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The Implementation, Deployment and Evaluation of a Mobile Personal Learning Environment

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Abstract: The application of ICT to learning, the Web 2.0 trends and the widespread use of technologies such as mobile devices make it necessary to provide new solutions to satisfy the needs of learners. Such solutions should treat the students as the centre of the learning process. The students should be able to decide which tools they will use to learn, and the learning institution must consider the behaviour of students in such personal learning activities independently of the location where learning activities are carried out. In addition, learners can choose the type of devices they will use with special attention to mobile technologies. The work described in this paper proposes a service-based approach to defining mobile personal learning environments that facilitates communication with institutional learning platforms. Such an approach is implemented as a proof-of-concept and evaluated via a pilot study to demonstrate that such types of mobile learning platforms are feasible and can increase students' motivation to help them learn.

Keywords: mLearning, mobile devices, Personal Learning Environments, Learning Management Systems, Students
Categories: L.2.0, L.2.1, L.2.2, L.2.3, L.3.0, L.3.6

1 Introduction

The contexts in which teaching and learning processes take place have changed due to various factors. In recent years, the application of Information and Communications Technologies (ICT) and the emergence of Web 2.0 trends have had different effects on those contexts.

The ICT applications have enabled the definition of a large number of educational software systems and the use of different tools in learning (i.e., the Internet, mobile devices, TVs, games and other options), and this has led to the introduction of different learning modalities, i.e., eLearning, mLearning, gLearning, etc.

However, although the application of ICT to learning and teaching processes provides new ways to carry out learning activities, it has not produced the predicted level of success for the following reasons: 1) institutional resistance to change with respect to the introduction of certain technologies in formal environments [Mott and Wiley, 09, Piscitelli, et al., 10]; 2) insistence on the application of technology in areas where it was not required or applicable as a solution [Chadwick, 01]; 3) requirements for digital literacy amongst teachers and students, many of whom are digital immigrants, and the younger generations who are digital natives [Bennett and Maton, 10, Bennett, et al., 08, Prensky, 01]; 4) a lack of connection between the formal (structured and certified learning related to educational institutions), non-formal (structured learning traditionally associated with workplace training) and informal learning (non-structured learning obtained in daily life) environments [COM, 01], which makes it difficult to improve learning processes in addition to the centralisation of the activity in only one context [Downes, 10, Piscitelli, et al., 10]; and 5) the definition of technological applications and tools without taking the final user into account, which means that subsequent adoption and use can be difficult [Downes, 05, Mott and Wiley, 09].

Most of these problems are reflected in the most representative eLearning solutions, i.e., Learning Management Systems (LMS), which are widely accepted and applied in various academic and workplace contexts [Prendes, 09, Wexler, et al., 08]. The use of an LMS provides students and teachers with a set of tools for improving and managing the learning processes. However, despite this high level of adoption, their use has not resulted in the predicted educational improvements, which might have been expected. Three principal reasons have been suggested for this outcome: 1) the tools provided were not applied properly and were often used as mere spaces in which to publish courses [Cuban, 01, Milligan, 06, Sakai-Pilot, 09]; 2) the LMS restricts opportunities for collaboration in student learning and for promotion of social constructivism that is not limited to a period of time (i.e., the academic year)[Brown and Adler, 08, Wesch, 09]; and 3) the tools focused on the course and the institution rather than on the students and their needs [Downes, 06].

To address these problems, learning institutions must shift their strategies and provide environments that are more closely adapted to the student and open to including a new set of Web 2.0 tools that are under the students' control. The rationale for the shift of this 'locus of control' is that personalisation can improve learning by empowering the students to manage their own learning at their own pace [Attwell, 07] using their own technology within the context of the activities of their daily lives, which they also manage using these same technologies. This goal can be accomplished via the Personal Learning Environment (PLE), which seeks to unburden the learner of the need to adopt new systems when they engage in formal learning. The PLEs facilitate the user learning process by allowing students to use the tools they choose and not binding them to an specific institutional context or learning period [Adell and Castañeda, 10].

The PLEs are not a replacement for LMSs because: 1) both environments support different types of learning (LMSs support formal learning while the PLEs are oriented to informal contexts) [Adell and Castañeda, 10]; and 2) LMSs have a high acceptance rate (especially in institutional environments), have been used over several years and have been strongly tested, teachers and students are used to them, and institutions have made a significant investment in their implementation, improvement and adaptation [Sclater, 08]. For these reasons, both environments should coexist. Given this context, it is necessary that environments that support formal learning (LMS) and those related to informal learning (PLE) contain a certain degree of integration and interoperability, and the higher the better. In this manner, the formal environments can export functionalities to the informal environments, and activities that are carried out in informal environments can be taken into account in the institutional learning platforms.

However, ICT application does not only imply the development of new software systems. New technologies have had an important impact on society and should be taken into account in learning contexts. One of the most popular technological trends is the use of mobile devices. In fact, there is currently an 86.7% penetration of this technology, including greater than 5981 million mobile devices connections, which means that the majority of the first world's population uses one or more mobile devices [ITU, 11]. This technology also has had influence on learning via an application known as mLearning.

Taking into account such high device use and the necessity of considering personal environments, the next step is to represent the PLE in a mobile device. The PLE should be open to other contexts but also must consider the connection with the LMS, which means that a need exist for mobile Personal Learning Environments that reflect the learners' activities within the institutional environments. Therefore, the aim of this work is to demonstrate an approach for how to represent and apply this type of PLE in a mobile device. In other words, we intend to show that it is possible to represent the PLE in different devices, and at the same time, demonstrate how the mobile PLE version is connected to the LMS. To fulfil these objectives, we describe a service-based approach and different methods of representing information.

This paper is structured as follows. The second section describes the research context and explores different possibilities for representing a PLE in mobile devices and options for connection with the LMS. The third section presents the architectural approach. The fourth section includes an implementation of the approach and an illustration of its application via a proof-of-concept. The fifth section reports on a pilot study carried out to validate the developed implementation. Finally, selected conclusions are provided in the last section.

2 Research context

As previously mentioned, the aim of the current paper is to define a method for implementation and deployment of a mobile Personal Learning Environment that can interact with the LMS. This goal implies two main issues that define the research context: the representation of personal learning environments in other contexts (such as mobile devices) and the interoperability between the LMS and the PLE.

With respect to the first issue, the current technological landscape makes it necessary to not only consider web environments but also new modalities, such as mobile devices or interactive TVs. In other words, the LMS and/or PLE should be assessed from a traditional perspective but must be open to other contexts as well. Several possibilities exist for achieving the desired portability.

Certain trends imply that adaptation is unnecessary in terms of information or functionality because the new devices themselves will provide all of the tools and frameworks that allow learners to personalise their experience [Attwell, et al., 09, Jenkins, et al., 06, Pettit and Kukulska-Hulme, 07]. For example, mobile devices or tablets could be understood as types of PLEs. This idea is correct, but the integration of the tools that students must learn to use is not clear because the students are not all located in the same space and tools that are valid in one context do not always work in others, which could mislead the learner as to the ultimate goal (which is to learn).

Other initiatives have defined tools for learning using the specific capabilities provided by the devices (GPS, camera, accelerometer, etc.). Good example include the CONTSENS Project [Cook, in press] used in several learning experiences in London, which is a Mobile Personal Environment (MPE) that helps students to communicate between each other and with experts using the mobiles [Thüs, et al., 11], and experiences in languages learning using the mobile and taking into account the context of the user [Perifanou, 10]. The problem with these solutions is that they greatly depend on the hardware and software of the specific devices (although software dependences may be solved in the near future due to the popularity of such operating systems as Android and iOS and other technologies such as HTML5 or widget-based solutions).

In contrast, many projects use mobile devices as PLEs by including learning functionalities and institutional tools. Two representative examples are the MOLLY project [Molly, 10], a free and open initiative integrated with the Sakai LMS that allows students to contact experts, access academic podcasts and libraries and obtain information related to an institution, and CampusM, a mobile application that provides different tools for each student adapted to his or her needs (internal messages, blogs, portfolio, maps, calendars, alerts, etc.) and allows integration with such LMSs as Moodle or Blackboard [Jennings, 11]. The main drawback of these solutions is that they are too specifically defined for given institution and technology, although this problem could be solved through the use of specifications and standards.

Another possibility is to use mobile communication features such RSS clients or SMS. Two examples of this use of mobile device features are the OnlineConnect Project, which sends customised information to each student's mobile phone [Frost, 09], and REACh (Researching Emerging Administration Channels), which sends alerts from the LMS to mobile devices using these technologies [Stubbs, 09]. The problem with these solutions is that they are quite limited by the use of the given communication technologies.

Other interesting initiatives exist to define PLEs, such as Elgg, which has released mobile versions to offer an easy way to build PLEs and access them through mobile devices [Razavi and Iverson, 06]. With this system, it is possible to access virtual communities defined by Elgg from a mobile device, but this tool is not always sufficient for defining a PLE because it should be enriched with other learning tools and offer communication with the LMS.

Moreover, it is also possible to employ widget-based solutions to define a PLE in other contexts. Several of these initiatives exist, including Aplix Web Runtime [Aplix-Corporation, 09], the Widget runtime: WAC-1.0 Compliant Golden for

Android [DEV.OPERA, 11] and the consortiums of different companies intended to define common interfaces for mobile applications [Sachse, 10]. Projects such as Webinos [Webinos, 10] are also related to widgets and should be considered. Webinos defines an open platform for sharing applications among different contexts, which means that an application can be used in a TV, mobile device, car navigation system, etc. Specifically, this technology defines interfaces to allow information exchange and component integration (components that are an extended version of the W3C widgets) [WEBINOS-Partnership, 11]. The problem with these solutions is that not all of them use standards to define the widgets, and thus they are not a valid solution for platforms different than the one in which they are defined.

Last but not least, it is possible to access the tools native to the LMS from a mobile device so that these tools can be combined with the device's own tools, and this is a common solution implemented by most LMSs [Alier and Casany, 08, Casany, et al., 09b, Conde, et al., 08, Meisenberger and Nischelwitzer, 04, Pratt, et al., 06, Sakai, 11, Yingling, 06]. However, these initiatives are closely linked to the institution, and it is not easy to integrate additional functionalities into the mobile PLE or to combine them with other tools.

All of these solutions show that it is possible to open the PLE to other contexts. However, the heterogeneity of communication interfaces, software and hardware together with the lack of control over the activities create obstacles to the definition of real and independent PLEs.

The other important issue to explore in this research context is the interoperability between the LMS and the PLE. Wilson and others have proposed three possible ways to integrate PLEs and LMSs [Wilson, et al., 08]:

1. The PLEs and LMSs could exist in parallel (as formal and informal environments, respectively) without any interaction or integration of the activities that occur in those contexts.
2. The LMSs could be opened through the inclusion of web services and interoperability initiatives. This integration trend includes *iGoogle*-based initiatives [Casquero, et al., 08], social networks connected with LMSs [Torres, et al., 08], LMSs that offers support for implementation of interoperability specifications [IMS-GLC, 11], PLEs with specific communication protocols [van Harmelen, 06] or integration based on service-oriented architectures (SOA)) [Peret, et al., 10]. Two main difficulties exist for these initiatives: institutional barriers to the opening of formal environments and the fact that those initiatives are focused on information exportation and not on interaction exchange. In other words, communication is oriented in one direction, from the LMS towards the external tools, and the information is exchanged with respect to what occurs on the platform but provides no information or interaction back to the LMS.
3. Integration of external tools into the LMS. In these initiatives, the user might not decide which tools s/he will use and will be limited to institutional decisions. Certain initiatives that can be included in this group are LMSs defined for the integration of external tools [Booth and Clark, 09], *Google Wave* Gadgets integrated into *Moodle* [Wilson, et al., 09], PLE introduction of tools based on log analysis [Verpoorten, et al., 09], initiatives based on tool integration driven by learning design activities [de-la-Fuente-Valentín,

> et al., 08] and integration architectures [Alario-Hoyos and Wilson, 10], among others. These initiatives pose several problems, including integration difficulties between tools, context integration difficulties, and inflexibility for customisation by the student. The tools that best overcome these problems are those that define a learning platform from the ground up or from a previous institutional development. This approach will greatly limit the scope of use of the solution, which will be applied to a rather specific context and will require the student to first learn how to use the new systems.

Taking all of these possibilities into account, together with their problems and proposed plans for remediation, a possible solution could be based on the combination of the second and third scenarios. In the current article, this goal is accomplished through the use of a service-based framework and a set of interoperability scenarios. This approach allows integration of tools from the LMS into the PLE, and any user interaction carried out in the personal environment is recorded in the institutional environment as well. In addition, it is possible to represent the functionalities in mobile devices.

3 Architectural approach used to define a Mobile PLE

The previous sections described the need for a Mobile PLE that is able to interact with the LMS. To achieve this objective, the best possibility is the use of service-oriented approaches and interoperability specifications. In a previous work, the authors of this paper defined a service-based approach designed to support such representation and interoperability [García-Peñalvo, et al., 11]. This approach consists of three main elements: the institutional context, the personalised context and the communication channels. In addition, certain other elements may be included, i.e., mediator elements (to facilitate the communication between specific instances of the LMS and the online tools included in the PLE) and/or the representation of these elements in other contexts (such as mobile devices).

The institutional contexts could include one or several LMSs in which the student performs his or her academic activities. This element represents the various institutional learning environments used by the student and focuses mostly on the course and not the user. The institutional context should be open to include new functionalities that allow it to evolve and, at the same time, export information and offer interaction such that the activity may be performed in other contexts (not only the formal context) and combined with other tools.

However, a personalised environment focuses on the learner, which facilitates informal learning and allows the student to add the types of tools that s/he uses to learn, including institutional tools. To this end, each tool should be able to operate independently but in a context that acts as a container. Therefore, it is appropriate to use a standard representation of those tools so they can be portable to other different application containers and can adapt depending on the context in which they are involved, i.e., in a web environment, a mobile device, or an interactive TV.

The other important element in the framework is related to the communication channels. The communication channels should provide standard and independent methods for exchanging information and interaction in a bi-directional manner (from the LMS to the PLE and from the PLE to the LMS) To achieve this goal, web services will be used to facilitate the integration of systems developed in different programming languages to guarantee a separate evolution of these systems (the LMS and the PLE) [W3C, 04]. Additionally, these channels must take into account the use of interoperability specifications, thus facilitating the portability of the solution to different platforms and the integration into the LMS of activities taking place in other contexts.

It is also possible that the framework includes mediator elements that perform activities related to the adaptation of the transferred functionality and information.

Moreover, and especially relevant for this paper, both web contexts and mobile devices should be considered and taken into account in the system.

All of these elements are included in the deployment diagram shown in [Fig. 1]. This diagram illustrates the distribution of the described elements into different nodes and the components that are included in each one.

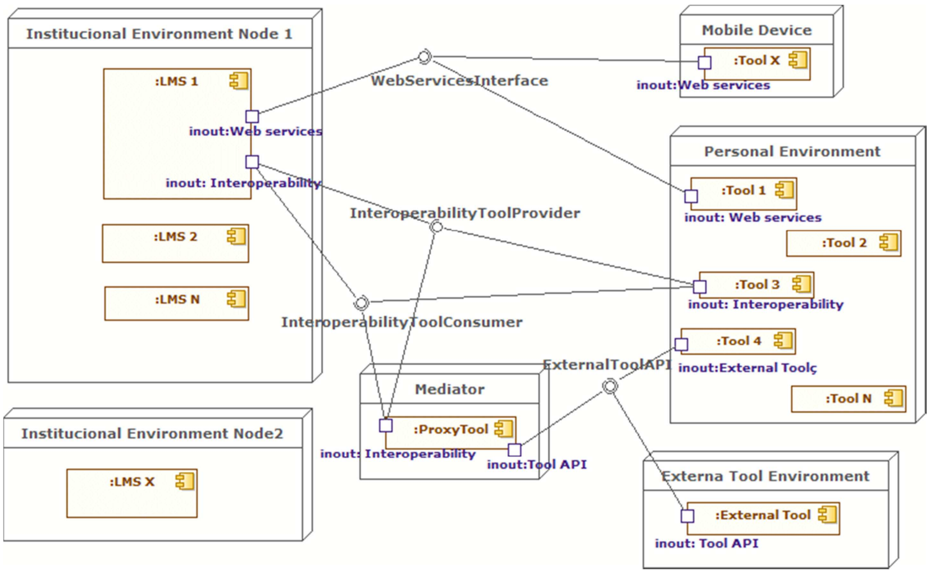
Institucional Environment Node 1
:LMS 1
inout:Web services
inout: Interoperability
:LMS 2
:LMS N
WebServicesInterface
Mobile Device
:Tool X
inout:Web services
Personal Environment
:Tool 1
inout: Web services
:Tool 2
:Tool 3
inout: Interoperability
:Tool 4
inout:External Toolç
:Tool N
InteroperabilityToolProvider
InteroperabilityToolConsumer
ExternalToolAPI
Mediator
:ProxyTool
inout: Interoperability
inout:Tool API
Institucional Environment Node2
:LMS X
Externa Tool Environment
:External Tool
inout: Tool API

Figure 1: Architecture deployment diagram, including two institutional nodes with different LMS, a proxy tool in a mediator node, the personal environment, an external learning tool and a mobile device.

To describe the most common interactions between the LMS and the PLE, certain interoperability scenarios were defined in previous works [Conde, et al., 11]. Although all of the defined interoperability scenarios can be exploited in mobile contexts, this case addresses one scenario and a subset of the components, which means that according to the previous diagram, only the institutional node with the LMS 1 and a web service interface used by a mobile device are considered.

This scenario addresses the export of functionalities from a LMS to other environments controlled by the user. To export that functionality, the LMS should include a web service layer, which is used by an external application to access the institutional functionality. As a result, the student can use the functionality from the

LMS in the PLE without entering the LMS, and the PLE can be represented in contexts such as mobile devices. The teacher can also follow the student's activity as if s/he were answering from the LMS so that the student activity can be assessed. Thus, teachers and students use their respective environments together with knowledge of events occurring in the other context. This scenario is open to inclusion of other tools and export of the functionality to other contexts other than the web or mobile devices. [Fig. 2] illustrates how the components involved in this scenario are connected. The tool, which is represented in the mobile device, uses an interface based on web services and is implemented by the LMS web service layer. This layer receives a request for an LMS service and access to the LMS core to return the results of the service; such information is later displayed in the mobile device. In this way, it is possible to carry out an activity using a Mobile PLE tool that provides information to the LMS of events occurring in the PLE.

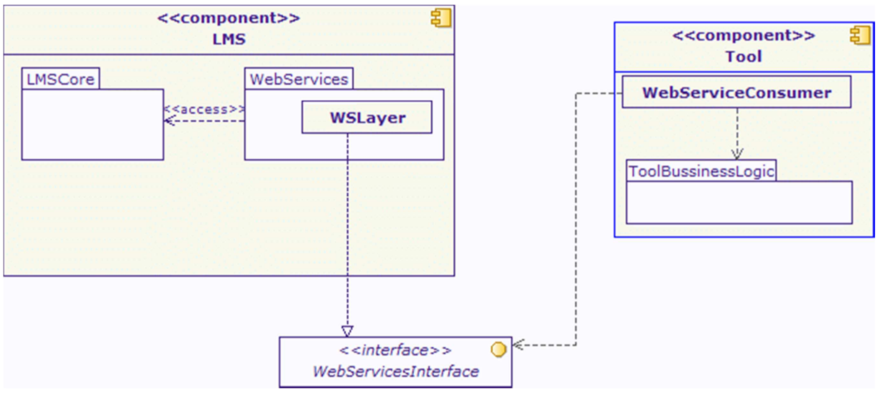

Figure 2: Connections among the components included in the approach, including the LMS, the WebServicesInterface used by the tool and the tool with a WebServiceConsumer.

The functionality in the mobile device could be represented in two possible ways, as a widget (a type of mini-application), which can be displayed in a widget container (such as Aplix Web Runtime or the Widget runtime: WAC-1.0-compliant Golden for Android described above), or as a LMS mobile version, which can include other tools such as Moodbile [Casany, et al., 12]. The widget option allows the user to combine functionalities exported from the LMS with other learning tools. The LMS mobile version includes several tools and also can include new options (although this possibility is conditioned by the solution selected from the existing options).

4 Implementation as a proof-of-concept

To verify the suitability of the framework, a proof-of-concept exercise is carried out, which implies decision-making and thus imposes certain 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 applied in the proof-of-concept. There are various reasons for using *Moodle* in this context. Apart from the fact that Moodle is one of the most popular LMSs all over the world, it is also: 1) open source, 2) developed and supported by an international community with greater than 1000000 members [MoodleStats, 12], 3) a system with more than 68000 installed servers used by over 58 million students, 4) translated to more than 75 languages [Alier, et al., 10, Cole and Foster, 07], 5) proven successful in different institutions [Molist, 08], and 6) it includes a web service layer that is open to new technologies and facilitates integration with service-oriented architectures [Casany, et al., 09a].
- Communication channels: To implement these channels, web services are used to exchange information and provide interaction with the LMS and BLTI to integrate the student activity performed in other environments and guarantee the portability of the framework to other contexts. The web services are those provided by the LMS, which can be extended using the Moodle extension protocol when necessary. However, it is not possible to use only web services because this implies that the framework must be adapted to the service layer of each platform in use. This problem is solved by applying BLTI, which is implemented by most LMS [IMS-GLC, 11].
- Personalised environment: The personalised environment should allow the user to add all types of tools that s/he uses to learn, including institutional tools. As mentioned previously, a tool container is chosen, but in this case, what matters is not the container but the fact that the applications can be exported and used with other environments and containers. Therefore, during the proof-of-concept, standard methods are used to represent such tools. In other words, the use of W3C widgets can be represented in different web contexts [W3C, 09], i.e., on desktop widgets, on mobile devices and (with minor changes) in other contexts such as interactive TVs and car navigation systems. For the container, *Apache Wookie* will be used, which facilitates the integration of the widgets and other options, such as *Google Gadgets* or *Open Social* widgets.

Taking into account these restrictions, [Fig. 3] presents the framework implementation.

The interoperability scenario in this work requires: 1) Moodle as the LMS in the institutional environment; 2) a W3C Widget [W3C, 08] to represent the tool in the mobile device [Wilson, et al., 08] (because it is the specification to define the widgets proposed by the W3C and therefore facilitates representation of these widgets in other contexts); 3) Moodbile as the Mobile LMS software to verify the other possible tool representations in the device; and 4) a web services interface to facilitate the interaction with the LMS. This implementation has considered a specific Moodle tool known as the forum. This tool is implemented as a widget for one of the representation options, and Moodbile includes it for the other options. Forum representation is based on the results returned by the Moodle Web Service Layer to different requests.

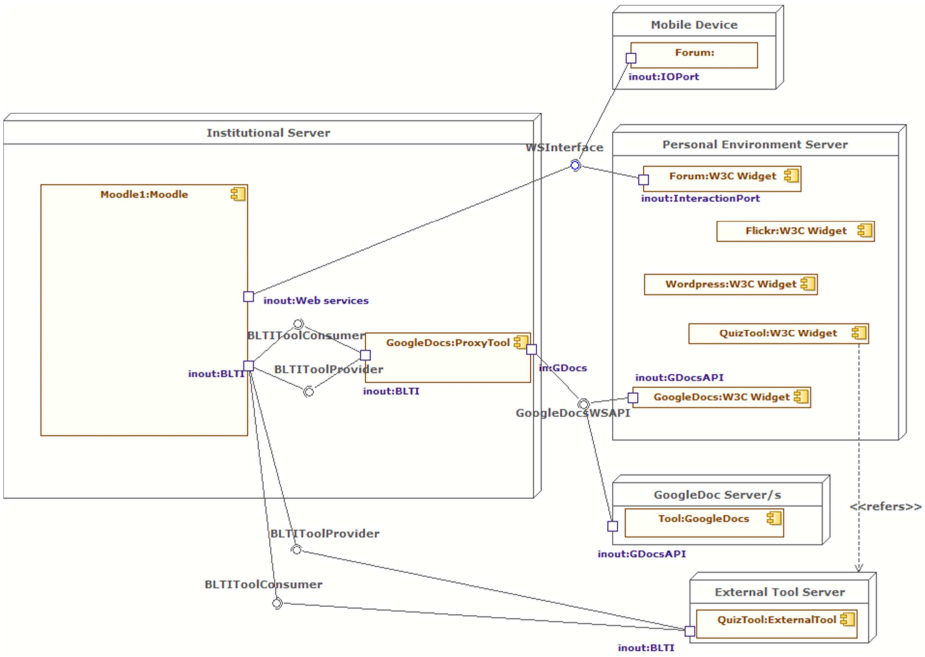
Mobile Device
Forum:
inout:IOPort
Institutional Server
WSInterface
Personal Environment Server
Moodle1:Moodle
Forum:W3C Widget
inout:InteractionPort
Flickr:W3C Widget
Wordpress:W3C Widget
inout:Web services
QuizTool:W3C Widget
BLTIToolConsumer
GoogleDocs:ProxyTool
inout:BLTI
BLTIToolProvider
in:GDocs
inout:GDocsAPI
inout:BLTI
GoogleDocs:W3C Widget
GoogleDocsWSAPI
GoogleDoc Server/s
Tool:GoogleDocs
<<refers>>
inout:GDocsAPI
BLTIToolProvider
BLTIToolConsumer
External Tool Server
QuizTool:ExternalTool
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Figure 3: Deployment diagram of the proof-of-concept system, with LMS as the institutional environment, Wookie as the PLE and the use of Webservices, BLTI and widgets.

[Fig. 4] shows the sequence of actions carried out to return a list of forum discussions in a BPMN (Business Process Management Notation) diagram [OMG, 08]. This diagram includes two main participants, the tool or widget and Moodle. A user requests the list of discussions, and the request is received and pre-processed by a RequestHandler (which means that the arguments are extracted from the messages in a manner that depends on the web services implementation, i.e., SOAP, REST, JSON-RPC). Next, the content of the request is sent to the request processor where the identity of the user who requested the list of discussions is verified. If s/he does not have permission for access, a response is sent with an error. If s/he is allowed to access the information, the discussion list is returned following the web service model used in the request. Once these data arrive at the tool, it is shown to the user. These actions are exactly the same for both representation choices but the manner in which the results are shown may be different.

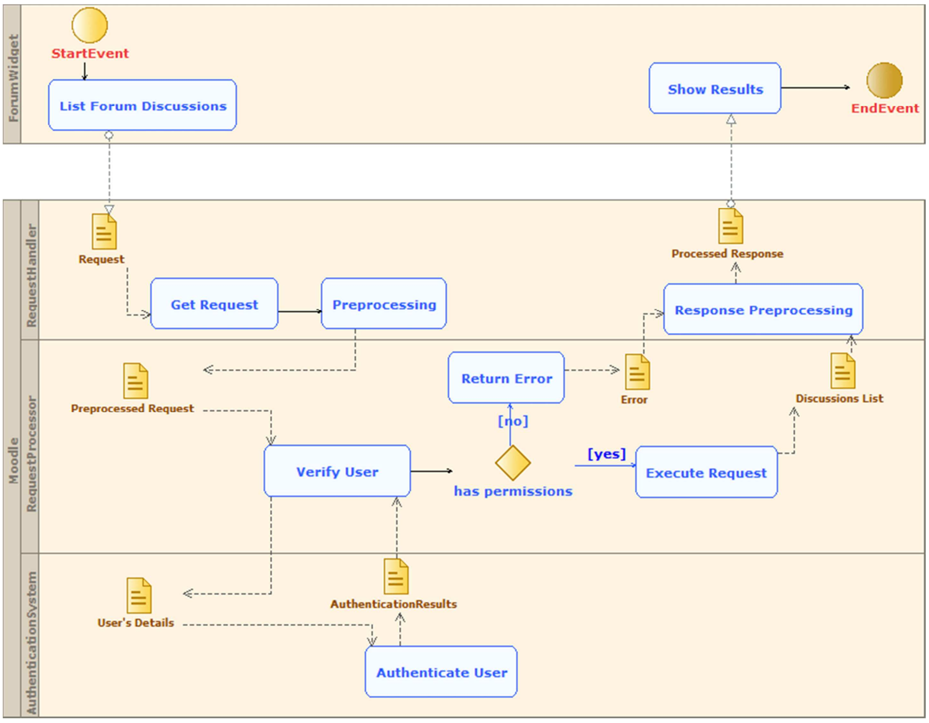
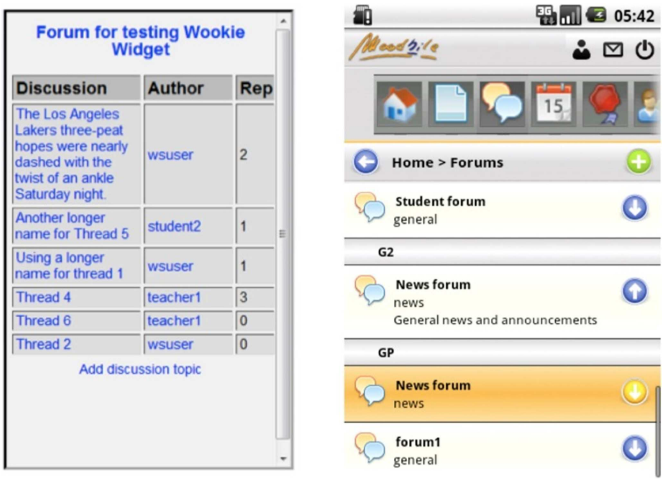

ForumWidget
StartEvent
List Forum Discussions
Show Results
EndEvent
Moodle
RequestHandler
Request
Get Request
Preprocessing
Processed Response
Response Preprocessing
RequestProcessor
Preprocessed Request
Return Error
Error
Discussions List
[no]
[yes]
Verify User
has permissions
Execute Request
AuthenticationSystem
AuthenticationResults
User's Details
Authenticate User

Figure 4: BPMN Diagram for describing the actions exchanged between Moodle and the ForumTool to list the discussion results.

Once the tool is represented in the Mobile PLE, it can be combined with other applications that the students use for learning. During this experience, a widget is enabled per the W3C recommendation and is included with the widgets of the widget runtime WAC-1.0-compliant Golden system for Android. This solution is valid for any container-based PLE such as Apache Wookie, and not only for a mobile device, which means that the tool will operate in different contexts. However, this system presents two main problems. The mobile run-time container is a beta product and certain widgets do not work properly with it, and the container is linked to a specific mobile operating system (a version for Android, another for iOS, etc). Taking these problems into account, the representation is also used with Moodbile, which provides a tool for Android Systems,as well as an HTML5.0 [W3C, 11] representation, which makes the PLE independent of the device system. Both representations are shown in [Fig. 5] (it should be noted that the defined widget is a prototype and thus the graphical design was not completely finished). The problems with this solution are that it is joined to a specific LMS, which means that is not easy to include other tools. This problem will be solved using the Moodle Webservices Layer and interoperability specifications such as BLTI, which facilitate tool integration that later could be included by the mobile adaptation. Taking this difficulty into account, the authors are currently working to define an HTML5 solution that uses these services. However, this example is not the only work in this area; the widget mobile system is currently undergoing evolution, and specific versions of the system for the most popular mobile systems (Android and iOS) are under development.



Forum for testing Wookie Widget

Discussion	Author	Rep
The Los Angeles Lakers three-peat hopes were nearly dashed with the twist of an ankle Saturday night.	wsuser	2
Another longer name for Thread 5	student2	1
Using a longer name for thread 1	wsuser	1
Thread 4	teacher1	3
Thread 6	teacher1	0
Thread 2	wsuser	0

Add discussion topic

Figure 5: Forum representation in a W3C widget (left side) and in Moodbile (right side).

5 Pilot application and results

To provide quantitative validation, a pilot study was carried out with Project Management students at the University of Salamanca. Specifically, all 40 participants in the course were involved. The methodology used to validate the system is a quasi-experimental design [Campbell and Stanley, 63, Campbell and Stanley, 70]. This methodology was chosen because this experiment involved pre-established groups of students (class groups) and thus it was not possible use a completely randomised group of subjects [Dendaluce, 94, Nieto and Necamán, 10]. Therefore, experimental design is not applicable.

Quasi-experimental design implies the definition of a hypothesis that is tested using an experimental group and a control group (independent variable). The same tests are applied in both groups: a pre-test at the beginning of the experiment and a post-test after the experiment. The students in the experimental group test the system (i.e., use the forum application in the mobile Personal Learning Environment) and the students in the other group do not. After running the experiment, the test data are analysed using probabilistic techniques to validate the initial hypothesis.

The scientific hypothesis for this experiment is as follows: “The students value the use of institutional functionalities in a mobile device as a positive asset that helps them to learn”. From such a hypothesis, a dependent variable is defined: “The impact of the use of institutional functionalities via mobile devices”. To operationalise this dependent variable, certain statements (also referred to as items) were proposed to the students, who graded their agreement with the following statements using five value levels (1=strongly disagree, 2=disagree, 3=indifferent, 4=agree, 5=strongly agree).

In the pre-test:

- I.1. I use my Smartphone to access to Moodle and its resources.
- I.2. I use my mobile device to learn using online tools and certain mobile applications.

In the post-test:

- I.3. The application of online tools, mobile native applications and Moodle functionalities in the mobile help me to learn.

The scientific hypothesis is accepted if the results of the pre-test are similar in both groups (which proves that both groups are similar and share a common knowledge base and background) and the results of the post-test between the persons involved in the experimental group and the control group are different (those who used the tool are expected to answer differently). Therefore, we propose the following null hypothesis for both groups: H0: μE = μC (where μE is the average grade for the experimental group and μC is the average grade for the control group). To check this hypothesis, two statistical tests are applied: Student's t-test and the non-parametric Mann-Whitney U-test. The second test is applied to further validate the results of the first test because: 1) the sample consists of only 40 students, and this number is near the recommended limit for the application of Student's t-test; and 2) the scale used to measure the students' perception is not exact (an ordinal scale). The results of the first test are shown in [Tab. 1] with a significance level of 0.05. If the significance of the item is less than 0.05, the null hypothesis is accepted; if not, it is rejected.

Pre-test results for Student's t-test						
VD	$\overline{X_E}$	S_{X_E}	$\overline{X_c}$	S_{X_C}	t	ρ
I.1	2,70	1,081	2,85	1,348	-0,388	0,700
I.2	3,15	0,933	2,75	1,209	1,172	0,249
I.3	4,05	0,759	3,35	0,988	2,512	0,016

Table 1: Results of Student's t-test: The table shows the mean ($\overline{X_E}$, $\overline{X_c}$) and standard deviation (S_{X_E}, S_{X_C}) for each item of the pre-test and post-test, the result of the contrast test (t) and the bilateral signification (ρ).

In [Tab. 1], we observe that in both pre-test items, the null hypothesis is retained (i.e., the experimental and control groups answer similarly) with a bilateral significance of 0,700 and 0,249, values that are greater than 0,05. In the post-test, the null hypothesis is rejected (the results of the experimental and control group are different). It should be noted that in item I1 and item I2, the average for the experimental and control groups are approximately 2 or 3, which means that most of the students do not use mobile devices to access Moodle or other learning tools. It is also interesting to examine the average of the experimental group in the post-test (4,05), which shows that the students who tested the system considered it useful for learning. These results are also endorsed by the results of the Mann-Whitney U-test

[Tab. 2], and therefore, it can be affirmed that the scientific hypothesis is correct. From the perspective of the students who used the mPLE, the initial hypothesis is correct, and the use of institutional learning functionalities in mobile devices helps them to learn.

Pre-test results for the Mann-Whitney U-test		
$VD_{pretest}$	Signification	Result
I.1	0,585	Retain null hypothesis
I.2	0,186	Retain null hypothesis
Post-test results for the Mann-Whitney U-test		
I.3	0,017	Reject null hypothesis

Table 2: Results of the Mann-Whitney U test: The table shows the significance per each item of the pre-test and post-test.

To support this conclusion, an opinion statement was posed to the students in the experimental group. This assertion was: "After using the Moodle forum using a mobile device, I believe that export tools such as those on mobiles make it easy for me to follow discussions and participate in the forums. Therefore, my learning has improved and forum use is more attractive, in my opinion". A total of 85% of the students agree or strongly agree with this assertion and consider it useful to export these types of functionalities.

Several semi-structured interviews were conducted to take into account the teachers' opinions. During these interviews, the system is presented to the teachers, and their opinions are elicited. The results show that 70% of the teachers agree or strongly agree with the exportation of institutional functionalities to mobile devices to improve student participation and enrich institutional learning. The other 30% believe that it is not easy involve mobile devices in all learning contexts.

The conclusions obtained from these experiences provide validation for the presented scenarios but only according to the students' and teachers' perceptions. In future work, these conclusions should be assessed in other contexts, with other types of students, etc.

6 Conclusions

This paper presents two main problems: one is related to a shift in learning contexts to the user, which leads to the definition of the PLE concept, and the other is related to how best to represent such elements in a mobile device and facilitate communication with the existing LMS.

To address these problems, an architectural approach is proposed and a proof-of-concept is described that implements a portion of this approach. In such an implementation, two possible methods have been developed to represent the system. The proof-of-concept was validated in a quantitative experiment with students and teachers at the University of Salamanca. The pilot study shows that from the students' perspective and in a controlled context, it is possible to represent the students' PLE in a mobile device that includes functionalities and/or information from the LMS that could be combined with other learning tools; this approach encourages them to participate in the subjects and helps them to learn. This conclusion is reinforced by teachers from different contexts who consider the system useful and engaging; however, they anticipate problems in several educational contexts such as the cost of mobile devices.

In future work, it would be interesting to exploit other interoperability scenarios into mobile devices, using BLTI and modalities other than web services to interact with the LMS. In addition, to guarantee the achieved results, the experiments should be repeated in other contexts, i.e., secondary and primary contexts. It is also necessary to consider the usability of the solution and the improvements it assumes in the students' grades. Moreover, certain improvements should be made in the system, i.e., new tools should be adapted for inclusion in the PLE, problems related to widget representation in mobile devices should be solved, new methods of representing content in such devices must be developed, support should be provided for offline work so that users can upload their results once they have access to the Internet (as facilitate by HTML5), and other possibilities.

As a final conclusion, we state that the definition and application of Mobile PLEs is possible, and though several approaches exists to carry out this effort, these approaches should primarily consider the interactions with the LMS.

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