Flipped Classroom and gamification in Automated Manufacturing lab classes

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Abstract: There is an increase in Higher Education initiatives focused on educational innovation and the Flipped Classroom paradigm are emerging as an increasingly expanded option. This paper deals with the implementation of the Flipped Classroom methodology in the laboratory practice sessions of the subject Automated Manufacturing of the Mechanical Engineering Degree. This methodology has been combined with questionnaires through Kahoot, a simple and versatile freeware platform. To carry out this study, additional audio-visual material was developed to illustrate the content of the practices so students could prepare them in advance. Once recorded and edited, the videos were made available through the Virtual Campus. Doing questionnaires at the beginning, and repeated at the end of the sessions, has been an element of reinforcement of learning while stimulating active participation during the classes. It was also a motivating element to work on skills such as proactivity, work organization, teamwork and time management. The students knew beforehand that the result of the questionnaires would influence the grade corresponding to the continuous evaluation. The result of this research concludes that the Flipped Classroom paradigm combined with gamification allows the students to reach good learning outcomes getting them engaged.

Keywords: Flipped Classroom, Gamification, Kahoot, Higher Education, Engagement.

1. Introduction
This study takes the concept of the inverted class as the basis for the methodological change of the traditional teaching-learning process. This strategy, whose origins date back to 1995 \cite{1}, began to take shape in 2007 thanks to two chemistry teachers from Woodland Park High School in Colorado. Jonathan Bergmann and Aaron Sams coined the term ‘flipped classroom’ for the method that allowed them to solve the problems experienced in the rural environment in which they were located and where some of the students did not attend classes due to distance and transportation problems to the school. With the implementation of this new methodology, where what was traditionally done in the classroom was now done at home, and what was traditionally done as homework was now done in class, the teachers realized that this was a tool with great pedagogical potential. It allowed them, among other things, to give greater attention to the particular educational needs of each student. Furthermore, they felt that recording the lessons, replacing direct instructions with videos, provided an ideal solution to the problem of students who could not attend classes regularly \cite{2}.

The use of inverted classes has been widely studied within high school \cite{3-6}, where it was proved that this methodology improves engineering skills \cite{7}, influences cooperation, innovation and task
orientation [8] and, in general, as an active learning methodology, increases student performance in science, technology, engineering and mathematics [9].

On the other hand, one of the most common concerns of the faculty and which the project aims to address, is the achievement and maintenance of student motivation during classes [10,11]. Classes are often not very active and do not adequately support learning, sometimes becoming an element of information delivery in which the student hardly participates [12]. In order to improve this situation, the Kahoot platform will be used, which is outlined as a self-assessment tool within the classroom that integrates gamification and the use of mobile devices to improve subject learning, encourage study habits among university students and motivate them through competitiveness [13]. Recent studies of B-Learning methods, such as the one carried out at Purdue University in Indianapolis, USA [14] involving almost one hundred university students, show results that suggest that student performance and engagement improves, compared to traditional ones, when teaching methods are used with Kahoot.

2. Methodology

The research was focused on the implementation of inverted class methodology combined with competitive games through questionnaires within the subject of Automated Manufacturing. The aim was to motivate students to participate actively in the classroom by encouraging autonomous and planned work through virtual education while, at the same time, allowing teachers to gain experience in the use of new methodologies that could later be applied to traditional lecture classes and other related subjects from the same area of knowledge.

According to the plan established for the study, teachers have complemented their role as knowledge transmitters with guidance and coordination of debates, while students have become more involved in the classroom. In order to do this, the contents had to be planned in line with the new methodology. It has been necessary to carry out an adequate multimedia preparation of the contents and the sessions have had to be redesigned to adapt to the requirements of the project. The main result we have tried to achieve is that students acquire habits of planned and autonomous work that allows them to make better use of the face-to-face classes and to be more motivated to participate actively in the classroom.

The methodology followed in the research was carried out according to the following tasks.

2.1. Rescheduling of classes according to the new inverted class methodology

The sessions were planned in such a way that the teaching material (contents of the practices, documentation and videos) was made available to the students one week in advance. This new scheduling involved defining the objectives to be achieved and the skills to be developed, structuring the times and spaces available and placing special emphasis on those tasks that the students were to carry out before and during the face-to-face classes. The lab classes, which lasted two hours (reduced to 1h 50' due to the COVID protocol), were sequenced as follows:

- 5 to 10 minutes to present and organize the session.
- 10 to 15 minutes for the first attempt of the test.
- 20 to 25 minutes to comment and discuss the questions on the questionnaire, the options, the correct answers and to clarify doubts and questions raised by the students.
- 60 to 65 minutes for the development of the tasks.
- 5 to 10 minutes for the second attempt of the test.

This hourly distribution of the laboratory classes in which the questionnaires were carried out is shown in figure 1 in percentage terms. The possibility offered by the Kahoot platform to apply scores, not only to the correct answers but also to those who answer first, promoted a competitive but also relaxed atmosphere among the students. This was mainly in the test at the end of the session, which meant that less time was spent on the questionnaire during this second attempt.
2.2. Multimedia: Recording and editing videos of each topic
This article is focused on the laboratory classes of the subject Automated Manufacturing, where individual and group activities are worked on three topics: programming of industrial robots, positioning and clamping solutions with modular tool systems and planning and programming with CAM software. The videos for each topic were produced in two different ways. Some videos were recorded with a fixed camera. The teacher explained the contents as if the lesson had been carried out by the traditional method. Another type of video was made from the recording of the teacher's computer screen. In the video, the teacher explains an example using a Computer Aided Manufacturing software. All students had access to the videos without any problem.

2.3 Instructions for new lab classes
To prepare the laboratory sessions, instructions were available for students on the Virtual Campus one week in advance. They had enough information and time to ask questions about the main concepts to be discussed. The arrival to classroom was very effective. Resolving doubts and clarifying new concepts and knowledge required a significant amount of class time.

2.4. Preparation of questionnaires for each topic
The evaluation questionnaires were designed and made available through the freeware Kahoot. At least one questionnaire was prepared for each topic. The students participated in the competition through their mobile devices or the laboratory PC’s. Five different questionnaires were prepared and repeated at the beginning and end of the lab sessions. The students answered twice a total of 40 questions on the three different topics. 43 students enrolled in Automated Manufacturing participated in the research, divided into four groups (PL1, PL2, PL3 and PL4).

2.5. Analysis of data
The students of Automated Manufacturing answered a total of 1,702 questions corresponding to the questionnaires. They also completed a final satisfaction survey about the project. The research key indicators taken into account referred to the level of satisfaction of the students, the attendance to class with the tasks previously carried out, the number of passes in each of the three topics and the improvement of results with respect to previous courses.

3. Discussion and Results
The most important remark is that the research highlighted the value of the flipped classroom methodology and the gamification of the laboratory sessions of the Automated Manufacturing subject. The objectives initially identified were fulfilled. It is important to point out the high value that the
students gave to the lab classes, as it is shown in the survey carried out, having also achieved the involvement of all of them in the project.

The innovation has been reached in four areas: in the area of teaching methodology, in the area of tutoring and guidance of students towards their professional future, in the area of transversal skills development in Higher Education and in the area of teaching coordination.

On the other hand, the sessions have been developed according to the planning. The use of the flipped classroom methodology allowed the improvement of the students' global qualifications. It also allowed to work on the acquisition of the competences defined in the project: task planning, time management and autonomous work.

The average number of correct answers was 57.73% in the first attempt (questionnaire made at the beginning of the class) and 90.54% in the second attempt (questionnaire made at the end of the class). On the one hand, it gives a clear idea of the previous preparation of the classes by the students and, on the other hand, of the beneficial repetition of the questionnaires to consolidate the knowledge. The results of the questionnaires distributed by practice groups (figure 2) were very homogeneous in both the first and second questionnaires.

![Figure 2. Right answer rates at the first and second attempts for each group of Automated Manufacturing lab practices.](image)

Considering the total number of tests taken, most of the students (76) obtained between 40% and 60% correct answers on the first attempt. The data are substantially better on the second attempt, with the greatest number of students (167) obtaining a percentage of correct answers of over 80% (figure 3).

![Figure 3. Aggregated tests by stretches at the first and second attempt.](image)
With regard to the overall scores for laboratory practices, the results show a very slight improvement over the previous academic year, with the average score going from 7.60 to 7.82 (figure 4), which represents an increase of 2.9%. Those passed in the industrial robotics practices represent 92.68% of the total, 56.10% in the tooling practices and 100% in the CAM practices.

However, if the results are analyzed independently for each of the topics, the methodology used had a lesser impact, in absolute terms, on the practice related to modular tooling systems. The average mark (5.76) has barely exceeded the qualification of passed even though it is the subject with the greatest capacity for improving qualifications.

The uniqueness of the project must also be taken into account. It is focused on laboratory classes and not on lectured ones as in most cases where the inverted class is valued. In addition, the relative weight of the evaluation of the work delivered with respect to the questionnaires carried out is very significant. This leads us to conclude that it is necessary to go the methodology used with a more in-depth work on the practical development of the tasks and not only the acquisition of basic skills and knowledge to carry them out.

In any case, it should be noted that the conclusions to be drawn from the results of the project must be contrasted with those obtained in future academic years. This is to avoid the variability of students enrolled between one course and the next.

Once the lab classes were over, a 13 questions anonymous satisfaction survey was made available to students through the Virtual Campus. The answers were given according to the Likert scale from 1 to 5, where 1 corresponds to a rating of ‘strongly disagree’ and 5 to ‘strongly agree’. Of the first 12 questions (figure 4), related to the goodness of the methodology, and the achievement of the proposed objectives, 84% of the answers are satisfactory corresponding to the options of agreeing or totally agreeing, while only 2% correspond to the answers of disagreeing or totally disagreeing, reaching an overall average result of 4.2. The questions refer to the development of the methodology, its impact on the acquisition of knowledge and skills, the role played by the teacher and the overall experience of the student in the project.

On the other hand, the answers collected in the last question of the survey, ‘The traditional class method is preferable’, show that most of the students prefer the inverted and gamified class to the traditional class method.
Finally, it should be pointed out the importance on the final grade of being proactive when preparing the laboratory classes in advance. The students of the Automated Manufacturing subject knew that the questionnaires at the beginning of the sessions would influence the grade of each practice. It was a motivating element for the student. The robotic topic tests were repeated with two groups of students (FI-PL3 and FI-PL5) of Integrated Manufacturing, a subject of the Master of Industrial Engineering. In this case, the result of the questionnaires was not going to be taken into account in the grading. Table 1 shows how the assessment of the questionnaires carried out at the beginning of the sessions (1st attempt) to both groups of students on the same topic, is substantially better when there is a motivating element, case of Automated Manufacturing (Degree), than when there is not, case of Integrated Manufacturing (Master).

Figure 5. Results of the student satisfaction survey. Likert scale.
Table 1. Comparative results between students from Automated Manufacturing (FA) and Integrated Manufacturing (FI).

| LAB Group | Introduction test | Exercise 1 test | Exercise 2 test |
|-----------|-------------------|----------------|----------------|
|           | 1st attempt | 2nd attempt | 1st attempt | 2nd attempt | 1st attempt | 2nd attempt |
| FA-PL1    | 55%        | 87%       | 60%         | 98%        | 50%         | 83%         |
| FA-PL2    | 45%        | 87%       | 51%         | 90%        | 63%         | 89%         |
| FA-PL3    | 53%        | 83%       | 50%         | 89%        | 65%         | 86%         |
| FA-PL4    | 43%        | 92%       | 49%         | 94%        | 78%         | 80%         |
| FI-PL3    | 25%        | 87%       | 47%         | 100%       | 55%         | 86%         |
| FI-PL5    | 35%        | 81%       | 47%         | 57%        | 43%         | 90%         |
| FA average | 49%       | 87%       | 53%         | 93%        | 64%         | 85%         |
| difference | 38%       | 40%       | 21%         |            |             |             |
| FI average | 30%       | 84%       | 47%         | 79%        | 49%         | 88%         |
| difference | 54%       | 32%       | 39%         |            |             |             |

The level of impact obtained with the project in terms of specific teaching was in line with the expected one. The percentage of the subject affected by the innovative experience represents 60% of the topics. The students have been aware of the importance of their participation in the project. An evaluation of the practices of 25% of the subject has been a motivating element. It had a substantial impact on the active participation of the students. 81% of students enrolled in the subject participated in the research.

The level of involvement has been high both on the part of the students and the teachers themselves. On the other hand, the improvement and strengthening of teachers’ collaboration is an additional incentive to replicate it in other subjects and with other teachers in this subject area of knowledge.

4. Conclusions
The main conclusions reached in this research are:

- The inverted class methodology, known as Flipped Classroom, is applicable and allows good results to be obtained, not only in lecture classes but also in laboratory sessions of the Engineering field.
- The gamification of the laboratory classes with competitive questionnaires, managed in an appropriate way, constitutes a motivating element for the preparation of the contents to be dealt with in the classroom, encouraging interest in the subject.
- The motivation of students to prepare the face-to-face laboratory classes increases if the results of the games, through questionnaires at the beginning of the sessions, have an impact on the final grade.
- Both teaching methods, game-playing and inverted class, allow the development of transversal competences while making students aware of it. Specifically, they help to develop autonomous work, planning, time management and, in general, work organization.
- The satisfaction of the students with the development of laboratory practices carried out in a different way to the traditional system is an important incentive for teachers in order to improve the quality and update teaching techniques in this type of class.
- The active participation of students in the classroom, one of the main concerns of teachers, is encouraged by learning methodologies such as those used in this project.
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