



PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE  
ESCUELA DE INGENIERIA

# **A CLOUD-BASED MOBILE SYSTEM TO SUPPORT EFFECTIVE COLLABORATION IN HIGHER EDUCATION ONLINE COURSES**

**JUAN SEBASTIÁN ROJAS RIETHMÜLLER**

Thesis submitted to the Office of Research and Graduate Studies in  
partial fulfillment of the requirements for the Degree of Master of  
Science in Engineering.

Advisor:

**ANDRÉS NEYEM**

Santiago de Chile, (January, 2017)

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*To my parents*

## **ACKNOWLEDGENTS**

Firstly, I would like to express my gratitude to my advisor Prof. Andrés Neyem for the continuous support during my postgraduate studies, for his constant guidance, motivation, and knowledge.

Besides my advisor, I would like to thank Prof. Mar Pérez, who has closely followed this work. Her insightful comments and encouragement helped me greatly during my research.

Finally, I must express my very profound gratitude to my parents for providing me with unfailing support and continuous encouragement throughout my years of study. Without them, none of my accomplishments would have been possible.

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## RESUMEN

Actualmente existen más de cuatro mil cursos MOOC ofrecidos mediante distintas Plataformas MOOC. Estas plataformas son robustas y soportan grandes volúmenes de datos y un alto número de usuarios. Debido a estas características, las instituciones de educación superior han adoptado estas plataformas para extender las prácticas del aula tradicional. La forma más común en que adoptan estas Plataformas MOOC, consiste en desarrollar cursos online exclusivamente para sus estudiantes. Estos cursos reciben el nombre de *Small Private Online Courses* (SPOCs), y solo pueden ser accedidos por un número reducido de estudiantes de dicha institución. El uso de las Plataformas MOOC permite a las universidades innovar y tener más flexibilidad en sus currículos. Sin embargo, estas plataformas no están preparadas para promover el aprendizaje colaborativo entre los estudiantes, ya que no cuentan con las herramientas necesarias. Respecto a este problema, *Mobile Cloud Computing* (MCC) ofrece varias ventajas para diseñar un sistema que promueva la colaboración entre estudiantes de educación superior, pero estas ventajas no han sido aprovechadas. Entonces, esta investigación se enfoca en el desarrollo de un sistema basado en MCC para promover la colaboración entre estudiantes en una Plataforma MOOC, en el contexto de la educación superior. Se siguió una metodología de *Design Based Research* para recopilar información, y producir y testear prototipos funcionales de manera iterativa e incremental. El sistema resultante es MyMOOCSPACE, un sistema MCC que incluye dinámicas de colaboración enriquecidas con elementos de gamificación. Se realizaron evaluaciones para medir la usabilidad y el efecto en la colaboración de MyMOOCSPACE. Los resultados de usabilidad muestran que los estudiantes se sintieron a gusto interactuando con el sistema, que logra también cumplir los requerimientos técnicos. Finalmente, los resultados muestran que MyMOOCSPACE logró generar un aumento en la colaboración y las interacciones entre los estudiantes.

Palabras Claves: MOOC, SPOC, Aplicación colaborativa, Mobile Cloud Computing, Sistema móvil, Aprendizaje Colaborativo, Aprendizaje Móvil

## **ABSTRACT**

Nowadays, there are more than four thousand MOOC courses offered through different MOOC Platforms. These platforms are robust, and support large volumes of data and a large number of users. Because of their characteristics, higher education institutions have adopted these platforms in order to enhance traditional classroom practices. The most common way in which higher education institutions use MOOC Platforms is through the development of online courses exclusively for their students. These courses are called Small Private Online Courses (SPOCs), and they can only be accessed by a reduced number of on-campus students. The use of MOOC Platforms allows universities to innovate and have more flexibility in their curriculums. However, these platforms are not prepared to support collaborative learning among students, because they lack the necessary tools. In response to this problem, Mobile Cloud Computing (MCC) offers several advantages for designing a system that promotes collaboration among higher education students, but these capabilities have not yet been exploited. This research focuses on the development of an MCC system to support collaborative learning among students on a MOOC Platform, in the context of higher education. A Design Based Research methodology was followed to gather information and to iteratively and incrementally produce and test functioning prototypes. The resulting system is MyMOOCSPACE, an MCC system that includes collaborative dynamics enhanced with gamification elements. Evaluations of usability and collaboration enhancement of MyMOOCSPACE were performed. Usability results show that students felt pleased while interacting with the system, and it fulfills the technical requirements for a collaborative tool in education. Finally, results also show that MyMOOCSPACE allowed increasing collaboration and interactions among students.

**Keywords:** MOOC, SPOC, Collaborative Application, Mobile Cloud Computing, Cloud-based Mobile System, Collaborative Learning, Mobile Learning.

## **PUBLICATIONS FROM THIS DISSERTATION**

### **Journal Papers**

Ramirez-Donoso, L., Rojas-Riethmuller, J. S, Perez-Sanagustin, M., Neyem, A, & Alario-Hoyos, C. MyMOOCspace: A Cloud-based Mobile System to Support Effective Collaboration in Higher Education Online Courses. *Submitted to Computer Applications in Engineering Education*

### **Conference and Workshop papers**

Ramirez-Donoso, L., Perez-Sanagustin, M., Neyem, A., & Rojas-Riethmuller, J. S. (2015). Fostering effective collaboration in MOOCs through mobile apps. *2015 CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON)* (pp. 401-408). IEEE.

Ramirez-Donoso, L., Rojas-Riethmuller, J. S, Perez-Sanagustin, M., & Neyem, A. Enhancing collaborative learning in higher education online courses through a mobile app game. *Submitted to International Conference on Computer Supported Cooperative Work in Design (CSCWD 2017)*

## 1 INTRODUCTION

Massive Open Online Courses (MOOC) are a type of online course that have gained significant popularity in recent years. As their name suggests, they are massive, which means they are aimed at a large-scale audience, and they are open, meaning anyone can sign up to these courses for free. They are also fully available online, and no face-to-face attendance is required. Also, they have an organized structure that the student should follow to advance through the course contents.

The history of MOOCs is very recent, the term having first appeared in 2008 to refer to a course entitled “*Connectivism and Connective Knowledge*” developed by Stephen Downes and George Siemens. Nearly 2300 students from around the world participated online. However, it was not until 2011 that MOOCs gained worldwide popularity. That year, Norvig and Thrun launched the course “*Introduction to Artificial Intelligence*” with an initial enrollment of 160,000 students. That same year, Stanford University offered three courses online and for free. Coursera ([www.coursera.org](http://www.coursera.org)), which is a for-profit technology company that offers MOOCs, was founded in 2012. Other organizations such as Udacity and Udemy were founded that same year (Baturay, 2015). Later, in 2013, edX ([www.edx.org](http://www.edx.org)), a non-profit organization that runs on open-source software, was created by MIT and Harvard University. Other platforms that offer MOOCs are the European Future learn and Iversity, among others. As of December 2015, there were more than 10 different platforms that offer MOOC courses, closely working with the most prestigious universities from around the world to offer their courses. There are more than four thousand courses available, and more than 35 million students have enrolled in a course (Shah, 2015).

As a result of their characteristics, universities have adopted MOOC Platforms in recent years as a resource for supporting blended learning methodologies (Pérez-Sanagustín, Hilliger, Alario-Hoyos, Kloos, & Rayyan, 2016). Small Private Online Courses (SPOC) are among the most common in this area (Delgado Kloos et al., 2014). SPOCs are a variant of MOOCs, but they are private and small, with closed and limited enrollment to smaller groups of students. Some initiatives are the TORQUEs project at ETH Zurich (Zurich, 2014), MIT’s Office of Digital Learning ([www.odl.mit.edu](http://www.odl.mit.edu)) and the

engineering courses at the Pontificia Universidad Católica de Chile, available at (<http://online.ing.puc.cl/>). The use of MOOC Platforms offers universities great opportunities and versatility to innovate in their curriculum.

However, these platforms are not prepared to support certain practices that are commonly carried out in traditional face-to-face education. Specifically, these platforms are very limited in their ability to facilitate collaboration among course participants (Guerrero & Domínguez, 2014). An analysis on the typical structure of a course reveals that most of them rely heavily on theoretical content, mainly based on text and video lectures as audiovisual complementation. This applies regardless of which MOOC Platform the course is hosted on. Moreover, most platforms include very limited tools for supporting collaboration, with forums and peer review activities being the most common (Manathunga & Hernández-Leo, 2015). Solving the lack of collaboration tools on MOOC Platforms is a relevant issue, as collaborating with another person strengthens learning (Breslow et al., 2013) and increases the student's positive attitude towards interacting with the course. It also creates bonds between course participants, which in turn contributes to increasing motivation (Sánchez Vera & Prendes Espinosa, 2014).

The research area that studies how people learn collaboratively through technology is called Computer Supported Collaborative Learning (CSCL) (Dillenbourg, Fischer, Dillenbourg, & Fischer, 2007). Although various authors have provided their own definitions for collaboration, they all agree that it is a process by which individuals negotiate and share meanings relevant to the problem-solving task at hand (Guitert & Pérez-Mateo, 2013), in which communication and interaction are key aspects. Also, as noted by Driscoll & Vergara, in order to achieve collaboration, it is necessary to cooperate in the carrying out of a task that cannot be accomplished individually (Driscoll & Vergara, 1997).

According to a study by Concari, the emerging technologies that will have a big impact in higher education in upcoming years will be, among others, mobile platforms and apps, game-based learning and MOOC/SPOC courses (Concari, 2014). It should be inferred that people will increasingly use their mobile devices to access course contents; as such, researchers are looking at ways to potentiate the relationship between MOOC Platforms and mobile devices (Sharples, Kloos, Dimitriadis, Garlatti, & Specht, 2015).

Mobile Cloud Computing (MCC) emerges as an attractive way to build this relationship (Rao, Sasidhar, & V. Satyendra, 2012) and to implement the lacking collaborative aspect. Mobile devices fulfill the requirements to promote collaboration (Stieglitz, Lattemann, & Brockmann, 2015) and the cloud offers educational institutions efficiency and costs benefits (Mehta, Danawade, Bulla, & Bhojannawar, 2016). Another concept that has had a positive impact in education in recent years is gamification, which is the inclusion of game mechanics in a non-game situation (Hamari, Koivisto, & Sarsa, 2014).

Following the trend of universities adapting MOOC Platforms for private use, the lack of tools to facilitate collaboration present in those platforms, and considering the emerging technologies in higher education, the research question arises: *How can we extend and enhance effective collaboration among students in a MOOC Platform in the context of higher education?*

This work proposes combining the areas of MOOC platforms, mobile devices and gamification to create an innovative solution to promote collaboration among students on a MOOC Platform in higher education. In this context, the overall objective of the thesis is the design, development and evaluation of a game-based mobile application called MyMOOCSPACE, implemented using MCC and aimed at supporting effective collaboration within online courses. The specific objectives are:

- To design and implement the cloud-based mobile system to facilitate effective collaboration among students.
- To test mock-ups of the system iteratively to reach a final design.
- To design the experiments and measurement instruments for testing the system.
- To evaluate the usability and collaboration enhancement capabilities of the implemented system.

The current chapter of this thesis is structured as follows: Section 1.1 presents a literature review on effective collaboration in CSCL, mobile technologies and game mechanics in online education environments and MCC implications in educational environments. Section 1.2 presents the methodology applied in this research. Section 1.3 presents the design of MyMOOCSPACE, its architecture and play dynamics. Finally, Section 1.4 describes the organization of the rest of the thesis.

## **1.1 Enhancing collaboration in higher education online courses**

This section presents a literature review of CSCL and relevant aspects on how to encourage collaboration in online courses. In recent years, the explosive growth of mobile technologies has led to a change in the way people access learning contents, with ubiquitous access being the increasing trend. Mobile devices and their capabilities have been further enhanced due to the inclusion of cloud-based architectures that expand their storage and processing power, creating a powerful opportunity to use them in learning contexts.

### **1.1.1 Effective collaborative learning in online courses**

Collaborative learning, the central focus of this research, is a relevant and highly important factor in achieving motivation and subsequent student participation on online platforms (Claros, Garmendía, Echeverría, & Cobos, 2014). Studies have shown that collaboration among students encourages bonding and makes students feel part of a learning community (Sosa, López, & Díaz, 2014); this in turn contributes to increasing students' motivation. It also enhances learning and increases grades (Breslow et al., 2013).

According to a study that analyses tools and mechanisms supporting collaboration in MOOC Platforms, there is a shortage of mechanisms that encourage collaboration and interaction among participants (Citadin, Kemczinski, Veloso de Matos, Cebrián Robles, & Duarte Freitas, 2014). The typical course design is based on theoretical content, which consists mainly in text material, with videos as audiovisual complementation. (Citadin et al., 2014) analyzed the major MOOC Platforms and found that the most common tools to support collaboration are forums and peer review activities. They also analyzed the tools included in these platforms using the 3C collaboration model (Fuks, Raposo, & Gerosa, 2007), which considers three dimensions that should be present in a collaborative tool: communication, cooperation and coordination. The results of this analysis show that the current tools used in online courses serve mainly to support: (1) asynchronous communication, such as forums; (2) asynchronous coordination; (3) cooperation through wikis and peer review activities, although the latter is only present in Coursera and edX. Thus, collaboration is only addressed superficially in these types of activities, and students



feel that true collaborative work is not carried out and that there is no sense of belonging to a learning community (Sosa et al., 2014). Furthermore, (Antunes, Herskovic, Ochoa, & Pino, 2014) identified that certain design elements answer specific needs of a collaborative application. Table 1-1 shows relevant collaborative design elements, their main function, and whether or not they are present in some of the major MOOC Platforms.

Table 1-1: Collaborative design elements in major MOOC Platforms

Design Element	Main function	Presence in major MOOC Platforms					
		Coursera	edX	Udemy	Udacity	FutureLearn	MiriadaX
Chat	Keep a shared sense of goals and achievements	No	No	No	No	No	No
Forum	Support the concept of “virtual place”	Yes	Yes	Yes	Yes	Yes	Yes
Sharing material	Allow the sharing of resources	No	No	No	No	No	No
Wikis	Provide public objects and resources	No	No	No	No	No	No

In the area of collaboration and CSCL, important mechanisms that help encourage collaboration should be highlighted. (Johnson & Johnson, 1999) proposed that there are certain key aspects for an activity to be considered collaborative:

- i. **Positive interdependence:** the perception that we are linked to others in a way so we cannot succeed unless they do.
- ii. **Individual responsibilities** for each student.
- iii. **Interaction** between group members.
- iv. **Social skills** must be promoted and students should be taught leadership, decision-making and communication, among others.
- v. Students must move forward as a group towards a **common goal**.

In the MOOC Platforms currently available on the market such as Coursera, edX, Udacity and Future Learn, among others, there is no direct support for the key aspects of collaboration mentioned above. From the studies that have analyzed collaboration capabilities in these platforms, it can be concluded that they are limited in their capacity to provide effective collaboration tools for students. Consequently, there is an opportunity to generate a positive impact by providing the means to facilitate interaction and collaboration among students in these platforms. By allowing students to collaborate, improved group learning and higher levels of learning according to Bloom's taxonomy can be reached (Valcke, Wever, Zhu, & Deed, 2009).

### **1.1.2 Encouraging collaboration through mobile technology and gamification**

In the past few years, mobile devices have had an explosive growth. In fact, a study mentions that mobile technologies will have a significant impact in education (Concari, 2014). They allow ubiquitous access to educational content, allowing students the freedom to learn without the limitations of a fixed time and location. This new way of learning has been named mobile learning (or m-learning) (Crompton, 2013). The disruptive implications of mobile technologies in this field has caused researchers to believe that the future of online courses is linked with the development of mobile technologies and has led them to investigate and propose solutions to generate collaboration through the use of mobile devices (Cheong, Bruno, & Cheong, 2012). In fact, more than 75% of students use their mobile devices to access online courses (De Waard, 2013). However, despite this trend of mobile access to education, a study of 22 MOOC Platforms revealed that only 4 of them had mobile apps for Android or iOS available on the PlayStore or AppStore (Grund & Cacheiro, 2015), showing that there is much work to be done to enhance the relationship between mobile technologies and MOOC Platforms. Table 1-2 shows the availability of a mobile app for the major MOOC Platforms and the collaborative design elements they include.

Table 1-2: Major MOOC Platforms Mobile Adaptability

MOOC Platform	Android/iOS App	Collaborative design element in mobile app			
		Chat	Forum	Share Material	Wiki
Coursera	Yes	No	Yes	No	No
edX	Yes	No	Yes	No	No
Udacity	Yes	No	No	No	No
Udemy	Yes	No	Yes	No	No
FutureLearn	No	-	-	-	-
MiriadaX	No	-	-	-	-

The use of mobile devices also serves to increase students' awareness (Herskovic et al, 2012), which can be defined as “an understanding of the activities of others, which provides a context of your own activity” (Dourish & Bellotti, 1992). (Antunes et al, 2014) identify awareness as an “important component of collaborative technology that helps user conducting interaction processes”. Mobile devices offer intrinsic capabilities to satisfy this, such as allowing different modes of communication and a high level of mobility (Herskovic, Ochoa, Pino, & Neyem, 2011).

Currently there are only a few tools, either mentioned in the literature or available to the public, that aim to foster the relationship between online courses in MOOC Platforms and mobile devices. MyLearningMentor (Alario-Hoyos et al, 2015) and GroupMOOC (<http://www.groupmooc.com/>), are two examples of mobile applications that aim to provide help in organizing students' tasks and activities within a course. Another proposed solution is AttentiveLearner (Pham & Wang, 2015), an intelligent mobile learning system that analyzes students' attention level using the device's camera and back sensors. The conducted literature review exposes that most proposals focus on individual learning and study habits, and only a minority favor teamwork and collaboration. One such system is proposed by (Sun & Shen, 2014), which aims to facilitate team work by providing a learning flow through a series of cloud services. Their results show that teamwork and collaboration can be positively affected by a mobile system.

Along with mobile technologies, another concept that has had a positive impact in the context of education is gamification, which consists of introducing game mechanics in

non-game situations (Hamari et al., 2014). The inclusion of game elements like points, timed tasks, levels or having an achievement system have proven to increase students' motivation and engagement in an educational context (Cheong, Cheong, & Filippou, 2013; Fitz-Walter, Tjondronegoro, & Wyeth, 2011). A report made by the observatory for educational innovation (Monterrey, 2016) on gamification, lists of the most common game dynamics and their objectives in an educational context (see Table 1-3).

Table 1-3: Game dynamics and their objective in an educational context

<b>Game dynamic</b>	<b>Objective in educational context</b>
Challenges and missions	Applying knowledge and performing specific tasks
Choosing between different paths or alternatives; tasks against time	Makes the student work on decision-making, problem solving, and creativity
Working in teams	Enhances collaborative work
Multiple opportunities to perform an activity ("life system")	Resilience and frustration tolerance
Levels	Offers students a sign of progress towards an objective
Badges and points	Rewards students' positive behavior

A study by (Anderson, Huttenlocher, Kleinberg, & Leskovec, 2014) analyzed how the inclusion of badges as a way of implementing an achievement system affected students' behavior in online courses. The results showed that it increased engagement and participation. Furthermore, game mechanics can enhance the social aspect of an application, and be used to promote interaction among participants (Simões, Redondo, & Vilas, 2013), making it an interesting option in the promotion of collaboration (Deterding, Dixon, Nacke, Sicart, & O'Hara, 2011).

When it comes to the relationship between gamification and online courses, there have been some proposals (Anderson et al., 2014; Romero, 2013), but they do not incorporate the game aspect into the core of the course. On the other hand, a very detailed

study was performed by (Borras-Gene, Martinez-Nuñez, & Fidalgo-Blanco, 2016). Their results show that implementing gamification in a MOOC Platform can enhance the motivation of participants. However, there are limitations, as integrating gamification into a course may be a difficult process depending on which MOOC Platform it belongs to.

Finally, the gamification-mobile relationship is without doubt a very developed area. There are many globally popular apps falling into this category, such as Waze, Foursquare or Duolingo. The proliferation of mobile apps that use game mechanics provides more evidence that gamification serves to increase user's motivation and engagement.

Summarizing, the current literature shows that **gamification** and **mobile devices** are an effective option to generate interaction among students in **online courses**. Although there are proposals to foster relationships between two out of the three aspects, we could not find a solution that combines these three concepts. There is therefore an existing gap that creates interesting research opportunities.

### 1.1.3 MCC applications in education

Cloud Computing (CC) refers to a computational model where processing and storage are not handled in the client device, but by a remote machine on a data center known as a *cloud*. It aims to deliver services, software and processing capacity over the internet, reducing cost, increasing storage, automating systems and providing flexibility and low coupling between services (Kovachev, Cao, & Klamma, 2011). This model brings a series of innovations compared to traditional computing: the appearance of seemingly infinite resources available on demand; allowing companies to start small and increase hardware resources as needed; and the ability to pay only for the resources used and release or increase them as needed (Armbrust et al., 2010).

There are three types of services that can be provided by CC, which are classified according to the abstraction level of the capability provided (Sultan, 2010). The first is Infrastructure as a Service (IaaS), where a full computer infrastructure is offered (i.e. servers, storage, networks, operating systems). The second one is Platform as a Service (PaaS), where the necessary tools to create an application or software are provided through the Internet. Finally, in Software as a Service (SaaS), an application is deployed and

delivered over the Internet. Figure 1-1 shows how these different service models would be managed from an educational institution perspective.

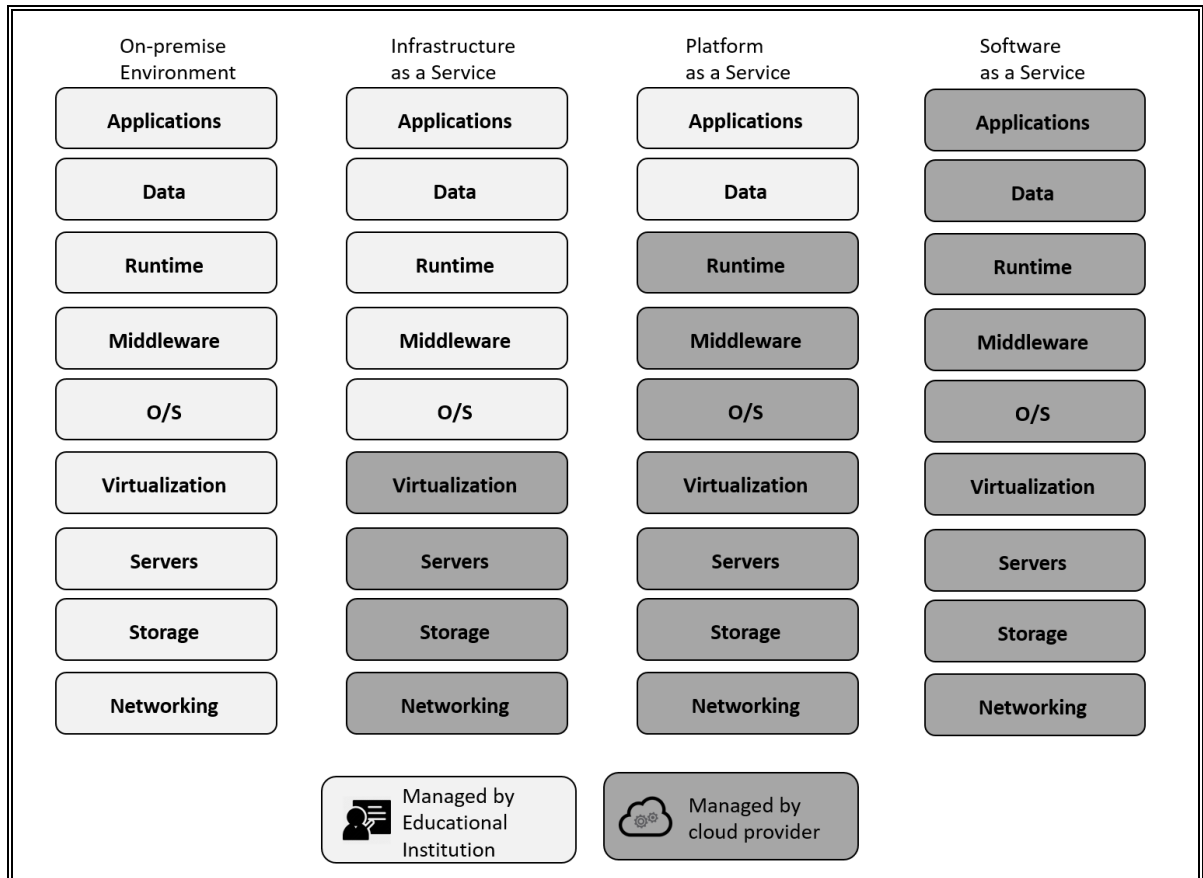


Figure 1-1: Cloud computing service models

There are many requirements that an IT department of a university must be able to fulfill, from providing each student and staff member basic functionalities (e.g. mail accounts), to having specialized software for researchers, developers and students (Sultan, 2010). Therefore, universities should constantly be on the lookout for new technologies that provide the broadest feasible and equitable solutions for students, academics and staff (Ercan, 2010). Cloud computing offers an attractive option for higher education institutions, as most of their requirements can be migrated into the cloud in one of its different service models. Also, there certain characteristics of IT demands in universities that correspond to typical use cases of cloud computing, such as a demand for the provided

services that varies with time (Armbrust et al., 2010). All information systems will be extensively used during an academic semester, but demand will fall during students' vacations. Introducing cloud computing not only produces important cost reductions, it also allows higher education institutions to concentrate more on teaching and researching than on configuring complex IT systems (Mircea & Andreescu, 2011).

Regarding this, Mobile Cloud Computing (MCC) aims towards using cloud computing techniques for storage and processing of data on mobile devices, extending their intrinsic capabilities (Chetan, Kumar, Dinesh, Mathew, & Abhimanyu, 2014). This becomes relevant following the explosive growth of mobile devices in recent years. According to (Cisco, 2015), more than 500 million mobile devices and connections were added in 2015, and the average smartphone use grew by 43%. By 2020, it is estimated that there will be 1.5 times more mobile devices with an Internet connection than people on the planet, and mobile data traffic will be 8 times what it is today. There is also evidence that applications will require more compute intensive capabilities, which also translates into heavier battery usage (Bahl, Han, Li, & Satyanarayanan, 2012). Therefore, the need to offload into the cloud arises, to provide users with a satisfactory experience while interacting with the applications on their mobile devices (Dinh, Lee, Niyato, & Wang, 2011).

As mobile devices become more important in people's lives, so do their implications in education. Mobile devices have been identified as one of the most impactful technologies in education in upcoming years (Concari, 2014). People will increasingly use their mobile devices to access educational content, and researchers are looking at ways to potentiate the relationship between MOOC Platforms and mobile devices (Sharples et al., 2015). However, as (Dinh et al., 2011) note "traditional m-learning applications have limitations in terms of high cost of devices and network, low network transmission rate, and limited educational resources". Mobile devices with augmented capabilities via CC can surpass these limitations, and have a huge impact in the way education is delivered, producing positive changes in learning behaviors and accessibility of learning opportunities (Rahimi, et al, 2014). MCC also allows for facilitating communication among students, and between teachers and students (Zhao, Sun, & Dai, 2010). The huge impacts that MCC can have in education has led to research being done to propose

frameworks that consider the factors that affect the learning experience and outcome of the learners (Gurung, Alsadoon, Prasad, & Elchouemi, 2016). Finally, m-learning through MCC is centered on the student, making it possible to have ubiquitous access to educational resources, and allows for collaborative interactions, promoting social learning perspectives (Mehta et al., 2016).

## **1.2 Methodology**

The objective of this research is to identify a way to enhance collaboration among students on a MOOC Platform in higher education. To propose a solution that can be practically applied, the problem must be studied in its natural context, that is, with real students in higher education institutions. Therefore, in the process of researching and designing the proposed cloud-based mobile system, the Design Based Research (DBR) methodology was used (Wang & Hannafin, 2005). As Barab & Squire stated: “DBR is a series of approaches, with the intent of producing new theories, artifacts and practices that account for and potentially impact learning and teaching in naturalistic settings” (Barab & Squire, 2004). There are four main characteristics to DBR (Gibelli, 2014):

- i. The decision to place the research in the natural context.
- ii. The purpose of producing specific changes in that context
- iii. The option for systemic approaches
- iv. The cyclic and iterative nature of the designs

Hence, DBR is an methodology that meets the requirements for the present research; to study a single learning environment as it passes through multiple iterations to develop new theories, mechanisms and practices that can also generally be applied to other MOOC Platforms (Barab & Squire, 2004). Using DBR allows this research to list the requirements needed to start the design of the proposed system before starting the development phase. It then allows iteration, by evaluating each prototype until a final system design is achieved (see Figure 1-2).



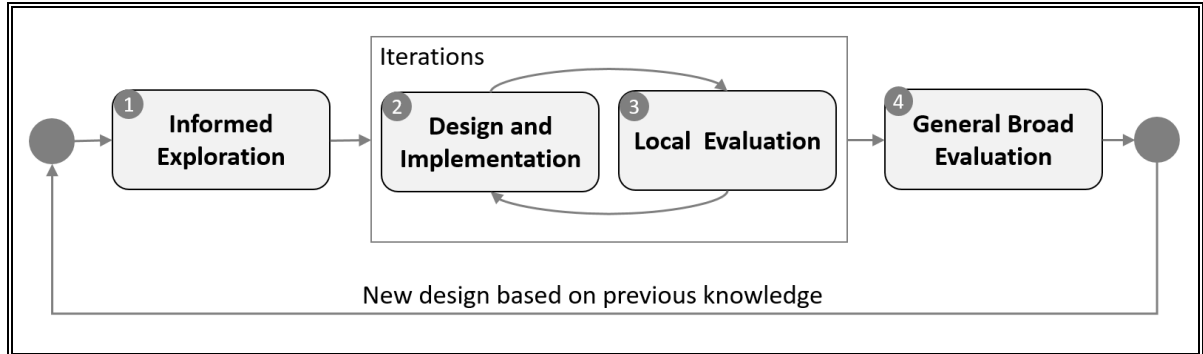


Figure 1-2 Design Based Research, adapted from (Wang and Hannafin, 2015)

In the Informed Exploration stage, several requirements arose from performing an extensive literature review in the topics related to collaboration in learning environments, CSDL and gamification. Also, the system's key architectural features were considered in this stage, by reviewing the state of the art in mobile technology applied to education. It was in this stage that the benefits of implementing an MCC architecture in the context of this work were discovered.

Once the collaboration and architectural aspects were explored, stage two, Design & Implementation, could be started, marking the beginning of the iterative process. During the first iteration, a mock-up of the system was built, where the aspects that promote collaboration (Johnson & Johnson, 1999) were integrated with game mechanics. In this iteration, a sample User Interface (UI) was designed, to be tested before implementing a functional prototype. Stage three was then carried out for the first time; in this stage, feedback was obtained from students who used the mock-up UI. This allowed for improvements to be made regarding usability and user experience, and for validating the dynamics and the proposed aspects of collaboration.

A second iteration consisted in the development of the MCC architecture, resulting in a functional mobile application with the backend running in the cloud (Chetan et al., 2014). The requirements and behavior of the system were tested, and improvements were made according to the results obtained. A third iteration consisted in testing the application with a group of students working in groups using a real SPOC course to gather data on the usability of the implemented system. A fourth iteration was conducted in order to study

how the collaboration and game dynamics of the application affected collaborative and interactive behavior among students.

The work and results of the first and second iterations are presented in detail in section 1.3 and the third and fourth iterations are presented in chapter 2, in a research article sent to *Computer Applications in Engineering Education*.

### 1.3 Distinctive features of the implemented solution

The implemented solution to enhancing collaboration in higher education online courses consists of a cloud backend and a mobile application. It aims to promote collaboration among students, using elements of gamification. In the design of the platform, three aspects of collaboration (Johnson & Johnson, 1999) were addressed via gamified dynamics. These aspects motivate students to work together toward a **common goal**, generating **positive interdependence** within the team and creating **individual responsibilities** for each student for the benefit of group progress. Also, a fourth aspect of **interaction and communication** was addressed by allowing students to communicate through an internal chat. This section presents an overview of the system's architecture (a full description of every component is presented in chapter 2), the game dynamics involved in MyMOOCSPACE and the use of the cloud backend in our solution.

#### 1.3.1 Architecture overview

The architecture of the system is based on the computational model Mobile Cloud Computing (MCC), where most of the application's logic is contained in services stored in the cloud, following the Mobile Backend as a Service (MBaaS) concept. The user's mobile devices connect to the cloud backend through REST APIs. It is through this connection that data and information is passed from the local device to the backend and stored. All communication is established using an Internet connection. This computational model makes it possible for both the storage and the processing of data to be carried out outside of the mobile device with the objective of saving resources (Chetan et al., 2014). In this case, we identified that a CMS is the best architecture for confronting the challenges that arise when designing a system dedicated to providing educational services via mobile devices. This is due to that fact that this architecture facilitates the development of

collaborative applications (González-Martínez, Bote-Lorenzo, Gómez-Sánchez, & Cano-Parra, 2015) and allows students to access and share centralized and updated information from anywhere in the world, provided that they have an active Internet connection. At the other end of the cloud backend is the MOOC Platform, managed by a higher education institution, which contains course information (e.g. content and questions) that needs to be extracted in order to store it in the database of our system.

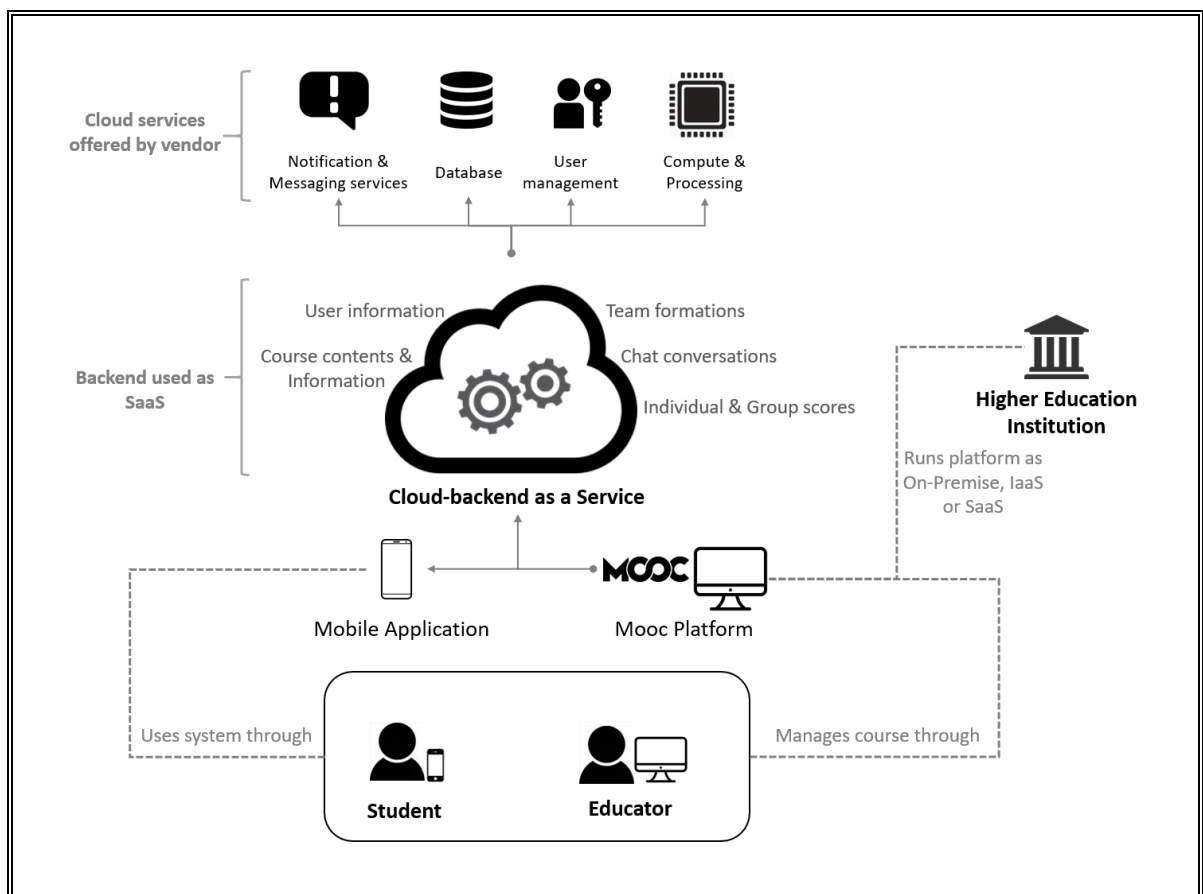


Figure 1-3: Proposed solution's architecture and use

Our proposed solution can achieve consistent information by extracting the course contents from the MOOC Platform, and storing them in our cloud database. The implemented architecture proposes that the core features (teams and user information regarding the course) are built into a software that has its logic and storage in the cloud, but are accessed through APIs by the mobile application. Following this model, students

who interact with the mobile application, and educators who interact with the course through the MOOC platform, see our solution as a SaaS, as shown in Figure 1-3. Further detail on the use of the CBaaS, and the benefits of using it in our solution are explained in section 1.3.3.

### 1.3.2 Mobile application dynamics

The MyMOOCSPACE dynamics are given by a spatial circuit, set up in stages and played in teams. Each team is composed of 3 or 4 participants randomly selected from the online course. The objective of the game is for each team to answer the highest number of multiple choice questions or alternative questions in the shortest amount of time possible. All questions are taken directly from the online course. The more answers the team answers correctly and the shorter the amount of time they take, the higher the score the team is awarded (Cheong et al., 2012, 2013).

The team can advance through the stages of the game if and only if each member has correctly responded to at least one official question. Given that each team member must contribute in order to continue moving forward in the game, we connect the aspects of collaboration to both **individual responsibility** and a **common goal**. The stages of the game are represented as planets that correspond to different modules or weeks of the online course.

The official question corresponds to the question that each team member should answer in the shortest possible amount of time. This question is what will earn the team points. The participants can practice while other team members are answering official questions. The practice mode lets participants answer practice questions without losing lives or points. All team members must answer the official question. If the time comes to answer the official question and the participant does not know the answer, they can pass the question on to another teammate before the time runs out so that the team does not lose points. However, if the participants answer without passing the question, they receive a badge. Upon passing the official question, the participant can only select teammates who have not responded yet. In this way, we link the aspect of collaboration with **positive interdependence**, encouraging interaction within the team to achieve the common goal in each stage.

Collaboration is fostered in the game when teammates are forced to support each other in order to answer the official question in the shortest possible amount of time. Collaboration is also promoted in practice mode, when the group begins to familiarize itself with its members' strengths and weaknesses. On the other hand, the application includes a chat feature as a fundamental tool for generating **interaction and communication** between the participants in a team. This tool links the dynamics of the game with the three aspects of collaboration in question, allowing students to foster greater communication to advance through the stages and overcome the difficulties of each planet's content.

MyMOOCSPACE includes a feature that allows viewing the team status relative to the rest of the participants. At any given moment, the team can compare itself against the other teams in the course, and students can even compare themselves against their own teammates using an internal ranking. The winning team is the one who wins the most points after having completed all the planets (course subjects). Each planet corresponds to a module of the online course, so it is proposed that at the end of the game, students would also finish the course, having completed the course's evaluations and demands.

In Figure 1-4 we see the design of MyMOOCSPACE's main screens. The participant can select the online course they want to play in (Figure 1-4a). Figure 1-4b shows the complete circuit of the selected course, in which each planet reflects an online course modules. Figure 1-4c shows how participants will get to know their team and how they can respond to the official question, along with the practice mode each teammate can use. Finally, Figure 1-4d shows how questions are displayed.

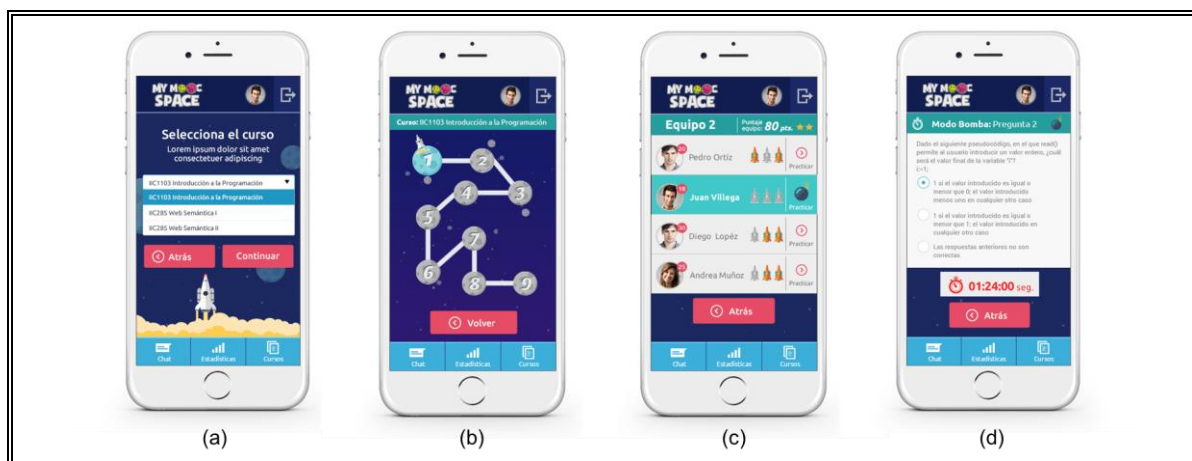


Figure 1-4: MyMOOCSPACE mock-up screens: (a) Selection of online courses; (b) Game track, showing the planets that must be completed; (c) Presentation of the team with the option to answer the official question; (d) Official question with alternatives

In these dynamics, we have addressed the three components from the 3C collaboration model (Fuks et al., 2007). The **communication** element is present with the inclusion of the chat. **Cooperation** is addressed because each student must complete certain tasks (e.g. answer an official question) in order for their team to advance. Finally, a group can achieve **coordination** by using the provided tools (e.g. the chat and passing questions between them) to know their teammates strengths and weaknesses, and using this internal knowledge to maximize their progress and score.

Table 1-4 shows the game dynamics present in MyMOOCSPACE, and the aspects of collaboration they were applied to. The **common objective** that students share is to advance through the course, which is represented in the game as completing each planet. **Positive interdependence** is needed among team members, as they cannot advance individually; instead, they have to do it as a group. Finally, each student is given **individual responsibility** for the group's performance, as every answer to the official question directly affects the group's score.

Table 1-4: Game dynamics applied to collaborative aspects

<b>Game dynamic</b>	<b>Collaboration aspect</b>		
	Common objective	Positive interdependence	Individual responsibilities
Working in teams	Yes	Yes	No
Levels	Yes	Yes	No
Tasks against time	No	No	Yes
Points, Scoreboards	No	Yes	Yes
Badges	No	No	Yes

### 1.3.3 Cloud BaaS

Information systems developed for an educational context must be able to fulfill certain requirements, such as being able to provide access to consistent information, having a high availability and being prepared for the number of users to grow. This means that information must be centralized, and that the servers used for this type of system must be able to scale and have backups that can activate quickly if the original server has a problem. As higher education institutions begin to adopt and use MOOC Platforms, they are faced with the option of either implementing and running the courses on servers of their choice or running all the functionalities directly from the platform's servers.

The first option is limited to certain MOOC Platforms, as some of them are open source and can be locally implemented (e.g. edX), but others are not (e.g. Coursera). If an institution opts to follow this path, it has yet another choice: to run the platform on a local server, or to use a cloud server. Running on a local server involves higher costs, as the institution is responsible for the operation and maintenance, but provides total control over the architecture. Running the platform from a cloud server benefits from the centralized information storage and scaling capabilities offered by cloud vendors; this option represents an Infrastructure as a Service (IaaS) model. However, both options (On-Premise

or IaaS) give the ability to edit certain functionalities of the MOOC Platform for better adjustment to the local context.

The second option involves running a course directly from the MOOC Platform provider (e.g. running a course from Coursera's or edX's own servers). By following this path, the course becomes Software as a Service (SaaS). In this case, the institution has access to the data and even to analytics, but cannot modify the structure or add functionalities to the platform. Universities have tended to run private or small courses on platforms they control (as On-Premise or IaaS) and leave courses with a larger audience on the MOOC Platform provider's server. This allows for a balance between platform control and reduction in implementation and architectural costs.

As our solution is directed towards supporting collaboration in MOOC Platforms in the context of higher education institutions, a cloud infrastructure makes sense, as it allows fulfilling the requirements of centralized storage, scaling of needed resources and user authentication, among others. Using a cloud backend in this case not only allows for extending the intrinsic capabilities of mobile devices (Chetan et al., 2014), but also facilitates the integration process of a specific MOOC Platform used by a certain university (The details surrounding the connection between a MOOC Platform and our CBaaS are explained in section 2.3). Finally, Figure 1-5 shows a sequence diagram of the process from extraction of the relevant information in the MOOC Platform to the user answering a question. In this diagram, it is clearly represented how the Cloud BaaS acts as the central component of the system, as it communicates both with the mobile application, and with the MOOC Platform.



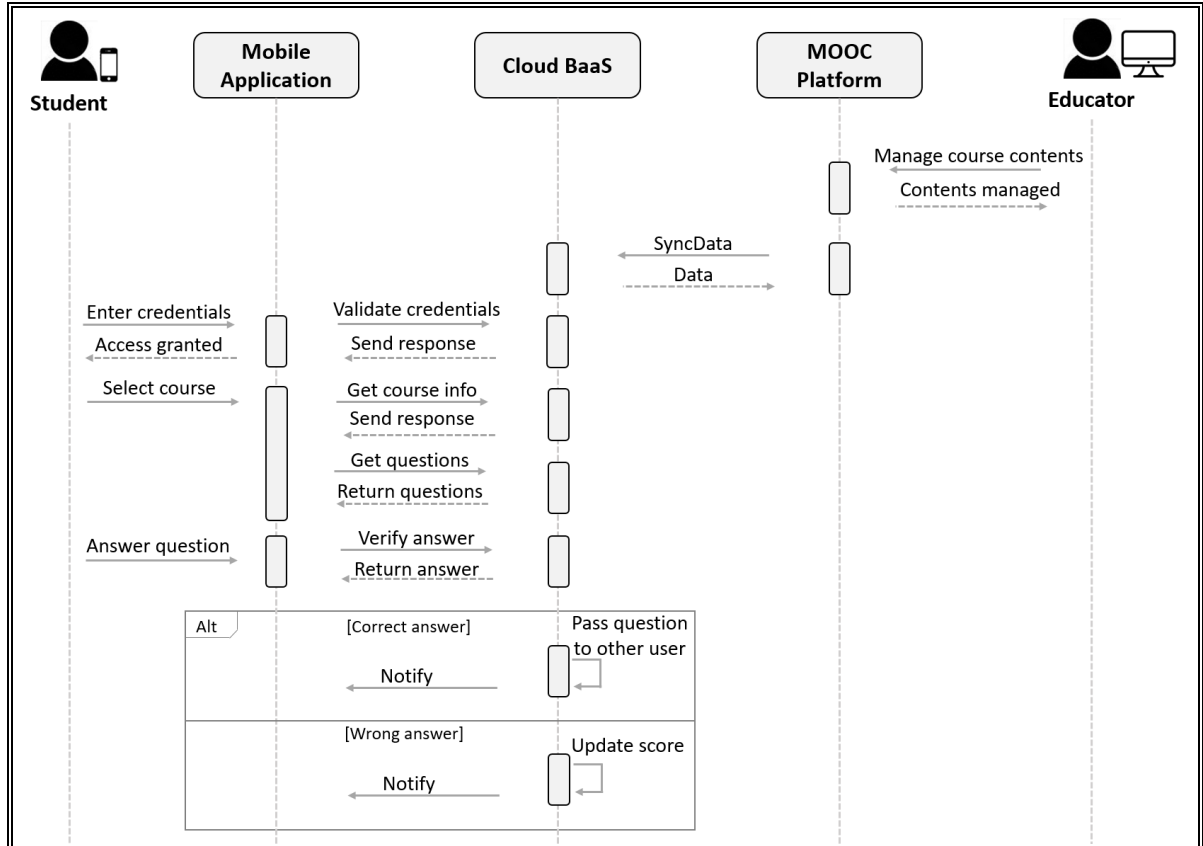


Figure 1-5: Sequence diagram showing interaction between mobile application, cloud BaaS, and MOOC Platform

## 1.4 Organization of the Thesis

This document is written based on the thesis by publication format, following the guidelines of the Office of Research and Graduate Studies from the School of Engineering.

The next chapters are structured as follows: Chapter 2 presents a research article sent to *Computer Applications in Engineering Education*, which presents the detail of every component of the architecture, and the usability and collaboration experiments that were used to evaluate the platform. Finally, Chapter 3 presents the conclusions and future work related to this investigation.

## **2 MYMOOCSPACE: A CLOUD BASED MOBILE SYSTEM TO SUPPORT EFFECTIVE COLLABORATION IN HIGHER EDUCATION ONLINE COURSES**

The content of this chapter is a research article submitted to *Computer Applications in Engineering Education* for publication.

### **2.1 Introduction**

In recent years, numerous universities have been offering Massive Open Online Courses (MOOCs) to thousands of students on several platforms, such as Coursera and edX, among others. Some of these universities have also adopted the platforms, technologies, and format of MOOCs as a resource for supporting on-campus blended learning methodologies. In this context, the concept of Small Private Online Courses (SPOCs) emerges. They are online courses for a controlled and reduced number of students that make use of the experience acquired in MOOCs (Claros et al., 2014), to innovate in the traditional learning environment (Delgado Kloos et al., 2014; Pérez-Sanagustín et al., 2016). The platforms where MOOCs (and SPOCs) are hosted (MOOC Platforms from now on) have been designed to scale according to the number of students, supporting great amounts of data and visits. However, these platforms present certain limitations regarding the development of certain traditional class activities, especially when it comes to supporting group work and collaborative learning activities (Guerrero & Domínguez, 2014).

The area of Computer Supported Collaborative Learning (CSCL) studies how to enhance collaborative learning through the use of computers. Within this area, effective collaborative learning can be defined as a situation where two or more people learn (or try to learn) something together, interacting through planned activities (Dillenbourg, 1999). Despite the fact that current MOOC Platforms have certain tools that promote interaction among peers in a MOOC (or SPOC), such as forums and peer review activities, the existing functionalities are not enough to generate effective collaboration that benefits

learning among students in a MOOC (Manathunga & Hernández-Leo, 2015; Sosa et al., 2014).

Some authors are trying to solve this problem from a pedagogical point of view, by proposing methodologies that promote collaboration in these types of platforms. For example, Collazos (2014) proposes a methodology based on monitoring and evaluation patterns of the collaborative learning process. Other researchers are trying to solve the lack of effective collaboration in MOOCs from a technological point of view, by proposing to extend the tools and functionalities that current MOOC Platforms offer. Many of these proposals are based on the use of mobile technologies, which have had a strong impact in higher education as an emerging technology (Concari, 2014; De Waard, 2011; Herrera & Fennema, 2011; Sharples et al., 2015). Finally, other authors choose to consider aspects of gamification to foster motivation and awareness of participation in the development of collaborative learning activities (Blanco-Izquierdo, González & Collazos, 2016). However, contributions that combine these three aspects to foster effective collaboration in MOOCs are very scarce in the literature.

In this paper, and taking as a reference the three points of view from prior work, we propose the following research question: *How can we design a technological solution to extend and enhance effective collaborative learning among students on a MOOC Platform?* To answer this question, we propose MyMOOCSPACE, a cloud-based mobile system aimed towards supporting effective collaborative learning on a MOOC Platform. In the design of this system, key aspects of effective collaboration according to the area of CSCL have been considered. During the process of design, implementation, and testing, we followed the Design Based Research (DBR) methodology, which proposes an iterative and incremental process that allows evaluating the system in a real context.

The remainder of this article is structured as follows. Section 2.2 presents the state of the art through a literature review on MOOCs and their relationship with CSCL, mobile technologies, and gamification. Section 2.3 presents MyMOOCSPACE as a technological solution to extend and enhance collaborative learning in MOOC Platforms. Section 2.4 presents an evaluation of MyMOOCSPACE based on three quasi-experiments that took place in four universities in Chile and Paraguay. Finally, section 2.5 presents the conclusions and future work of this research.

## 2.2 State of the art

This section presents the results of a literature review on studies in three areas: studies in Computer Supported Collaborative Learning (CSCL) that define the key elements for the development of effective collaboration in MOOCs; an analysis of works that use mobile technologies in MOOCs; and a review of articles that use gamification to enhance students' motivation in MOOCs. The results of this literature review provide the foundations for the design and implementation of MyMOOCSpace.

### 2.2.1 Computer supported collaborative learning

The area of CSCL, offers alternatives, tools, methodologies, and models to potentiate and enhance collaborative learning. In this area, important aspects to generate effective learning based on collaboration have been defined. According to Johnson & Johnson (1999), and Blanco-Izquierdo, González & Collazos (2016), there are fundamental aspects that must be considered to promote a collaborative learning environment. Among these key aspects, we can mention: (1) A **common objective** among participants of a course; (2) **Positive interdependence** between the actions of every participant; (3) **Interaction and communication** between participants; (4) **Individual responsibilities** for each individual; (5) Promoting **social skills**, such as leadership and decision making; (6) **Joint rewards** to generate incentives as a group; (7) Definition of the **type of activity** to be performed; (8) **Nature** of the participants; (9) **Heterogeneity** of the group; (10) The **period of collaboration** based on the time range in which the activities are performed.

Additionally, among the models that CSCL proposes to achieve effective collaboration is the 3C model (Fuks et al., 2007). This model suggests that tools that aim to enhance collaborative learning should support three dimensions: Cooperation, Coordination, and Communication. Using this model, Citadin et al. (2014) performed an analysis of the main MOOC Platforms. Their results show that the tools present in these platforms serve mainly to support: (1) Asynchronous communication via forums, (2) asynchronous coordination via messages and emails, and (3) cooperation via wikis and peer reviews.

These cooperation, communication and asynchronous coordination tools only allow generating superficial collaboration among the participants of a MOOC. This superficial collaboration occurs, for example, with peer reviews, as every time a mandatory activity that has to be evaluated between students, only little interaction is generated. Therefore, a collaborative environment is not built. It also occurs in forums, where a topic is proposed by a student for the rest to give their opinions, which produces only very limited interaction among learners (Citadin et al., 2014). Tools such as wikis generate only an environment of superficial collaboration, as they do not allow for a direct interaction among participants. Instead, they simply provide a virtual space where authors can enter and edit contents on a web platform. Another common tool used in MOOCs are emails. Emails are used only for unidirectional communication from the teacher toward the students, so they do not foster an environment of collaboration.

Therefore, current MOOC platforms lack enough tools to enhance effective collaborative learning (Citadin et al., 2014; Manathunga & Hernández-Leo, 2015). Furthermore, the low interaction and collaboration among the participants of a MOOC generates inequality in the process of knowledge construction, which in turn produces a greater distancing between students (Bratitsis, 2010; Guerrero & Domínguez, 2014). According to the principles of CSCL, by facilitating tools that promote interaction in a MOOC, a potential increase in active participation; therefore, a more effective collaboration among students will be generated (Dillenbourg, 1999; Hrastinski, 2008; Kreijns et al., 2004). Moreover, collaboration contributes to learning in work teams and represents a relevant aspect in the motivation and participation of students in a MOOC, also creating bonds between students (Anderson et al., 2014; Guerrero & Gros, 2013; Sánchez Vera & Prendes Espinosa, 2014).

### **2.2.2 Mobile technologies**

One of the approaches employed during recent years to support traditional and online education is mobile learning (m-learning). M-learning can be understood as a process that makes it possible for students to use the advantages that mobile technologies offer as a support for learning (Sharples et al., 2008). This support is associated to the rapid expansion in the use of mobile devices, the improvements in mobile technologies in recent

years, and the evolution of web-based technologies that facilitate the integration with mobile technologies (Conde, Muñoz, & García, 2008).

There are studies showing that the future of MOOC Platforms is associated with the increased use of mobile devices (C. González & Area, 2013). Accessing educational content through mobile devices would produce learning experiences that provide a continuity in the learning context (Wong, Milrad, & Specht, 2015). This refers to the idea of seamless learning, that students can continue their studies independent of their location, having easy access to information through their mobile devices (Sharples et al., 2015).

Various studies mention that mobile technologies can be useful for supporting learning in MOOCs. Some MOOC Platforms have made efforts to complement their services through mobile applications (e.g. Coursera, edX, Udacity). Nevertheless, these apps do not include complementary activities when compared with the original platforms; instead, they only serve as a new access channel to their courses. In this same vein, there are approaches such as MobiMOOC, a MOOC course based on m-learning (De Waard et al., 2011), where the platform is designed to allow students to access the course contents using their mobile devices. This experience shows that most students enrolled in the course used their mobile devices to access course content and activities as they could access these regardless of their present location or time.

There are other contributions that extend MOOC Platforms through mobile applications, and aim to enhance the interaction between MOOCs and students. Examples of these include GroupMOOC and MyLearningMentor (MLM) (Alario-Hoyos et al, 2015). GroupMOOC is an application that offers functionalities for organizing MOOC courses, in which students share their results. MLM is a prototype of a mobile app that provides personalized planning and goal-setting tools for students in a MOOC. Another interesting contribution in the mobile technologies and MOOCs environment is AttentiveLearner (Pham & Wang, 2015). This is a mobile learning tool optimized for displaying videos of a MOOC. It uses the device's sensors to determine the student's heart rate and infer their level of attention towards the video, generating an intuitive control of video reproduction.

From the examples discussed above, it can be seen that most of the existing m-learning approaches do not support learning as their main objective. Instead, they mainly aim at improving students' interaction with MOOC contents. However, some very recent

proposals (Manathunga & Hernández-Leo, 2016) have shown that there exists a potential to enhance learning in MOOCs through mobile solutions. This opens research opportunities for the development of mobile applications that interact with MOOC courses, due to their increasing usage and the possibility to integrate them with MOOC Platforms.

### **2.2.3 Gamification**

Gamification dynamics generate a positive effect in learning, producing an increase in student motivation and fostering relationships among participants (Borras-Gene et al., 2016). General results in the area of gamification show that using game-based dynamics is effective, but results depend on the context in which they are applied (Hamari et al., 2014). There are studies that mention the main benefits of using gamification in an educational context, which include (Bruder, 2015; Kapp, 2012; Zichermann & Cunningham, 2011): generation of cooperation; increase of motivation; a safe learning environment; increase in knowledge retention; recognition of student's capabilities to overcome difficulties. In this context, EduTrends from the Technologic in Monterrey (2016), in their edition on gamification, identify certain game elements that have a positive effect in education. These are: offering challenges and missions, having a defined set of rules, working in teams, levels, tasks against time, points associated to completing tasks, and badges as a form of offering acknowledgment to students.

Another aspect of gamification is having an achievement system, which means offering recognition for completing a certain goal. These recognitions take the form of points, bonuses, or the offering of badges or medals (Štogr, 2012). Fitz-Walter, Tjondronegoro, and Wyeth (2011) performed an experiment to measure the effects of implementing an achievement system in higher education. Their results suggest that this mechanic benefits the students' learning process, and it adds value to the tool that uses it. QuickQuiz (Cheong et al., 2013) is another approach of gamification applied in education. This approach is a mobile application in which users answer a quiz using game-based dynamics such as scores and working against time. The gamification elements present in this experiment proved to be useful for increasing commitment, entertainment, and improving the overall learning experience. Another important approach in this area is Duolingo, a web and mobile tool that teaches languages using game elements. It has

achieved excellent results from the point of view of usability, design, and its high levels of gamification (Vesselinov & Grego, 2012).

There are researchers that have studied the impact of including gamification in learning environments, especially in MOOCs (Borras-Gene et al., 2014). For example, the MOOC “Introduction to Entrepreneurship” (using the LORE platform) includes gamification elements within its contents with the objective of motivating students and enhancing learning (Romero, 2013). The main challenge that these approaches face is parting from the predominant design of MOOCs, which is based on video lectures, audio, and text. Another proposal by Alario-Hoyos et al. (2015) is the integration of a MOOC hosted on edX with Greenfoot (Kölling, 2010), a game designing tool aimed towards teaching programming to students that incorporates elements of gamification in a simplified way. Goligoski (2012) proposes the use of Mozilla Open Badges with the idea of gaining digital acknowledgement through badges and medals. This recognition is awarded to students who show certain qualities outside the academic environment with the objective of achieving new educational opportunities.

Therefore, and according to the prior work, the effective incorporation of gamification elements generates an increase in student motivation, which in turn increases participation and improves the overall learning process. However, there are still only a few gamified tools that integrate with MOOCs, thus, there is an opportunity to keep exploring in this area.

#### **2.2.4 CSCL, mobile technologies, and gamification as combined fields of analysis with MOOCs**

As it has been shown in sections 2.2.1, 2.2.2, and 2.2.3, there are some proposals in the literature that integrate elements of CSCL to enhance effective collaboration in MOOCs, others that propose the use of mobile technologies, and others that incorporate elements of gamification. Nonetheless, the contributions that combine these three aspects to extend MOOC platforms are very scarce. This section presents a review of previous works that combine at least two of these three aspects in the environment of MOOCs.



In the field of CSCL and mobile technologies in MOOCs there have been only a few experiments that have as their objective enhancing collaborative learning. One of the examples that use mobile technologies to foster collaborative learning is MyVote, a hybrid tool composed of a collaborative learning system, and a clicker system. Its objective is to allow individuals and groups to answer questions associated to course contents, strengthening critical thinking (Cheong et al., 2012).

In the field of CSCL and gamification, González et al. (2016) propose a model to incorporate game elements in a MOOC based on three categories. The first category is game “Dynamics”, based on CSCL propositions, that define the structures that a MOOC must include to foster interaction among its participants. The second category are the “Mechanics”. They define the relevant aspects to keep in mind when designing the activities in a MOOC, including challenges and goals that motivate students to advance through the course. Lastly, the third category are the “Components”, which define the way of implementing the game dynamics and mechanics throughout the MOOC.

In the field of mobile technologies and gamification in MOOCs, Borrás-Gene et al. (2016) propose how to design mobile applications for MOOCs using a gamified cooperative model on MOOCs (gcMOOC). This model includes gamification strategies to enhance student’s participation and commitment. The objective of this proposal is to achieve a deeper learning, and to retain a larger number of active participative students at the end of the course.

In the field of CSCL, mobile technologies, and gamification, we found only two proposals that combine these three aspects. The first one is PyramidApp, which implements a scaling pedagogical method named Snowball, based on the use of a CSCL collaboration pattern named Pyramid. Its objective is to support collaborative learning in a course (Manathunga & Hernández-Leo, 2016). The second work was presented by González, Collazos, & García (2016). They propose a model that incorporates CSCL collaborative learning aspects, with elements of m-learning and gamification. It is implemented as a service oriented multiplatform architecture to effectively manage students’ knowledge in a MOOC.

From these previous studies, it follows that contributions that incorporate elements of CSCL, mobile technologies, and gamification to enhance effective collaboration in

MOOCs are very scarce. The most significant approaches are only on a model or prototype stages, and do not have implementations that allow for experimenting with the proposed tools. Following this line of work, many research opportunities are generated towards enhancing collaborative learning, thus, it is advised to keep working in this area.

## 2.3 MyMOOCSpace

MyMOOCSpace is a cloud-based mobile system that aims to promote collaboration between students in a MOOC by using gamification elements. In designing this system, we have taken an iterative and incremental approach following the Design Based Research methodology (Wang & Hannafin, 2005). The system follows the observation by Breslow et al. (2013), to allow for students' collaboration. It combines aspects of collaboration (Johnson and Johnson, 1999) with game-based dynamics, as studies show that gamification has proven successful in increasing student engagement and motivation (Hamari et al., 2014). In these game-based dynamics, three of the main elements for supporting fruitful collaboration defined by authors in the CSCL field were directly addressed, as they could be easily incorporated into game elements. These are specifically: making the students work in a group towards a **common goal**, promoting **positive interdependence**, and creating **individual responsibilities** for each student to benefit the group's progress. Also, **interaction and communication** between students is fostered through an internal chat. The following subsections present the different components of MyMOOCSpace, which has been tested by interacting with the Open edX platform.

### 2.3.1 Overview of the architecture

The architecture of this system incorporates Mobile and Cloud Computing (MCC) components, making it a Cloud-based Mobile System (Abolfazli, Sanaei, & Ahmed, 2014; Rahimi et al., 2014). This type of architecture consists of a mobile component and a cloud component connected over the Internet through a mobile network. We opted for this computational model as mobile devices are becoming a popular way to access educational contents, but traditional m-learning has certain limitations (Dinh et al., 2011) that can be surpassed with an MCC architecture. In this context, other researchers have followed a

similar approach in designing applications to promote teamwork and collaboration (Sun & Shen, 2014).

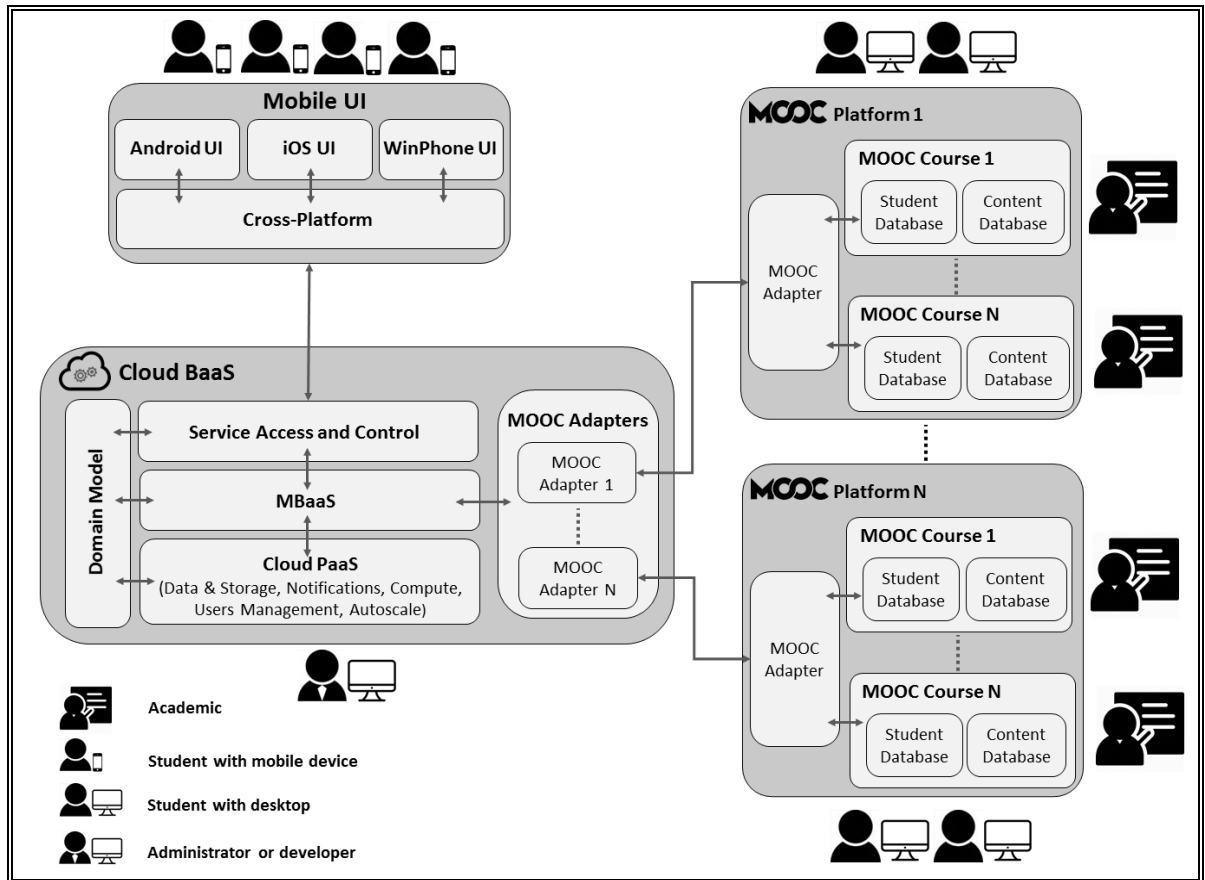


Figure 2-1: The general architecture for the proposed cloud-based mobile system. Its main components are the Mobile UI and the Cloud BaaS. It supports four roles: Academic, Student, Administrator, and Developer

We propose a cloud-based mobile solution for promoting knowledge sharing in MOOCs that combines elements of MCC and gamification. The proposed solution creates a direct connection between data in a MOOC and the Backend as a Service (BaaS). This guarantees data consistency and the automated transfer of information, so that any changes made by the MOOC administrator will be reflected instantly in the mobile application. Figure 2-1 shows the general architecture of the cloud-based mobile system, which has two

main components connected to the MOOC platform through adapters. These are the *Mobile UI* and the *Cloud BaaS* (CBaaS).

The first component, the Mobile UI, corresponds to the application installed on the devices of MOOC participants. It interacts with the second component, the CBaaS, through the service and access controls, which are the bindings between the mobile application and the Mobile Backend as a Service (MBaaS) API endpoints, serving to promote loose coupling between the mobile application and a specific cloud vendor.

The CBaaS contains the APIs that handle the business logic and connect to the services provided by the cloud vendor in the MBaaS. The services used in our system are an SQL database, push notifications, and user identification. This component extracts data from a MOOC platform (e.g., Coursera or edX), making use of an adapter pattern (Gamma, Helm, Johnson, & Vlissides, 1995). As there must be a specific MOOC adapter for each MOOC platform, we have designed this interaction to be loosely coupled from the rest of the architecture. Therefore, if a specific platform makes changes in the way it formats its data, adjustments are only required in the related MOOC adapter. An adapter for the Open edX platform has been developed and tested; this involved analyzing how the data is structured and contained within this platform. It was found that this platform stores student information in SQL databases and course contents in MongoDB. In this particular case, processing the data to build the adapter was a very straightforward process, as each course module has its contents in JSON and XML formats, which are standard to every course. The most difficult part of this process was to establish a connection between the CBaaS and the platform databases. Since every MOOC platform stores its information in different formats, the preferred method of implementing the information retrieval component is through a REST API, where a GET request is issued to call the platform, and a POST request is generated to load data into the CBaaS database.

There are four roles supported in this architecture. The student role corresponds to the end user of the mobile application, having read-only access to information in MOOC platforms. This role is assigned to students enrolled in a MOOC. The academic role can access and modify content in MOOCs. This role is assigned to teachers or course administrative staff. The final two roles can be regarded as the support and maintenance team. The administrator is responsible for supervising the CBaaS and ensuring that the

services are functioning correctly. The developer is responsible for implementing new MOOC adapters for different MOOC platforms that may be used in the future.

### 2.3.2 Mobile application

The mobile application is the primary tool by which we aim to enhance the learning experience, by promoting knowledge sharing and collaboration between the students enrolled in a MOOC. The game-based application consists of a spatial circuit which is played in teams of 3 or 4 students (Ramirez-Donoso et al., 2015). They have to advance in this spatial circuit, where each stage corresponds to a module of the MOOC course, and is represented in the game as a planet. To allow the team to advance through the circuit, all team members must participate and answer questions in every level. The objective of the game is for each team to answer the highest amount of multiple choice questions in the shortest amount of time. All questions are taken directly from the online course. The **common goal** aspect of collaboration consists in the desire to advance through the course, by completing stages. **Positive interdependence** is generated by only allowing a team to advance when every member has participated. Also, when a student answers a question, it adds or subtracts points from the total group score, thus, every member is given **individual responsibility**. Though not directly promoted through the game mechanics, **interaction and communication** between members is fostered through a group chat. Finally, students can pass questions between them; this further promotes interaction, and allows for students to know their teammates' strengths and weaknesses. Table 2-1 shows the game dynamics included in MyMOOCSPACE, and the collaborative aspect they are applied to.

Table 2-1: Game dynamics applied to collaborative aspects

Game dynamic	Collaboration aspect		
	Common objective	Positive interdependence	Individual responsibilities
Working in teams	Yes	Yes	No
Levels	Yes	Yes	No

Table 2-1 continued			
Tasks against time	No	No	Yes
Points, Scoreboards	No	Yes	Yes
Badges	No	No	Yes

Figure 2-2 shows the main screens of the mobile application. The screenshots show the final designs that were tested and evaluated with actual learners in a previous study (Ramirez-Donoso et al., 2015). When the user first starts the application, their credentials are requested and validated (Figure 2-2a). If they are valid, the user then gains access to the main menu (Figure 2-2b). The application shows user and group statistics in the form of a leaderboard. Students can also access the courses they are enrolled in. Each course is then divided into planets (Figure 2-2c), where each planet represents a module or a unit of the course. In each planet, the user may answer questions related to the content of the unit.

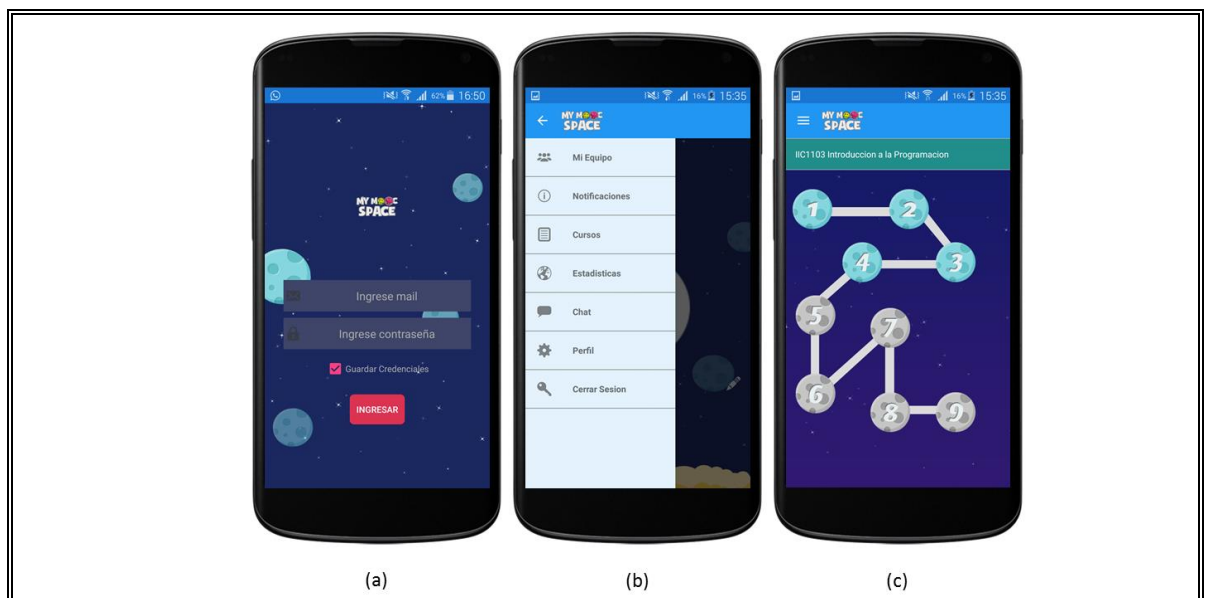


Figure 2-2: Mobile App screens 1: (a) User Login (b) User Options (c) User Course Levels

Figure 2-3 shows further functionalities of the mobile application. The standard question type is multiple choice (Figure 2-3a) due to the simplicity of assessing answer validity. In order to unlock a new planet, every student of the group must have answered at least once what we have termed the “timed question” (Figure 2-3b), which is a special question that must be answered within a time span of 24 hours. Students lose points if they answer the “timed question” incorrectly, and gain points for clearing a level. Figure 2-3c shows a course leaderboard.



Figure 2-3: Mobile App screens 2: (a) Question (b) Group Visualization (c) Course Leaderboard

The application includes a chat for facilitating communication and allowing asynchronous interaction between the students. It also considers that when students are on the move, their Internet connection might not be stable. That is, the application must be able to function with an unstable connection, without losing information consistency and availability. To solve this issue, each operation is validated before trying to send or receive data from the cloud storage. Additionally, when a chat message is sent, if the device is online, it is sent to the cloud storage. If it is not online, it is stored in an internal database and sent when the connection is restored.

### **2.3.3 Cloud service as a backend**

In order to ease the integration of cloud services and mobile clients, there has been a recent surge of Backend as a Service (BaaS) providers that allow developers to establish complex mobile-cloud interactions with very little configuration. These solutions provide programmers with two major features: on the client side, there are custom libraries for mobile clients made specifically for each relevant mobile operating system; on the server side, there are control panels that make extensive configuration possible in a matter of minutes. BaaS enables not only the connectivity and scalability that comes with all cloud-based services, but also supplies solutions for common mobile development challenges like user authentication, push notifications, data storage, social media integration, geospatial queries, offline sync, analytics, machine learning, and more. This provides a consistent way to manage mobile backend requirements as services, and removes the need to develop custom ad-hoc solutions more often in order not to suffer from serious performance and security issues.

The proposed cloud-based mobile system uses BaaS as a key component of its architecture. Students enrolled in a MOOC may come from different backgrounds and geographic locations. Thus, to effectively provide a system that enables them to collaborate, share, and create knowledge, access to and storage of centralized and consistent information is a crucial requirement. Also, students in a MOOC may drop-out and abandon the course, therefore, the group formation must be flexible. If a student does not participate, not allowing the group to advance, the other team members can send “warnings” to that user. When every member has sent a “warning” to a certain person, he or she will be forced to leave the group. Another important factor is scalability. The number of students enrolled in a course may vary from less than a hundred to more than a hundred thousand. This makes demand estimation difficult in terms of requests to the backend, making a backend that can scale as the audience grows a necessity. Notifications being sent when another user generates a state update creates a better user experience as it removes the need for the user to constantly check for any changes (Chetan et al., 2014). In our solution, notifications are sent whenever a significant event takes place.



The requirements exposed above (consistent and synchronized database, push notifications, and scalability) are among the most common services needed by a mobile cloud client and offered by mobile cloud servers/vendors (Chetan et al., 2014). Therefore, we opted to implement a CBaaS in our proposed system, as it provides a means to overcome limitations regarding processing and storage capabilities of devices through the availability of computing resources and scalability in the cloud. It also allows students to access, share, and synchronize learning contents anywhere and anytime, provided they have an active Internet connection (González-Martínez et al., 2015).

To populate the database in the cloud platform, data is extracted and processed from the MOOC platform through the MOOC adapters in the CBaaS. The processing of this information is vital to ensure that it fits the format of the SQL cloud database. As every MOOC platform has its own database structure (SQL or NoSQL), which differs from other platforms, there must be one adapter for every MOOC platform from which data will be extracted. This creates a one-to-one relationship where the adapter in the CBaaS receives and adapts the data from the adapter of a specific MOOC platform. This also allows the system to expand to other platforms with less work than it would require without the adapter pattern, as only changes in the adapters must be made, leaving the rest of the architecture out of the process.

## **2.4 Evaluation**

The evaluation of MyMOOCSPACE has been carried out by performing three quasi-experiments in four different higher education institutions in Chile and Paraguay. The objectives of the evaluation are: (1) to validate the usability of the implemented solution and to measure the user's experience when interacting with the platform; and (2) to effectively measure how MyMOOCSPACE affects collaboration among students of a course working on a MOOC Platform (Open edX).

### **2.4.1 Methodology of the experiment**

The evaluation of the platform follows a quasi-experimental methodology to analyze a series of research questions. The main question is (RQ): *How can we design a*

*technological solution to extend and enhance effective collaborative learning among students on a MOOC Platform?* From this question, two research subquestions (SQ) arise:

*(SQ1) Does the proposed solution have good acceptance from students in terms of usability?*

*(SQ2) Does the proposed solution help to extend and enhance collaboration among students in a MOOC Platform?*

To answer these questions, three quasi-experiments were designed and performed (Christensen, Johnson, & Turner, 2014). Since we could not randomize the samples because all participants signed voluntarily to participate and use the proposed system, quasi-experiments were the most appropriate methodology for the evaluation. The first quasi-experiment was a One-Group Posttest-Only design (see Table 2-2), where students were asked to interact with the system to evaluate its usability. The second experiment involved a One-Group experiment where students interacted with the system, and the platform's behavior was evaluated. The third experiment consisted of a One-Group Pretest-Posttest design. The objective of this third group was to measure how MyMOOCspace enhanced collaboration among the students, according to Collaborative Problem Solving Skills (PISA, 2013) and team performance dimensions (Smith-Jentsch, Zeisig, Acton, & McPherson, 1998).

#### **2.4.2 Quasi-Experiments: context and participants**

The evaluation of the platform was carried out with a total of 68 students in three different quasi-experiments (Table 2-2). 9 undergraduate and postgraduate students from the Computer Science Department from the Pontificia Universidad Catolica in Chile participated in the first quasi-experiment. These students interacted with the platform for one day in order to obtain their feedback regarding the usability of the application and their general experience from interacting with the system. To make sure that every component of the application was addressed by the participants, they were given instructions and asked to complete certain tasks (e.g., log in, then, identify the navigation drawer and go to the courses menu). After they had finished, they were asked to complete a system usability questionnaire described in the next sub-section. The students had experience in software engineering and software usability testing due to their academic background.

34 students from an MBA course at Universidad Americana in Paraguay participated in the second quasi-experiment. Most of these students had backgrounds in engineering or IT-related fields. These students were further divided into 9 teams, 8 of them with four members, and 1 with two members. The group with two members had four members initially, but two students decided to abandon the experiment shortly after it began. These groups interacted with the system for two weeks in order to assess its correct behavior. During this quasi-experiment, students were asked to enroll in the SPOC (hosted on Open edX MOOC Platform) on Trigonometry from the Pontificia Universidad Catolica in Chile. This course is composed of 7 modules with 18 video lectures, 21 exercises and a final exam. MyMOOCSPACE is able to extract the number of modules and exercises from this course through a MOOC adapter designed for Open edX.

The third quasi-experiment counted with the participation of 25 students from INACAP (a professional institute) and Universidad Bernardo O'Higgins, two Chilean higher education institutions. They all belonged to engineering and IT-related majors. These students were divided into 7 groups, 3 with three members and 4 with four members. The objective of this third experiment was to measure how MyMOOCSPACE enhanced collaboration among students. During this experiment, the same Trigonometry course hosted on Open edX as in the previous experiment was used, and students were asked to enroll before using MyMOOCSPACE. This third experiment had a duration of three weeks, where students could interact freely with the application in order to advance through the course. At the beginning of the experiment, students were handed over a questionnaire that evaluates individual collaborative skills. After the experiment, they were asked to complete another, which evaluated their team's performance. Both questionnaires are described in the following subsection.

It is important to note that students in the three quasi-experiments had similar backgrounds in terms of academic formation; all of them belonging to engineering and IT-related fields. They were all familiar with mobile applications, but none of them had major experience with collaborative systems. Table 2-2 presents a summary of the three experiments.

Table 2-2: Summary of the three quasi-experiments

<b>Experiment Number</b>	<b>1</b>	<b>2</b>	<b>3</b>
<b>Name</b>	Usability	Platform Behavior	Collaboration Enhancement
<b>Type</b>	One-Group Posttest-Only	One-Group	One-Group Pretest-Posttest
<b>Date</b>	July 2015	March 2016	June 2016
<b>Duration</b>	1 day	2 weeks	4 weeks
<b>Objective</b>	Measure the usability of MyMOOCSPACE	Evaluate the correct behavior of MyMOOCSPACE under a real case scenario	Measure MyMOOCSPACE effects on collaboration enhancement among students
<b>Participants</b>	9	34	25
<b>Group setting</b>	Individual	8 groups of 4 members 1 group of 2 members	3 groups of 3 members 4 groups of 4 members
<b>Research question addressed</b>	RQ, SQ1	RQ, SQ1	RQ, SQ2
<b>Evaluation instrument (Section 2.3.4)</b>	Usability questionnaire	Database information	Collaborative Problem Solving and Team Dimensional Training questionnaires

### 2.4.3 Instruments and data collection

In order to collect quantitative and qualitative data and analyze it according to the research questions, we could not find a specific instrument during the literature review that suited the context of the quasi-experiments. Therefore, we have designed questionnaires that aim to measure the usability of MyMOOCSPACE and its effect on collaboration among students. The instruments and methods of data collection are presented according to the specific question they aim to address.

*SQL: Does the proposed solution have good acceptance from students in terms of usability?*

In order to assess the functionality of the system, a questionnaire was designed and given to each participant to be completed after interacting with the system (Ramirez-Donoso et al., 2015). The questionnaire considered five criteria proposed by Nielsen (1993) to measure the usability of a system. These are:

- I. Easy to Use: It should be easy for a new user to learn how to use the application.
- II. Efficient to Use: The steps needed to use the application should be efficient.
- III. Easy to Remember: Users should remember how to use the application, even after a period of not interacting with it.
- IV. Few Errors: The application should have few errors, and be fault tolerant.
- V. Subjectively Pleasing: Users should find the application pleasing to use.

To evaluate each criterion, 51 Likert-scale questions were used and evaluated with values 1 (minimum) to 5 (maximum). Of these 51 questions, 16 were directed to evaluate criterion I, 9 were directed at criterion II, 6 were used to assess criterion III, 9 were aimed at criterion IV, and 11 to measure criterion V. This questionnaire also included a space where students could write their comments and opinions; this allows for the obtention of qualitative feedback.

In addition to the questionnaire, relevant information was also extracted from the system database. During the design phase, it was considered that information regarding the interaction of users with the platform could be used and stored for further analysis. Such data includes, among others, the number of attempts to answer a question per user, the

progress each team made in the course, the number of messages in the chat per user and individual and group scores. This information is used to analyze how students interact with the platform, and how the implemented features affect their behavior.

*SQ2: Does the proposed solution help to extend and enhance collaboration among students in a MOOC Platform?*

To measure how the system affected collaboration among students, two questionnaires were elaborated, one to be applied before the participants interacted with MyMOOCSPACE, and the other one after they had finished working in groups. The initial questionnaire is based on PISA propositions to measure a student's collaborative problem solving skills (CPS). Following PISA recommendations (PISA, 2013), a set of abilities that indicate student's competencies are obtained by making an intersection between the basic CPS skills and the four stages of problem solving. To evaluate each criterion, 21 Likert-scale questions were used and evaluated with values 1 (minimum) to 5 (maximum), therefore, if a student answered with 5 all questions, the maximum score would be 105 points. Based on these abilities, three levels of CPS skills arise:

1. **Low:** Students who make little or no contribution to the team's progress; they barely respond to requests from their teammates. In general, they work individually without considering their teammates. Students that got a score of 50 or less fall in this level.
2. **Medium:** Students who contribute, but only when directly addressed by another member (they are not proactive). This level is for students that received between 51 and 84 points.
3. **High:** Students who actively respond and request information from teammates, solve conflicts and adapt to changes. They are responsible and proactive. Students that received a score of 85 or more fall into this category.

After the experiment, students were asked to complete a second questionnaire. This questionnaire evaluates the student's perception of the team's performance throughout the course. A team's performance is evaluated according to four dimensions of Team Dimensional Training (TDT) (Smith-Jentsch et al., 1998). 15 questions were elaborated to measure TDT, and evaluated by using a Likert scale with values from 1 to 5 (this gives the

questionnaire a total of 75 points). Three possible team performance levels were differentiated, according to these dimensions:

1. **Low:** Team with little or no communication, each member acts individually. A score of 39 or less can be classified as low team performance.
2. **Medium:** Team that communicates, but key information is missed. There may be a leader, but the rest of the members are not proactive. A score of 40 to 60 points falls into this category.
3. **High:** Team with efficient and effective communication, with support and feedback between team members. Leadership and proactive behavior are clearly shown. More than 60 points can be classified as a high team performance.

#### 2.4.4 Data analysis

A series and combination of methods were used to analyze the data obtained from the different questionnaires and platform database. To obtain data that allowed us to answer SQ1, we analyzed every usability criterion in an independent way, as they address different aspects that are not necessarily related to each other, and can give individual insight on what features could be improved in terms of usability. By extracting the average score, standard deviation (SD), and maximum and minimum scores obtained for each of the five usability criterion, we can have an idea of the users' opinion. Because every criterion has a different range of possible scores, the average score obtained for each criterion was normalized in a scale of 0 to 100. To gain further knowledge of the system behavior, database information was analyzed in search for problems during the experiment executions.

To carry out the analysis regarding the effects of MyMOOCspace on collaboration among students (SQ2), we obtained the average score, standard deviation, maximum and minimum scores for both CPS skills and TDT performance. Then, we classified the individual CPS results into their respective level (Low, Medium or High) according to the obtained score; an analog process was carried out with the TDT scores. To further analyze the results, normality tests of the obtained scores on CPS skills and TDT performance were carried out by performing the Anderson-Darling test. It was found neither the data of CPS (AD-value 0,6; p-value 0,08) or TDT (AD-value 0,3; p-value 0,9) followed a normal

distribution, but both of them followed a linear relationship. To identify a possible correlation between individual CPS skills and team performance TDT, a correlation test using Pearson's method was performed. This was identified as the best method in this case, because of the linear relationship present in both CPS and TDT scores. As this test is very sensible to unusual data (outliers), two students were eliminated from the sample, as they had to be removed from their respective groups during the experiment, leaving a resulting sample of 23 students.

#### 2.4.5 Results

The results presented in this section are organized per the 2 research questions addressed:

*SQ1: Does the proposed solution have good acceptance from students in terms of usability?*

The normalized results of the obtained score for each criterion in the Usability Questionnaire during the first quasi-experiment are shown in Table 2-3.

Table 2-3: Usability results obtained (N= 9 students)

Criterion	Number of Questions	Normalized Avg. Score
Easy to use	16	76,2%
Efficient to Use	9	50%
Easy to Remember	6	62,9%
Few Errors	9	80,6%
Subjectively Pleasing	11	83,8%

According to Nielsen's criteria, the application had good acceptance by the users. Students found MyMOOCSPACE easy and intuitive to use from the beginning and had no problems remembering available actions and options in the application. The weakest point found during this experiment was the efficiency in the steps needed to use the system. Feedback provided by the students mentioned the in-app navigation could be confusing, as some steps of the navigation were redundant. Using the knowledge gained, we simplified



the navigation including the Navigation Drawer shown in Figure 3b. Overall, students felt that using the application was a pleasing activity.

During the second quasi-experiment, with 34 students, the behavior of the platform was under permanent scrutiny. The observations made by the researchers did not identify any issue or incident associated with incorrect behavior of the system. The server that contains the proposed architecture was stable with regards to the response time of each interaction with the game, with an average response time of less than 2 seconds. During the experiment, there were times when all 34 students were simultaneously using the application. There were no problems due to concurrent requests to the server in terms of consistency in the cloud database. Although this is not a great enough number of users to create a stress in the architecture of the system, this should not be a concern, as having the backend in the cloud following an MCC computational model allows for automatic allocation of more computing resources if needed.

It is worth noting that during this quasi-experiment, we corroborated the importance of allowing communication between team members within the application. Students used the internal chat provided by MyMOOCSPACE to exchange messages with their group members; they asked each other for information, reminded each other of ongoing tasks, and allowed creating a sense of group bonding. It provided an easy way to reach each other without having to exit the application, or use other external messaging services. This result agrees with earlier studies showing that participants value tools that allow them to be in touch with their peers (Alario-Hoyos et al., 2013).

*SQ2: Does the proposed solution help to extend and enhance collaboration among students in a MOOC Platform?*

Results from the initial questionnaire that measures individual CPS skills are presented in Table 2-4. From these results, it was observed that students who participated in this quasi-experiment had high CPS abilities, with most of them falling within High (52,2%) and Medium (43,5%) levels. This means that they should tend to work collaboratively if given the appropriate tools.

Table 2-4: CPS results obtained (N= 23 students)

<b>Criteria</b>	<b>Avg. Score</b>	<b>SD</b>	<b>Min. Obtained</b>	<b>Max. Obtained</b>	<b>Min. Possible</b>	<b>Max. Possible</b>
CPS	80.13	13.719	42	98	21	105
<b>Rating of students in CPS</b>						
Low		Medium		High		
1 (4,3%)		10 (43,5%)		12 (52,2%)		

The results of Table 2-5 show that the majority of students recognize that the members of their team made significant contributions while they were interacting through MyMOOCSPACE. They recognize that their team provided an exchange of information, good communication, and positive behavior and support (52.2% qualify their team at a Medium level, and 39.1% at High level). This means that students were able to build bonds with their peers, allowing them to feel part of a learning community, at least with their direct team members. When we compare the data between CPS and TDT, it seems at first that there is a direct relationship between the CPS scores and the TDT performance of a team. However, the Pearson correlation test revealed that the correlation is 0.3, which is a moderate value. The phenomenon occurring is that while the total number of students in each level remains mostly the same, students who classified as having High CPS skills tended to rank their team performance in TDT as Medium, and students with Low and Medium CPS skills ranked their team as having a higher TDT performance. This might be explained by students with Low and Medium CPS skills expecting less communication and information exchange when working collaboratively, thus perceiving a better team performance and ranking their team as High in TDT. The opposite holds true for students with High CPS skills. However, the impact is mostly positive, as every student is immersed in a collaborative environment, and students who are used to working individually benefit from students with higher collaborative skills. Also, students with higher collaborative skills can act as an impulse for the rest of the team.

Table 2-5: TDT results, and correlation with CPS (N = 23 students)

Criterion	Avg. Score	SD	Min. Obtained	Max. Obtained	Min. Possible	Max. Possible
TDT	56.35	12.13	19	71	15	75
Rating of students in CPS						
Low			Medium	High		
2 (8.7%)			12 (52.2%)	9 (39.1%)		
Pearson correlation between CPS and TDT scores						
0.3						

The data obtained from the database indicates that all teams were able to complete the seven modules of the course. Also, all groups used the internal chat to communicate with their team members. This agrees with the results found in the quasi-experiment with the second group, that providing a way to allow communication within the application is crucial because it allows students to share information and create virtual relationships among them. According to the students' opinion, MyMOOCSPACE allowed them to interact with their peers and work together to advance as the course progressed. Without the dynamics provided by MyMOOCSPACE, this exchange of information and communication would not have been possible.

With regards to enhancing collaboration possibilities between students on a MOOC platform, the data obtained from the platform, together with the comments expressed by the students, validate MyMOOCSPACE and its proposed architecture as a tool that allows for the extension of interaction and collaboration features of current online course platforms. Students appreciated the dynamics of collaboration, which were considered attractive and innovative with respect to what was offered by the existing platforms: mainly forums and peer review activities.

The results obtained from this experiment show that MyMOOCSPACE contributes to enhancing collaboration between students in an SPOC. Students' comments, as well as the data obtained from the database, show that the system managed to generate greater student

motivation, as it was perceived as interesting and entertaining. It allowed for better communication and virtual relationships among peers.

Finally, having answered both subquestions, we can provide an answer to the main research question (RQ). By taking into account the emerging and most impactful technologies in education, such as mobile technology and gamification, we can design a technological solution that fulfils the necessary requirements of a collaborative system to be used in a higher education context. We have addressed key architectural issues such as scalability and consistent information by using a cloud backend. The data obtained regarding usability shows that students felt comfortable and pleased while interacting with MyMOOCspace. Lastly, the collaborative dynamics enhanced with gamification elements have shown to increase collaboration among students, allowing them to create bonds and interact with their peers.

## **2.5 Conclusions and future work**

Understanding the mechanisms of collaboration, and the fundamental aspects to promote collaborative learning in MOOC Platforms, is a field of research of great interest. However, the lack of tools to enhance collaboration in these platforms leaves an opening to analyze the synergy that is generated with the intersection of MOOCs with the areas studied in this article: CSCL, Mobile technologies and Gamification. This paper has proposed MyMOOCspace, a cloud-based mobile system based on the idea that by combining these three aspects, it is possible to enhance collaboration among MOOC participants.

MyMOOCspace has been designed as a result of conducting a Design Based Research (DBR) methodology, which allowed for the early identification of relevant factors to consider in its design and implementation, thus, speeding up the development process. This methodological process included three quasi experiments conducted in SPOCs in which both qualitative and quantitative data were collected to test the tool within a controlled environment and improve its usability and collaboration elements.

Results obtained on usability show the application had good acceptance by the users, according to the 5 evaluated aspects proposed by Nielsen (1993), answering the first research subquestion (SQ1). Unlike collaboration enhancement results, usability results

can be extrapolated to a massive environment. This is because the literature proposes that only 6 representative participants are enough to answer a usability questionnaire (Nielsen, 1993). Therefore, with any number of participants greater than 6 ( $N > 6$ ), results are equally valid, but there might be redundancy. Also, the architecture of MyMOOCSPACE performed without issues during the experiments, presenting fast response times and permanent uptime. Thus, it enhanced the user's experience while interacting with the system.

In the case of activities for supporting collaboration, including game dynamics implies not only addressing individual needs, but also establishing interaction among members of a team via game-based elements. In this way, the experiments performed answer the second research subquestion (SQ2), with results showing that teams expressed supporting behavior, communication, and worked towards a common goal. Furthermore, the obtained results convey that the dynamics included in MyMOOCSPACE serve to enhance effective collaboration among students. These results validate MyMOOCSPACE as a tool that extends and enhances interaction and collaboration possibilities among students in a MOOC Platform. Moreover, it is worth mentioning that to generate a collaborative environment, it is important to provide specific and well defined functionalities and game dynamics. By doing this, it will be possible for a team of MOOC participants to advance through the course in an environment that fosters cooperation and interaction between them (González & Area, 2013). Otherwise, if the game dynamics are not applied in a way that fosters collaboration, they might still produce benefits such as an increase in motivation, but only in an individual level.

Despite of the good results obtained in these quasi experiments, their extrapolation to MOOCs is not straightforward. However, these experiments were the necessary beta test for analyzing the use of the tool in an actual situation before launching it in a massive environment. Given this context, and as future work, experiments in real environments using MOOC courses from the Universidad de Cuenca from Ecuador and Pontificia Universidad Católica in Chile will be performed. During the development of the upcoming experiments, the feasibility of using a Technology Acceptance Model (Venkatesh, Morris, Davis, & Davis, 2003) is being studied, to allow us to measure variables related to the massiveness of users, and to collect more data on the behavior of the platform. Finally, MyMOOCSPACE still has room for improvement, and we aim to continuously work to

make it better, as new aspects and dynamics for enhancing collaboration appear in the literature that could be included in future versions of the system. Therefore, to continue the experimentation process is a key issue; as the iterative and incremental approach following DBR methodology has proven useful, further work should keep using it.

### 3 CONCLUSIONS AND FUTURE WORK

Following a DBR methodology, it was found that there are certain aspects that have the potential to make a big impact in higher education. These are CSCL, mobile devices, and gamification. CSCL proposes key aspects that foster effective collaboration among students; mobile devices offer the possibility to access educational content without depending on time or location; gamification has shown to increase students' motivation and engagement. By combining these three aspects, we can fulfill students' needs in enhancing effective collaboration. On the other hand, Cloud Computing offers the means to address the technological requirements of a collaborative tool that works with MOOC Platforms. Thus, we propose MyMOOCSPACE, a cloud-based mobile system that uses CSCL aspects of collaboration enriched with gamification elements, to extend and enhance effective collaboration among students in a MOOC Platform.

The way in which the architecture of MyMOOCSPACE was designed is highly important in the correct behavior of the platform. Having a Cloud-backend makes it possible to scale in the available resources as the number of users grows. It also allows for having a fast response time to requests generated from the students' mobile devices, a critical aspect from the user's perspective. The data obtained on usability show that students felt pleased while interacting with the system. Furthermore, the results obtained in the collaboration enhancement quasi-experiment, validate MyMOOCSPACE as a tool that extends collaboration and interaction possibilities among students in a MOOC platform. These results show that the game-based dynamics included in the application allowed to promote students' collaborative aptitudes. Within the participating teams, supportive behavior and communication were shown, and students worked together towards a common goal.

The quasi-experiments performed were developed in real environments with higher education students who worked on a SPOC course. Nonetheless, MyMOOCSPACE has not been tested in a massive environment (MOOC), thus, the limitation of this study is that it has yet to scale to a massive environment. Although there should not be any problems concerning usability, because the architecture of the system was built with scalability in mind, results regarding collaboration enhancement cannot be generalized to a massive

environment. Also, when testing in a massive environment, additional variables come to play an important role, such as cultural differences, language barriers and different time zones. Therefore, future work should concentrate on experiments on massive courses, and should take into account the new variables associated with this context.

Finally, the contributions of this research are: identifying the aspects and technologies that have an impact on higher education, and that could be used to enhance effective collaboration (CSCL, gamification, mobile technologies). Then, using these technologies, proposing a scalable architecture that fulfills the requirements of a collaborative tool to be applied in an educational context. Lastly, proposing a tool that extends and enhances effective collaboration among students in a MOOC Platform.



## REFERENCES

- Abolfazli, S., Sanaei, Z., Ahmed, E., Gani, A., & Buyya, R. (2014). Cloud-based augmentation for mobile devices: motivation, taxonomies, and open challenges. *IEEE Communications Surveys & Tutorials*, 16(1), 337-368. s.
- Alario-Hoyos, C., Estevez-Ayres, I., Perez-Sanagustin, M., Leony, D., & Kloos, C. D. (2015). MyLearningMentor : A Mobile App to Support Learners Participating in MOOCs. *Journal of Universal Computer Science*, 21(5), 735–753.
- Alario-Hoyos, C., Kloos, C. D., Estévez-Ayres, I., Fernández-Panadero, C., Blasco, J., Pastrana, S., Villena-Román, J. (2015). Diseñando un MOOC en edX: Introducción a la Programación con Java – Parte 1.
- Alario-Hoyos, C., Pérez-Sanagustín, M., Delgado-Kloos, C., Muñoz-Organero, M., & Rodríguez-de-las-Heras, A. (2013, September). Analysing the impact of built-in and external social tools in a MOOC on educational technologies. In *European Conference on Technology Enhanced Learning* (pp. 5-18). Springer Berlin Heidelberg.
- Anderson, A., Huttenlocher, D., Kleinberg, J., & Leskovec, J. (2014, April). Engaging with massive online courses. In *Proceedings of the 23rd international conference on World wide web* (pp. 687-698). ACM.
- Antunes, P., Herskovic, V., Ochoa, S. F., & Pino, J. A. (2014). Reviewing the quality of awareness support in collaborative applications. *Journal of Systems and Software*, 89(1), 146–169.
- Armbrust, M., Fox, A., Griffith, R., Joseph, A. D., Katz, R., Konwinski, A., ... Stoica, I. (2010). A view of Cloud Computing. *Communications of the ACM*, 53(4), 50–58.
- Bahl, P., Han, R. Y., Li, L. E., & Satyanarayanan, M. (2012, June). Advancing the state of mobile cloud computing. In *Proceedings of the third ACM workshop on Mobile cloud computing and services* (pp. 21-28). ACM.
- Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *The Journal of the Learning Sciences*, 13, 1–14.
- Baturay, M. H. (2015). An overview of the world of MOOCs. *Procedia - Social and Behavioral Sciences*, 174, 427–433.
- Blanco-Izquierdo, Francisco González, C. S., & Collazos, C. A. (2016). Modelado y Evaluación de la Interacción en el Aprendizaje CSCL y Juegos Colaborativos. *Development*, 190(3), 4921–4921.

- Borrás-Gené, O. B., Núñez, M. M., & Blanco, Á. F. (2014, October). Gamification in MOOC: challenges, opportunities and proposals for advancing MOOC model. *In Proceedings of the Second International Conference on Technological Ecosystems for Enhancing Multiculturality* (pp. 215-220). ACM.
- Borras-Gene, O., Martinez-Nuñez, M., & Fidalgo-Blanco, Á. (2016). New Challenges for the motivation and learning in engineering education using gamification in MOOC. *International Journal of Engineering Education*, 32(1), 501–512.
- Bratitsis, T. (2010, July). Using Computer-based Interaction Analysis tools for evaluating blog participation in tertiary education: An exploratory proposal. *In International Conference on ICTs in Education, ICICTE* (pp. 8-10).
- Breslow, L., Pritchard, D., DeBoer, J., Stump, G. S., Ho, A. D., & Seaton, D. T. (2013). Studying Learning in the Worldwide Classroom Research into edX's First MOOC. *Research & Practice in Assessment*, 8, 69–82.
- Bruder, P. (2015). Game on: gamification in the classroom. *Education Digest*, 80(7), 56.
- Cheong, C., Bruno, V., & Cheong, F. (2012). Designing a Mobile-app-based Collaborative Learning System. *Journal of Information Technology Education Innovations in Practice*, 11, 97–119.
- Cheong, C., Cheong, F., & Filippou, J. (2013). Quick Quiz: A Gamified Approach for Enhancing Learning. *PACIS* (p. 206).
- Chetan, S., Kumar, G., Dinesh, K., Mathew, K., & Abhimanyu, M. A. (2014). Cloud Computing for Mobile World. *International Journal of Computer, Information Systems and Knowledge Management*, 1(1), 26–37.
- Christensen, L. B., Johnson, R. B., & Turner, L. A. (2014). *Research methods, Design, and Analysis* (pp. 1-539). Allyn & Bacon.
- Cisco. (2015). Cisco Visual Networking Index (VNI) Update Global Mobile Data Traffic Forecast. *Vni*.
- Citadin, J. R., Kemczinski, A., Veloso de Matos, A., Cebrián Robles, D., & Duarte Freitas, M. do C. (2014). Análisis de Herramientas de Colaboración con MOOCs.
- Claros, I., Garmendía, A., Echeverría, L., & Cobos, R. (2014, April). Towards a collaborative pedagogical model in MOOCs. *In 2014 IEEE Global Engineering Education Conference (EDUCON)* (pp. 905-911). IEEE.
- Collazos, C. A., González, C. S., & García, R. (2014). Computer Supported Collaborative MOOCs: CSCM. *Proceedings of the 2014 Workshop on Interaction Design in Educational Environments*, 28-32. ACM.

- Concari, S. B. (2014). Tecnologías emergentes ¿cuáles usamos? *Latin-American Journal of Physics Education*, 8(3), 494–503.
- Conde, M. A., Muñoz, C., & García, F. J. (2008). El mLearning y la revolución de los procesos de Aprendizaje. In *V Simposio Pluridisciplinar sobre Diseño y Evaluación de Contenidos Educativos Reutilizables*. Salamanca.
- Crompton, H. (2013). A historical overview of m-learning: Toward learner-centred education. *Handbook of Mobile Learning*, 3–14.
- De Waard, I. (2011). Technology , Strategy , and Explore a New Learning Frontier : MOOCs History of MOOCs. *Learning Solutions Magazine*, 2011, 11–13.
- De Waard, I. (2013). mMOOC Design: Ubiquitous, Open Learning in the Cloud. *Handbook of Mobile Learning*, 356–368.
- De Waard, I., Koutropoulos, A., Keskin, N., Abajian, S. C., Hogue, R., Rodriguez, C. O., & Gallagher, M. S. (2011, October). Exploring the MOOC format as a pedagogical approach for mLearning. In *Proceedings of 10th World Conference on Mobile and Contextual Learning* (pp. 138-145).
- Delgado Kloos, C., Munoz-Merino, P. J., Munoz-Organero, M., Alario-Hoyos, C., Perez-Sanagustin, M., Parada G, H. A., Sanz, J. L. (2014). Experiences of running MOOCs and SPOCs at UC3M. In *2014 IEEE Global Engineering Education Conference (EDUCON)* (pp. 884–891). IEEE.
- Deterding, S., Dixon, D., Nacke, L., Sicart, M., & O’Hara, K. (2011). Gamification: Using Game Design Elements in Non-Game Contexts. *Proceedings of the 2011 Annual Conference Extended Abstracts on Human Factors in Computing Systems (CHI 2011)*, 2425–2428. ACM.
- Dillenbourg, P. (1999). What do you mean by collaborative learning? *Collaborative Learning Cognitive and Computational Approaches*, 1, 1–15.
- Dillenbourg, P., Fischer, F., Dillenbourg, P., & Fischer, F. (2007). Computer-supported collaborative learning : The Basics. *Zeitschrift Für Berufs- Und Wirtschaftspädagogik*, 21, 111–130.
- Dinh, H. T., Lee, C., Niyato, D., & Wang, P. (2011). A survey of mobile cloud computing : architecture , applications , and approaches. *Wireless communications and mobile computing*, 13(18), 1587–1611.
- Dourish, P., & Bellotti, V. (1992, December). Awareness and coordination in shared workspaces. In *Proceedings of the 1992 ACM conference on Computer-supported cooperative work* (pp. 107-114). ACM.

Driscoll, M. P., & Vergara, A. (1997). Nuevas Tecnologías y su impacto en la educación del futuro. *Pensamiento educativo*, 21, 81-99.

Ercan, T. (2010). Effective use of cloud computing in educational institutions. *Procedia - Social and Behavioral Sciences*, 2(2), 938–942.

Fitz-Walter, Z., Tjondronegoro, D., & Wyeth, P. (2011). Orientation Passport: using gamification to engage university students. *Proceedings of the 23rd Australian Computer-Human Interaction Conference on - OzCHI '11*, 122–125.

Fuks, H., Raposo, A., Gerosa, M. A., Pimentel, M., & Lucena, C. J. (2007). The 3c collaboration model. *The Encyclopedia of E-Collaboration, Ned Kock (org)*, 637-644.

Gamma, E., Helm, R., Johnson, R., & Vlissides, J. (1995). Design patterns: Elements of reusable object-oriented software. *Reading: Addison-Wesley*, 49(120), 11.

Gibelli, T. (2014). La investigación basada en diseño para el estudio de una innovación en educación superior que promueve la autorregulación del aprendizaje utilizando TIC. *Congreso Iberoamericano de Ciencia, Tecnología, Innovación Y Educación*.

Goligoski, E. (2012). Motivating the Learner : Mozilla ' s Open Badges Program. *Access to Knowledge*, 4(1), 1–8.

González-Martínez, J. A., Bote-Lorenzo, M. L., Gómez-Sánchez, E., & Cano-Parra, R. (2015). Cloud computing and education: A state-of-the-art survey. *Computers & Education*, 80, 132–151.

González, C., & Area, M. (2013). Breaking the Rules: Gamification of Learning and Educational Materials. *Proceedings of the 2nd International Workshop on Interaction Design in Educational Environments*, (2013), 47–53.

González, C. S., Collazos, C. A., & García, R. (2016). Desafío en el diseño de MOOCs: incorporación de aspectos para la colaboración y la gamificación. *Revista de Educación a Distancia*, 7(48), 1–23.

Grund, F. B., & Cacheiro, M. L. (2015). MOOC Study of Adaptability of MOOC Platforms to Mobile Devices. *Revista de Educación a Distancia*, (47).

Guerrero, C., & Domínguez, F. (2014). Dilemas pedagógicos sobre el desarrollo de los massive open online course (MOOC). *II Congreso Virtual Internacional sobre Innovación Pedagógica y Praxis Educativa INNOVAGOGÍA 2014 (pp. 1399-1409). AFOE*.

Guerrero, C., & Gros, B. (2013). Aprender en red: de la interacción a la colaboración, (Vol. 52). Editorial UOC.

- Guitert, M., & Pérez-Mateo, M. (2013). La colaboración en la red: hacia una definición de aprendizaje colaborativo en entornos virtuales. *Teoría de La Educación. Educación Y Cultura En La Sociedad de La Información*, 14(1), 10–31.
- Gurung, R. K., Alsadoon, A., Prasad, P. W. C., & Elchouemi, A. (2016). Impacts of Mobile Cloud Learning ( MCL ) on Blended Flexible Learning ( BFL ). In *Information and Digital Technologies (IDT), 2016 International Conference on* (pp. 108-114). IEEE.
- Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work? - A literature review of empirical studies on gamification. *Proceedings of the Annual Hawaii International Conference on System Sciences*, 3025–3034.
- Herrera, S., & Fennema, M. (2011). Tecnologías móviles aplicadas a la educación superior. In *XVII Congreso Argentino de Ciencias de la Computación*.
- Herskovic, V., Neyem, A., Ochoa, S. F., Pino, J. A., & Antunes, P. (2012). Understanding presence awareness information needs among engineering students. *Proceedings of the 2012 IEEE 16th International Conference on Computer Supported Cooperative Work in Design, CSCWD 2012*, 258–264.
- Herskovic, V., Ochoa, S. F., Pino, J. A., & Neyem, A. (2011). The Iceberg Effect: Behind the User Interface of Mobile Collaborative Systems. *Journal of Universal Computer Science*, 17(2), 183–201.
- Hrastinski, S. (2008). What is online learner participation? A literature review. *Computers & Education*, 51(4), 1755–1765.
- Johnson, D. W., & Johnson, R. T. (1999). Making cooperative learning work. *Theory Into Practice*, 38(2), 67–73.
- Kapp, K. M. (2012). The gamification of learning and instruction: game-based methods and strategies for training and education. *John Wiley & Sons*.
- Kölling, M. (2010). The Greenfoot Programming Environment. *ACM Transactions on Computing Education*, 10(4), 1–21.
- Kovachev, D., Cao, Y., & Klamma, R. (2011). Mobile Cloud Computing : A Comparison of Application Models. *Information Systems Journal*, abs/1107.4(4), 14–23.
- Kreijns, K., Kirschner, P. A., Jochems, W., & van Buuren, H. (2004). Determining Sociability, Social Space, and Social Presence in (A)synchronous Collaborative Groups. *CyberPsychology & Behavior*, 7(2), 155–172.
- Manathunga, K., & Hernández-Leo, D. (2015). Has Research on Collaborative Learning Technologies Addressed Massiveness? A Literature Review. *Journal of Educational Technology & Society*, 18(4), 357–370.

- Manathunga, K., & Hernández-Leo, D. (2016). PyramidApp: Scalable Method Enabling Collaboration in the Classroom. *In European Conference on Technology Enhanced Learning* (pp. 422-427). Springer International Publishing.
- Mehta, S. J., Danawade, V. M., Bulla, C. M., & Bhojannawar, S. S. (2016). Mobile Cloud Computing in Education. *International Journal of Engineering Science and Computing*, 6(6), 197–202.
- Mircea, M., & Andreescu, A. (2011). Using Cloud Computing in Higher Education: A Strategy to Improve Agility in the Current Financial Crisis. *Communications of the IBIMA*, 1(2), 1–15.
- Monterrey, T. de. (2016). *EduTrends - Gamificación*.
- Nielsen, J. (1993). *Usability engineering*. Academic Press.
- Pérez-Sanagustín, M., Hilliger, I., Alario-Hoyos, C., Kloos, C. D., & Rayyan, S. (2016). Describing MOOC-based Hybrid initiatives: The H-MOOC Framework. *European MOOCs Stakeholders Summit EMOOCs*.
- Pham, P., & Wang, J. (2015). AttentiveLearner: Improving Mobile MOOC Learning via Implicit Heart Rate Tracking. *Lecture Notes in Computer Science*, 9112, 883.
- PISA. (2013). Draft Collaborative Problem Solving Framework.
- Rahimi, M. R., Ren, J., Harold, C., Vasilakos, A. V., & Venkatasubramanian, N. (2014). Mobile Cloud Computing: A Survey , State of Art and Future Directions. *Mobile Networks and Applications*, 19(2), 133-143.
- Ramirez-Donoso, L., Perez-Sanagustin, M., Neyem, A., & Rojas-Riethmuller, J. S. (2015). Fostering effective collaboration in MOOCs through mobile apps. *2015 CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON)* (pp. 401-408). IEEE.
- Rao, N. M., Sasidhar, C., & V. Satyendra, K. (2012). Cloud Computing Through Mobile-Learning. *arXiv preprint arXiv:1204.1594*.
- Romero, M. (2013). Game based learning MOOC. Promoting entrepreneurship education. *Elearning Papers, Special Edition MOOCs and Beyond*, 33, 1-5.
- Sánchez Vera, M. D. M., & Prendes Espinosa, M. P. (2014). La participación del alumnado en los cursos masivos (MOOC). *In II Congreso Internacional de Innovación Docente*.
- Shah, D. (2015). By The Numbers: MOOCs in 2015. *Class Central*.

- Sharples, M., Arnedillo-Sánchez, I., Milrad, M., & Vavoula, G. (2008). Mobile Learning Small devices, Big issues. *Book Chapter to Appear in Technology Enhanced Learning: Principles and Products, Kaleidoscope Legacy Book*, chapter 14.
- Sharples, M., Kloos, C. D., Dimitriadis, Y., Garlatti, S., & Specht, M. (2015). Mobile and Accessible Learning for MOOCs. *Journal of Interactive Media in Education*, 2015(1).
- Simões, J., Redondo, R., & Vilas, A. (2013). A social gamification framework for a K-6 learning platform. *Computers in Human Behavior*, 29(2), 345–353.
- Smith-Jentsch, K. A., Zeisig, R. L., Acton, B., & McPherson, J. A. (1998). Team dimensional training: A strategy for guided team self-correction. In *Making decisions under stress: Implications for individual and team training*. (pp. 271–297).
- Sosa, M. J., López, C., & Díaz, S. R. (2014). Comunidad de aprendizaje y participación social en un curso MOOC. *IJERI: International Journal of Educational Research and Innovation*, (1), 1–13.
- Stieglitz, S., Lattemann, C., & Brockmann, T. (2015). Mobile applications for knowledge workers and field Workers. *Mobile Information Systems*, 2015.
- Štogr, J. (2012). Badges For (Lifelong) Learning-Gamification, Enhanced Visibility Of Reached Achievements And Continuous Building Of E-Portfolio As Data Source For Learning Analytics. *7th DisCo Conferen New Media and E*.
- Sultan, N. (2010). Cloud computing for education: A new dawn? *International Journal of Information Management*, 30(2), 109–116.
- Sun, G., & Shen, J. (2014). Facilitating social collaboration in mobile cloud-based learning: A teamwork as a service (TaaS) approach. *IEEE Transactions on Learning Technologies*, 7(3), 207–220.
- Valcke, M., Wever, B. De, Zhu, C., & Deed, C. (2009). Supporting active cognitive processing in collaborative groups: The potential of Bloom's taxonomy as a labeling tool. *The Internet and Higher Education*, 12(3), 165-172.
- Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly*, 27(3), 425–478.
- Vesselinov, R., & Grego, J. (2012). Duolingo Effectiveness Study. *City University of New York, USA*.
- Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development*, 53(4), 5–23.

Wong, L., Milrad, M., & Specht, M. (2015). Seamless learning in the age of mobile connectivity. Singapore: Springer.

Zhao, W., Sun, Y., & Dai, L. (2010). Improving computer basis teaching through mobile communication and cloud computing technology. *In 2010 3rd International Conference on Advanced Computer Theory and Engineering (ICACTE) (Vol. 1, pp. VI-452). IEEE.*

Zichermann, G., & Cunningham, C. (2011). Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps. O'Reilly Media, Inc.

Zurich, E. (2014). TORQUEs : A turning point for teaching, 1–8.