Muñoz-Merino, Pedro J.; Ruipérez-Valiente, José A.; Delgado Kloos, Carlos; Auger, María A.; Briz, Susana; Castro, Vanessa de; Santalla, Silvia N. (2017). Flipping the Classroom to Improve Learning with MOOCs Technology. *Computer Applications in Engineering Education,* 25(1), pp. 15-25.

DOI: https://doi.org/10.1002/cae.21774

Flipping the Classroom to Improve Learning With MOOCs Technology

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Received 16 April 2016; accepted 9 October 2016

ABSTRACT: The use of Massive Open Online Courses (MOOCs) is increasing worldwide and brings a revolution in education. The application of MOOCs has technological but also pedagogical implications. MOOCs are usually driven by short video lessons, automatic correction exercises, and the technological platforms can implement gamification or learning analytics techniques. However, much more analysis is required about the success or failure of these initiatives in order to know if this new MOOCs paradigm is appropriate for different learning situations. This work aims at analyzing and reporting whether the introduction of MOOCs technology was good or not in a case study with the Khan Academy platform at our university with students in a remedial Physics course in engineering education. Results show that students improved their grades significantly when using MOOCs technology, student satisfaction was high regarding the experience and for most of the different provided features, and there were good levels of interaction with the platform (e.g., number of completed videos or proficient exercises), and also the activity distribution for the different topics and types of activities was appropriate. Comput Appl Eng Educ 25:15–25, 2017; View this article online at wileyonlinelibrary.com/journal/cae; DOI 10.1002/cae.21774

Keywords: MOOCs; data analysis; evaluation; distance learning; flipping the classroom; learning analytics; SPOCs

INTRODUCTION AND RELATED WORK

Massive Open Online Courses (MOOCs) [1,2] are defined as courses (the content is structured and there is a start and finish date) which might involve a high number of students (Massiveness), registration, access, and participation to the activities is free (Open) and all the course interaction takes place using the Internet (Online).

Masters [3] understands the MOOCs phenomenon as the fourth stage in the evolution of online education, which follows the third stage in which the Learning Management System (LMS) is the central element. Some of the differences in this fourth stage, with the introduction of MOOCs are, according to Masters [3]: a change in the roles of teachers, who might not be monitoring all students' actions; an increase in active learner participation, independent learning, or that learners decide what to learn; and the intensity of learning.

The introduction of MOOCs usually implies a combination of learning technologies and learning activities. The use of short video lectures and automatically graded exercises is typical in MOOCs environments [4,5]. Moreover, other learning technologies can be present in MOOCs such as communication tools [5] through the use of LMS communication functionality, external tools such as Twitter or Facebook, learning analytics functionality [4], or tools like gamification to motivate students.

Although the learning technologies used in MOOCs are not new (e.g., videos, automatic grade exercises, learning analytics, or communication tools), the mode of use and combination of these technologies is different from the typical use in LMSs. MOOCs enable user-independent learning, the establishment of the learner's own goals, the change of role of the teacher and a more active learning philosophy [3]. For this reason, new MOOCs platforms such as Open edX, Udacity, and Coursera have been created to adapt better to the new necessities. MOOCs platforms

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have many similarities with LMSs but one aspect that is added in MOOCs platforms is the integration between videos and exercises [6].

Flipping the classroom is one of the typical uses of MOOCs [4,6,7]. Students first interact with an online course using MOOCs technology and next go to face to face lessons with the purpose of focusing on specific issues where they have questions, instead of receiving a traditional classroom lesson. The application of the flipping the classroom philosophy using MOOCs has been proposed for example by [8] for Physics, which is also analyzed in this paper but with a very different setup and conditions, and with different research objectives. In addition, there are other approaches to flipping the classroom that do not use MOOCs, such as for learning circuits [9].

MOOCs technologies and models can be used for a small group of students as a complement to classroom teaching in so-called SPOCs (Small Private Online Courses) [10,11]. There are several examples of running SPOCs such as for learning informatics [12] or programming [13].

Although there is a considerable increase in the use of and research on MOOCs, there is controversy around them [14]. Some important issues and problems have been described [2,15] such as high dropout rates, sustainability, cheating, and plagiarism. A review of about 50 different MOOCs [16] shows low levels of completion rates in MOOCs, ranging from 0.7% to 32 %, and typically about 7%. Therefore, a question arises: Is the use of MOOC technologies adequate? An hypothesis is that not all students enrolled in MOOCs are really interested in completing the course but they might only want to revise some of the materials or they are curious about the topic, which can explain the high dropout rates. However, the situation might be different in SPOCs since they are targeted for specific cohorts of students which take the course as part of their syllabus or degree course program. Therefore, an hypothesis is that the dropout rates of SPOCs might be lower.

The research on MOOCs technologies is at a preliminary stage [17], the effectiveness of MOOCs is an open question [18] and there are no studies to support learning outcomes on MOOCs [15]. There is a need for studies to determine the success or failure of MOOCs technologies in order to know whether their introduction is adequate or not. As there are different learning technologies, topics, and models which can be applied with MOOCs technologies, very different learning experiences should be reported and analyzed, changing different factors.

In this paper, we aim to analyze the success of an experience with a course in Physics of the SPOCs category, applying the flipping the classroom methodology and incorporating videos, automatic graded exercises, gamification, a forum, and learning analytic features. Specifically, we analyze the success of this course based on these research objectives:

- Analyze if students' performance improved the year that the MOOC technology was introduced compared to previous years without the use of MOOC technology.
- Analyze different students' interactions with MOOC technology: if students interacted enough with videos and exercises, if students finished the videos and solved the exercises correctly, if students accessed the different topics in a balanced way.
- Evaluate students' satisfaction with the different functionality and resources enabled for the learning experience (e.g., videos, exercises, learning, gamification features, etc.)

METHODOLOGY

The Context of Courses

Traditionally, 1st year Engineering students have special difficulties in passing the exams of basic academic subjects such as Physics. These are some of the difficulties associated with understanding Physics:

- Many university students confuse concepts such as electric and magnetic fields and they have difficulties in choosing those concepts that are adequate to account for a specific situation [19].
- Even if students have the required conceptual knowledge, many of them are not able to apply it due to their lack of the necessary metacognitive skills [20]. This deficiency leads students to resort to methodologies based on memory and to apply the learned procedures without reflecting on their adequacy [19].
- Even though all the students have to pass a university entrance exam to access Spanish universities, the previous Physics knowledge of the students is not at all homogeneous, which requires a greater effort of adaptation during the 1st year.

In order to overcome all those problems, our university began to offer introductory courses (called "0 courses") in 2000. The objective of these courses was to provide the students with the minimum level of Physics required to follow the Physics course in Engineering studies (Industrial, Telecommunication, and Computer degrees). This is a remedial course for engineering students of Industrial, Telecommunication, and Computer degrees to try to overcome an issue in engineering education, that is, students do not have the proper knowledge to pass the initial Physics courses and there is a high rate of failure, so this remedial course tries to mitigate this issue. The course duration was initially 3 weeks, but changed to 1 week in course 2008/2009.

Flipping the Classroom

The "flipped classroom" aims to flip the traditional learning model, where students receive professors' lectures at school and later they do the homework at home. Instead, the "flipped classroom" promotes that students can first learn the basic concepts at home, usually with video lessons and basic exercises, and next they can do more active learning activities in face to face sessions such as problem solving, collaborative activities, or question solving with lecturers. The flipped classroom or inverted classroom has been described in detail and supported from many years and experiences [21,22].

There are several successful studies applying this methodology with successful results. For example, it was concluded that a methodology based on the flipped classroom improved the learning gains of students (with a pre-, post-test design) with respect to traditional classroom [23]. In addition, the work presented by [24] received great survey results, where 81% of the students preferred the flipped format over a more traditional one. More recent studies have also been reported which include the flipped format, for example [25]. However, not all the students in a class will feel motivated by flipped lessons [26]. Some of the reasons for this lack of motivation are that they do not want to learn from other peers but from experts, or that there is extra work due to all the formative activities, which do not contribute to their final grades.

This flipping the classroom methodology has been applied to this experience. The instructors designed a set of contents which students had to carry out at home prior to the face-to-face sessions. These contents (exercises and videos) were made available for students for an entire month previous to the classroom lessons. Students had to revise all the materials before the start of the face-to-face lessons. The learning activities during the face-to-face lessons were based on an active learning approach. The learning activities included solving problems, which were more complex than the exercises of the online phase; activities of questions and answers of students in which teachers asked students about the specific videos in the on-line phases and whether they had problems understanding them and students were able to ask additional questions to lecturers; and collaborative activities in which students had to solve problems in groups.

Regarding the process of evaluating the performance of students in the flipped classroom, all students get a final grade which can be only pass or fail. This pass/fail grade is based only on the face to face evaluations but not on the online activities. This is because it is easier for students to cheat during the online activities and the final grade is obtained in a controlled environment. However, students solve different exercises during the online phase, watch different videos, etc. and students receive different feedback about their performance in the online phase. But these are only formative activities that are not used for the certification of the course. Depending on their performance in the KA-U platform, students are classified in different face-to-face groups. Therefore, the performance of the students in the online phase is used to group them in the face to face phase so that more active learning activities were provided to the groups with students with better performance. For example, students who did not interact in the MOOC platform at all are classified in a group where traditional face to face sessions are provided.

The Khan Academy Platform and Adaptation to Our Context

The main resources in the Khan Academy platform are videos and exercises. The exercise type most used in our course is the parametric one. A parametric exercise defines several variables. Each variable has a range of allowed values. Every time that a student accesses an exercise after solving it correctly, the system chooses different parameters. In order to master a skill, students must successfully solve an exercise correctly several times, and then the student will achieve a proficiency level in that skill.

Khan Academy also incorporates several innovative elements. There are many gamification features embedded in the system's functionality such as badges or energy points. Gamification is usually used in several systems to try to motivate students, for example, in [27]. Gamification techniques have been applied in many different experiences with successful results [28,29]. Furthermore, Khan Academy implements a powerful learning analytics module which enables individual and class visualizations. Students can use these visualizations to check on their work and gain self-awareness. Instructors can use this visualization dashboard for more in-depth control of students, but also to detect global problems in resources (videos or exercises). The default learning analytics module has been extended with our developed ALAS-KA module [30]

We have installed a local Khan Academy runtime environment, which has been adapted and personalized for our university. We name this local installation KA-U. This platform can be logged from outside the university at any time before the face to face sessions and at any place with an Internet connection. This way, students do not need to be on the campus and they can connect into the platform from other places. However, only students with a registered account can log in to the authentication system and use the platform. Students who can get a registered account are only those whose are enrolled in the university for 1st year engineering degrees.

In addition, the educational materials provided by Khan Academy are not used. Instead, the educational materials (videos and exercises) have been completely developed by our university. These materials are in Spanish as it is the official language for Courses 0. Figure 1 shows an example of developed exercise at our university in the Khan Academy exercise player.

In addition, the Moodle platform was also used in the experience. The Moodle platform provided a forum for communication by students as well as a structure of the contents in a course. The Khan Academy platform does not provide a

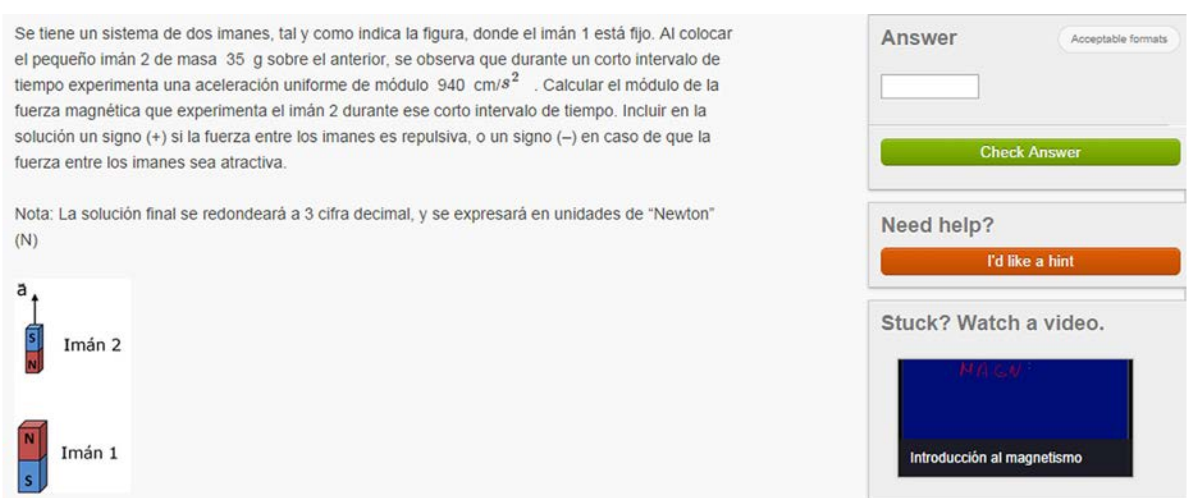

Figure 1 Example of exercise in the Khan Academy platform that was used in the experience.

general forum for discussion. In addition, the Khan Academy platform does not provide the same type of structure of contents. Therefore, we added the Moodle platform to extend the functionality of the experience, including features which were not present only in Khan Academy. This way, the technology used as a combination of Khan Academy plus Moodle might be considered as an xMOOC instead of a quasi-MOOC [2].

Generation of Materials: Videos and Exercises

Recording of the videos was carried out using the following materials: A Wacom Bamboo graphic tablet [31] and a pen, the SmoothDraw software tool [32] and the Camtasia studio 7 [33], to write down and record the contents to be explained. A common format was used for all recorded videos. The specific contents to be recorded on each video were restricted so that videos did not last longer than around 15 min, with the objective of maximizing students' attention on the particular basic concept to be revised.

For each video, a series of exercises or questions was also prepared so that students could check if they had understood the basic concept explained on that particular video. Several hints were also available upon request to help students solve the exercises.

In the 2012/2013 academic year, 26 topics were grouped into five general subjects, and 26 specific videos were available in the Physics 0 SPOC. Some of the videos have more than one related exercise.

Learning Process

During the course edition 2012/13, where the MOOC-driven approach was included, the following sequence of events took place in this order:

1. Students had the possibility to interact with the KA-U platform for one month: watching videos, solving exercises, earning badges, or setting goals. The students used the platform in their spare time before the face to face sessions. This way the classroom is inverted: students study the theoretical concepts using the platform in their spare time, while they solve problems, do active learning activities, etc. during the face to face sessions.
2. Students who were able to interact with the KA-U platform were requested to fill in an online survey after the interaction about their satisfaction with the MOOC-driven experience and technology.
3. Students attended face-to-face traditional classroom sessions for a week. An active learning approach was followed as described in the "flipping the classroom" sub-section. Students were classified in different face-to-face groups depending on their performance on the KA-U platform, and more active learning activities were provided to the groups with better performance on the KA-U platform, while more theoretical classical lessons were provided to the groups with worst performance on the KA-U platform.
4. All students got a grade of pass or fail based on the face to face activities. In addition, some students completed a final exam, obtaining a grade. The final exam took place during the final face to face session.
5. Teachers discussed with students their experience with the course and the KA-U platform.

RESULTS AND DISCUSSION

Comparison of Student Grades

In every course edition students are evaluated just with a pass/not pass. However teachers often evaluate students with a grade from 0 to 10 at the end. This scale is not mandatory, therefore it is up to each teacher whether to use it or not. For this reason, there is not a mark for all the students enrolled in the 0 Course for a given edition. Moreover, data from the 2010/11 edition have been removed because a different scoring criterion was used that year.

The different course editions are divided into two groups:

- Control group: All students only had traditional classroom sessions, in which students interacted with teachers for learning Physics. First, students had traditional teaching during 1 week, and after that they were evaluated by teachers with a grade using a final exam. This group includes data for three course editions: 2008/09, 2009/10, and 2011/12, as the MOOCs technology was not included during these course editions. Data before course edition 2008/09 are not used because the face-to-face lessons were for 3 weeks, but from the 2008/09 edition, the face-to-face lessons were for 1 week.
- Experimental group: All students had traditional classroom sessions. In addition, some of them interacted with a course with MOOCs technology, using a flipping the classroom methodology, following the phases of the "research phases" sub-section. This group includes data for course edition 2012/13.

It is important to note that we are not comparing students who selected to carry out the MOOC phase with students who selected not to carry out the MOOC phase, which would not be a reliable separation of experimental and control groups since good students might select to do the MOOC phase. Instead, we are comparing students that had the option to make a selection about using the MOOC phase (experimental group) with students that did not have the option to make this selection (control group).

Table 1 shows descriptive statistics of the control and the experimental groups. The mean of the grades for the control group was 5.43 ($N = 205$ students) with std. deviation of 2.15, being the mean within the confidence interval (5.14, 5.73) with a 95% confidence level. While the mean of the grades for the experimental group was 7.50 ($N = 43$ students) with std. deviation of 1.89, being the mean within the confidence interval (6.92, 8.09) with a 95% confidence level. In the former case, the number of students 43 is less than the total number of students because not all students did the final exam.

An independent t-test between the grades of the control group and the experimental group reveals that there is a statistically significant difference in favor of the experimental group ($t = 5.85$, $P < 0.0001$), being the confidence interval of the difference between both groups within the interval (1.37, 2.77) with a 95% confidence level.

TABLE 1 Descriptive Statistics for the Control and the Experimental Groups

Type of group	Mean	Median	Mode	Std. deviation
Control	5.43	5.95	5.00	2.15
Experimental	7.50	8.03	8.56	1.89

Moreover, the analysis should take into account that not all the students of the experimental group interacted with the educational materials provided by the MOOC-driven approach. A total of 68 students interacted with the materials of the KA-U because the interaction was not mandatory and the students decide if they want to make use of the platform and which materials to access. If all the students of the experimental group had interacted with the MOOCs technology, a greater grade increase might have been obtained.

The factors that caused the significant better results of the experimental group should be explained based on the differences with respect to the control group, which are mainly the following:

- There is more time to work with active learning methodologies in the face-to-face lessons for the experimental group because students had already studied the concepts in the on-line phase. More exercises, collaborative activities and reflection activities are done in the experimental group in the face-to-face lessons, which promotes better learning.
- A better attention to the diversity. First, because students' previous knowledge is very different, so the use of short videos enables them to customize their own learning. Second, because heavier active learning load is set up to students with a good performance in the KA-U platform as students are grouped depending on their previous performance.
- Students' attention regarding the theoretical concepts can be held more easily by providing short videos rather than in longer lectures or training sessions.
- The use of online automatically graded exercises enables students to self-test their knowledge in different topics anytime and anywhere. Self-regulated learning is not easy to achieve in a traditional class, as neither individual feedback nor evaluation can be delivered immediately by the class teacher.
- Meta-cognitive skills of students are trained while using an environment such as KA-U because students can learn about how to set goals or when to ask for help, for example, using the hints.

As far as we know, there are no similar studies that compare a situation with the use of MOOCs technology using flipping the classroom with respect to a situation without the use of MOOCs technology in terms of grades. However, there are some studies that compare students' grades when using or not using a flipping the classroom methodology without using MOOCs technologies. For example, student performance improved in a flipping the classroom methodology, with 83% of students gaining a C grade or better, compared with 56% when there was a traditional course methodology [34].

Student Surveys

The survey consisted of a set of questions, rated using a five-point Likert scale. The survey was provided through the on-line platform but not all the students answered the survey. The survey was taken by 23 students although there were some questions which were not answered by all students. The results of the survey are presented in Table 2. While the boxplots diagrams for each variable of the survey are shown in Figure 2.

The mean score given to the platform interface ranged between 3.9 and 4.3, so it can be concluded that it was easy in general. The cause of this result can be explained by the useful design of the Khan Academy platform, which validates this user interface for this type of students. The videos are satisfactory according to the students. Moreover the usefulness of the exercises was marked with 3.9 which is a very good result. The students were also asked about their involvement in the learning process. They considered that they had learnt quite a lot since most of them marked this question between 3 and 4. The factors that helped to obtain these encouraging results can be explained thanks to the appropriate design of the videos and exercises, which made the learning experience valuable.

TABLE 2 Results of the Student Surveys

Questions	Mean	Median	Mode	Std. deviation
Ease of access (*ease_access*)	4.3	4.0	5.0	0.82
Ease of navigation (*ease_navigation*)	4.1	4.0	4.0	0.75
Ease to find the different resources (*ease_resources*)	3.9	4.0	4.0	0.87
Usefulness of videos to learn/ review concepts of Physics (*useful_videos*)	4.3	5.0	5.0	0.88
Usefulness of exercises to learn/ review concepts of Physics (*useful_exercises*)	3.9	4.0	4.0	0.87
From your point of view, how much have you learned with this methodology? (1: very little, 5: very much) (*learning_perception*)	3.6	4.0	3.0	0.90
How many videos have you watched? (*video_activity*)	3.6	4.0	5.0	1.37
How many exercises have you done? (*exercise activity*)	3.9	4.0	5.0	1.24
The forum to answer questions with other classmates was helpful (*forum_usefulness*)	3.5	4.0	5.0	1.20
The reports of my activities in the KA-U platform are helpful (*report_usefulness*)	3.8	4.0	4.0	0.66
I enjoyed the participation in this course (*enjoyment*)	4.3	4.0	4.0	0.69
I would recommend it to other colleagues and prospective students (*recommend*)	4.5	5.0	5.0	0.80

More than half of the students watched more than 16 videos and did more than 16 exercises, according to the survey. To analyze these results it is necessary to take into account that the videos had to be watched during August, which is the typical vacation month in Spain, as mentioned before. In addition, students can skip some materials that they already knew as it is a review course. Therefore one can conclude that the response to this initiative has been very satisfactory. The score received on the communication section is slightly lower (3.5). In part, this would be due to the same reason as the one stated above (the experience took place at the end of August, outside the academic period) so it is more difficult to be aware of an online forum. The internal reports (statistics) provided to the students by the KA-U platform were quite helpful for them, according to the results of the survey on this point (3.7). Finally, the overall result of this initiative is very positive (4.3). The students enjoyed participating very much and they would recommend the course to others.

Most of the student surveys in MOOCs in the literature do not focus on the success of the MOOCs experience after completing a MOOC as in this research, but on the different profiles and

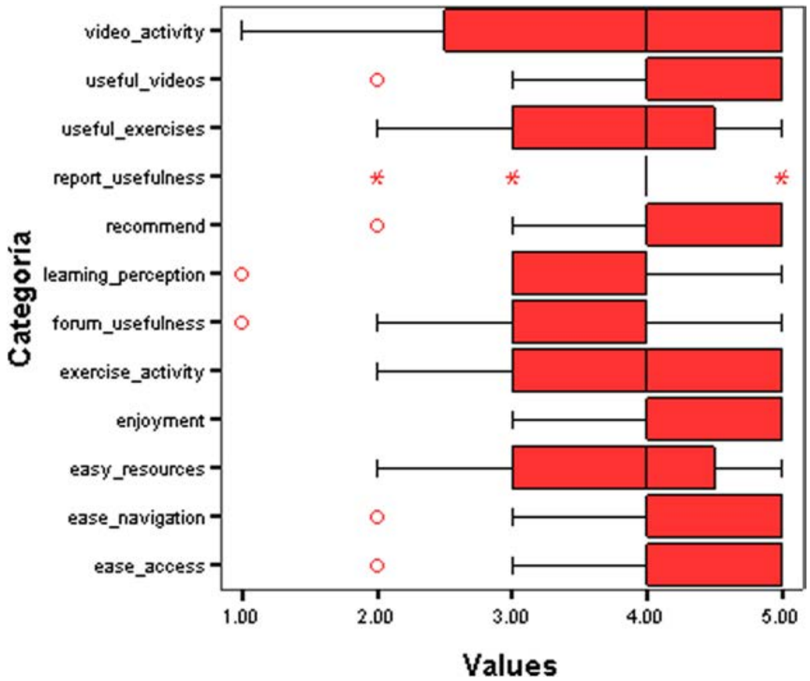

Figure 2 Boxplot diagrams for the questions of the survey.

expectations of participants [35], reasons for enrolling a MOOC [36], and work with collaborators or educational level [37].

Conversely, our survey focuses on the success of the experience when using a MOOC, and different general aspects are evaluated (e.g., student perception of learning, user interface or global satisfaction with the experience) and also specific features and elements (e.g., videos, exercises, gamification, and learning analytics elements). In the work proposed by [15], the perceived learning outcomes are measured in that experience, which is quite close to the perceived learning question of our survey, but just one of the questions. The results of perceived learning are quite similar in that experience and in our question, with mean 3.6.

Use of the Platform

A total of 68 students were considered out of 102 that were registered in the platform. The students who were not taken into account for this analysis (34 out of 102) were discarded, because they did not log into the platform or they had a very low interaction.

The total time invested in the platform by these 68 students was 402 h (215 for solving exercises and 185 for watching videos), so there is an average value of time invested of about 6 h per user. There was not a big difference between the time spent in watching videos and exercises, so neither of the two activities was prevalent over the another one. Moreover, students logged into the platform 6.4 different days on average, and the average user spent around 1 h each day. As students may interact for about 4 weeks, this means an average of 1.5 h per week interaction with the platform.

The total time spent in different learning activities was also analyzed by Breslow et al. [36]. Each of the certificate earners of that MOOC accessed approximately 2 h per week of videos and 1 h per week of exercises, but it varies depending on the week. Although, the time interacting with exercises is less than interacting with videos, the summation of the time invested in exercises plus homework was a little greater than the time watching videos. In addition, students devoted time to other MOOC learning activities. In order to compare the results of [34] with our results, it is important to note the very different contexts and ways of calculation. First, our context is a SPOC in which we took 68 out of 102 students (67%) for the time statistics, while that MOOC took only certificate earners, which is 7,100 out of 155,000 (7.5%). If we took for our SPOC just the 7.5% with better achievement, then the times would increase considerably. But we cannot take certificate earners in our SPOC to compare with this statistic as the SPOC is designed to review concepts of Physics and there is no grade. In addition, that MOOC was structured in different weeks in which the content was delivered while our content is delivered all at the beginning. The amount of content was also different between that MOOC and our SPOC, as well as the topics, their difficulty and their design. Finally, the number of weeks was also different (14 vs. 4).

Considering the percentage of started and completed videos per user, an average user started 48.12% of videos and completed 37.5 % of them. In this direction, other studies such as [38] have reported on the median percentage of videos viewed ranging from 21% to 77%, depending on the total time of absence of students. In any case, each specific context with its own features should be evaluated when making a comparison. The video access distribution has been analyzed in a MOOC [39].

In our SPOC, there were three users who completed all the videos in the platform. The 68 students started a total number of 891 videos and 696 of them were completed. Thus, 78% of started videos were also completed, which is a high percentage.

An analysis of the videos that are started but not finished is also done by [9], giving a dropout rate of 55.2%. The comparison of this 55.2% with our obtained 22% should not only be explained by the different context (e.g., types of videos, SPOC instead of a MOOC, etc.) but also that the definition is different. In that work, the calculation is done by sessions, so if a user accessed a video four times and completed it one of them, then this is computed as 75% dropout rate. While in our case we consider the video as a whole, and in that case we consider the dropout rate as 0% for this video as at some time it was completed even if it was not in the same session.

Students were presented with a total of 35 different types of exercises. Considering the percentage of exercises that a student did not attempt, exercises where a student solved them correctly at least once and exercises where a student achieved proficiency, then an average user did not attempt 50.16% of the exercises, solved it correctly at least once in 44.9% of exercises, achieved proficiency in 34.25% of the exercises, and was not able to solve correctly even after several attempts in 4.04% of different types of exercises. According to [38] the median percentage of assessment taken varies from 17% to 62% depending on the total period of absence. In any case, these results are for a specific MOOC with different conditions with respect to our SPOC. But the decrease in attempts of exercises with respect to videos that is observed in that MOOC is not observed in our SPOC. Other calculations of the effectiveness can be done e.g. following the PES methodology [40]. We can see the number of proficient exercises achieved by students in our SPOC more in detail in Figure 2.

From these results, as the participation in videos and exercises was around 50% on average per each student and each student devoted 6 h to the course on average, we consider it as a positive participation data in the platform.

In addition, we can also observe that the ratio of videos that were started but were not completed was low, and that the percentage of exercises that students were not able to solve correctly even after several attempts was very low. These are both good results, since it indicates that students did not only access the resources but they completed many videos and solved exercises correctly at least once. Moreover, it is interesting to note that the percentage of proficient exercises is also high, which denotes that students did not only solve a type of exercise only once correctly, but they solved it several times correctly (most of the cases being parametric versions of the same exercise), which is good, as students can reinforce how to do the same type of exercise.

Each user needed an average of 80 s to solve an exercise correctly the first time, needed two attempts, and asked for an average of 0.5 hints. These are reasonable values which indicate that students did not need too many previous attempts to get the correct solutions.

The exercises and videos are grouped into 26 topics. Figure 3 presents the total time percentage distribution spent by all students (watching the videos and completing the exercises) in the different topics. Moreover, the different topics are grouped by subjects with different colors according to the five general different groups. It can be observed that the time distribution per topic is quite homogeneous: topics such as scalar product, inclined plane and parabolic shot hold the highest percentages, with the sum of the total time devoted by all students (in videos and exercises) being more than 2000 min in each of these topics. On the other hand, there are other topics where students devoted very little time, such as power generation and Larmor radius, with only 1% of the total time. These are interesting results since they help to determine the topics where students have lacked most from high school. In any case, above all, there are no topics with exaggerated percentages and the time distribution is fairly balanced so most of the resources were useful for the students.

The time distribution in videos and exercises is different from one topic to another. This can be caused by a variety of effects such as complexity or interest in one topic. The order of the different videos and exercises in the course structure might also have an influence on the results. For this reason, Figure 4 shows the different videos and exercises in the correspondent order. There are 19 topics where the time spent on videos is higher than that spent doing exercises, and only seven where the opposite case happens. This can be seen as normal because it is expected that students can solve exercises quicker than watching videos. However, the total time devoted in exercises is higher than in videos because there are a few topics where the time spent in exercises was very high. We can see a more in-depth graphic in Figure 5 where the time spent on each topic is shown in cumulative bars. Blue represents the time spent on exercises and red the time spent on videos.

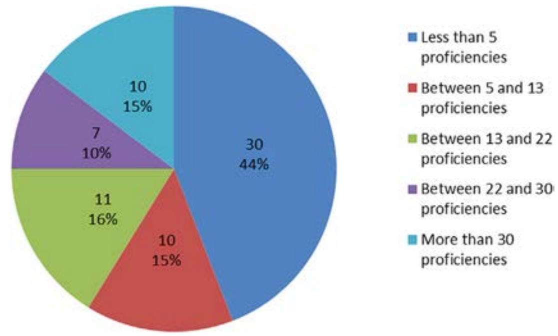

Figure 3 Number of proficient exercises achieved by user.

The main factors that caused this data analytics results are the following:

- Students who interacted in the SPOC were motivated and interested in reviewing Physics concepts because they need to know them in the 1st year of university. No one can access the SPOC but just the students who are starting a university degree and request for the course. This makes that the dropout rate was much lower than in other MOOCs reported in the literature where any person (because they are completely open) can enroll on the course but many of them access them just for curiosity. In addition, this makes that students completed a lot of percentage of videos they started, as these are students really interested in the course.
- The facts that the SPOC took place in August (vacation period in Spain) and was optional might reduce the activity level of students.
- As corroborated by the student survey, the good features of the platform (interface, gamification, learning analytics, etc.), as well as the good design of videos and exercises helped to provide a pleasant experience when interacting with KA-U platform.
- This was a course for reviewing concepts of Physics that students should have covered in high school, so many students already knew several of the topics and concepts of the course and they were allowed to decide not to take the parts they have already mastered. For this reason, many students just interacted with just some parts of the course.
- The similar amount of time spent in videos and exercises per topic can be explained because students usually made both the video and the related exercise when they wished to learn a topic. Although solving an exercise once would usually be less time consuming than watching the correspondent video, the student should repeat it several times (parametric exercises) to get the proficiency.

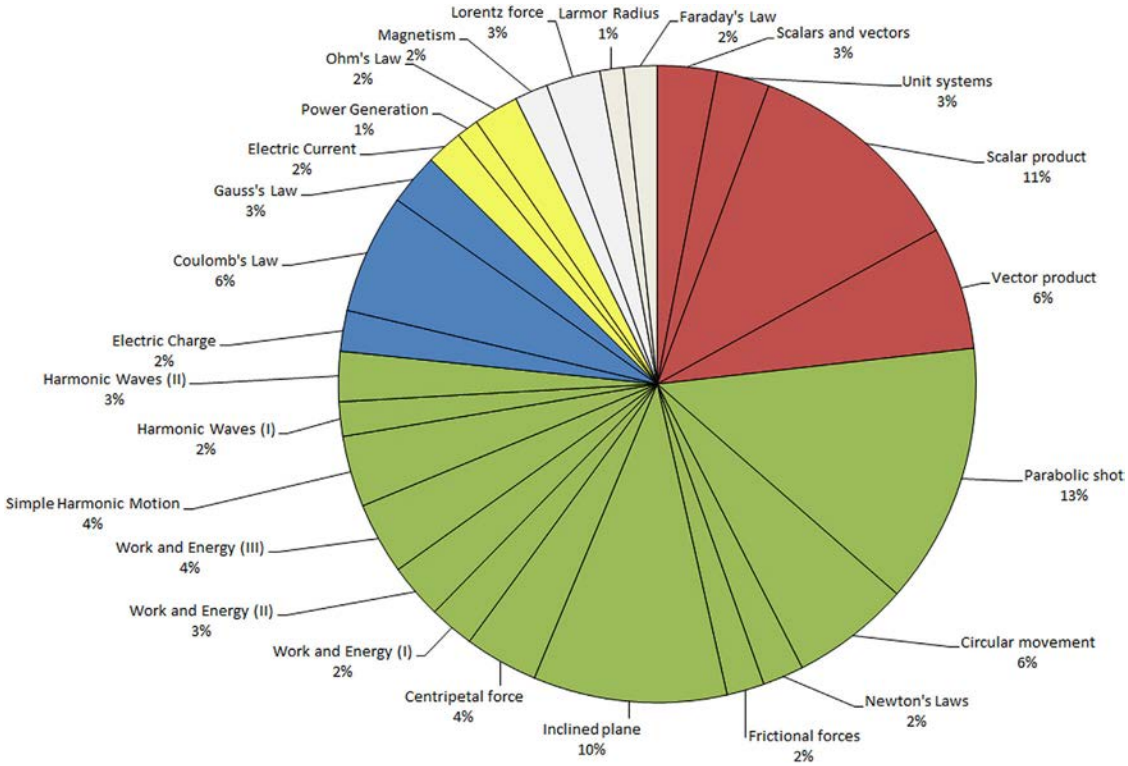

Figure 4 Time distribution at the different topics in the course.

- In some occasions the repetition of an exercise with different parameters can be a bit boring for students. However, a big percentage of students repeated the exercises until achieving the proficiency, because of the gamification features, which provided energy points and badges related to getting the same exercise correctly several times. However, there is a percentage of students who only solved the exercise correctly once or a limited number of times until they thought they mastered the concept regardless of the gamification features, so for this reason the percentage of proficient exercises is lower than the one of correct exercises.
- A factor that influenced watching more videos and solving more exercises was that they were located first in the course structure. However, this was just a slight effect and the time

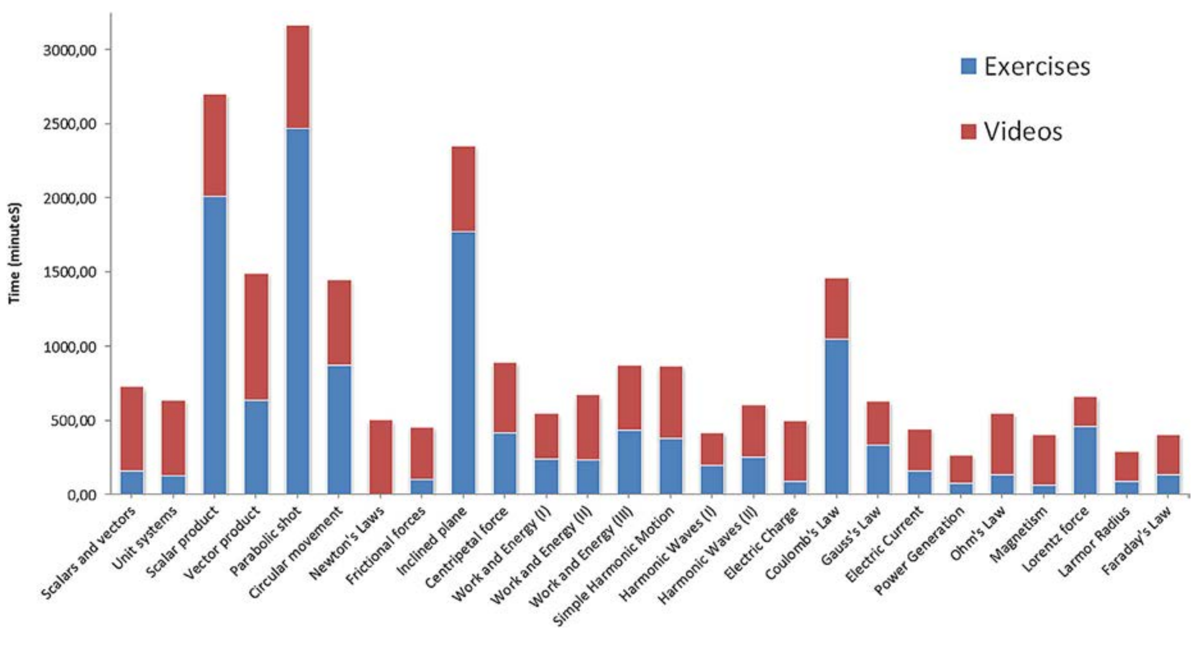

Figure 5 Time spent on each topic. Exercise time in blue and video time in red.

distribution among topics is quite distributed, which should be explained because students devoted more time for the more difficult topics. Therefore, students focused on the aspects they had more difficulties having low effect the order in which they are presented in the course structure.

CONCLUSIONS

First, we can conclude that students performed better with the introduction of the MOOCs technology flipping the classroom rather than with the traditional approach, as supported by the comparison of grades between the experimental and the control groups and the responses of students to the learning questionnaire. The factors of this improvement of learning is the use of a more active learning methodology in the face-to-face lessons, a better attention to the diversity, better student attention, enablement of self-regulated learning and training of meta-cognitive skills. As far as we know this is the first research that compared flipping the classroom with MOOCs technology versus traditional lessons regarding grades with a control and experimental group.

The dropout rates and the rates of uncompleted videos are lower in this experience than in other works of the literature because in this experience the subset of students are not just any people from Internet but students who are interested in learning Physics before starting their 1st year in university. Although the high dropout rates are a typical concern in MOOCs, this research shows that attrition can be reduced in SPOCs when the students are really interested in learning the contents.

The fact that some contents were in a specific order or location of the course structure did not influence a lot that students focused more on them. Instead, we can observe that each student focused mainly on the concepts they had a lack from high school, watching videos and solving exercises of not all the topics but just on the ones they had to reinforce. This was a factor that was not studied in other studies. The time spent in videos and exercises was similar as also reported in previous works.

Moreover, we can conclude high student satisfaction with the user interface, the videos, exercises, the gamification and learning analytics features and the overall experience with the MOOCs technology as revealed by the answers to the survey. This type of student survey about satisfaction in a SPOC had not been done before as far as we know and validates the use of a set of features like the ones used in this experience.

It is also important to note that the introduction of the MOOCs technology for this experience implied a great effort: the design and creation of new videos and exercises; the installation, configuration and adaptation of the MOOC platform; new code developments for the platform; and the codification of exercises to the correct format. As the results point out, this was a successful experiment. We think that the increase in grades, the student satisfaction and the students' interactions are good enough to justify the introduction of the MOOC-based approach.

There are many ways to improve the learning process in MOOCs. One of the most prominents is the introduction of adaptive learning, giving personalized recommendations taking, for example, a service oriented distributed philosophy [41].

In a future, the own learning activities of the online phase might take part of the final evaluation of the students. In order to overcome the problem of plagiarism and cheating, some systems, for example, based on face recognition and sensors might be introduced. There is current research on these issues [42].

These results are valid for a specific context: Physics elementary concepts, flipping the classroom model, private course, not delivered by weeks but everything accessible at the beginning, short videos, exercises similar to the ones in Khan Academy, use of forum, as well as specific gamification and learning analytics features. Any change in these and other variables might have an effect on the final results. Experiences with MOOCs technologies changing these and other variables should be studied in the future to better understand in which contexts the introduction of MOOCs technology makes sense and can successfully improve the learning process.

ACKNOWLEDGMENTS

This work has been supported by the "eMadrid" project (Regional Government of Madrid) under grant S2013/ICE-2715, the "RESET" project (Ministry of Economy and Competiveness) under grant TIN2014-53199-C3-1-R, the IRENE project (Ministry of Economy and Competiveness) under grant PT-2012-1036-370000 and the European Erasmus+ SHEILA project under grant 562080-EPP-1-2015-BE-EPPKA3-PI-FORWARD.

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Vanessa de Castro is an assistant professor in the Department of Physics at the University Carlos III de Madrid. She holds a MSc in Physics and a PhD in Materials Science. She has also worked at the European University of Madrid, the Materials Science Institute (ICMM) at the Spanish National Research Council and in the Department of Materials at the University of Oxford. Her areas of research in the educational field include investigating on cooperative and active learning. In the Materials Science field, her research focuses on the development of novel steels for fusion reactor structural applications.

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