A FLIPPED LEARNING EXPERIENCE IN EMBEDDED SYSTEMS IN MASTER DEGREES IN COMPUTER ENGINEERING

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Abstract

Flipped learning is a blended learning approach where content delivery and direct instruction are scheduled for individual space activities before class, whereas face-to-face group activities in class are designed to be active and work through a wide range of high level cognitive tasks. In the last two decades, the benefits of this pedagogical approach have been supported by a large body of research. Reversing a traditional class into a flipped class is neither an obvious nor an easy task, and its adoption must consider the impact on both students and lecturers. The key for the flipped learning approach to be effective relies on students completing the individual space activities designed by the instructors before attending the class. Thus, the instructors must guide, orient and motivate students to be engaged and to fulfil all the proposed pre-class activities. Otherwise, students may struggle with these activities and attend the class without the prerequisites to participate effectively in the scheduled group activities. In addition to being prepared for the in-class activities, in this stage of the flipped learning approach students acquire self-regulated learning skills while coping with the provided learning materials. This paper focuses on describing the experience of flipping two “Embedded and Ubiquitous Systems” courses taught in two Master Degrees in Computer Engineering, one at the University of Oviedo and one at the University of Almería (Spain). These courses have been taught for several years using the traditional model. Individual space activities include video lectures, readings and exercises, all of them available online through the course LMS. They were designed by the courses’ instructors for each student to acquire the knowledge required to attend the in-class activities. Student participation in pre-class activities was tracked by instructors through the LMS. In addition, student success in these activities was assessed based on questionnaires addressed at the beginning of each class. Students answered the questionnaires using smartphones, tablets or laptop computers and the Kahoot! game-based, personal response system. Besides promoting student participation, emerging technologies are included in the class space and a vast amount of time is saved, which can be used for other learning activities. Our experience in teaching “Embedded and Ubiquitous Systems” following the described flipped learning approach proved successful from the point of view of student satisfaction. Among all the students enrolled in the courses, roughly 90% are in favour of active learning in class, specially peer-to-peer discussions, and 80% feel more engaged. In addition, 70% of the students express they prefer the flipped learning model, whereas 20% prefer the traditional model and 10% remain neutral. In all cases, students also feel teachers are more engaged and committed using the flipped learning model than they are in the traditional model. Although student feedback was very positive, there is space for improvement, incorporating suggestions made by both lecturers and students.

Keywords: Blended learning, active learning, flipped classroom, clickers.

1 INTRODUCTION

This paper describes the experience designed and developed to flip two Embedded and Ubiquitous Systems courses of two Master Degrees in Computer Engineering, one at the University of Oviedo, a public university of 22,000 students in the North of Spain, and one at the University of Almería, a public university of 12,000 students in the South of Spain. In this experience we apply the flipped learning model to some lessons of each course. The two masters are offered to holders of a 4-year degree in Computer Engineering. The former is a 90-ECTS-credit degree taught following a face-to-face model, whereas the latter is a 72-ECTS-credit degree combining on-line and face-to-face classes. This experience is designed based on previous experiences in learning contexts that make use of active methodologies, such as problem based learning [1], flipped classroom [2] and cooperative learning [3].
Flipping a classroom requires that events that have traditionally taken place in the classroom now take place outside the classroom and vice versa [4]. In the traditional learning model, students receive new material in class meetings and perform high-level work, such as application, synthesis and evaluation on this material through individual, non-supervised activities after class. In these class meetings, instructors do not know the knowledge level of the audience and, thus, the lecture may be too difficult or too easy for the students. Usually, flipping a classroom relies on networking and computing technologies, such as appropriate learning management systems and mobile applications, to meet the needs of students in the twenty-first century. In the last two decades, the benefits of this pedagogical approach have been supported by a large body of research [5].

The flipped learning model focuses on putting direct instruction into the individual space before class [6]. By making the content available on-line, students can go through it at their own pace; those who are familiar with the concepts can move quickly, while others may re-watch the content of even read or watch other resources at the same time. An important benefit for all students is that they can schedule the learning activities when they fit better for them, instead of at fixed hours as in in-class activities. In addition, the flipped learning uses face-to-face class meetings for students to participate actively in creative activities through a wide range of cognitive tasks [6], moving from passive listening to active work. The benefit here is that teachers are available when students need them most, that is, when they are trying to apply their knowledge. Therefore, this model counts on face-to-face interaction and tries to optimize it, allowing one-to-one interaction with students, which would be impossible in the traditional model. In brief, this model switches from an instructor-focused learning model to a student-focused learning model.

Designing activities for both the individual and the group space, and associating learning outcomes to them, may be a challenge for instructors. According to the revised Bloom's taxonomy [7], the concept of learning is depicted as a pyramid with six levels of learning. In the flipped learning model, as described in [8], the two lower levels of the pyramid—remember and understanding—occur in the individual space, where students may review or watch the materials provided as many times as needed without teacher supervision. The middle levels of the pyramid—analysing and applying—occur in the group space working with the peers and with the help of the teacher. Finally, the top levels of the pyramid—evaluating and creating—can also occur in the group space or in the individual space after class.

Reversing a traditional class into a flipped class is neither an obvious nor an easy task, and its adoption must consider the impact on both lecturers and students [9]. On one hand, there is a need to provide existing resources in different media, particularly pre-recorded lectures [10]. In addition, the effort required to prepare interactive materials is really high and most of the times requires support staff as well as an information technology support department to assist with technological issues. On the other hand, students need to have clear understanding of the teaching methodology to reduce their frustrations with both the time taken to carry out individual space activities [11] and to take responsibility of their own learning progress [12].

The effectiveness of the flipped learning approach relies on students using the learning materials and completing the instruction designed for the individual space, usually computer-assisted instruction. If students lack of self-regulated competence, they may struggle with these activities and attend the class without the prerequisites to participate effectively in the scheduled group activities. Therefore, the instructors must guide, orient and motivate students to be engaged and to fulfil all the proposed pre-class activities at their own learning pace while acquiring self-regulated learning skills [13].

This experience was designed within an educational innovation project with the following goals: i) develop a teaching methodology based on flipped and cooperative learning to teach some lessons in courses related with Embedded and Ubiquitous Systems; ii) design activities for students that teachers can supervise in class through the use of the students’ mobile devices; and iii) foster the collaboration among teachers of different universities and different teaching models applied for similar courses.

2 METHODOLOGY

2.1 Participants

The participants in this experience were enrolled in two Embedded and Ubiquitous Systems courses of two Master Degrees in Computer Engineering, one at the University of Oviedo, including 10
students, and one at the University of Almería, including 5 students. The Master at the University of Oviedo is designed following a face-to-face traditional model, whereas the Master at the University of Almería is designed following a blended model combining face-to-face and on-line classes.

Students enrolled in a Master's Degree in Computer Engineering have been previously graduated from a Bachelor's Degree in Computer Engineering, or from a similar undergraduate program. Hence, these students have been in contact with computing technology for at least four years. Therefore, activities involving clickers, online quizzes, streaming videos, etc. are easily to follow for them.

The number of students per group is not too large and this can help addressing the difficulties that instructors may face when adopting a teaching methodology based on flipped learning. However, this reduced number of students may limit the results of this experience.

2.2 Instruments

The effectiveness of a flipped class can be assessed by multiple ways. However, evaluating or assessing educational outcomes related with high order thinking skills in a flipped learning environment, such as improved problem solving, inquiry and critical or creative thinking, is covered by very few researchers [9].

In this experience quantitative evaluation is used for direct educational outcomes, such as students' grades, and qualitative evaluation is used for indirect educational outcomes, such as students' participation in activities, satisfaction and course perception.

As mentioned above, for the flipped learning environment to be effective, it is essential that students use the learning materials and complete the individual space activities designed by the instructors before attending the class. Therefore, in this experience the Moodle LMS used to manage the courses registers the evolution of each student on the pre-class activities. In addition, at the beginning of each face-to-face class, students are required to answer several questions about the pre-class activities using clickers.

2.3 Course design around flipped learning

Designing a course is a high demanding task that involves determining the learning goals, the activities and the structure of each class; developing the grading system; and writing the course syllabus, among other things. Different frameworks can be used to help with this task. For instance, Dee Fink proposes a framework to design courses for significant learning [14].

In this work we follow the procedure to flip a class described by Robert Talbert, which is based on seven steps to build a single instructional unit in a flipped learning environment [15]:

1. Determine the list of learning objectives for the lesson.
2. Remix the learning objectives so that they appear in order of cognitive complexity.
3. Create a rough design of the group space activity.
4. Split the learning objectives list into basic and advanced objectives.
5. Finish the design of the group space activity.
6. Design and construct the individual space activity.
7. Design and construct post-group space activities.

2.3.1 Embedded and ubiquitous systems course

As stated by ACM/AIS in the Global Competency Model for Graduate Degree Programs in Information Systems, "the pervasiveness of computing technologies is undeniable, and computing solutions are increasingly deeply embedded in products and services that have an impact on a wide variety of aspects of our lives" [16]. Hence, education in this area should help to overcome the limitations of currently available technologies for embedded systems, such as specification languages, models, tools generating implementations from specifications, timing verifiers, system software, real-time operating systems, low-power design techniques, and design techniques for dependable systems [17].

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Therefore, a course in embedded systems is commonly designed to focus on fundamental techniques and foundations that allow students to understand future developments in the area of cyber-physical systems (CPS) and Internet of Things (IoT), rather than in latest trend technologies that will be soon surpassed.

2.3.2 Designing the framework for each lesson

The teachers of the courses involved in this experience designed the activities for the individual and the group space, based on the learning outcomes of each lecture. As an example, we show the learning outcomes of the first lesson of such courses:

- Understand basic concepts about embedded and ubiquitous systems.
- Understand the main differences between embedded systems and general purpose computers.
- Understand the main challenges in the design and development of embedded systems.
- Understand different layer architectures of embedded systems.
- Understand the toolchain required to develop embedded applications.
- Understand the need of a software update plan for the embedded application.
- Determine the optimal components for an embedded application.
- Design an embedded system at the basic level.

Once the learning outcomes for each lesson have been determined and ordered according to their cognitive complexity, a rough design of the group activities, that is, the face-to-face activities in the classroom, is proposed. Then, the individual space and the post-class activities are designed.

To check whether the students have achieved the learning outcomes for each lesson, the teachers of the courses designed activities based on the next criteria (the examples of activities provided are for the first lesson of the course):

- To work on the “understand” outcomes, online videos produced by teachers, readings and web resources are provided to the students to work with outside the class. Teachers also designed questionnaires that students answer using Kahoot! in the face-to-face classes.
- To work on the “determine” outcome, teachers have designed face-to-face activities for students to work in groups (cooperative learning) searching on the internet the components that fit best an embedded application proposed by the teacher.
- To work on the “design” outcome, teachers have designed a face-to-face activity for students to work in groups on a proposal of a new embedded system. Students can use up to 10 minutes to complete their design. Then, each group will be required to make a 3-minute elevator pitch presenting their design to the rest of the students in the class as well as to the teacher. After the presentation, the teacher and the rest of the students have the opportunity to ask questions to the presenters.

3 RESULTS

We evaluated this experience based on direct and indirect learning outcomes. Direct measures are based on exams and tests about the lessons that have been flipped, whereas indirect measures are based on perceptions and feelings of the students.

Taking into account direct learning outcomes, Table 1 shows the marks obtained by the students in the lessons that were taught following the flipped learning model. As can be seen, the grades of students enrolled in the flipped course at the University of Oviedo have decreased slightly compared to those of the previous academic years, although the difference is not statistically significant. On the other hand, the grades of the students enrolled in the flipped course at the University of Almería have increased compared to the previous academic year, and reach the higher value in the last three years. At this point it is important to note that all the courses of the master degree at the University of Almería are taught following a blended learning model, and thus these students are more used, trained and maybe confident with this model, which is reflected in the grades.
Indirect learning outcomes are assessed based on the use of the resources provided by the teachers of the course, as well as on surveys that students filled at the end of the lessons taught following the flipped model.

Table 1. Grades of students enrolled in Embedded and Ubiquitous Systems in the lessons that have been flipped, in the last three academic years (in the range [0-10])

<table>
<thead>
<tr>
<th></th>
<th>University of Oviedo</th>
<th>University of Almería</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>6.93</td>
<td>6.67</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>1.58</td>
<td>0.48</td>
</tr>
</tbody>
</table>

The students had access to video lectures, readings and exercises designed for the individual space activities, all of them available online through the course LMS. These activities were designed by the courses’ instructors for each student to acquire the knowledge required to attend the in-class activities. Student participation in pre-class activities was tracked by instructors through the LMS. Table 2 shows the percentage of students that accessed each resource published through the LMS of the course to follow the pre-class activities as well as the average number of accesses to each resource by the students. As can be seen, all students have accessed at least once to all the resources published for the pre-class activities of the lessons flipped in the courses and, in average, students access these resources between three and four times each.

Table 2. Usage of materials provided for pre-class activities

<table>
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<tr>
<th></th>
<th>University of Oviedo</th>
<th>University of Almería</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of students that accessed each resource for pre-class activities</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Average number of accesses per student</td>
<td>3.8</td>
<td>3.2</td>
</tr>
</tbody>
</table>

At the end of the lectures taught following the flipped learning model, we surveyed the students of both courses with questions using a Likert scale. The results of these questionnaires are shown in Table 3. As can be seen, the students of both courses think that the learning model has enhanced their learning and makes them to be more engaged in both their studies and in the discussions in the face-to-face classes.

As can be seen in Table 3, students enrolled in the course at the University of Almeria show a more positive perception about the flipped class and the related activities, providing higher rates in their answers. This may be due to the fact that these students are enrolled in a master’s degree that follows a blended learning model in all courses, and thus, students are more used, trained and maybe confident with this model.

Given the fact that the students enrolled in the course at the University of Oviedo are also enrolled in courses in the same master’s degree that do not follow a blended learning model, two additional questions were addressed to these students. The results are shown in Table 4. As can be seen, students assess the use of active methodologies in class really high. However, when they are asked if they prefer the traditional model, even though the average of the answers shows disagreement, the variation is high and reflect that some students are not comfortable with the flipped classroom and they prefer the traditional class model.
### Table 3. Feedback provided by students enrolled in the Embedded and Ubiquitous Systems courses at the University of Oviedo and at the University of Almería

<table>
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<tbody>
<tr>
<td>The knowledge and the competences acquired in the course are relevant for my professional future</td>
<td>3.6</td>
<td>0.8</td>
<td>4.0</td>
<td>0.7</td>
</tr>
<tr>
<td>The materials and resources provided are adequate</td>
<td>3.8</td>
<td>1.0</td>
<td>4.6</td>
<td>0.9</td>
</tr>
<tr>
<td>I have watched the pre-recorded lectures before the face-to-face class</td>
<td>5.0</td>
<td>0.0</td>
<td>4.0</td>
<td>1.0</td>
</tr>
<tr>
<td>The pre-recorded lectures have helped me to improve my learning</td>
<td>4.0</td>
<td>0.8</td>
<td>4.4</td>
<td>0.5</td>
</tr>
<tr>
<td>Learning key concepts prior to face-to-face classes improves my learning with the material in class</td>
<td>4.4</td>
<td>0.7</td>
<td>3.8</td>
<td>0.8</td>
</tr>
<tr>
<td>The usage of clickers (Kahoot!) have helped me to ask questions in the face-to-face class</td>
<td>3.7</td>
<td>0.9</td>
<td>3.8</td>
<td>0.8</td>
</tr>
<tr>
<td>The learning methodology have engaged me in the course</td>
<td>3.9</td>
<td>1.6</td>
<td>5.0</td>
<td>0.0</td>
</tr>
<tr>
<td>The learning methodology have helped me to be more engaged in the proposed activities in class</td>
<td>3.9</td>
<td>1.2</td>
<td>4.4</td>
<td>0.5</td>
</tr>
<tr>
<td>These methodologies make me more engaged in my studies</td>
<td>3.7</td>
<td>0.9</td>
<td>5.0</td>
<td>0.7</td>
</tr>
<tr>
<td>I have been involved and engaged in discussions on the concepts studied in face-to-face classes</td>
<td>4.0</td>
<td>0.7</td>
<td>4.2</td>
<td>0.8</td>
</tr>
<tr>
<td>The instructors have encouraged students to participate actively in face-to-face classes</td>
<td>4.9</td>
<td>0.3</td>
<td>4.3</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### Table 4. Feedback provided by students enrolled in the course at the University of Oviedo.

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Std. Dev.</th>
</tr>
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<tbody>
<tr>
<td>My general assessment of the use of active methodologies is high</td>
<td>4.4</td>
<td>0.7</td>
</tr>
<tr>
<td>I prefer the traditional class model</td>
<td>2.3</td>
<td>1.3</td>
</tr>
</tbody>
</table>

### 4 CONCLUSIONS

This paper describes the experience of flipping some lessons of two courses about Embedded and Ubiquitous Systems taught in two Master Degrees in Computer Engineering following two different approaches: a face-to-face traditional model and a blended model combining face-to-face and on-line classes. The main limitation of this experience is that the number of students enrolled in the courses was not large.

Teacher coordination has been carried out both at the level of sharing materials and discussing the activities that best suit this teaching model. This coordination has allowed to improve and refine the activities to adapt them to the flipped classroom and cooperative learning.

The students enrolled in both courses report a high level of satisfaction when attending a course following the flipped learning model. However, the students that are enrolled in a master’s degree where all courses are taught based on a blended model assess highly the use of flipped classroom. These students seem to be more used, trained and maybe confident with this model, which is also reflected in their grades. Taking into account the results provided by the students enrolled in the master’s degree taught using the face-to-face model, maybe a deeper description would have been required at the beginning of the course for all the students to have a clear understanding of the flipped class model.

Overall, the analysis shows that the flipped learning model is considered adequate to teach courses related with embedded and ubiquitous systems to enhance the learning experience of students while acquiring competences on foundations and fundamental techniques about these systems. Students
enrolled in a course like this must also acquire problem solving, team-work and social skills, and the flipped learning model can contribute to this goal.

ACKNOWLEDGEMENTS

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