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Implementation and design of a service-based framework to integrate personal and institutional learning environments

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HIGHLIGHTS

- LMS and PLE are going to coexist and they should interact.
- Existing initiatives don't support a complete interoperability among these contexts.
- A service-based framework to facilitate this interoperability is defined.
- It includes several interoperability scenarios that are tested in the university.
- Interoperability between PLE and LMS is possible.

ARTICLE INFO

Article history:

Received 1 May 2013

Received in revised form 18 October 2013

Accepted 30 October 2013

Available online xxxx

Keywords:

Learning platform

Personal learning environment

Interoperability

Web services

SOA

ABSTRACT

The landscape of teaching and learning has changed in recent years because of the application of Information and Communications technology. Among the most representative innovations in this regard are Learning Management Systems. Despite of their popularity in institutional contexts and the wide set of tools and services that they provide to learners and teachers, they present several issues. Learning Management Systems are linked to an institution and a period of time, and are not adapted to learners' needs. In order to address these problems Personal Learning Environments are defined, but it is clear that these will not replace Learning Management Systems and other institutional contexts. Both types of environment should therefore coexist and interact. This paper presents a service-based framework to facilitate such interoperability. It supports the export of functionalities from the institutional to the personal environment and also the integration within the institution of learning outcomes from personal activities. In order to achieve this in a flexible, extensible and open way, web services and interoperability specifications are used. In addition some interoperability scenarios are posed. The framework has been tested in real learning contexts and the results show that interoperability is possible, and that it benefits learners, teachers and institutions.

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<http://dx.doi.org/10.1016/j.scico.2013.10.012>

Please cite this article in press as: M.Á. Conde et al., Implementation and design of a service-based framework to integrate personal and institutional learning environments, Science of Computer Programming (2013), <http://dx.doi.org/10.1016/j.scico.2013.10.012>

1. Introduction

The application of Information and Communication Technologies (ICT) to education, triggers changes that affect the way in which people learn and teach, raising new challenges in for learners, teachers and institutions. ICT makes available new tools to support learning activities that can help to satisfy particular needs of learners and teachers. For example various kinds of software (online) can be used tools to manage and develop learning activities [1]; trends such as web 2.0 involve a shift to the user, who is enabled to participate in the learning process in a more active role than that of content consumer [2]; communication and channels for the exchange of information are enhanced, making it easier for informal learning to become explicit [3], etc.

But this support requires that several issues be addressed: in the first place, the diversity of technologies and tools used in learning contexts forces students to use many different systems during their training and studies, and they may become confused; secondly, we should not regard learning as being limited to formal learning environments, since people learn throughout their lives in various informal contexts (lifelong learning), the problem is to know what happens beyond those formal learning environments; thirdly, teachers and instructors are usually constrained by their institution when it comes to the use of specific set of tools for learning activities; and finally, despite the emergence of new solutions designed for learning, their inclusion in institutional learning environments is rather complex due to the slow evolution of such environments.

Many of these issues are ignored in technological solutions such as Learning Management Systems (LMS). These are systems that [4]: 1) fulfil institutional learning management requirements; 2) provide teachers and academic staff with tools for the management of courses, students, resources, activities, etc.; and 3) create specific areas for students in which they may perform their academic activities, supplement their lectures and (to a greater or lesser extent) collaborate with other students and teachers. These systems are focused on the course and provide with tools, which not only support but also extend the traditional concept of classroom. However these systems raise problems because their focus is on the support of learning processes that happens in specific periods of time, such as academic courses (though it is not impossible to use them in other ways) [5]; they are monolithic and so it is a complex task to adapt them in response to new technological trends or tools (such as 2.0 tools, export of functionalities and information to non-web based contexts, etc.) [6]; and also to evolve the towards new models of learning or to other contexts [7].

Students do not only use institutional learning environments to learn, they use other services, tools, devices and learn in other contexts that are not necessarily linked to an institution or an academic course [8]. The PLE (Personal Learning Environment) approach is a response to this situation. A PLE is more than a technological environment, it is best understood as a concept, rather than a thing. As Wilson has remarked “The PLE is not a piece of software. It is an environment where people, tools, communities and resources interact in a flexible way” [9].

A PLE is not a replacement for an LMS because the two environments support different kinds of learning. On the one hand LMSs are institutional tools that facilitate management, control and assessment of learning, generally focused on the course and with a low level of support for personal needs and tools. They have are widely implemented (especially in institutional environments) [10–13], have been used during several years and are thoroughly tested, both teachers and students are accustomed to their use, and institutions have made a major investment in their implementation, improvement and adaptation [14]. On the other hand the PLE is focused on the learner and their needs. If we accept that both contexts of use are necessary then some degree of integration and interoperability is clearly necessary. In this way, the LMS can export functionalities to the PLE and the activity that is carried out in these environments can be tracked and taken into account from the institutional environment. There are several approaches that can be classified in three strategies posed by Wilson, Sharples and Griffiths [15]:

- Strategy 1. PLEs and LMSs could exist in parallel, as formal and informal environments respectively, without any interaction or integration of the activity that takes place in those contexts.
- Strategy 2. LMSs could be opened up through the inclusion of web services and interoperability initiatives. Included within this approach are iGoogle based initiatives [16]; social networks connected with the LMS [17]; LMS support for implementation of interoperability specifications [18]; PLEs with specific communication protocols [19]; or integration based on service-oriented architectures (SOA) [20]. The main difficulties faced by these initiatives include institutional barriers to the opening of formal environments and the fact that those initiatives are focused on information export and not on interaction exchange. That is to say, communication is unidirectional, from the LMS towards the external tools; basically this communication consists on the exchange of information about what happens on the platform, providing no interaction or information back to the LMS.
- Strategy 3. External tools could be integrated into the LMS. In these initiatives, the user might not decide which tools she is going to use and the final decision to authorize tools would exclusively in the hands of the institution. Some initiatives that can be included in this group are: LMSs designed for the integration of external tools [21]; initiatives based on tool integration driven by learning design activities [22]; PLEs based on the inclusion of tools depending on information stored in the learning environments log [23]; or integration architectures [24]. The main difficulties faced by these initiatives involve the integration between tools or contexts, rigid configurations impeding customization by students, etc. At the present time the greatest success in overcoming these problems has been achieved by initiatives that define an entirely new learning platform or build on a prior institutional development. This greatly limits the scope

of use of a solution, which is intended to be applied to very specific contexts, and presents other problems such as the lack of adoption and the need for users to learn new software [25].

Taking all these solutions into account, each with its problems, it may be said that integration between the LMS and the PLE is unresolved, and that it requires the adaptation of both. The use of web services and interoperability specifications facilitates the opening up of LMSs, but they are very laborious.

In order to provide a solution to the interconnection and interoperability between such different (yet related) worlds, this paper proposes a service-based framework to enable and facilitate interoperability between institutional and personal learning environments. It merges integration strategies 2 and 3. The framework consists of a set of components, services and interfaces which facilitate the interaction and exchange of information between these two educational contexts. Since both perspectives should be considered, the framework is completed by a basic set of interoperability scenarios between these two worlds. The technological approach to support this proposal is based on the use of specifications for interoperability and web services, resulting in an open solution able to incorporate any tool, flexible enough to adapt to technological changes and portable for use on other devices. The framework is implemented as a proof of concept in order to validate it in real contexts.

The present paper is structured as follows. The second section describes the service-based framework. After that, in the third section, the implementation of the framework is shown describing the specific techniques and methodologies applied. In the fourth section an interoperability scenario is described and the results of its evaluation and application are shown. Finally some conclusions are posed.

2. The interoperability approach

In the previous section the need to facilitate the interaction between personal learning environments and institutional environments has been justified.

In this section the proposed solution is described and the service-based framework and its main components and interfaces are presented. Later on the possible interoperability scenarios and their implementation are described, together with the methodologies and techniques used.

2.1. Service-based framework main elements

One of the principal goals of the service-based framework in this proposal is to facilitate communication and interaction between the institutional (represented by one or more LMS) and personal learning environments. This communication is based on the use of services and standards so as to guarantee the independence of the solution from the underlying technology (i.e. the independence of the various LMS, PLE or online tools), its extensibility (it should be easy to add other tools or LMS) and the portability of the approach to other contexts [26].

The proposal consists of three main components: the institutional context, the personalized context and the communication channels. In addition some other elements may be included, such as mediator elements (to facilitate 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). Fig. 1 shows these elements in a deployment diagram.

The institutional contexts can include one or several LMS in which the students carry out their academic activities. This element represents the different institutional learning environments that the student acts within, focused mostly on the course and not on the user. The framework does not define the specific LMS to be used, nor the number of LMSs to be included in a node. However the LMSs should satisfy a minimum set of requirements defined in terms of support for web services and interoperability specifications. In Fig. 1, the LMS implements a web service interface (WebServicesInterface) and an interface as the consumer of an interoperability specification (InteroperabilityToolConsumer). In addition, it uses the interface implemented by the tools to integrate them, that is the InteroperabilityToolProvider.

On the other hand, there is a personalized environment focused on the learner which facilitates the integration of the different tools that students use in their learning, including institutional tools. to achieve this, each tool should be able to work independently, but within a context that acts as a container. Three types of tools are taken into account:

- Tools that do not interact with the LMS. These can be employed in learning activities but are limited in that in order to check the learner's activity the teacher has to leave the institutional LMS and enter the tool. An example is the use of Flickr.
- Tools that use the web services of the LMS. Such tools use the web services provided by the learning platforms in order to access to information and functionalities from outside of this environment. The tools should include a web service consumer that uses the web service interface provided by the LMS.
- Tools that can integrate the students' activity through the use of interoperability specifications. These tools make use of interoperability specifications in being configured and instantiated as learning activities by the teacher in the LMS. In this way the student can use them in the PLE and the outcomes achieved by the learners can be returned to the LMS. The teacher does not need to access other contexts to check what the learner has done.

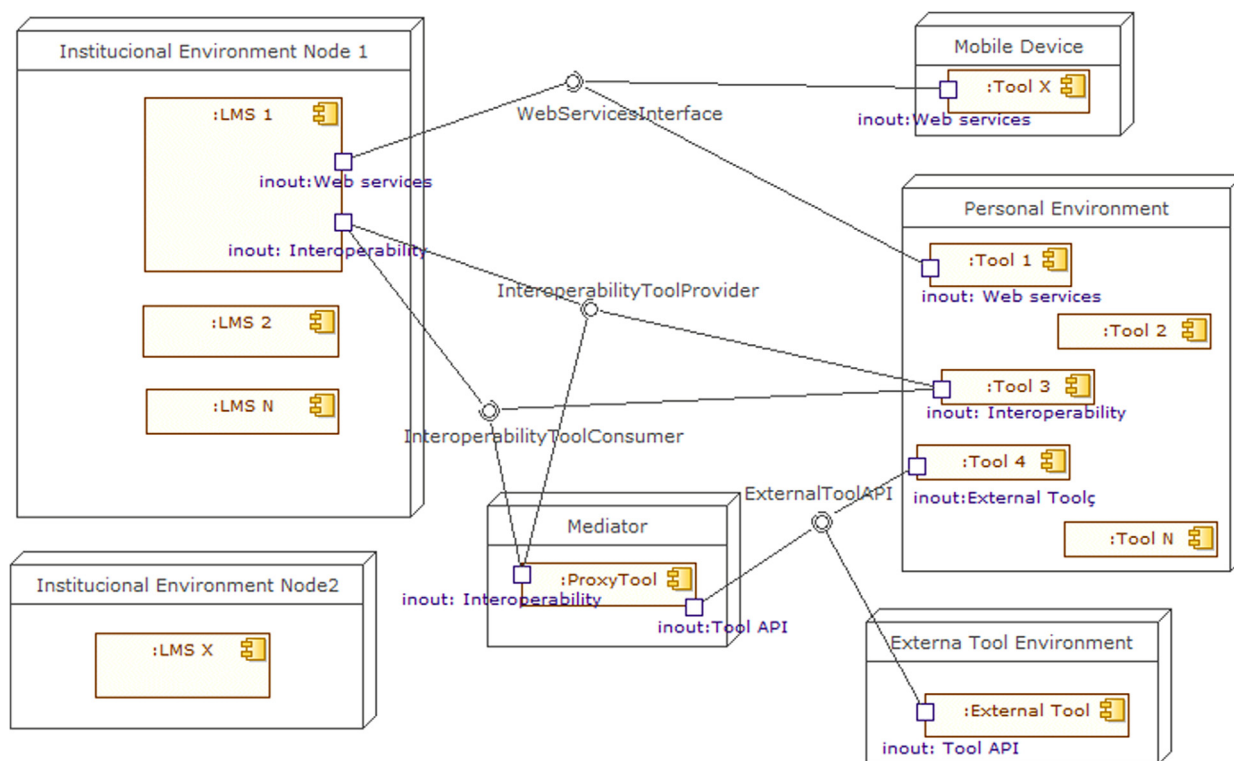


Fig. 1. Deployment diagram for the framework approach. It shows two institutional nodes with several LMSs, the PLE that integrates the different tools and some additional elements and interfaces that facilitate interoperability among the systems.

It should be noted that a tool can consume web service and also use or support interoperability specifications.

The other important element in the framework related to communication channels. Communication channels should provide standard and independent methods for bi-directional information exchange and interaction (from the LMS to the PLE and from the PLE to the LMS). There are three main types of interfaces:

- **WebServicesInterface**. This is implemented by the LMS and facilitates access to functionalities and information from the learning platform. Those tools that want to use it must be able to consume web services.
- **Interoperability Interfaces** (**InteroperabilityToolConsumer** and **InteroperabilityToolProvider**). The LMS and the tools to be integrated should implement these interfaces in order to integrate into the LMS the results of the students' learning activities carried out using external tools.
- **Interfaces to access to external tools**. They permit access to the public functionality of the tools in order they can be used from other contexts, or other tools such as the mediators. An example is the Flickr external API.

The technology or protocols to implement these interfaces are not defined in the framework. Optional additional components are mediators, also known as Proxy Tools. These components facilitate communication between tools and learning environments. They have two main objectives: the first is to facilitate the integration of tools that cannot implement a Tool Provider (i.e. their code cannot be changed to facilitate interoperability specification adaptation), as in the case of tools which cannot be accessed for source code modification purposes. In this case, the mediator also interacts with the tool using the interfaces they provide (**ExternalToolAPI**). The other aim of the mediator is to provide additional functionalities or to pre-process data. For instance, it can be used to provide an interface to evaluate learners' activity in tools, which are now integrated but were not originally conceived as learning tools. More information about this framework is available at [27].

All these elements configure the service framework but in order to describe the interaction it is necessary to classify it in a set of interoperability scenarios that are presented in the next section.

2.2. Interoperability scenarios

The components included in the framework interact among them to facilitate the communication between the PLE and the institutional environment. In order to do this there are different possibilities. These are included in a set of interoperability scenarios [28]:

- Scenario 1 – Export of institutional functionalities to personalized environments. This scenario aims to export 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 functionality from LMS in the PLE without entering the LMS. 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 from the PLE such as could be mobile devices. An example is to export Moodle forum to other contexts.
- 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 the teacher should assess such activity by accessing other contexts different from LMS. 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 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 a teachers' extra effort.
- 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. To do this, interoperability specifications are used and, therefore, a Tool Consumer (TC) in the LMS and a Tool Provider in the external Tool (TP). The TC uses an interface provided by the TP to set up and launch the tool instance and the TP uses an interface implemented by the TC to return the results of the student activity within the application. In this case the teacher sets up and launches the activity in the LMS and the student can carry this activity out in the PLE. Once the activity is finished the teacher can gather from the LMS the activity of the students in the external application.
- Scenario 4 – Use of external online tools (not defined as educational ones 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. To address this problem interoperability specifications and mediator tools are used. They provide support for these specifications in tools which code can be modified and also provide the assessment interface to tools not conceived with educational aims. As in the previous scenario the activity is carried out by the student in her PLE where the tool is represented and the outcomes of this activity are returned to the LMS where the teacher can use them.

Given these components, interfaces and interoperability scenarios the framework is implemented as a proof of concept. This implies to establish some design constraints that are described in the following section.

3. Implementation as a proof of concept

This section describes the implementation of the framework. It is divided into two parts, first the design constraints related to the software development are presented and after that the methodology and modeling techniques employed are commented

3.1. Implementation design constraints

In order to check the suitability of the framework, a proof of concept has been implemented and analyzed. This involves making some pragmatic decisions and thus imposes some design restrictions over the elements previously mentioned. Those restrictions are:

- Institutional Context. Although different LMSs could be used, several *Moodle* 2.1 instances will be used in the proof of concept. There are various reasons for using of *Moodle* in this context. In addition to the fact that *Moodle* is one of the most popular LMSs world-wide it is also: 1) open source; 2) developed and supported by an international community with more than 1 000 000 members [29]; 3) a system with more than 68 000 installed servers in which there are more than 58 millions of students; 4) translated to more than 75 languages [30]; 5) has great success in different institutions [31]; and 6) it includes a web service layer that open it to new technologies and facilitates its integration with service oriented architectures [32].
- Communication channels. In order to implement communication between the LMSs and the PLE, web services are used to exchange information and interaction with the LMS and BLTI (Basic Learning Tools Interoperability) [33] to integrate the students' activity performed in other environments and to guarantee the portability of the framework to other contexts. The web services will be those provided by the LMS, which can be extended by following the *Moodle* extension protocol in case of need. However, it is not possible to use web services exclusively because this would mean that the framework should be adapted to the service layer in each target platform. This is solved by using BLTI, which is implemented by most LMS. Nevertheless, it is not be used in the traditional way (to integrate tools into the LMS)

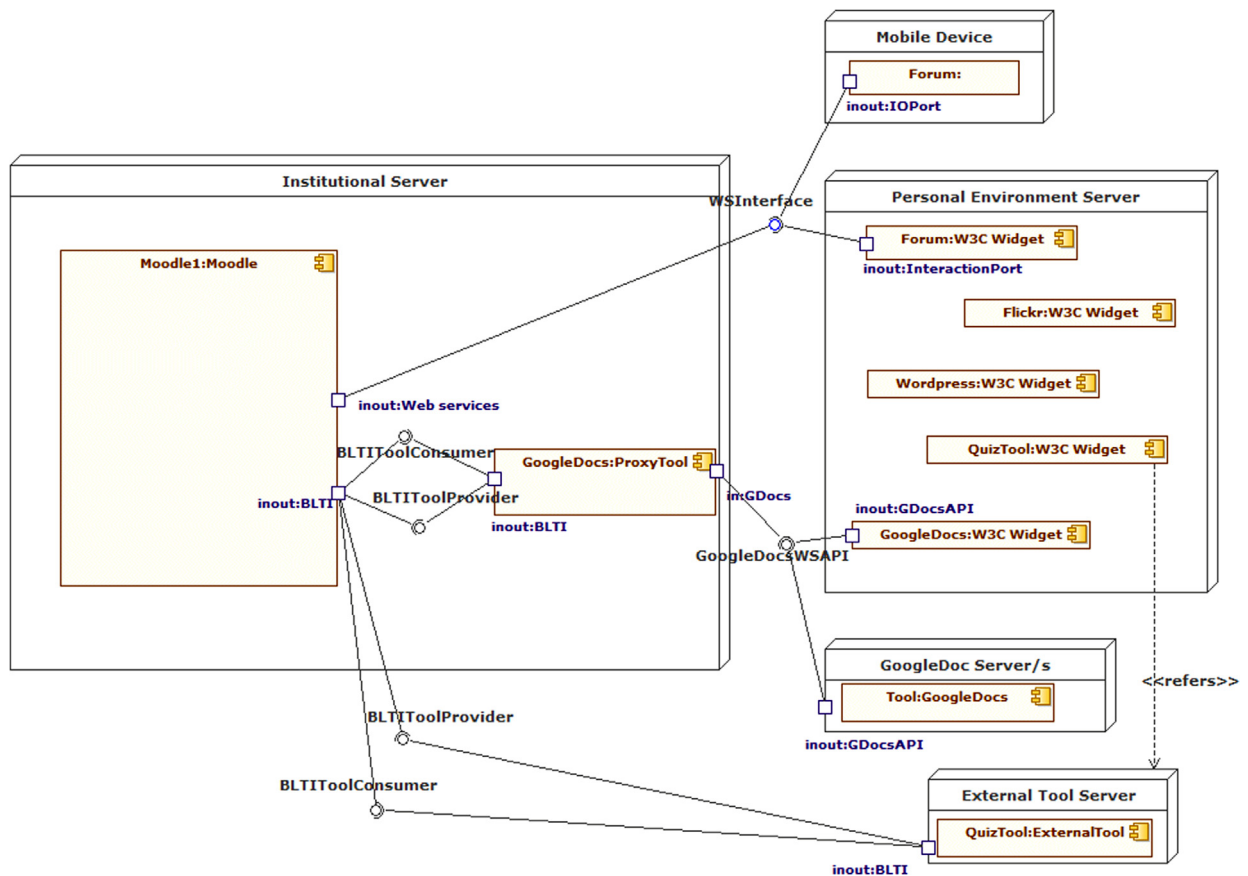


Fig. 2. Deployment architecture for the proof of concept. On the left side the Institutional Server appears with one *Moodle* instance and the proxy tool for *GoogleDocs*. On the right side there is a node for the Personal Environment, the Mobile Device and the external tools.

because this would limit the student's freedom to choose the tools she wants to use in her learning [15]; instead, it is used to return information to the LMS about what the user has done inside the PLE [34]. Regarding the security models for the exchange of data, this depends on the kind of web services used and on the use of BLTI (because this requires the use of an early version of OAuth) [24,35].

- The Personalized Environment. The personalized environment should allow the user to add all kinds of tools she uses to learn, including institutional tools. As mentioned above, a tool container is used; but in this case what matters is not the particular container employed to implement the PLE, but the fact that the applications can be exported and used in other environments and containers. That is why in the proof of concept, standard ways to represent such tools were used. That is, the use of W3C widgets that can be represented in different web contexts [36], as desktop widgets, on mobile devices and with minor changes on other contexts such as interactive TVs, cars navigation systems, and so on. *Apache Wookie* [37] is used as the container of W3C widgets but also others such as *Google Gadgets* [16] or *Open Social widgets* [38].
- Ad-hoc Mediator. These are proxy tools that facilitate the integration of tools that cannot implement the interoperability specifications support.

In Fig. 2 the deployment diagram of the implementation is shown.

In the institutional server two main components can be identified. The first is the *Moodle* component, representing the institutional learning environments. It provides several communication interfaces with the PLE environments (specifically the web services interfaces for the scenario 1 and a mobile version of it, and the BLTI Consumer interfaces for the scenarios 3 and 4). In this case, just one instance of *Moodle* is shown but during the proof of concept different instances are used. In addition, there is also a mediator component that facilitates the evaluation of the student in external online tools included in this server (scenario 4). It is included into the institutional node, but that is not necessary (it could be in an independent node or even in the personal one).

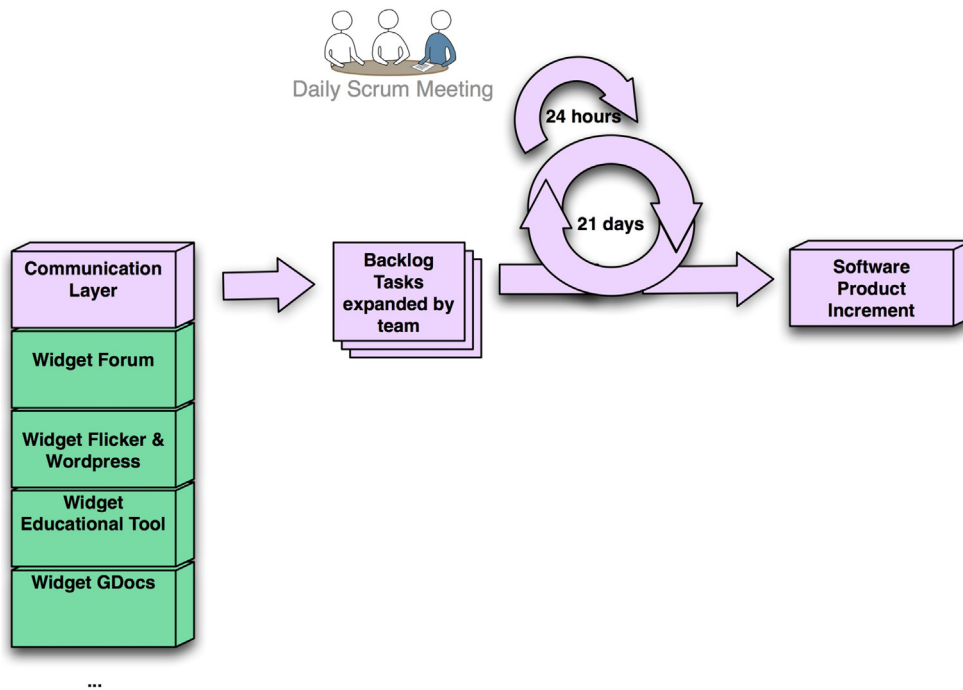


Fig. 3. SCRUM application to the framework development. The diagram shows in the left side the different sprints that will be considered during each 21 days period.

3.2. Modeling techniques and tools

In order to model the system several techniques and tools have been used. The description of the initial architecture is done by using UML 2 (Unified Modeling Language) [39], specifically component and deployment diagrams. The scenarios are described by using BPMN (Business Process Model Notation) [40]. This aims to provide a notation that is readily understandable by all business users, from the business analysts that create the initial drafts of the processes, to the technical developers responsible for implementing the technology that will perform those processes, and finally, to the business people who will manage and monitor those processes.

With regard to the development the process SCRUM [41] is used. This is an agile development framework which provides the process, rules, practices, roles and artefacts needed to increase the productivity of a development team based on an iterative and incremental software development process [42]. This process is particularly appropriate for this research because it allows for adjustment of the rules and practices to fit the working group, and because it facilitates flexible adaptation of the code in response to emerging user needs.. In this specific case the team is very small, and requirements can change easily. Consequently the system is defined incrementally and several meetings with the client may be carried out to check the evolution of the project. In total, nine prioritized tasks are identified. Each of them is divided in smaller elements with which it is possible to work easily and that are implemented in each Sprint (execution cycle of a task). These sprints last approximately 21 days and in each of them a new software increment is achieved. Using this approach 12 Sprints are carried out, so some tasks are divided in more than one Sprint. An example of this process can be seen in Fig. 3.

In order to clarify and enrich the initial deployment and components diagrams some other techniques are used. For example OOWS is used to represent the interfaces of the widgets [43]; SOAml [44] (an extension of UML 2.0 that describes the UML profile and the meta-model to design services for Service Oriented Architectures), is employed to model the services used for the communication in the interoperability scenarios; and the business logic of these scenarios is described using BPMN.

The following section describes one of the interoperability scenarios and describes the application of some of these techniques.

4. Case study. Using GoogleDocs in the PLE

4.1. Scenario description

In order to better understand this research one of the interoperability scenarios is described. The selected scenario is the integration of the users' outcomes in an external non-educational tool into the LMS (scenario 4).



Fig. 4. Evaluation interface for *GoogleDocs* learning activities. This interface facilitates tools for the evaluation of a non-educational tool and to return such results to the LMS.

With the emergence of 2.0 trends, many different tools could be used to carry out learning activities, tools such as *Twitter*, *Slideshare*, *Flickr*, *Wordpress*, *GoogleDocs*, etc. However, those tools were not initially designed to be used for learning and they do not include interfaces to track and evaluate learners' activity. This scenario describes how these tools can be used in the PLE and how the learners' outcomes can be taken into account from the LMS. During the proof of concept the scenario is implemented by integrating the results of a *GoogleDocs* activity into the LMS. The scenario is based on the initiative of Alier et al. [45], but whereas that research was based on the integration of *GoogleDocs* tools into *Moodle*, the present scenario focuses only on the integration of the students results, in such a way that the learners can use *GoogleDocs* as a tool in their PLE and teachers can take into account of what has happened in their personalized environment. Thus there are two main participants involved in the scenario, teachers and learners, and some technical components, *GoogleDocs*, *Moodle* and a proxy tool that communicates between them.

In the scenario the teacher sets up and launches a *GoogleDocs* based activity into a *Moodle* course. The activity is instantiated in each of the *GoogleDocs* accounts of the *Moodle* course students. They can work on a non-institutional platform. Once the teacher considers that the activity should have finished or when the deadline arrives, she can evaluate the activity of the learner through the interface provided by a mediator, also known as a proxy tool, Fig. 4. Mediator has an especially important role in the scenario because it does not only facilitate an evaluation interface, but also returns the results of the evaluation by using IMS BLTI. To do this, the mediator implements the IMS BLTI tool provider interface and uses the tool consumer implemented in *Moodle*. Moreover, it interacts with *GoogleDocs* through its public API (<http://code.google.com/intl/es-ES/apis/documents/>) in order to instantiate the activity for the students of the *Moodle* course. The business process is shown in Fig. 5.

The learners see a new activity in *Moodle* and once they click on it they are informed that they can carry it out outside the institutional learning environment (maybe in their PLE). During the proof of concept a W3C widget has been defined to integrate *GoogleDocs* into the PLE (shown in Fig. 6).

4.2. The pilot and the methodology

In order to evaluate the interoperability scenarios several pilots were carried out. These were intended to answer a research question "is it possible to define approaches which enable the interoperability between PLEs and traditional learning platforms so as to facilitate students' learning, guaranteeing the integration of the non-institutional learning outcomes into the institutional environment? Do these approaches should provide channels to exchange information and interaction between both contexts?" This is a wide research question that covers all interoperability scenarios. In order to address it a hypothesis was defined and validated for each of the scenarios.

For the current scenario the hypothesis was: "The possibility of evaluating from the LMS the students' activity carried out in tools not originally designed for learning proposes, enriches students' learning". This hypothesis was validated in an experiment carried out in the context of the course in Project Management at the University of Salamanca. During the experiment, the teacher created an activity based on *Google Docs* that is completed by the students in their PLEs. Later the teacher evaluated the activity that the students carried out. The 40 students taking the course were involved in the experiment and also 10 teachers from this and other subjects.

The validation of the scenario was based on quantitative and qualitative techniques, a mixed methodology [46] which provided a wider perspective on the information measured.

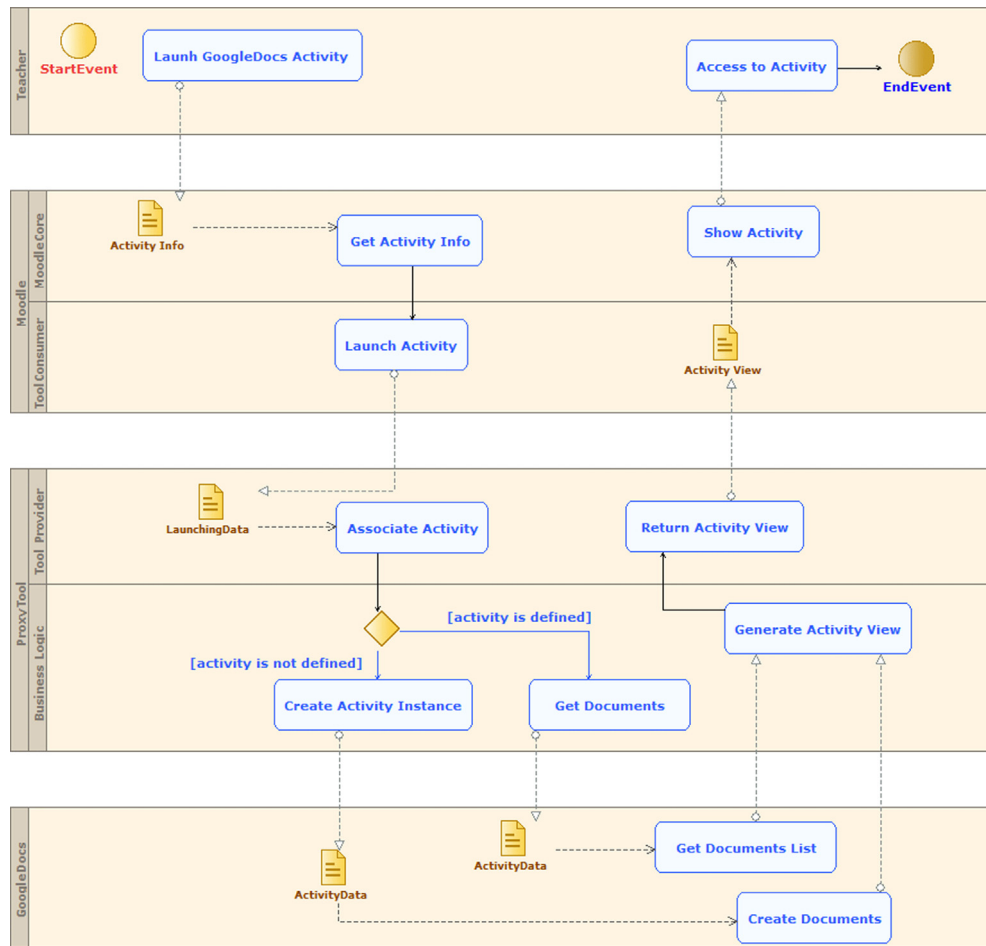


Fig. 5. BPMN diagram describing the launching of a *GoogleDocs* based learning activity. It shows the different participants (the Teacher, Moodle, the Proxy Tool and *GoogleDocs*) and how they exchange information to instantiate a *GoogleDocs* activities.

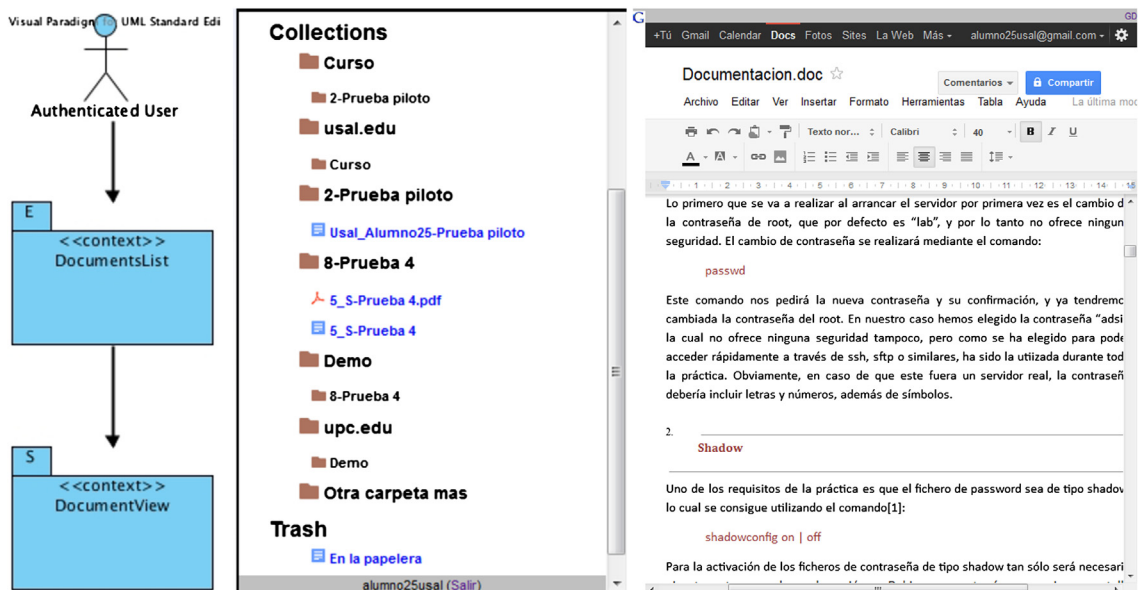


Fig. 6. W3C Widget for *GoogleDocs*. On the left side there is a navigation diagram describing the widget, in the middle the list of documents in the widget is shown and on the right side a document is shown.

The methodology used with the students is a quasi-experimental design [47]. This was used because in this experiment pre-established groups of students (class-groups) were involved, so it was not possible to establish fully randomized groups [48] and therefore a control study approach was not possible.

Quasi-experimental design facilitates the validation of the defined hypothesis by using an experimental and a control group (independent variable). From the hypothesis, a dependent variable is derived which is operationalized through several assertions. These assertions are presented to the students of both the experimental and control groups, who grade them using a Likert-5 scale (from 1, corresponding to strongly disagree, to 5 – strongly agree). Scale-based questionnaires are the most studied, informed and contrasted methods for measuring attitudes [49] and also one of the most widespread technique for data gathering in social research [50]. In the experiment, the objective is to measure the students' perception of their learning enrichment when what they do in external non-educational tools is taken into account from the LMS. Students' perception of learning is related to the idea of self-perception and self-efficacy and this kind of scale was used as measurement instrument. Prior research supports the use of self-report instruments to measure "self-perceived competence" [51,52], so the items for the instrument have been defined so as to reflect learners' perceived self-efficacy with the system.

In both groups the same tests are applied, a pre-test at the beginning of the experiment and a post-test after it (these tests can be seen in Appendix A). The students of the experimental group test the system while the people in the other group do not. After running the experiment, data is analyzed by using probabilistic techniques to validate the initial hypothesis.

The hypothesis is accepted if the results of the pre-test are similar in both groups – which proves that both groups have a common knowledge and background – but the results of the post-test are different for both groups – i.e., those who have tested the tool should have different perceptions about the use of the tool. In order to confirm if there are differences between the pre-test and post-test results, two statistical tests were applied: Student's T-test and the non-parametric Mann–Whitney's U-test. The second was used to confirm the results of the first, since the lower limit for the application of Student's T-test is around 40 people. In addition, the Mann–Whitney U-test is recommended for ordinal scales [53], such as the one used in this study.

For the Student's T-test, a null hypothesis is posed for each item; null hypothesis acceptance means that there are no significant differences between experimental and control groups ($H_0: \bar{X}_E = \bar{X}_C$). The null hypothesis is accepted if the bilateral significance of the item is under 0.05; otherwise, the null hypothesis is rejected. On the other side, the Mann–Whitney's U-test is based on a range comparison between the experimental and the control group and in this case the null hypothesis is $H_0: R_E = R_C$ (e.g., the range of the experimental group is equal to the control group). As with the T-test, signification should be greater than 0.05 to accept the null hypothesis.

Moreover, for this scenario the results of the experiment are enriched with some questions that gathered students' opinion about the system.

Regarding the teachers, their opinions were also assessed by means of semi-structured interviews, and also by answering a survey – items are shown in Appendix A; their responses were gathered through a form, which allowed for a qualitative analysis supported with quantitative data. The qualitative analysis is based on open questions related to teachers' opinion about if the integration of external online tools (non-originally designed with educational proposes) can improve students' learning and the possibility to evaluate students from other perspectives different from the traditional ones. After analyzing the text of the teachers' answers, responses were grouped based on topic-proximity criteria. In this case the group units were integration of non-educational tools, evaluation (of external tools from the LMS), participation (how it affects to students' course participation) and problems (for teachers and learners). The results from this analysis were shown in a matrix in order to be able to extract conclusions from that information [54].

4.3. Results and discussion

In order to carry out the experiment a dependent variable was derived from the previously described hypothesis ("Take into account into the LMS the students' activity carried out in non-educational tool, enrich students' learning"). This variable was: "The improvement in learning processes achieved by integrating in the LMS students' activity carried out in non-educational tools". It was operationalized in several assertions (see Appendix A) that the students graded. Later on, the statistics techniques were applied.

The results for the Student's T-test are shown in Table 1. Each row represents an item or statement – identified by their id in the DV column – and includes the average value for the experimental and control groups (\bar{X}_E and \bar{X}_C), the standard deviation for the experimental and control groups (S_{X_E} and S_{X_C}), the contrast variable (t) and the bilateral signification (ρ).

Table 1 shows that in the pre-test item the null hypothesis is retained (that is, the experimental and control group answers are more or less the same) and in the post-test the null hypothesis is rejected (so the results from the experimental and control groups are different). This indicates that, both groups use more tools than those provided by the LMS to carry out learning activities. Some of them are educational tools and other tools not designed with educational proposes. However the experimental group members that test the system, consider that the LMS does not satisfy their learning needs because it does not integrate the outcomes they have achieved with the tools not included in these environments (something that can be understood from their answers to item 2). These results are also endorsed by the Mann–Whitney U-test (Table 2), so it can be affirmed that the initial hypothesis is correct. We therefore conclude that from the student's

Table 1

Results of the Student's T-test for scenario 4.

VD	\bar{X}_E	S_{X_E}	\bar{X}_C	S_{X_C}	t	ρ
Pre-test results for Student's T-test I.1	3.60	1.353	3.80	0.696	−0.588	0.560
Post-test results for Student's T-test I.2	4.35	0.671	3.05	1.356	3.842	0.000

Table 2

The results of the Mann–Whitney U-test for the scenario 4.

VD	Signification	Result
Pre-test results for Mann–Whitney U-test I.1	0.954	Retain null hypothesis
Post-test results for Mann–Whitney U-test I.2	0.002	Reject null hypothesis

Table 3

Results of the text analysis for teachers grouping the text by the units defined.

	Integration	Evaluation	Participation	Problems
Teacher 1	New possibilities	Easy to do	More tools more participation	Adapted interfaces
Teacher 2	Useful	Not necessity to go to the Tool	Other possibilities to students	Each tool a new interface
Teacher 3	Helpful	Good interfaces	More popular tools	None
Teacher 4	Indifferent	Positive	–	Where is feedback returned
Teacher 5	Interesting	–	Indifferent	–
Teacher 6	Other possibilities	From the LMS	Tools commonly used as learning tools	Restricted to some tools
Teacher 7	Evolution	No extra work	–	Gmail accounts
Teacher 8	More options	–	The same	–
Teacher 9	No extra work	Helpful interfaces	Other kind of activities	No
Teacher 10	Easy	Centralization	–	Gmail account

perspective the possibility of using other online tools (non-defined as educational tools) in the institutional environment can improve students learning.

To support this conclusion an opinion assertion about the experience was posed to the students of the experimental group (see [Appendix A](#)). From this assertion was possible to see that 75% of the students agree or strongly agree that the use of online tools, such as collaborative tools as *GoogleDocs*, helps them to learn, so the use of other online tools beyond those provided by *Moodle* and its consideration in the LMS is useful for them.

With regard to the teachers' opinions, the results of the qualitative analysis are shown in [Table 3](#).

From [Table 3](#) it is possible to conclude that most of the teachers perceived that the integration of the majority of the activity that students carry out in external non-educational tools as being valuable in the learning process. It provides new possibilities in designing learning activities and does not involve extra work. Moreover, the fact that the activities can be evaluated from within the LMS without going to the specific tool, is seen by teachers as being very positive. This is because the approach taken also facilitates interfaces for the evaluation of learning activities based on those tools. Regarding the learners participation in activities, some of the teachers thought that it would remain at the same level. However, others considered that the possibility of using more tools, especially tools that students commonly use to learn, could increase their motivation and therefore their participation. Finally, the teachers reported some possible problems: each tool used will have specific evaluation requirements and interfaces may need to be adapted to them; it is not easy to provide feedback to the students through the framework; and not all students have a Gmail account as would be necessary in this case. Some of these problems are taken into account for future work lines, such as the definition of generic mediators with an adaptable evaluation interface, study of how to reduce the cost of adaptation and of the ways in which web services can be used to return feedback to the tools. These conclusions are backed by the results from the quantitative techniques: 80% of the teachers agree or strongly agree with the idea that students' learning is improved by adding external online tools non-originally defined as educational tools; and 90% of teachers consider that by using the framework it is possible to evaluate students from perspectives other than different from the traditional ones, because new tools in informal environments can be taken into account.

5. Conclusions

This paper has argued that there is a need of interoperability among LMSs (used by institutions to support their learning activities) and PLEs (supporting an alternative learning model which is more focused on the learner). The two environments support different learning approaches and therefore they should coexist. There are several initiatives that try to facilitate

Table 4

Measurement instrument: Questionnaire items.

Pre-test	I1	For learning, I use additional online tools from those provided by Moodle, regardless of whether they are defined as educational tools or not (such as Flickr, Wordpress, GoogleDocs, Twitter, Slideshare, etc.).
Post-test	I2	The fact that Moodle does not facilitate the integration of activities based on the use external online tools (such as Flickr, Wordpress, GoogleDocs, Slideshare, etc.), suppose that this platform does not satisfy some of my learning needs.
Additional Opinion from students	Op1	Carry out activities based on the use of online tools, such as collaborative tools as GoogleDocs help me to learn.
Additional Opinion from teachers	Op2	Students' learning is improved by adding external online tools not originally defined as educational tools.
	Op3	The possibility to take into account what the student does in external tools not defined with education proposes, allows me to evaluate them from other perspectives different from the traditional ones, because new tools could be taken into account in the informal environments.

the interoperability between both learning contexts, however they are focused on the integration of tools, the exportation of specific information, and the definition of solution from scratch. We have argued that it is necessary to find a way to interconnect the existing LMS and PLE in a bidirectional way.

To achieve this a framework has been defined. It facilitates, on the one hand, the export of functionalities from the LMS to external contexts, opening up institutional environments to a wealth of tools. On the other hand it integrates the results of other external tools (included or not in the PLE) into the LMS, so this environment can be enriched and evolve more easily. Teachers also have the possibility of using other tools in their platform and have more information about what their students do outside of institution. Finally, this framework may help students to access learning through a single point of entry and some of the activity that they carry out in the PLE can be taken into account from the LMS.

The framework has been implemented as a proof of concept. The various interoperability scenarios were validated with students and teachers and one of them has been presented in this paper (scenario 4). From these validation activities, it was possible to identify errors and issues, which have informed the identification of future research lines, including: definition of a generic mediator model to integrate any non-educational tool effortlessly; creation of feedback channels between the LMS and the PLE; and adaptation of the framework to use IMS LTI and to contribute to the development of that specification that has replaced IMS BLTI.

Returning to the overall purpose of our work, our final conclusion to this work, is to affirm that interoperability between LMS and PLE is possible, given an adaptation effort in both contexts. This interoperability makes it is possible to export functionalities to enrich other learning contexts (such as the PLEs) and to track and evaluate learners' activities in non-institutional tools that may be included as part of a learner PLE.

Appendix A. Measurement instrument

This appendix shows in Table 4 the questionnaire items used during the tests and the questions used to gather students' and teachers' opinions.

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