Moodbile: A Framework to Integrate m-Learning Applications with the LMS

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Learning Management Systems (LMS) have become widespread among most centres for education and training. Being a mature technology, LMS have left the vanguard of innovation. Educational usages of the Web 2.0, Personal Learning Environments, Game-based Learning and particularly the introduction of mobile phones and tablets in education are happening outside the boundaries of the LMS. This paper proposes a way to integrate mobile devices and educational applications with the LMS through webservices; introducing the Moodbile project that provides an extension of Moodle 2.0 webservices for mobile integration and two mobile clients ready to use on real courses.

ACM classification: *K.3 (computers in education), D.2.12 (Interoperability), D.2.11 (Software Architectures)*

1. Introduction

E-learning has experienced an extraordinary growth over the last years; learning paradigms, technological solutions, methods and pedagogical approaches have been developed, but some of them discarded. We have reached a point in time when most of learning institutions have adopted Learning Management Systems (LMS), either from commercial vendors or from Free Open Source Communities. LMS are systems that organize and provide access to online learning services (such as access control, provision of learning contents, communication and administration of users and groups tools) for students, teachers and administrators (Paulsen, 2002). They take and organize learning content in a standard way, usually as a course divided into modules and lessons, supported with quizzes, tests, forums and discussions (Downes, 2006).

Today, LMS have reached the goal of mimicking the structure and (traditional) ways of schools, universities and other educational institutions. So, many LMS are currently integrated into the college and into the institution's information system. They are integral elements of a university's teaching and learning infrastructure (Obexer and Bakharia, 2005). The key points of the LMS success have been: 1) LMS copy the structure and practices of educational institutions, for example organizing contents in online courses; 2) LMS organize the processes and business rules

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of educational instructions, for example they allow delivery of online assignments and 3) for quite a long time they have been an important source of innovation in education, for example alerts sent to mobile phones when the deadline of an assignment was close (Downes, 2006; Alier, Pedro, Casany, Piguillem and Galanis, 2010). Nowadays, the success of LMS is so great that over 90% of Spanish universities and colleges use a LMS (Prendes, 2009), 95% of the learning institutions in the US also use an LMS (Lonn and Teasley, 2009), and 79.5% of large companies use these systems during their training program (Wexler, Grey, Miller, Nguyen and Barnevelda, 2008).

Despite their success, LMS are relatively inflexible systems for many students. In LMS, the standard organizational unit is the course, and this structure restricts students to the content designed for a particular course and to interact only with the other participants of the course. Therefore, students' engagement in LMS is lower in contrast to their engagement in other environments or tools such as mobile devices, Web 2.0 tools or game consoles. These environments provide opportunities for customization, communication and a sense of ownership impossible in current LMS (Sclater, 2008; McLoughlin and Lee, 2007).

In order to evolve, LMS will have to be able to: 1) interact with external applications such as social networks, blogs, mobile applications, virtual environments etc. (Sclater, 2008), 2) go beyond the limitations of the unit/course paradigm, 3) put more emphasis in the learning process and in the actions, performed by the learners and 4) allow networked learning through easy collaboration and communication tools (Obexer and Bakharia, 2005). This interaction between the LMS and other tools will require flexibility and interoperability techniques.

On the other hand, the expansion of mobile devices with new browsing capabilities and touch interfaces provide new ways to learn (this is usually called mobile learning or m-learning). M-learning puts the control of the learning process in the hands of the learner himself (Downes, 2006) and enhances collaboration and flexibility. Even though, there are many successful m-learning experiences, sometimes they are isolated from the rest of the learning process limiting in this way their impact. For example, many teachers do not use m-learning applications because they rely on and are used to e-learning platforms that are integrated with the information system of their institution.

One possible way to promote m-learning applications and to overcome some of their limitations may be the integration with the LMS. This integration will also facilitate LMS evolution, interoperability improvement and its adaption to new social needs and new technologies. In this paper, we propose a first step in this direction, which is an interoperability solution to extend LMS to the world of mobile devices. This paper is organized as follows. Section two describes the research scenario including a description of the problem of interoperability between m-learning applications and LMS. It also includes a state-of-the-art of the current solutions to the problem. Section three presents an architectural proposal to solve this problem to the specific case of the LMS Moodle, and we show the main results we have obtained by the use of our prototype. Section four presents a brief discussion where the main advantages of the proposed architecture are presented. Finally, Section five summarizes conclusions and future work.

2. Research Framework

In this section, we describe the opportunities and challenges of mobile learning (m-learning) and the main approaches to integrate m-learning applications to LMS. Finally, we summarize related work.

2.1 Mobile Learning: Opportunities and Challenges

The portability of mobile devices and their ability to connect to the Internet (for a relatively low cost) almost anywhere, make such devices ideal tools for storage of learning experiences and reference materials as well as a general tool to enhance the learning process. The *Horizon Report* (Johnson, Smith, Levine and Haywood, 2008) identifies mobile phones as a priority technology, which will have a wide impact on learning and teaching within the next years. Mobile phones are ideal tools for mobile learning (m-learning). M-learning is a new learning approach to support personal learning demands that may happen anywhere and/or at any time; or in response to the process of coming to know, by which learners in cooperation with their peers and teachers, construct transiently stable interpretations of their world (Sharples, Taylor and Vavoula, 2005).

Mobile technologies have a special role, because they increase our communication and conversation opportunities. According to Sharples *et al* (2005), this radical constructivism extends the notion of learning as a constructive process beyond the individual to describe how organizations, communities and cultures learn and develop.

M-learning introduces some opportunities and challenges in the learning process. Some of the contributions of m-learning are: 1) it is learner-centred (Naismith, Lonsdale, Vavoula and Sharples, 2004), 2) it is a new alternative for information delivery (for example, providing access to learning materials to remote users or old people), and 3) it enhances collaborative learning (Sharples *et al*, 2005). Therefore, we may state that m-learning increases learning flexibility by customizing learning to be more personalized and learner-centred (Vavoula and Sharples, 2002; Bull and Reid, 2004).

On the other hand, m-learning faces several challenges such as: 1) lack of teacher confidence, training or technical difficulties with mobile devices (Cobcroft, Towers, Smith and Bruns, 2006; Zawacki-Richter, Brown and Delport, 2007), 2) lack of institutional support (Cobcroft *et al*, 2006; Zawacki-Richter *et al*, 2007), 3) interoperability problems with LMS which usually are designed as monolithic or layered systems (Alier, Casany, Conde and García-Peñalvo, 2010), and 4) limited impact because many initiatives are isolated from the rest of the learning process (Martin, Gil, SanCristobal, Díaz, Castro, Peire and Milev, 2009).

One possible solution to overcome these challenges and to avoid LMS extinction is the integration of m-learning initiatives with LMS. This approach has several advantages. From the technological point of view, the LMS can be a tool to spread learning innovation and m-learning projects can be more than isolated experiments or limited experiences because they would be integrated with the learning dynamics of the educational institutions. From the student's point of view, they could personalize their learning process thanks to mobile devices as well as collaborate with peers. From the teacher's point of view, they could continue to use LMS as their working platform, leaving mobile devices for students.

2.2 Integrating m-learning with LMS: Related Work

This section analyses some of the previous projects that have extended the LMS to the mobile scenario as well as the m-learning initiatives that integrates web 2.0 tools or external applications into the LMS.

The integration between m-learning applications and LMS is not an easy task, because LMS do not usually include interoperability standards to communicate with external applications; they are usually designed as monolithic or layered systems (Sclater, 2008). The integration of m-learning applications with LMS has two scenarios: 1) Extending LMS to the mobile world using web services and interoperability initiatives and 2) integrating external m-learning applications into the LMS.

2.2.1 Extending the LMS to the Mobile World

The first scenario is based on the creation of m-learning applications that extend the scope of the LMS. Such mobile applications usually follow one of two different approaches. The first approach focuses on engagement with mobile devices and mobile native applications. The benefits of this approach include access to engaging design, free use of hardware features and fast and lightweight technology. However, the main limitation is that applications are device specific, which usually requires high development costs. The second approach focuses on the interaction with a browser, so the technology is ubiquitous and device-independent. However it may also be slower and it may be harder to access for some smart phones. For example, the LMS Blackboard is focused on native applications for mobile devices, while Moodle is focused on browser technology as well as mobile native applications (Delta_Initiative, 2010).

Usability and online/offline work are important issues when extending LMS to the mobile world. Specific restriction on mobile devices to display information and to interact with the user must be taken into account, and properly adapted. Some m-learning applications allow offline work when network coverage is not available or expensive. These m-learning applications must keep some kind of persistent storage unit to support offline work. Offline work also implies that mobile applications must, at some point, synchronize the data stored locally on the device with the data stored on the LMS (Trifonova and Ronchetti, 2004).

To sum up, extending LMS to the mobile scenario transforms the LMS into a web platform that must provide services to mobile devices usually using web service technology.

Lehner and Nosekable (2002) did one of the first studies about mobile devices interacting with virtual campuses. In this study, m-learning complements traditional learning. The *Welcome* system was developed to offer access to certain contents and services (such as calendars or events) of the virtual campus of the *Regensburg University* using mobile devices. The communication between the virtual campus and the mobile device is done mainly using SMS messages.

Triffonova and Ronchetti (2004) and Colazzo, Molinari, Ronchetti and Trifonova (2003) make a classification of the services and functionalities of a LMS. LMS functionalities are separated in four groups: data resources, e-learning specific services, common services (such as authentication, authorization or event management) and presentation of contents. They also identify the main issues of a LMS's architecture that may be considered when these services are offered to a mobile device. These architectural issues are: 1) context discovery (the system must check automatically the mobile device features and decide which services may be provided), 2) adaptation of contents and 3) synchronization between the mobile device and the LMS. This work presents a custom-made LMS developed in the University of Trento that follows this architecture in order to support mobility.

Hinkelman (2005) developed in Japan, a module of Moodle 1.6 to do testing using mobile devices. This version mainly offered testing services and feedback to students. Due to technological issues, this project was developed to work with Japanese mobile phones (because the tool is based on CHTML and 98% of the Japanese mobile phones supported this language). Afterwards, (Cheung *et al*, 2006) presented a study to adapt Moodle to mobile devices centred in the adaptation of contents.

The *Open University* has been working on Moodle extensions to mobile devices for quite a long time. Students (as habitual mobile device users) promoted this initiative since they were asking to access Moodle from their mobile devices. In 2009 they presented Mobile VLE for Moodle, a m-learning application to access Moodle from mobile devices. This application provides a subset of Moodle functionalities to be accessed by means of a mobile device. This selection was done by popular polls to students. Students rated very high the following LMS functionalities as candidates to be provided as services to mobile devices: assessment scores, messages (read course messages and unread forum posts), tasks ('*tick-boxes*' to see the progress of course activity), planning (see current week and its tasks, also the following weeks and the whole course) and resources (read resources from mobile devices and download if it is supported by the mobile phone) (Thomas, 2010).

Momo (*Mobile Moodle*) and MLE (*Mobile Learning Engine*) projects developed m-learning applications to access some Moodle 1.9 functions (Momo, 2008; MLE, 2009). The Momo m-learning application is based on J2ME (Java 2 micro edition, a java version for mobile devices) while the MLE project developed a J2ME client application and an additional web version to access Moodle courses from mobile browsers. Some of the Moodle modules/activities supported by this project are the following: lesson, quiz, task, resource, forum, survey, choice, wiki (read only), database (search and query) and message.

Project MPage develops a Moodle 1.9 client for iPhone (MPage, 2010). Some of the Moodle modules/activities supported by this project are the following: view course categories, access MyMoodle, edit events, access to resources in different formats, chat, choice, forum and Quiz.

The MLE and Mpage projects are designed as Moodle hacks (a solution to add functionality or fix a system that is inefficient, inelegant, or even unfathomable, but which nevertheless works). Both systems offer their main functionality using the Moodle block (Blocks are items which may be added to the left, right or centre column of any page in Moodle). MLE re-implements the logic of some Moodle services to offer them to mobile web clients using XML plus CSS (Cascading Style Sheets) mobile. This XML code may be parsered by a middleware server called Gateway to provide data to the J2ME native application. The Mpage system offers two proprietary mobile applications that access the Moodle data using a proprietary web service. It rewrites part of the Moodle code to offer its functionality to mobiles.

Moviltest is a J2ME application to download Moodle 1.9 tests and execute them in the mobile phone. After finishing the test, the results can be sent back to the Moodle server (Cosme, Pedrero and Alonso, 2008). The tests and their questions are extracted from the Moodle database and stored in a XML file on the Moodle server, which is accessed afterwards from the mobile client application (using a server URL) to download the tests and their questions.

Moodle.org has published a list of functionalities for an iPhone client for Moodle. The main functionalities they want to offer are the following:

- To upload video, audio and other file formats to the user's private space in the Moodle server.
- To view courses where the user is enrolled as well as to view other users enrolled in the same courses.
- To view activities and content of a course and to download these contents to the mobile client.
- To view student grades, to make grade assignments and to download these assignments.
- To receive notifications from the Moodle server, as well as to create and send new internal email messages.

- To view forums, discussions and create and reply posts.
- To view calendar events and assignment deadlines.

The current version of the prototype designed by *Moodle.org* only allows uploading files to the user's private space in the Moodle server, view course participants and view the list of activities and contents of a course.

2.2.2 Integrating External m-learning Applications into the LMS

The second scenario is based on the integration of external m-learning applications into the LMS. Since most LMS are not service oriented, any attempt to integrate external applications with the LMS must be done ad hoc. This approach has important disadvantages such as the difficulty in maintaining and extending the new integrated system or the limited impact of these solutions (Alier, Casany and Piguillem, 2009; Alier *et al*, 2010a).

Very few m-learning experiences to include features of external applications into the LMS have been found. Among them, Chan and Ford (2007) presented a project to integrate m-learning e-portfolios with Moodle. In this project they used mobile phones to take pictures, videos or audio recordings to recover evidences of a fieldwork to create an e-portfolio. An e-portfolio is a tool to digitally store evidences of the knowledge acquired by a student during their learning process, and they can be used to evaluate the student's learning evolution. Moodle is used as a repository to store evidences recovered by students as well as the place where teachers could create assignments. Moodle provides to teachers an administrative tool to evaluate students and to deliver assignments and other activates. Some Web 2.0 tools such as Flickr or YouTube repositories have been adapted to Moodle.

Ryad and Ei-Ghareeb (2008) designed a service-oriented architecture to integrate mobile assessment activities into the LMS. A special activity that supports mobility is created inside the LMS. The students that must do the assessment test, access this activity and receive in his/her mobile phone the list of questions s/he must answer. Once answered, responses are sent to the LMS using SMS messages.

Martin *et al* (2009) and Martin, Díaz, SanCristobal, Gil, Castro, Peire and Boticki (2010) propose the M2Learning framework to build advanced mobile applications mainly to facilitate access to sensors and multimodal interfaces in remote or virtual labs. These m-learning applications send the results of the learning process (e-portfolio) to the Moodle platform. M2Learning also includes a context m-learning application based on twitter. This m-learning application communicates with the Moodle Blog service.

2.2.3 Summary of Related Work

Table 1 summarizes the above proposals of related work. The first part of the table summarizes the proposals for the first scenario, and proposals related to the second scenario are summarized afterwards. For each one, we state its main characteristics.

In the first scenario, all projects propose to extend the LMS functionality to mobiles devices. The work of Triffonova and Ronchetti (2004) and Colazzo *et al* (2003) defines the main issues that an architecture to extend the LMS to mobile devices must consider. Although these issues are valid, they do not consider other important problems such authentication to the LMS from mobile devices, logging of information generated in the mobile device and authorization. Finally, the integration of the mobile plug-in in the LMS architecture (the connector that allows the LMS to

Proposal	Main characteristic of the proposal
LMS to Mobile	
Lehner and Nosekable (2002)	Communcation between LMS and mobiles via SMS
Triffonova and Ronchetti (2004)	Define an architecture to extend the LMS to info mobility
Hinkelman (2005)	Used only in Japan
Thomas (2010)	Select the Moodle features to be used from mobile devices from LMS log analysis and pools to students
Momo/MLE	Moodle Hack works on version 1.9. Part open source
Mpage (2010)	Moodle hack. Works from version 1.6 to 1.9. Mobile client not open source
Cosme *et al* (2008)	Used only to do tests. Not an integration proposal
Moodle.org	Very limited functionality
Mobile to LMS	
Chan and Ford (2007)	Mobile phones used to take pictures or capture video to create a e-portfolio in the LMS
Ryad and Ei-Ghareeb (2008)	Create a special activity in the LMS course to be used from mobile devices
Martin *et al* (2009, 2010)	Used to access sensors in remote or virtual labs

Table 1: Summary of different proposals involving m-learning and LMS integration

support mobile clients) must be designed in order to be maintained and evolved as easily as possible.

The MLE, Mpage, Cosme *et al* (2008) and Moodle.org projects have several drawbacks. On one hand, some of them try to create a clone mobile LMS allowing most of the LMS functions in mobile devices, without taking into account limitations of mobile devices such as data input or screen size. On the other hand, they are not extensible platforms where additional services may be added. They cannot be updated easily when a new Moodle version is published because they are hacks and finally they are not well-integrated with the Moodle internal subsystems (such as security or authentication subsystems).

The Cosme *et al* (2008) project is a massive data extraction process to extract the quiz questions from the Moodle database to export them to mobile devices. It is not an integration proposal but a data extraction proposal. Thomas (2010) presents neither architecture details of their system nor webservices specifications.

In the second scenario, all projects propose to integrate m-learning applications with the LMS. Chan and Ford (2007) use mobile devices to take pictures or videos that are attached when a task is answered. The last two proposals of the table provide mobile assessment creating a special activity for mobiles in the LMS.

3. Moodbile

This section describes the main goals of the Moodbile project, an initiative designed to open up the LMS Moodle to the mobile scenario. First, we describe the previous work done in adapting Moodle to the service paradigm. Second, we define the analysis requirements of the project. Third, we describe a layered architecture to adapt Moodle to the service paradigm. Finally, two m-learning applications designed to validate the architecture are presented as proof of concept as well as a pilot test.

3.1 Project Definition and Motivation

The Moodbile project aims to enable mobile learning applications (and other kinds of applications for education) to work together with the LMS. Moodbile is an open source project. The LMS Moodle is used as host LMS platform in the first stage of the project. Rather than just creating mobile applications that replicate the LMS functionalities on a mobile device, Moodbile provides the developers of applications for education with the necessary tools to interact with the LMS (http://moodbile.org).

Moodbile is a project initiated by the SUSHITOS Research Group of the Universitat Politècnica de Catalunya – BarcelonaTech (http://sushitos.essi.upc.edu) in collaboration with the GRIAL Research Group of the Universidad de Salamanca (http://grial.usal.es/). Some members of the SUSHITOS Research Group have been involved with the Moodle.org community since 2004, participating in the development of the Moodle 2.0 Wiki, the Webservices subsystem and the IMS LTI consumer.

The motivation of the Moodbile project is to open up the most commonly used e-learning platforms and LMS, originally designed as monolithic or layered systems, to the service paradigm. This work is an interoperability solution to extend LMS to other environments such as the mobile world. Its aim is to contribute in adapting LMS to the current generation of e-learning 2.0. Its first LMS target is Moodle.

To communicate Moodbile with the LMS, some Moodle functions and features are redesigned as services and they may be used to integrate external applications into Moodle. For example, to create a mobile client for Moodle or to customize Moodle services in widgets in order to create *Personal Learning Environments* (PLE) (García-Peñalvo, Conde, Alier and Casany, 2011).

3.2 Why Moodle?

Open Source (OS) LMS platforms are suitable for universities and other learning institutions because (Itmazi *et al*, 2005) 1) they allow learning institutions to have the control of their software, 2) the cost of using the license is very low and 3) OS licence allows any change, modification and improvement on the LMS. On the other hand, one of the main drawbacks of OS LMS is that if any organization modifies the source code too dramatically, the ability to upgrade to future versions is compromised (Machado and Tao, 2007).

According to the study performed in the United States by Wexler *et al* (2008), Blackboard and Moodle are the LMS with higher market quota, even though Moodle has a greater satisfaction among users than Blackboard. In our project, Blackboard has been discarded and we chose Moodle since it is an open source LMS.

There are several studies that analyse and evaluate OS LMS. The *Centre d'Educació I Noves Technologies* (CENT), at University Jaume I of Castellón assessed an evaluation of some OS LMS to select an e-learning platform to improve educational processes of the University. Some of the LMS considered were ATutor, Moodle and .LRN. The final report proposes to use Moodle as a virtual learning platform, because it offers better didactic features, its modular design pays more attention to user interface and the degree of openness and dynamism is higher (CENT, 2004).

Graf and List (2004) made OS e-learning platform evaluations based on the following criteria: active communication, a stable level of software development, quality of documentation and didactic principles. Moodle reached the first position followed by Dokeos, .LRN, Ilias and Sakai.

Based on Aberdour (2007) criteria, Black, Beck, Dawson, Jinks and Diplietro (2007) performed a study in primary and secondary education. The best LMS was Sakai followed by Moodle, Atutor and Ilias. Although Moodle has a greater visibility, it is not the most advanced software for primary and secondary education. Sakai has better results in accessibility and integration with external administration systems.

Considering these studies and our involvement in the Moodle community, we selected Moodle for the first step of our work. Moodle is a good candidate since it is the most used open source LMS, it is supported by a large international community, it has been translated to more than 75 languages and many Spanish educational institutions (our universities too) use it (Alier *et al*, 2010a; Aberdour, 2007).

3.3 Previous work

3.3.1 The Campus Project

The Campus Project (http://www.campusproject.org), promoted by the Government of Catalonia's *Secretaria de Telecomunicacions i Societat de la Informació* (STSI), was the initiative of several Catalan universities, which came together to create a virtual open source campus infrastructure. The Campus project had to bind in the same open source *Virtual Learning Environment* (VLE) up to 23 different educational existing applications developed by the project partners. The VLEs used in the campus project were Moodle and Sakai (Santanach, Dalmau, Casado and Alier, 2007; Santanach, Gener and Almirall, 2007).

The general idea was to be able to launch external applications from the LMS providing external applications with the basic user authentication and authorization information. Besides, the external application had to provide logging information (i.e. students' activity) to the LMS.

The campus project was designed as an integration platform of e-learning applications and was based on a service-oriented architecture (SOA). Part of the architecture consisted in the creation of a web service layer for Moodle so that Moodle could provide external applications with authorization and authentication information. The OKI (*Open Knowledge Initiative*) OSIDs (OKI, 2002), IMS AF (*IMS Abstract Framework*) (IMS AF, 2003) and TI (*IMS Tools Interoperability*) (IMS LTI, 2012) were used as framework to integrate all these applications in the LMS.

3.3.2 The Moodle Webservices Architecture

Moodle is composed of three major elements: the *Core*, the activity *Modules* and the *Plugins*. The *Core* includes the basic functionality of the learning platform and from Moodle 2.0 these functionalities are offered as a more structured API (Application Programming Interface). Activity *Modules* implement the educational activities such as the forum, wiki, lesson and assignment. Moodle also allows third party activity *Modules* to be created. *Plugins* are pieces of software that add concrete extensions to the system. Inside Moodle, different plugin interfaces may also be found. One of these interfaces is the *Webservice Interface*, which is extensible and guarantees the system scalability in terms of communication protocols.

Based on the experience of the Campus project, in 2008 the SUSHITOS research group designed a solution to enable Moodle to provide some of its functionalities using webservices. This solution was the *Moodle Webservices Architecture*, which has been implemented for Moodle 2.0 and released in late 2009 (Alier *et al*, 2009). Moodle 2.0 only incorporates a few webservices from the many available, while Moodle 2.2 will add several more services. Moodle 2.0 provides tools to extend webservices in a standard way so that third-part webservices could be added to the system.

The *Moodle Webservices Architecture* adds two logical layers to Moodle's architecture (shown in Figure 1). The first one, called *Moodle External API* is a set of php files that include the logic of each service. The second one is the *Webservices Connectors* layer. The *Moodle Webservices Architecture* is not bound to a specific webservices protocol; it is designed to be protocol independent. For each supported protocol (SOAP, REST, XML-RPC, etc.) there is a specific webservices connector module in this layer. Each webservices connector implements the translation of the methods implemented in the Moodle External API to the specific protocol and syntax. Additionally, the *Webservices Connector* also provides other necessary services as authentication, authorization and other infrastructure services. The *Webservices Connectors* layer is an extendible layer that allows the addition of new communication protocols.

A key element in the design of the *Moodle Webservices Architecture* is its extendibility based on plugins. The *Moodle External API* can be extended in a safe way, giving full security control to the Moodle administrator. If a new kind of webservices protocol or authentication method (such as Oauth as it happened) is needed, a developer can create a new webservices connector to implement it.

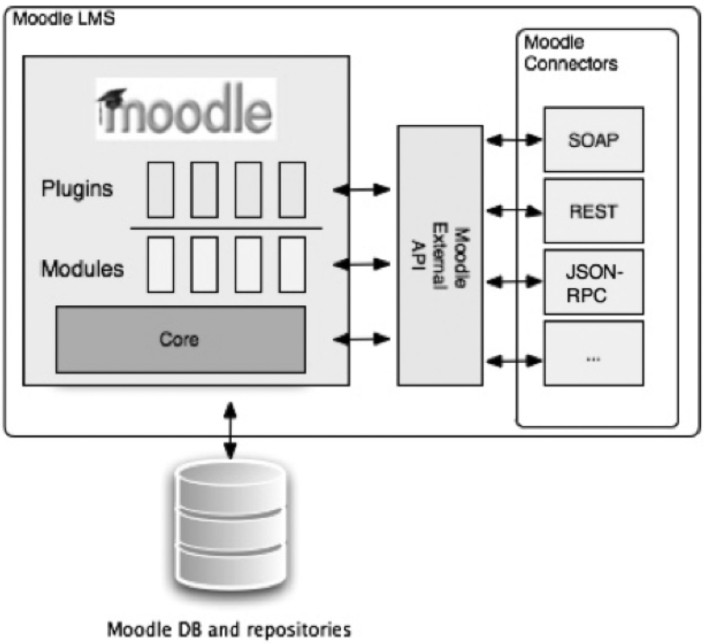

Figure 1: Moodle webservices architecture

3.3.3 Moodle Webservices, not enough

The *Moodle Webservices Architecture* released with Moodle 2.0 in 2010 enabled a collection of webservices that made easier the integration of Moodle with other systems. But these webservices where not designed for integration with mobile devices and other learning applications. Moodle 2.0 focused on developing an API suitable for massive batch actions like user or course creation and inscriptions. This kind of method is not suitable for mobile or external applications.

On the other hand, security management is also an open issue to be considered. The *Moodle Webservices* can be configured to work just with a specified IP address and other security measures that are not designed for multiple clients with non-fixed IP's or non-secure wireless connections.

Therefore, Moodbile project was initiated to design a Moodle webservice extension that would turn Moodle into a webservices provider for mobile applications solving these limitations.

3.4 Moodbile Requirements

The *Moodle External API* layer described in the previous section provides only basic services such as course enrolment, group and user management, etc. This layer does not provide services to access additional Moodle features such as activity modules or plugins. Therefore, it must be extended to provide additional services to allow mobile application interact with the LMS.

Our goal was not to create a web-service layer to access every single Moodle activity feature, but to design an extension of the *Moodle Webservices Architecture* that provides access to the most suitable Moodle features for mobile applications. To gather these features two information sources have been used: 1) the related work and experiences of other projects (some of them described in Section 2), and 2) a log analysis of the Moodle server of our university: Universitat Politècnica de Catalunya – Barcelona Tech. Analysing the Moodle logs we found that the most performed activities from mobile devices were: view course resources, view course activities, do quizzes, participate in forums and upload assignments (Casany, Alier and Mayol, 2012). Therefore, we identified that the most accessed Moodle features accessed from mobile devices are as shown in Table 2 below.

Finally, in the first step of the Moodbile project we have included the following features: view course activities, view course participants, view student's grades, view resources, view and

	From Related Work	From UPC Moodle log Analysis
Internal Message	x	
Forum posts	x	x
Forum discussions	x	x
Task /assignment	x	x
Resource	x	x
Choice and quiz	x	x (quiz only)
Course activities (view)	x	x
Course participants (view)	x	
Grade (view)	x	

Table 2: Most used Moodle features

upload assignments, access forums and discussions, read and reply posts, do quizzes, view upcoming calendar events and view user profile.

3.5 Moodbile's Architecture

This section proposes the necessary extension of the *Moodle Webservices Architecture* to provide additional webservices to integrate mobile applications. This extension should be compatible with the *Moodle Webservices Architecture* and must evolve and be maintained independently with the minimum effort. The *Moodle Webservices* is maintained and evolved by Moodle community and is distributed through the Moodle official releases. Therefore, our extension which we call *Moodbile Connector* will be developed, maintained and tuned to work with Moodle official releases. This extension has been released as open source and as part of the *Moodbile Server for Moodle*.

Since the Moodbile Connector is an extension of the Moodle *Webservices* architecture, it is composed of the same two layers: the *External* API layer and the *Webservices Connectors Layer* (Casany, Alier, Conde and García-Peñalvo, 2009; Conde, García-Peñalvo, Casany and Alier, 2009).

The *External API Layer* is an extension of the *Moodle External API*. This layer can basically access methods from the standard Moodle *External API* and the Moodle core. In this layer is where the actual services for mobile integration are defined.

The *Webservices Connectors* layer is used to provide additional webservice protocols and authentication methods such as Oauth (Oauth, 2010). Webservices connectors translate methods implemented in the External API to specific protocols.

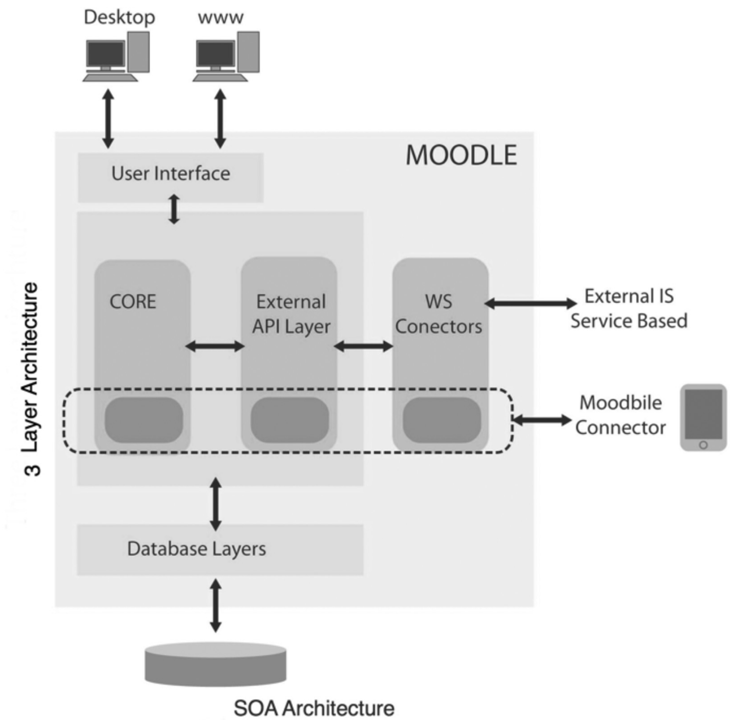

Figure 2: Moodbile Connector Architecture

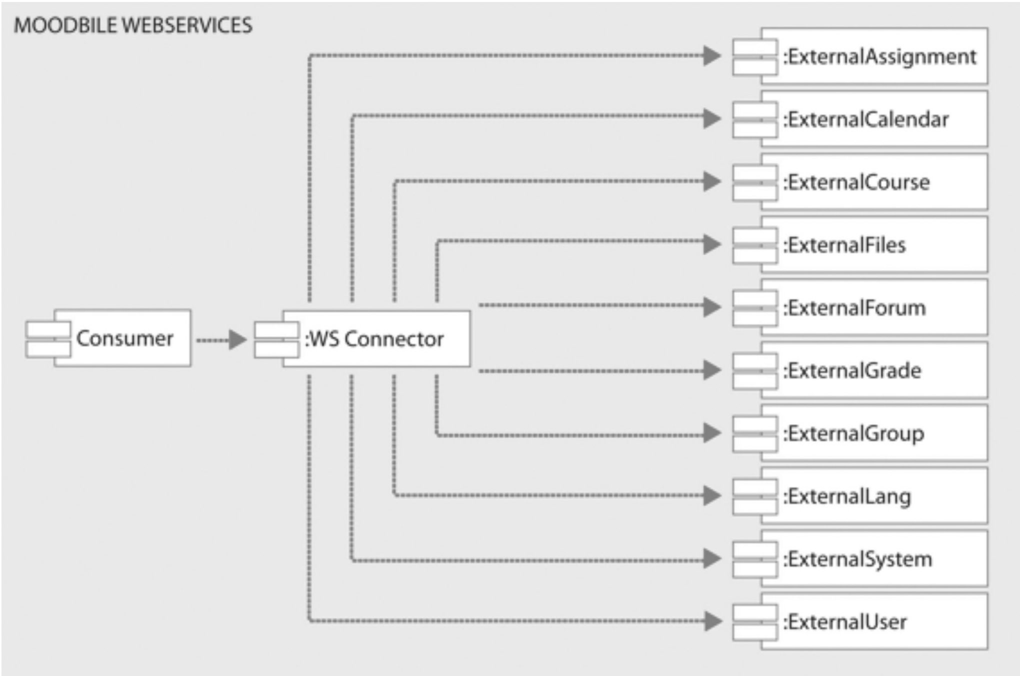

Figure 3: Moodbile services

In addition, for implementation purposes, Moodbile adds an extension of the *Core* layer that re-implements some features that the Moodle core does not provide properly to be used by Webservices. This extension also adapts minor features specific to Moodbile that are not provided by the Moodle core. For future Moodle versions part of this extension is scheduled to be developed by Moodle. Figure 2 shows the Moodbile Connector architecture.

A List of the services designed for the Moodbile project are shown in Figure 3. In this diagram the consumer is the mobile learning application that accesses the External API Layer using a webservice connector protocol as an intermediary. The services in the diagram are grouped by contexts such as forum, user, group, grade, course etc. There are other webservices such as FilesWebServices and LangWebServices that are used to manage files and languages respectively.

Additionally, the Moodbile architecture shown in Figure 2 takes into consideration relevant issues in the integration of m-learning applications with Moodle. These issues include mobile data synchronization with the Moodle server or logging issues. These issues are represented graphically as components in Figure 4. This figure also shows the interaction of these components with the layers of the presented architecture extension. The purposes of these specific components re summarized next:

1. Synchronization (sync) manager: is responsible for data synchronization between the Moodle server and the mobile client application (in case the client uses persistent storage).
2. Log manager: is responsible for managing the data-log generated in the client application (such as learning activity) that has to be logged in the LMS for further analysis (learning analytics techniques).

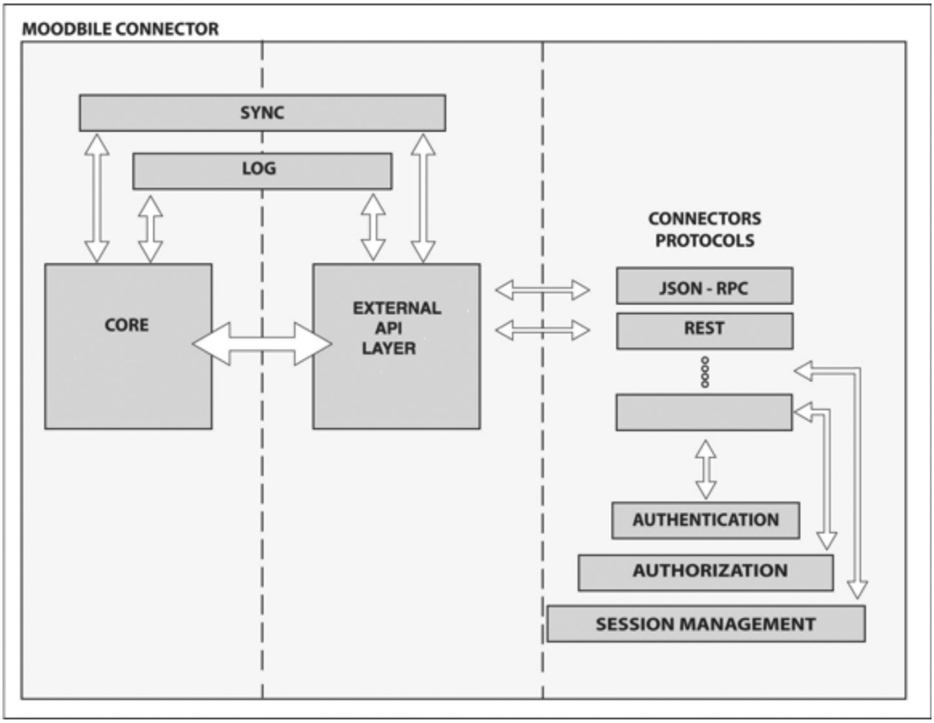

Figure 4: More specific Moodbile Connector components

3. Authentication manager: every connector protocol is responsible for managing user authentication. Every connector may implement the authentication protocol they wish.
4. Authorization manager: is responsible for managing user authorization. Moodle authorization system is based on a set of privileges that a user must have to access every single function. The authorization process is so complex that it is a transversal task to all the Moodle and Moodbile layers. Moodbile connector must check among other things that the user that requests to call a webservice has the appropriate capabilities as well as check that these capabilities are available for the communication protocol used in the call.
5. Cache manager: when a user logs in a Moodle server, the system does many checks to get the courses (and all the related information) where the user is enrolled. This process takes some time and to optimize it Moodle uses the HTML session to keep this information on memory after it is retrieved the first time. The next accesses to user courses are then optimized because the related information is already on memory. In the design of the Moodbile connector authors will implement a similar session mechanism to optimize information retrieval.

3.6 Validating the Proposal

To date two mobile clients have been developed for Moodbile. A HTML 5.0 mobile client application developed to access Moodle services from a web browser on most smartphones in the market and an android-native application. These clients validate the Moodbile architecture. Both client applications implement most of the functions described in 3.4. The HTML5 client uses CSS3

(Cascading Style Sheets) to create a lightweight client and the Android-native applications support online and offline work when network coverage is not present or expensive. The Android-native application has a persistent data storage for the contents retrieved from the Moodle server. When working offline this feature allows a quick access to the local contents using a memory cache. The synchronization with the Moodle server is under development.

An implementation of the Moodbile Connector has also been developed as a plug-in for Moodle 2.0.x. This server implementation supports additional webservices communication protocols (such as JSONP or JSON-RPC plus OAUTH authentication protocol) to the ones supported by Moodle natively (i.e. AMF, SOAP or REST).

Moodbile's current version provides alternative clients for Moodle designed to be used in mobile devices. We have conducted a pilot test to determine if providing an alternative way to access the Moodle classroom has a positive or negative impact, or does not impact at all in the learning process. The context of the pilot has been a Project Management Subject in the last year of the University of Salamanca Computer Science Degree. Specifically 40 students that use Moodle during the subject have been involved. During the pilot experience, the teacher proposed the students to post in a forum using their critical opinion about a method to estimate project costs based on use case complexity.

The methodology used during this pilot experience is a quasi-experimental design (Campbell and Stanley, 1963; Campbell and Stanley, 1970). This methodology is adequate for these kinds of tests, since we have pre-established groups (class-groups) of users and it is not possible to have a complete randomized group of people (Dendaluce, 1994; Nieto and Necamán, 2010). Quasi-experimental design implies the definition of a scientific hypothesis that is checked using an experimental and a control group. In both groups the same tests are applied, a pre-test at the beginning of the experiment and a post-test afterwards. The students of the experimental group test the system (that is to say they participate in a subject using Moodbile), while the students in the other group do not (this different treatment for both groups will define the independent variable). After running the experiment, data is analysed by using probabilistic techniques to validate the proposed hypothesis.

The scientific hypothesis of this experiment has been "The students value as a positive asset to have a mobile friendly version of the LMS for their learning". From this hypothesis the next dependent variable is defined "The impact of the introduction of Moodbile in the classroom". To operationalize the dependent variable, some asserts (also known as items) have been proposed to the students and they have graded their agreement using five value levels (1=strongly disagree, 2=disagree, 3=indifferent, 4=agree, 5=strongly agree).

- In the pre-test:
  - I.1 Sometimes I use my Smartphone to access to Moodle and its resources.
  - I.2 I use my mobile device to learn through online tools and some mobile applications.
- In the post-test:
  - I.3 The application of online tools, mobile native applications and Moodle functionalities into the mobile device, help me to learn.

The scientific hypothesis is going to be accepted if the results of the pre-test are similar in both groups (which prove that both groups are similar and have a common knowledge and background) and the results of the post-test between the students involved in the experimental

Pre-test results for Student's T test						
$VD_{pretest}$	$\overline{X_E}$	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
Post-test results for Student's T test						
I.3	4,05	0,759	3,35	0,988	2,512	0,016

Table 3: Results of Student's T statistical tests

group and the control group are different (those who have tested the tool should answer in a different way). So the following hypothesis for both groups is proposed H_0: $\mu_E = \mu_c$, meaning that the distribution of the experimental and control group for the assertion considered is similar. To check this hypothesis, two statistical tests are applied, the Student's T for independent samples test and the non-parametric Mann-Whitney U test. The second test is applied to check the results of the first one, because in the experiment only 40 students have participated, and this number is near to the limit for the application of T Student's test. Another reason to use the Mann-Whitney U test is that the scale used to measure students' perception is not exact (it is an ordinal scale). The results of the first test can be seen in the Table 3. In Table 3, the average for the experimental and control groups ($\overline{X_E}, \overline{X_c}$), the standard deviation for the experimental and the control group (S_{X_E}, S_{X_C}), the result of the contrast test (t) and the bilateral signification (ρ) are included.

Table 3 shows that in both pre-test items (I.1 and I.2) the hypothesis is validated (that is, the experimental and control groups answer more or less the same) and in the post-test (I.3) the initial hypothesis is rejected (so the results between 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 around 2 or 3, which means that most of them do not use mobile devices to access Moodle or other learning tools. It is also interesting to consider the average of the experimental group in the post-test (4,05) which shows that the students who tested the system consider it useful for learning. These results are also corroborated by the Mann-Whitney U test, shown in Table 4. Therefore, we can conclude that the initial hypothesis is accepted: "The students value as a positive asset to have a mobile friendly version of the LMS for their learning".

To support this conclusion a short poll about the experience was posed to the students of the experimental group. The question posed was the next: "After using the Moodle forum through a mobile device I consider export tools like that to mobiles make it easier to follow discussions and participate in the forum, so my learning is improved and the forums use is in my opinion more attractive". The 85% of the students agree or strongly agree with the assertion, they consider useful to export this kind of functionalities.

Pre-test results for 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 Mann-Whitney U test		
I.3	0,017	Reject null hypothesis

Table 4: Results of Mnan-Whitney U statistical test

In order to take into account the teacher's opinion several semi-structured interviews have been conducted. On them, the system is presented to the teachers, and afterwards their opinion is requested. The results are: 1) 70% of the teachers agree or strongly agree with the exportation of institutional functionalities to mobile devices in order to improve students participation and enrich institutional learning. The other 30% consider that it is not easy to have mobile devices involved in all kind of learning contexts.

4. Discussion

The Moodbile project aims to propose an interoperability solution to integrate m-learning applications with the LMS, starting with Moodle. The Moodbile connector is an extension of the *Moodle Webservices Architecture* that has the following advantages regarding other approaches: 1) it is an extensible architecture where new services may be added easily, 2) it supports the addition of new communication protocols (for example the JSON-RPC connector was implemented to add a lightweight protocol that can be used efficiently from a mobile phone), and 3) it may be easily updated when a new Moodle version appears. Finally, the Moodbile project provides an open specification of services that could be implemented by other LMS and remains stable with independence of the Moodle version.

5. Conclusions and Further Work

M-learning enhances collaborative learning and increases learning flexibility by allowing it to be more personalized and student-centred. But on the other hand, m-learning faces interoperability problems with LMS (the basic e-learning infrastructure of many educational institutions). The Moodbile project aims to propose an interoperability solution to integrate m-learning applications with the LMS, incorporating m-learning applications into the learning process of educational institutions. This will allow m-learning applications to widen their scope instead of being isolated from the learning process. It also will allow LMS to be more flexible e-learning platforms.

Although there are several solutions to this lack of integration problem, Moodbile aims to propose an open specification of webservices to support the integration of external applications with the LMS. The initial version of the specification works for Moodle, but authors are working to adapt this specification to other LMS such as Sakai and Olat, to create an LMS-independent specification. Since this specification is open-source, it is open for developers of third-part applications to use it. Authors are also working in the design of special m-learning activities inside the LMS. These activities are intended to be used from mobile devices, but are created inside the LMS.

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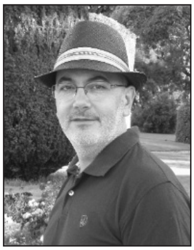

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