of institutional functionalities to personalized environments. This scenario aims to the export of functionalities from a LMS to other environments controlled by the user. In order to export that functionality, the LMS web service layer is used. In that scenario the tool connects with the learning platform by using the web services to access the functionality. This means that the student may use a functionality from the LMS in the PLE. The teacher can also follow the student activity as if she was answering from the LMS, so she can be also assessed. Thus, teachers and students use their respective environments while having knowledge about what is happening in the other context. The scenario is open to include other tools and to export the functionality to other contexts different than the PLE.
- Scenario 2 - Taking into account the use of external learning tools from the institutional environment. In this scenario no interoperability between the LMS and the PLE is proposed. It takes into consideration the students' activity into the PLE from the institutional environment but such activity should be assessed by the teacher who would access to the context in which is the tool used by the student in order to check the activity that she has carried out. For example, a student accesses an online tool from the PLE, and performs (in agreement with the teacher) a task by using it; then, the teacher should

enter into the online tool or the PLE, check her activity and perform her assessment from the LMS. This scenario is quite common in different institutions and it requires an extra effort from the teacher.

- Scenario 3 - Use of external online educational tools (with evaluation support) in the PLE, and recover information from LMS. In this scenario the activity is done in the external educational tool but it is integrated in the LMS. The teacher defines an instance of the educational tool into the LMS: this will create a context only accessible by teachers and through which they can see the results of the task completed by the student; the student accesses her personalized environment and can use, among others, the educational tool adapted to return information about the student's activity to the LMS. The tool should be able to assess the activity carried out by the student or provide the interfaces needed by the teachers to do that (i.e. a tool to carry out quizzes, a simulator, a serious game, etc.). The interoperability described in this scenario is based on the use of Interoperability specifications, so it will need the TC, TP and interoperability interfaces described in the previous sections. The application of the specification minimizes teachers' effort in order to check the activity outside the LMS (because they do not need to access to other environments to check it).
- Scenario 4 - Use of external online tools (not defined as educational and thus without an evaluation interface) in the PLE and recover the information from the LMS. This scenario aims to gather the students' activity in online tools included in the PLE. Those tools are not necessarily educational tools so they are not going to provide an interface to assess the students' outcomes. The teacher defines an instance of the online tool into the LMS; this will create a context that only teachers can access and through which the results of the activity performed by the student can be returned or the evaluation could be facilitated. The student accesses to her personalized environment and can use, among others, the online tools adapted to return information about the student activity to the LMS. The tool in this case is not necessarily created with a learning objective, so they do not include assessment interfaces, something that is needed to grade the student's activity. This assessment interface will be provided by the mediator (or proxy tool), which interacts with the online tool and with the LMS. The implementation of the scenario also requires the use of Interoperability specifications in order to return the activity from the PLE to the LMS. As in the previous scenario, this involves including a TC in the LMS and a TP in the Tool, the TP could be included in the mediator because in many of those tools it is not possible to have access to the code and introduce the TP (in example in Google Docs).

4.3 Example of Interoperability Implementation by using IMS BLTI

The components and interoperability scenarios have been implemented has a proof of concept and later evaluated in education environments (in the University of Salamanca subjects). In order to carry out such implementation the LMS is represented by Moodle, due to its widespread (`http://moodle.org/stats/`) and because it includes an open web service layer [18] that is used in the interoperability scenario 1. In addition to this LMS any other which provide a web service layer could be employed. The tools of the PLE are represented following W3C widget recommendation (`http://www.w3.org/TR/widgets/`) and the PLE by using Apache Wookie (Incubating) [52], this is because, by following this specification it is possible to facilitate the portability of the solution to other environments and contexts. As interoperability specification it was decided to use is IMS BLTI, this is because of its uptake in the LMS context (`http://www.imsglobal.org/cc/statuschart.cfm`) and because despite of the few quantity of services it provides, it is possible to use different extensions as outcomes and memberships (which facilitates to gather the grades achieved in a tool and the roster of students involved in an activity) that make able the implementation of the interoperability scenarios. Other reason to use BLTI is the existence of a BLTI Tool Consumer integrated with Moodle as a module (`http://code.google.com/p/basiclti4moodle/`), so it is not necessary to define one from the scratch. It is also necessary to consider that the scenarios need to include different adapted tools to be represented as widgets into the PLE. During the proof of concept these tools are: Moodle Forum (in scenario1), Wordpress and Flickr adaptations (in scenario 2), an ad-hoc quiz tool as an educational external tool (in scenario 3) and GoogleDocs as a collaboration external tool (in scenario 4).

In order to illustrate the use of the interoperability approach the Scenario 3 is described. In such scenario there are two roles involved, teachers and students and it requires the use of several components.

One of the components is Moodle and the integrated BLTI ToolConsumer that uses an interface to configure and launch the external tool (the tool provider interface) and implements an interface called ToolConsumerInterface that is going to be used to return information to the LMS. The BLTI Tool provider should be configured in Moodle to link an external tool and after that it will be possible to create learning activity instances based on such tool in the LMS.

The other component to consider is the external tool, that in this scenario should be an educational tool. This means that the tool should be able to evaluate students' activity or provide an evaluation interface (i.e: a simulator, a case tool, a quiz tool, etc.). A quiz tool has been created for the proof of concept. It allows the teacher to define a self-evaluation quizzes, that students can carry out in a web environment or in a widget integrated into the PLE. The quiz tool includes a BLTI ToolProvider that facilitates the communication with the LMS, implementing a ToolProviderInterface and using a the ToolConsumerInterface that provides Moodle.

Given this context the teacher can enter into her Moodle course, create an activity based on the quiz tool and launch it. The launching implies the definition of a quiz in the external tool that would be available for the students of the course. In order to do so it is necessary the BLTILaunching service to set up the activity, and the Memberships BLTI extension to recover the id of al the students that participates on the course; once created the activity and associated the learners the view of the quiz is return to the ToolConsumer (Figure 2). The students could carry out the activity in the widget included in the PLE or in the quiz tool web environment. When the activity was finished the teacher is able to recover the grades achieved by the students in the external tool from the LMS, to do so Outcomes BLTI extension is employed.

This is not the traditional way to use BLTI, which use to integrate the tool into the LMS and there is used by teachers and students. In this case the teacher can access to an activity view in Moodle from which she can recover the students' grades, however the students do not need to carry out the activity through the institutional environment and can do it in the PLE (Figure 3). In this way an interoperability channel has been established that allows the teacher to control what is happening in an activity included in the PLE and the learner can combine an institutional activity with other tools she uses to learn.

4.4 Interoperability Scenarios Validation

The interoperability scenarios has been evaluated through several pilot experiences carried out with students of the University of Salamanca and a set of semi-structured interviews

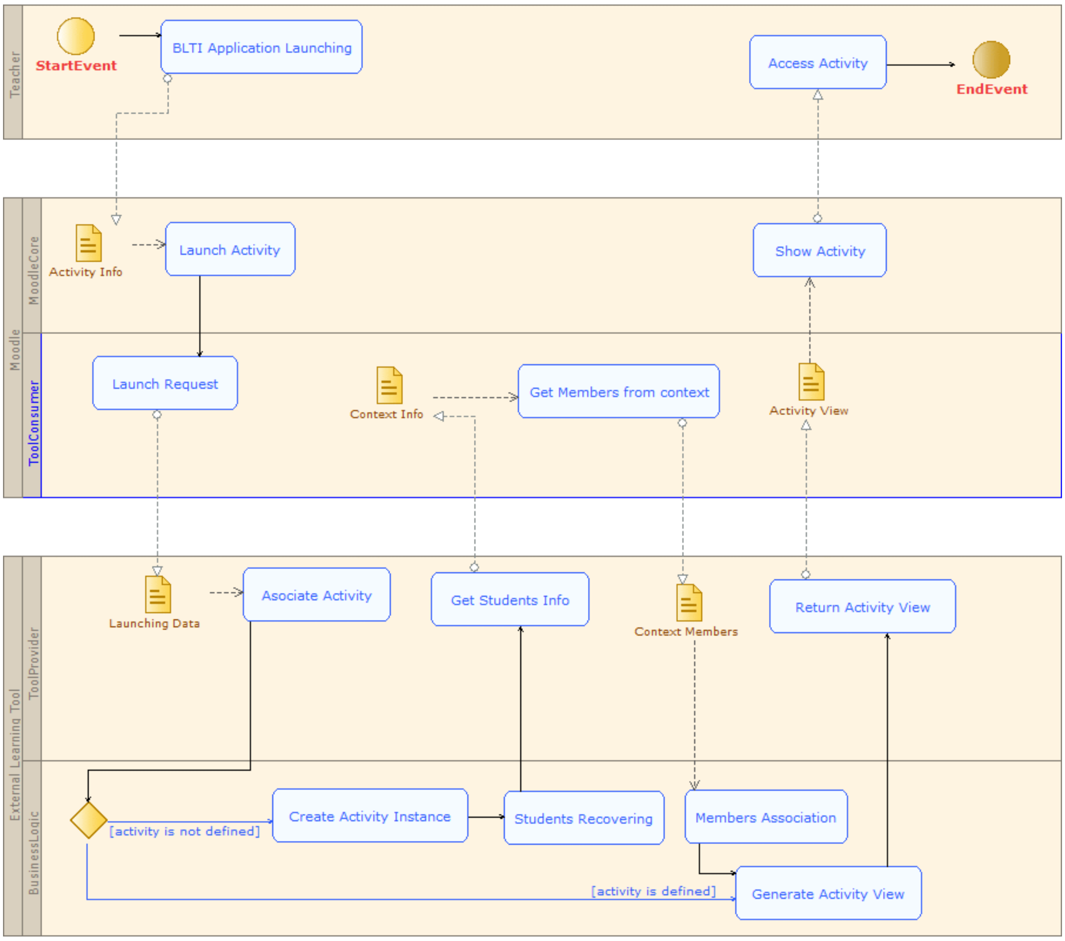

Figure 2 BPMN diagram to define the launching activity of an external tool from a LMS. The figure show the different participants involved in this action and the messages exchanged between them.

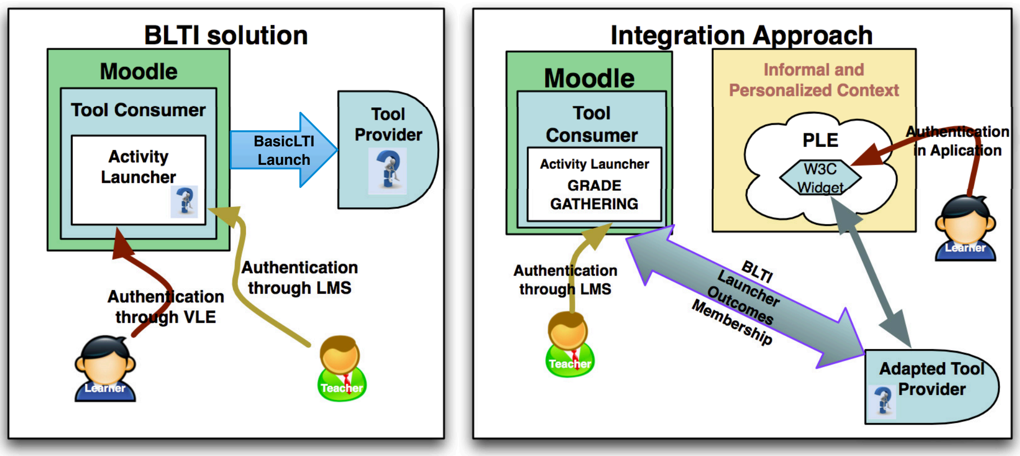

Figure 3 BLTI approach Vs. Integration approach. On the left side, quiz tool integration launched inside the LMS. On the right side, quiz tool integrated in the PLE and accessed by the learner from it and the BLTI extensions used.

with teachers. In order to analyze the data a mixed methodology is used [26], which means that quantitative and qualitative techniques are employed. In this paper the results of the quantitative methodology application in scenario 3 are shown as an example of the evaluation carried out. Firstly the methodology is presented and after that the results and discussion.

4.4.1 Methodology

During the experiment are involved 50 students of the subject Project Management. With them students it has been applied a quantitative methodology and with the teachers a qualitative one endorsed with quantitative results.

The methodology used with the students is a quasi-experimental design [13]. It is used because in this experiment pre-established groups of students (class-groups) are used, so it is not possible to have a complete randomized group of people [30] and therefore neither is possible a control study approach. Quasi-experimental design implies the definition of a scientific hypothesis, from which a dependent variable is derived. Such variable is operationalized through several assertions that are proposed to the students of the experimental and control group (independent variable). These assert are graded by the students using a five-value levels scale (1=strongly disagree, 2=disagree, 3=indifferent, 4=agree, 5=strongly agree). In both groups the same tests are applied, a pre-test at the beginning of the experiment and a post-test after it, but the students of the experimental group test the quiz widget in the PLE, while the people in the other group do not. After running the experiment, data is analysed by using probabilistic techniques to validate the initial hypothesis.

The scientific hypothesis is going to be accepted if the results of the pre-test are similar in both groups (which proves that both groups are similar and have a common knowledge and background) and the results of the post-test between the people involved in the experimental group and the control group are different (those who have test the tool should answer in a different way). This has been checked using two statistic tests Student's T test and Mann Whitney's U test. This last one is applied because with a sample of 50 students the test is near to the limit in which it can be applied in a robust way and also because the data to consider is ordinal. With this statistic test is proposed the null hypothesis for the Student's T is $H_0 : \overline{\mu_E} = \overline{\mu_C}$ (where X refers to the average range, E refers to the experimental group and C refers to the control group), which compare the average grade of each item between the control and the experimental group. In Mann Whiney's U what is checked is the difference of ranges through the following null hypothesis $H_0 : \overline{R_E} = \overline{R_C}$ (where R refers to the average range, E refers to the experimental group and C refers to the control group).

4.4.2 Data Analysis and Discussion

During the quantitative study of students' opinion the scientific hypothesis was "The inclusion of the activity carried out by the student in external educational tools into the LMS, improves her learning, the knowledge the institution have about her and facilitates her evaluation". To test this hypothesis, some assertions have been proposed to the students.

- In the pre-test:
  - I1. Moodle provides a great variety of tools to use in the subjects and no more are needed.
  - I2. I use other online educational tools than those provided by Moodle to learn (such as simulators, resources libraries, external quizzes, etc.).

- In the post-test:
  - I3. The fact that Moodle does not facilitate the introduction of my activity in other external tools (such as simulators, resources libraries, self-evaluation tests, etc.) supposes that it does not satisfy properly my learning needs.
  - I4. The fact that Moodle does not facilitate the introduction of my activity in other external tools (such as simulators, resources libraries, self-evaluation tests, etc.) supposes that I was just partially evaluated.

The results of the Student's T test can be seen in the Table 1, with a signification of a 0.05. If the signification of the item is under 0.05 the null hypothesis is accepted, if not it is rejected.

Table 1 Results of the Student's T-test. The table shows the medium and variance for each item of the pre-test and post-test, the result and the bilateral significance.

Pre-test results for Student's T test						
VD	$\overline{X_E}$	S_E	$\overline{X_C}$	S_C	t	ρ
I.1	2.40	0.968	2.15	0.587	1.033	0.307
I.2	3.90	1.348	3.55	1.234	0.930	0.357
Post-test results for Student's T test						
I.3	3.57	0.817	2.40	0.821	4.937	0.000
I.4	3.47	0.973	2.55	0.823	3.461	0.001

In the table is shown that in both pre-test items the null hypothesis is retain (that is to say the experimental and control group answer more or less the same) and in the post-test the null hypothesis is rejected (so the results between the experimental and control group are different). From the pretest data it can be also concluded that, in the student perception, Moodle needs more tools than those included and students use more tools that those provided by Moodle to learn. From the pretest it can be seen that the students who has experimented other tools integrated into Moodle consider that this platform does not satisfy their learning needs and that in their opinion they are not properly evaluated. The difference in the pre-test and pos-test between the experimental and control groups in every assertion means that the scientific hypothesis should be accepted, but in order to check it, Mann Whitney U test is also applied (Table 2). In this table is shown that for the pre-test assertions (I1 and I2) the differences in ranges are minimum, so null hytothesis is retained for each of them; whilst after the experiment (in the postest) the difference in the assertions (I3 and I4) is significative so the null hypothesis is rejected. This endorse the results of the Student's T test.

Table 2 Results of the Mann-Whitney U test. It shows the average range for experimental and control groups, the result of contrast statistic and the significance per each item.

Pre-test results for Mann-Whitney U test					
VD	$\overline{R_E}$	$\overline{R_C}$	U	Significance	Result
I.1	26.77	23.60	262.0	0.412	Retain null hypothesis
I.2	27,63	22,30	236.0	0.186	Retain null hypothesis
Post-test results for Mann-Whitney U test					
I.3	31.97	15.80	106.0	0.000	Reject null hypothesis
I.4	30.28	18.33	156.5	0.003	Reject null hypothesis

To support these conclusions an assertion about the experience was posed to the students of the experimental group. This assertion is: "The activity I carried out in external online tools should be integrated into the LMS because it would enrich my learning". The 80% of the experimental group students agrees or strongly agrees with the assertion, which means that in their opinion the inclusion of external activity into the institution open new ways to enrich learning with additional tools.

In order to consider also the teachers' opinion several semi-structured interviews have been carried out. On them, the system is presented to the teachers, they used it, and their opinion is recovered. The results are: 1) The 100% of the teachers agree or strongly agree that by including students' activity on external tools it is possible to assess them in more comprehensive way; and 2) The 90% consider that this evaluation can be easier for them if the students' activity outcomes are directly integrated into the LMS so they do not need to check these results in external environments.

5 Conclusions

Along this paper is shown that interoperability is one of the key factors to define systems based on different tools, architectures and technologies. This kind of interoperability is much more necessary today because the users require specific services and are not too much interested in downloading, install and use a set of different systems that are not customized to their necessities. In order to achieve this, it is necessary to join different applications to provide a service that satisfy user's specific needs. In the eLearning landscape the situation is similar to this. There are several LMS, different portfolio systems, repositories, contents and so on. These elements are developed in different programming languages, use different contexts and most of the times are not able to talk with other systems to compose learning services more adapted to real student necessities.

On the other hand there is a shift in the "locus of control" in learning environments, the student needs spaces more adapted to her necessities, because she does not learn only in the institutional context but also along her life and by using different tools from different systems in different context related or not with different institutions. PLEs are defined to address this problem, as a concept that provides support to all those tools. However a PLE is another element that is not communicated with the existing tools such as the LMS so interoperability specifications and standards need to be applied to open real interaction channels valid for a changeable context. This interoperability application is difficult because of the variety of interoperability specifications; the difficulty to implement them and that it requires changing the LMS; and also the tools that need to interoperate.

Given this context a service-based framework approach has been posed. Such framework takes into account the LMS, the PLE and a set of interfaces that facilitates the interoperation between them. In addition it includes the most common interoperability scenarios that can be employed. In order to validate the framework it has been implemented as a proof of concept and the scenarios have been evaluated. In this paper one of these scenarios and its evaluation has been described, in this case the integration in the LMS of students' results carried out in an educational external tool included in the PLE. From that experience, and in the opinion of the students and teachers involved in the experience, it can be seen that the students use other tools than those included by Moodle to learn and that it is necessary to take what they do into them into account, because in this way the students will be more motivated to learn and teachers will have more knowledge about students' skills. An evaluation similar to this has been done for each of the other scenarios and also qualitative techniques has been applied to exploit some of the information gathered with the semi-structured interviews with teachers. With the previous framework and the mentioned experiences it is possible to conclude that interoperability between LMS and PLE is possible, and that informal learning can be taken into account from the formal environments, while informal learning can be enriched with functionalities of the institutional contexts as well. In addition, this interoperability facilitates students the definition of their own PLE in a seamless way, so that they only need to access the LMS for a minimum set of indispensable activities. Moreover, interoperability also gives teachers more information about what the students do in the external environments and give them a more broad set of tools for the proposal of learning activities. All these tools may heavily contribute to the evolution of the LMS.

As a future work it would be possible to integrate other scenarios to our proposal, other contexts, to collaborate in the definition of the new IMS LTI (taking into account the experiences carried out) and define pilot experiences with other students.

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