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MyMOOCSpace: A Cloud-Based Mobile System to Support Effective Collaboration in Higher Education Online Courses

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Abstract— In recent years, institutions of higher education have been using Massive Open Online Courses (MOOCs) as an alternative to enhance and innovate traditional classroom practices. One of the approaches to this type of innovation consists of using the platforms where MOOCs are hosted for the development of courses that are aligned to their on-campus curricular contents. They are known as Small Private Online Courses (SPOCs), which allow online access to knowledge for groups of students with a well-defined profile. The platforms where MOOCs (and SPOCs) are hosted have been designed to support large volumes of data and visits. However, these platforms present important limitations regarding the implementation of collaborative learning activities. To address this problem, this article presents MyMOOCSpace, a cloud-based mobile system aimed at supporting effective collaboration in MOOCs, by combining key aspects of collaboration from the research area of Computer Supported Collaborative learning (CSCL) with game-based dynamics. MyMOOCSpace has been tested in three quasi-experiments that were run in four Latin-American universities with a total of 68 participants. The objective was to assess its usability and its effect in enhancing collaboration among students in a SPOC. The results obtained on usability show that MyMOOCSpace is easy to use, and that participants felt pleased with while using it. Finally, it was observed that MyMOOCSpace managed to enhance interaction and collaboration among students.

Keywords: MOOC-SPOC, CSCL-Collaboration, Gamification, m-Learning, Cloud Computing

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, SPOCs (small and private online courses) are closed and limited courses in the number of participants and use the same infrastructure as a MOOC course, but in more traditional teaching environments [1]. For this reason, SPOCs are a good environment for measuring some functional interactions and validating the participant's behavior. That is, SPOCs are environments that can be useful as first validation of methodologies or technologies thought for MOOCs [2],[3]. They are online courses for a controlled and reduced number of students that make use of the experience acquired in MOOCs [4], to innovate in the traditional learning environment [5], [6]. 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 [7]. 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 [8].

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 [9]. 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 [7],[10],[11].

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)[12] 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 extending the tools and functionalities that current MOOC platforms offer [7]. 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 [13]–[18]. Finally, other authors choose to consider aspects of gamification to foster motivation and awareness of participation in the development of collaborative learning activities [19]. 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 presents the state of the art through a literature review on MOOCs and their relationship with CSCL, mobile technologies, and gamification. Section 3 presents MyMOOCSpace as a technological solution to extend and enhance collaborative learning in MOOC Platforms. Section 4 presents an evaluation of MyMOOCSpace based on three quasi-experiments that took place in four universities in Chile and Paraguay. Finally, section 5 presents the conclusions and future work of this research.

2. State of 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.

2.1 Computer Supported Collaborative Learning - CSCL

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)[20], and Blanco-Izquierdo, González & Collazos (2016)[19], 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 [21]. 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)[22] 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 [22]. 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 [10], [22]. 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 [8], [23]. 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 [9], [24], [25]. 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 [26]–[28].

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 [29]. 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 [30].

There are studies showing that the future of MOOC Platforms is associated with the increased use of mobile devices [31]. Accessing educational content through mobile devices would produce learning experiences that provide a continuity in the learning context [32]. 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 [15].

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 [33], 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) [34]. 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 [35]. 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 [36] 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.

2.3 Gamification

Gamification dynamics generate a positive effect in learning, producing an increase in student motivation and fostering relationships among participants [37]. 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 [38]. There are studies that mention the main benefits of using gamification in an educational context, which include [39]–[41]: 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 [42]. Fitz-Walter, Tjondronegoro, and Wyeth (2011)[43] 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 [44] 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 [45].

There are researchers that have studied the impact of including gamification in learning environments, especially in MOOCs [46]. 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 [47]. 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)[48] is the integration of a MOOC hosted on edX with Greenfoot [49], a game designing tool aimed towards teaching programming to students that incorporates elements of gamification in a simplified way. Goligoski (2012)[50] 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.

2.4 CSCL, Mobile Technologies and Gamification as combined fields of analysis with MOOCs

As it has been shown in sections 2.1, 2.2 and 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 [51].

In the field of CSCL and gamification, González et al. (2016)[52] 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, Borras-Gene et al. (2016)[37] 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 [36]. The second work was presented by González, Collazos, & García (2016)[52]. 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.

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 [53]. The system follows the observation by Breslow et al. (2013)[54], to allow for students' collaboration. It combines aspects of collaboration [20] with game-based dynamics, as studies show that gamification has proven successful in increasing student engagement and motivation [38]. 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.

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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 [55], [56]. 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 [57] that can be surpassed with an MCC architecture. In this article, we will refer to Smartphones and Tablets as mobile devices. In this context, other researchers have followed a similar approach in designing applications to promote teamwork and collaboration [58].

Figure 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 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. In order to provide easy access to information to all students, the application cannot be restricted to a certain mobile OS. The mobile application was, for this reason, implemented using a multiplatform paradigm. Some of the advantages of this paradigm are that it can overcome the constraint of utilizing different languages and frameworks for each platform. The platform chosen to implement the cross-platform application was Xamarin, as it is able to overcome one of the main concerns of multiplatform development: the fact that its access to some features of the mobile device may be limited [Xamarin Inc., Mobile Application Development to Build Apps in C# - Xamarin. http://xamarin.com/platform (accessed April 18, 2017)]. Xamarin claims its applications have access to the full spectrum of functionality exposed by the underlying platform and device, including platform-specific capabilities like iBeacons and Android Fragments, and their performance is comparable to native applications. Moreover, Xamarin has several specific features and API level settings in order to determine the compatibility of the app with multiple versions of Android or iOS. 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 implementation of this CBaaS version is based on different cloud services (web and worker roles). In Azure, a cloud service role is a collection of managed, load-balanced, Platform-as-a-Service virtual machines that work together to perform common tasks. Cloud Service roles are managed by Azure fabric controller and provide the ultimate combination of scalability, control, and customization. Thus, this implemented solution coordinates existing technologies in order to achieve a consistent way to manage mobile backend requirements as services and removes the need for having to develop custom ad-hoc solutions that often suffer from serious performance and security issues.

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 [59]. As there must be a specific MOOC adapter (REST API) 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. Further, the role of the administrator is able to execute the action of extracting a copy of the evaluation contents from the MOOC platform, with which the content of the questions that appear in each planet of the game is loaded. Then the game is executed with the features and gamification elements proposed on the loaded contents. The developer is responsible for implementing new MOOC adapters for different MOOC platforms that may be used in the future.

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 [60]. 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 1 shows the game dynamics included in MyMOOCSpace, and the collaborative aspect they are applied to.

Table 1: Game dynamics applied to collaborative aspects

Fig. 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 [60]. When the user first starts the application, their credentials are requested and validated (Fig.2a). If they are valid, the user then gains access to the main menu (Fig.2b). Students can also access the courses they are enrolled in. Each course is then divided into planets (Fig.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: Mobile App: (a) User Login (b) User Options (c) User Course Levels

Fig. 3 shows further functionalities of the mobile application. The standard question type is multiple choice (Fig. 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" (Fig. 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 (Fig. 3c). The application shows user, group and course statistics in the form of a leaderboard.

Figure 3: Mobile App: (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.

The minimum requirements for using MyMOOCSpace are:

1. To enable download unknown app for mobile.
2. To enable the permissions of interaction and communication through the chat when they are consulted by the installation process.
3. Internet connection for interaction with the questions of each module of the course.

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 [61]. 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 [61]. 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 [62].

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.

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).

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 [63]. 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), 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 [64] and team performance dimensions [65].

4.2. Quasi-Experiments: Context & Participants

The evaluation of the platform was carried out with a total of 68 students in three different quasi-experiments (Table 2). 9 undergraduate and postgraduate students from the Computer Science Department from the Pontifical Universidad Catholica 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 Pontifical Universidad Catholica 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 (see Table 3). 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 presents a summary of the three experiments.

Table 2: Summary of the three quasi-experiments
Table 3: Users features and distribution

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.

RQ1: 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 [60]. The questionnaire considered five criteria proposed by Nielsen (1993)[66] 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 know 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[64], 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 get 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 got a score of 85 or more fall in 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) [65]. 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:

4. ***Low:*** Team with little or no communication; each member acts individually. A score of 39 or less can be classified as low team performance.
5. ***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 in this category.
6. ***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

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.

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 regarding the obtained score for each criterion in the Usability Questionnaire during the first quasi-experiment are shown in Table 4.

Table 4: Results obtained on Usability (N = 9 students)

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 [67].

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 5. 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 5: Results obtained on CPS (N = 23 students)

The results of Table 6 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 6: Results obtained on TDT and correlation between CPS and TDT (N = 23 students)

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.

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)[66], answering the first research subquestion (SQ1). Unlike collaboration enhancement results, usability results can be extrapolated to a massive environment. It is important to emphasize that the efforts of the experiments are focused on aspects of usability and stability, so extrapolating results to a massive environment is feasible. On the other hand, this is because the literature proposes that only 6 representative participants are enough to answer a usability questionnaire [66]. 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 [31]. 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. These countries have been selected because of the fast penetration rates of mobile devices and their high approach to the development of MOOC courses under similar platforms. This reflects a real challenge, since it will be necessary to measure other variables to control the heterogeneous behavior of students. That is why, during the development of the upcoming experiments, the feasibility of using a Technology Acceptance Model [68] 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. In future experiments, we will study the persistence and motivation of students when using the game. 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.

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