Strengthening mathematical skills through MOOCs: a case study

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Abstract

Recently there has been a huge development in Massive Open Online Courses (MOOC) with the aim to ease and complement the learning process, especially at university level. In this context we presented four MOOCs entitled 'Basic Mathematics: Numbers and Terminology, Differentiability, Integrals and Algebra' on the platforms UPV[X] and EdX, aiming to match the freshmen's level in mathematics at engineering grades.

We have used these courses to reinforce theoretical knowledge during the first year of university and to promote them as an educational complement among the students showing more difficulties in mathematics.

The implementation of these MOOCs as an element of the learning process has brought new methodological opportunities. The resources and tools offered make learning a more social and collaborative process as connect students with each other, allowing new methodologies focused on problem-solving techniques. In addition, although the MOOCs impose a sequence of contents, this is usually quite adaptable and contributes to the individualization of learning, allowing students to work at their own pace and in an environment of their choice.

The procedure has been based on tracking students with lower academic performance or those showing mathematical gaps and offering them the opportunity to reinforce such knowledge through the use of specific MOOCs.

The process has been done mainly online but with periodic meetings with the teachers to evaluate student progress. This methodology (based in a blended learning methodology) is intended to enhance the motivation and improve the performance of the students, avoiding dropouts.

The results of the students joining these courses are presented versus the results from the students that did not participated.

1. Introduction

New technologies have brought an educational revolution, allowing innovative teaching methodologies, both inside and outside the classroom. Among all of the advantages they provide, the availability of the knowledge and the interaction between users are two of particular importance. Regarding the first one, in the recent years there has been a huge development on Massive Online Open Courses (MOOC). Prestigious universities, such as Harvard and Oxford, started a project a few years ago [1] with the objective to offer MOOCs to students from around the world about topics of interest from the academic world. The main features of these courses (open, online, massive) represented an important milestone in the acquisition of knowledge. In EdX platform, more than 70 institutions, among prestigious universities, are involved generating quality content in multiple languages. Similar projects have slowly been growing around the world and today there exist many educational platforms offering such courses successfully.

These courses and contents have allowed students to broaden, strengthen or supplement their academic curriculum and have enabled teachers to change some educational strategies. However, despite its rapid expansion in the academic world, its use is usually restricted to complement the knowledge, and not as an active learning tool. Nevertheless, these courses have much more methodological possibilities that are being implemented gradually [2].

The implementation of MOOCs as an element of the learning process during the academic year has brought new opportunities in the applied methodologies. These courses offer resources and tools that make learning a more social and collaborative process as connect students with each other and allow methodologies focused on problem-solving techniques. In addition, MOOCs are quite adaptable and contribute to the individualization of learning, allowing students to work at their own will, and in the environment of their choice. This gives the student an extra motivation.

Recently the Polytechnic University of Valencia (UPV) has become a collaborative partner of the EdX platform, offering several courses on different subjects. Four of these courses (*Basic Mathematics: Number and Terminology, Basic Mathematics: Differentiability, Basic Mathematics: Integrals and*

Basic Mathematics: Algebra) have been conducted in collaboration with the Department of Applied Mathematics. Their main objective was to reinforce freshmen mathematics level, offering a pre-university course in which all the contents needed were reviewed. The contents have been designed to be affordable to any student, starting from the ground up. The standard format of these courses consists in a series of short videos in which a subject or a part of a subject is developed. Then the student is assessed about the contents using different methods of evaluation. An online forum can be used anytime to interact with other students and the teachers, the latter acting as moderators.

On the other hand, nowadays many methodologies and assessment systems enable teachers to identify the needs and gaps of students' knowledge during the academic year, but still we lack the necessary tools to amend successfully these situations. In addition to the mentoring hours, new digital elements can be used to help students achieve successful skills.

In this study, we used MOOCs as an educational tool to reinforce and review mathematical skills. The self-assessment tests available in the MOOCs give immediate feedback, so students have a chance to correct mistakes. Communication via the forums also plays an essential role, allowing students to interact with peers, sharing knowledge and experiences and promoting personal and professional growth.

We have offered these MOOCs to different grades at the UPV, and we present here the results on the Grade in Electrical Engineering (2013/2014) and two groups of the Grade in Agricultural Engineering (2014/2015). The results have been really good, increasing the skills and abilities of students. Also a survey about this methodology is presented.

2. Blended Learning

Blended learning is the term that describes a learning methodology in which e-learning is combined with more traditional learning forms [3].

Many authors suggest that blended courses emerge where between 30 to 80 percent of the instruction is delivered online, although online teaching is only a complement to on-campus teaching and not a replacement [4].

According to David Nagel [5] there are six models of blended learning:

1. The "face-to-face driver" model, in which a teacher in a traditional classroom instructional setting employs online learning for remediation or supplemental instruction;
2. The "rotation" model, in which students move back and forth between online and classroom instruction;
3. "Flex", a model in which the curriculum is delivered primarily through an online platform, with teachers providing onsite support;
4. The "online lab" approach, wherein an online course is delivered in a physical classroom or computer lab;
5. "Self-blend", a model in which students choose on their own which courses they take online to supplement their schools' offerings;
6. The "online driver" model, where the courses are primarily online and physical facilities are used only for extracurricular activities, required check-ins, or similar functions.

In our study we have applied a blended methodology mixing 3 and 6. Students work mainly outside of the classroom, but they are given the chance to meet with the teachers several times per week in order to exchange points of view. This methodology has been tested apart from the usual performance of the academic year.

3. MOOCs

Massive Open Online Courses (MOOCs) are classes delivered in an online environment with significant differences from previous approaches to online education.

Following [6] the fundamental characteristics of a MOOC are:

- Open: Participation in a MOOC is free and open to anyone who has access to the Internet. The work that is generated through the course (both by the facilitators and learners) is shared and available publicly.
- Participatory: The learning in a MOOC is enhanced by participation both in the creation and sharing of personal contributions and in the interactions with the contributions of others.
- Distributed: MOOC is normally based on the connectivist approach; therefore, any knowledge should be distributed across a network of participants.

However, in [7] two types of MOOCs are presented and discussed. The first one is based on the connectivism theory of learning aforementioned, which stimulates networks of learners evolving informally. These are known as cMOOCs. The type known as xMOOCs are more closely resemble traditional educational models. This type of MOOCs allows the university to incorporate them into the existing curricula. Deadlines for completing tasks, and an online form of continuous assessment allow the course administrators to assign marks and credits. Online participants who are not interested in obtaining credits can participate.

xMOOCs remained relatively unknown until 2011 when a number of the leading Universities in the United States began to offer MOOCs via

commercial platforms such as Coursera, Udacity or EdX.

Since 2012, a growing number of universities have offered MOOCs worldwide and the public and academic discourse around MOOCs has been strengthened. MOOCs have been recognized as a major advancement of higher education [8].

As we can find in [9], the impact of MOOCs goes beyond providing free and open education and is now leading to new blended learning scenarios at schools and universities. In these contexts, MOOCs are exploited to enhance teaching and learning in the form of successful flipped classrooms (i.e. students watch videos with the theoretical concepts from home and practice these concepts with automatic correction exercises, and later attend to the classroom to solve problems with teachers). Such use of the affordances that emerge from MOOCs to improve the quality of teaching and learning in traditional educational settings leads to what has been called SPOCs (Small Private Online Courses) in the media [10].

4. Procedure

Continuous assessment has been a fundamental pillar in education for many years. One of the main advantages it provides is the possibility to do a detailed monitoring of student's learning process, allowing us to detect mathematical deficiencies in our students. We have redesigned the massive use of the MOOCs ([11],[12],[13]) to employ them as a tool targeted at students who have problems in their mathematical learning. These MOOCs allow them to reinforce the knowledge they need through a progressive and effective teaching methodology in a reasonable period of time. It also allows teachers to track the evolution of the students participating in the MOOC's assessments and assignments.

Since we are able to choose the MOOC or the specific part of a MOOC each student needs to reinforce his/her mathematical knowledge, we can consider this methodology as an adaptive methodology that boosts the monitoring of the students and helps them to accomplish their objectives.

Most of the learning has been done outside of the classroom, but also periodic office hours have been part of the process. Nevertheless forum has been very important in the development of the MOOCs. It has been a constant link between teacher and students, allowing feedback in both directions. This way we have been able to track the progress of our students.

For the group of Electrical Engineering enrolled in the subject Mathematics I (2013/2014), students are assessed four times during the academic year, apart from the final evaluation.

The first test of the subject Mathematics I is devoted to complex numbers and its applications to solve basic mathematical problems. The use of these complex numbers involves handling properly many basic mathematical properties, so the results of this first test allow us to detect the students with deficiencies in mathematics. The following tests are devoted to Differential Calculus, Integral Calculus and Algebra. It is worth noting that MOOCs do not cover the topics taught during the academic year, but establish the basic mathematics needed to understand perfectly the subject Mathematics I.

Students showing the worst results are cited in a personal interview in which they are offered the possibility to follow several MOOCs on basic mathematics. These MOOCs, as mentioned before, normally consists in a sequence of units, videos and assessments covering a concrete topic. Figure 1 shows a screenshot of the MOOC *Basic Mathematics: Differentiability*, in which a video is about to start.

These MOOCs are performed during the academic year, always one month before each academic test, so the students are able to overcome the mathematical deficits on time. These courses incorporate their own assessments at each unit and the results are available immediately for both the student and the teacher. Through MOOCs' assessments teachers can track students' progress in great detail. Figure 2 shows the progress of a student during a MOOC, although more details can be obtained.

One of the fundamental tools MOOCs offer is the forum. Through it students can consult doubts with teachers or peers. The use of the forum has allowed us to achieve a closer link between teachers and students, granting us the opportunity to solve specific questions and boosting the motivation of our students. Figure 3 shows a screenshot of the forum in which students can contact the teachers. When necessary, students have been provided with more exercises, further explanations, tutorial videos and screencasts to supply the knowledge they need.

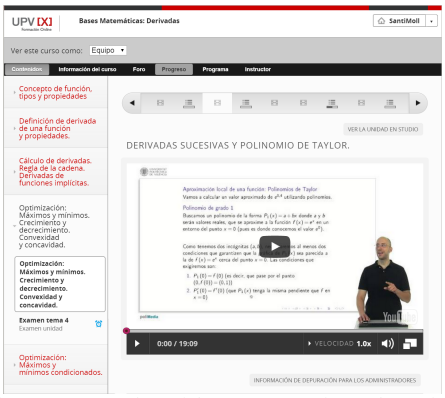

Figure 1. Screenshot of the MOOC Basic Mathematics: Differentiability.

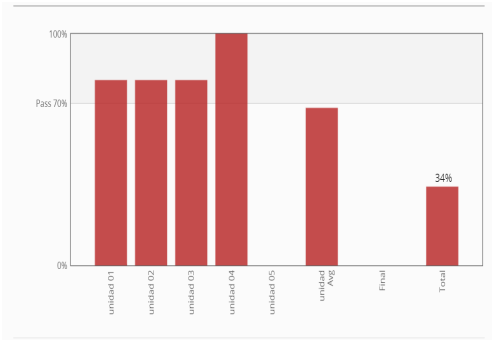

Figure 2. Screenshot of the progress of a student of Basic Mathematics: Differentiability.

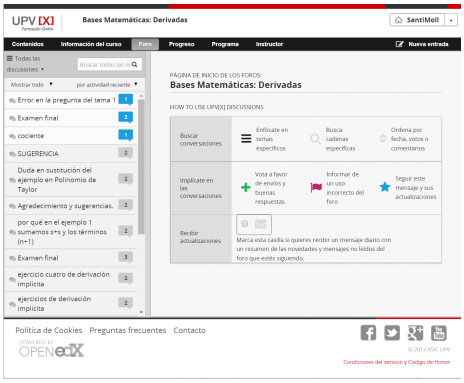

Figure 3. Screenshot of the forum of Basic Mathematics: Differentiability.

The other two groups correspond to Agricultural Engineering enrolled in the subject Mathematics I (2014/2015). In these cases, the topics of the MOOCs correspond with the ones taught at class. The procedure has been the same, encouraging students with deficiencies to follow the MOOCs.

5. Results

We present the results obtained in two groups, corresponding to the Electrical Engineering, and Agricultural Engineering.

The Electrical Engineering group enrolled in Mathematics I at the UPV during the 2013/2014 academic year is composed of 43 students. From the results of the first tests 24 students were offered to join MOOCs, but only 12 accepted. Table 1 shows the mean scores for each test for the group that participated in the MOOCs and the group that did not participated. It can be appreciated that the means of the MOOC groups show an upward trend and less variability.

But not only the overall averages increase at each test, individually, a significant improvement in the grades is also appreciated. Figure 4 shows the progression of each student that took part in the MOOCs during the academic year. It can be seen a significant improvement, with a very low variability. On the other hand, the group not joining MOOCs shows more variability with no clear trend of improvement.

Table 1. Means of the academic tests for MOOC and no-MOOC groups.

ELECT. ENG.	MOOC		No MOOC	
	Mean	Std. Dev.	Mean	Std. Dev.
Test 1	3.59	0.60	4.13	1.73
Test 2	5.26	0.78	4.02	1.66
Test 3	6.15	0.91	3.15	1.40
Test 4	6.53	0.81	3.54	1.65

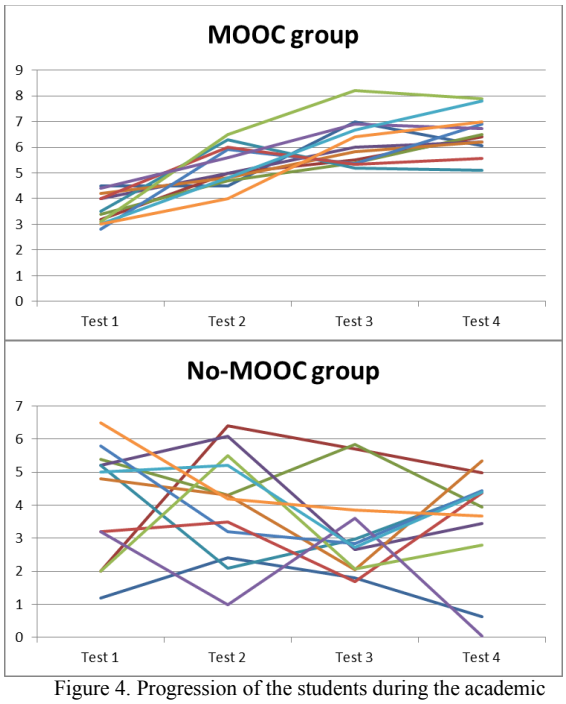

Figure 4. Progression of the students during the academic year.

As a result, almost 92% of the students of Electrical Engineering that completed MOOCs courses passed the final exam. Furthermore, all these students increased their grades in more than 2 points from their initial test (Test 1).

The Agricultural engineering group enrolled in the subject 'Mathematics I' during 2014/2015 academic year is composed of 82 students, divided in two groups: A and B. From the results of the first tests 12 were offered to join MOOCs, but only 9 accepted. Table 2 shows the mean scores for each test for these two groups.

As in the previous group, it can be appreciated that the means of the MOOC groups increased during the academic year, and individually, a significant improvement in the grades is also appreciated. Figure 5 shows the progression of each student taking part in the MOOCs. As in the previous case, it can be appreciated a significant improvement, with a very low variability in the MOOC group.

Table 2. Means of the academic tests for MOOC and no-MOOC groups of the Agricultural Eng. Grade.

Agr. Eng.	MOOC		No MOOC	
	Mean	Std. Dev.	Mean	Std. Dev.
Test 1	4.16	0.85	3.75	1.60
Test 2	4.29	0.80	3.64	1.04
Test 3	4.52	1.24	4.09	1.93
Test 4	6.07	0.70	3.74	2.07

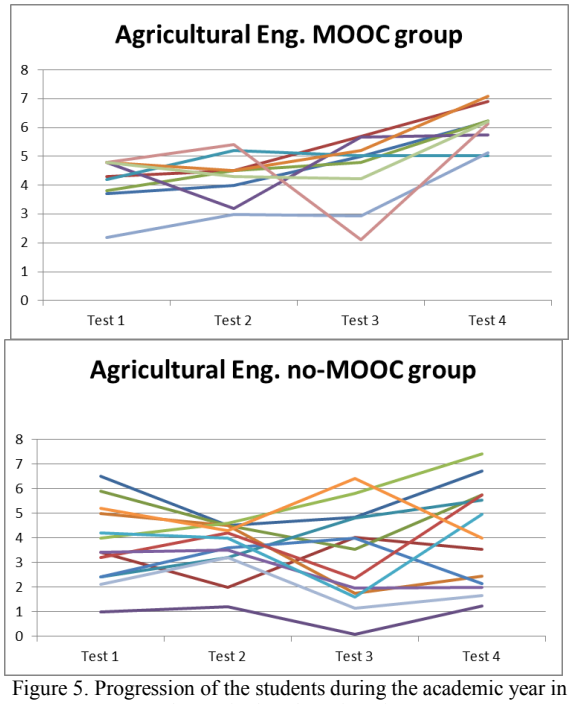

Figure 5. Progression of the students during the academic year in the Agricultural Engineering.

As a result, 75% of the students of Agricultural Engineering that complete MOOCs passed the final exam.

It is worth mentioning that all the students participating in this methodology passed successfully all the MOOCs. We have no merit in this fact, because the design of these courses allows students to have several attempts at each assessment.

6. Opinions

When the course was ending we gathered feedback from students about this methodology. The questionnaire tried to collect the acceptance of the new methodology. In the following tables we can compare them.

Table 3. Students' opinion about joining MOOCs and the result on the learning process.

Do you think MOOCs have helped you in your learning process?	
Nothing	0%
A little	1%
Much	15%
A lot	84%

In Table 3 it can be appreciated that there has been a wide acceptance of this methodology: 99% of students found the courses useful in their learning process.

Regarding internal MOOC's assessments, students have shown a very positive acceptance as shown in Table 4.

Table 4. Students' opinion about MOOCs' assessment.

I think that being evaluated at the end of each MOOC is good for my learning:	
Nothing	0%
A little	6%
Much	26%
A lot	68%

MOOCs' forums have been one of the greatest successes of this methodology. It has been use to strengthen the communication between teachers and students and to solve doubts about basic mathematics. Students' opinion about the forum is shown in Table 5.

Table 5. Students' opinion about MOOCs' forum.

Do you think MOOC's forum have helped you with your doubts?	
Nothing	0%
A little	0%
Much	9%
A lot	91%

We also surveyed the students on whether to recommend or repeat this methodology in other subjects, obtaining very positive results: 87% would strongly recommend this methodology. See Table 6.

Table 6. Students' opinion about repeating or recommending this methodology.

Would you repeat/recommend this methodology if necessary?	
No	0%
A little	0%
Much	13%
Strongly	87%

In order to know which parts of the MOOCs are more appreciated by students, we ask them to give each of them a numerical value between 0 and 10, being 0 the value corresponding to "No use at all" and 10 meaning "Completely useful". In the following table we can see the grades students gave to each element of the MOOC.

As we can see in Table 7, students have evaluated positively the Forum and the Extra Material. Videos and assessments obtained really good grades also.

Table 7. Students' grade about the elements of the MOOCs.

Elements of the MOOC	Grade
Forum	9.2
Videos	7.6
Assessment	8.4
Extra Material	9

7. Conclusions

We have used four MOOCs covering Complex Numbers, Differential Calculus, Integral Calculus and Algebra in order to strengthen the knowledge of students with significant gaps in basic mathematics. The results have been extremely good. Students enrolled in the MOOCs have increased their grades significantly. Using these MOOCs they have been able to review the knowledge required to understand and succeed in the subjects of Mathematics. The main advantages MOOCs have offered have been:

- the possibility to monitor student's assessments with great detail
- the strong interaction between teachers and students through the forum, apart from the office hours
- the capability to adapt MOOCs to the needs of the students

In average, a 98% of the students following this reinforce methodology have increased their grades during the course and 83% of these students passed the academic course with success. Also this methodology has reduced the dropout rate, which is higher among students who have difficulties in the learning process.

The courses have been modified to attend the students' needs, adding extra materials or new videos when necessary. In order to do so, we have had to adapt MOOCs to a small number of students, for this reason some authors have called this courses SPOC, Small Private Online Courses, even though our courses were not private at all.

8. References

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