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Impact of the flipped classroom methodology on the development of argumentative skills and academic performance of engineering students

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Abstract

At the Tecnologico de Monterrey, we face two great challenges: working under a new student-centered educational model, which focuses on the development of skills and competencies; and on the other hand, the return to face-to-face learning after preventive isolation to which we were subjected due to the Covid-19 contingency. In the classrooms we observed problems in the teaching-learning process such as lack of attention, difficulty concentrating and adaptation problems.

This study is an evidence-based practice that assesses the impact of the flipped classroom methodology in the Static Equilibrium Analysis course from the engineering program. The study was conducted for 10 weeks, split in two periods of 5 weeks each. A control group that worked the first period with traditional classes and the second period with the flipped classroom methodology. The second group worked with the flipped classroom methodology during the two 5-week periods. At the end of the 10 weeks of analysis, both groups presented an argumentative evaluation.

The results of this study show that flipped classroom has a significant impact on the development of argumentative skills. However, when analyzing academic performance of both groups, the evaluations show that this methodology did not have a significant impact.

Keywords

Higher Education, Flipped Classroom, Blended Learning, Educational Innovation, Transversal Competences.

Introduction.

The Tecnologico de Monterrey is working under a new student-centered educational model, which emphasizes active participation of students in their own learning process and adaptation of learning to the individual needs of each student. Unlike the traditional educational model that focuses on the transmission of knowledge in a unidirectional way, this new model looks for the students to develop disciplinary and transversal competences that allows them to comprehend theoretical concepts and to apply them in real life contexts.

This educational model arises as a response to the great challenges that the labor sector demands of new professionals, where it is expected for graduates to demonstrate work competences: a construct that considers knowledge, skills, and attitude [1]. Within the educational model, two kinds of competences are defined: Disciplinary and Transversal. Disciplinary competences refer to the specific skills, knowledge and abilities in a particular field of study; while transversal competences are skills and knowledge that apply to multiple contents, that is, they are not linked

to a particular field of study, which allow, in general, a personal and professional development of students. In order to develop competences, the model encourages active education, which makes the role of the teacher fundamental to change the way of transferring and generating knowledge.

Within the transversal competencies to be developed by an engineer, argumentative skills have a great importance in the Tecnologico de Monterrey educational model. As engineers work with multidisciplinary teams, they must be able to communicate, show, and defend their solutions effectively, justifying and explaining their decisions clearly and convincingly [2]. In addition, argumentation can improve critical thinking and communication skills in engineering students [3].

Nevertheless, the return to face-to-face classes after the self-isolation measures derived from Covid-19 represents a great challenge for educational institutions. In our University, we could observe that students presented academic weaknesses: a greater degree of distraction, difficulty concentrating, boredom and, in some cases, adaptation problems.

In order to attain these problems, a critical aspect to enhance competence development and to motivate participation of students in the classroom is the teacher's ability to change the way of teaching. This is particularly important to allow the student to have an active role in the development of their argumentative skills and generation of their own knowledge. On this aspect, the current use of smartphones and computers within the classroom allows the teacher to pursue new academic strategies that allow development of skills and to enhance the students' engagement.

Among the different teaching methodologies found in literature, Blended Learning has been commonly used to approach students in virtual courses and post-Covid face-to-face classes. This study is focused on a specific approach of Blended Learning: flipped classroom. This methodology focuses on making the most of classroom time by engaging in collaborative activities that promote the development of knowledge and skills in students [4].

Recent research shows positive effects of the flipped classroom methodology on multiple elements of the educational process. Some of these effects are the increase of motivation and participation of students in activities outside and inside the classroom; improvement of general understanding and retention of the subjects taught; generation of an environment of collaboration and discussion in the classroom; and boost of the development of competencies and skills [5].

These aspects allow greater interaction between students and teachers, enhancing a better academic performance and an increase in the argumentative skills of the students. To implement the flipped classroom methodology, it was necessary to develop audiovisual material of the topics addressed in the course, considering that these contents would serve as support for students.

Literature Research

Current academic scope has change in recent years due to industry requirements of new professionals with adequate competences to successfully approach complex and uncertain situations. Therefore, education priorities have switch into looking for inclusion and equity in

education, enhancing lifelong learning, enhancing competences and motivation, and supporting digital transformation [6].

This change of paradigm generates the need of educational strategies that focus on competence development and flexibility of how contents are delivered and evaluated [7]. One of these strategies is Blended Learning, a methodology created more than two decades ago, but still being used within different contexts in higher education [8].

There exist different meanings for the term Blended Learning, which imply the combination of at least two different learning approaches [9]. For the purpose of this study, we can define Blended Learning as a combination of asynchronous online activities and synchronous in-class activities to engage students and enhance learning. Due to 2020 Covid-19 pandemic, educational institutions were forced to move towards online courses and blended learning was commonly incorporated into courses [10]. Moreover, in the post-pandemic education framework several of these learning methodologies remain active and are still being applied.

Literature has shown that blended learning methodologies may contribute to promote learning and engage students, however, not all methodological aspects and implications have been approached and require further study [11]. Particular research during Covid-19 pandemic found that student engagement was compromised during lockdown, while online classes and blended learning techniques were the common approach. Lack of student's response during classes and technology complexity were pointed out as a constraint for teachers and students to generate meaningful learning during classes [12]. Moreover, literature also shows that students have a greater preference to face-to-face interaction with the teacher than Blended Learning techniques when Covid is not an issue for attending to classes. This motivation responds to the fact that students perceive more socialization during physical interaction, supporting engagement towards class activities [13].

Post-pandemic learning, however, has required the modification of content delivery methods to satisfy the needs of students of social interaction, but also to maintain the technological literacy developed during Covid-19- lockdown, which may contribute to a more dynamic and interactive experience for students [14]. One of the technological trends of Blended Learning is Video based flipped classroom, which implies dividing a class in two moments:

1. Video – assisted teaching, where students are exposed to explanatory and demonstrative videos that they can visualize as many times as required and at any moment, that is, not necessarily during class.
2. In class practice and feedback, where students are able to demonstrate their acquired knowledge and receive feedback from the teacher.

Video based flipped classroom has been demonstrated to increase flexibility of learning and to enhance skill development [15]. Similarly, literature also show that incorporating video based learning significantly increase engagement of students [16] and contribute to increase evaluation scores in academic courses [17].

Aligned with current educational challenges, and with Tecnologico de Monterrey student – centered educational model requirements, this study looks for contributing literature by incorporating flipped classroom into an engineering course and assessing the impact in students' competences and skills, looking for significant changes in which students prepare for the future.

Methodology

Our educational model is focused on the development of skills in students, hence, for the Tecnologico de Monterrey it is of vital importance that students develop these skills throughout all of their courses, at the same time that they acquire the necessary technical and theoretical knowledge for their professional development. The purpose of this study is to measure the impact that the implementation of the flipped classroom methodology can have on students' academic performance and on the development of argumentative competences.

A quasi – experimental design was used for this study, involving 48 engineering students, enrolled in the course Analysis of Static Equilibrium. This course is one of the most complicated for students, since it is the first course that gives them a closer approach to the reality they will face in their professional life. Students self registered for the groups offered by the school services department, once the registration period was over, we start the semester working with two groups of 24 students from the mechanical engineering, mechatronics engineering, and civil engineering programs. This study was developed during the August-December 2022 semester, in a time of 10 weeks, split into two periods of 5 weeks each. One group was considered as *control* and the other group as *experimental*.

The control group was exposed during the first period of 5 weeks to a *traditional* class in which the teacher gave them face-to-face sessions and answered doubts or questions from the students during the exposition of the topics. During these sessions, the teacher demonstrated the solution of examples, and at the end, homework exercises were assigned. At the end of this first period, a partial evaluation of knowledge was carried out to evaluate the understanding of the fundamental principles of Static Equilibrium Analysis. The deployment procedure is as shown in Figure 1.

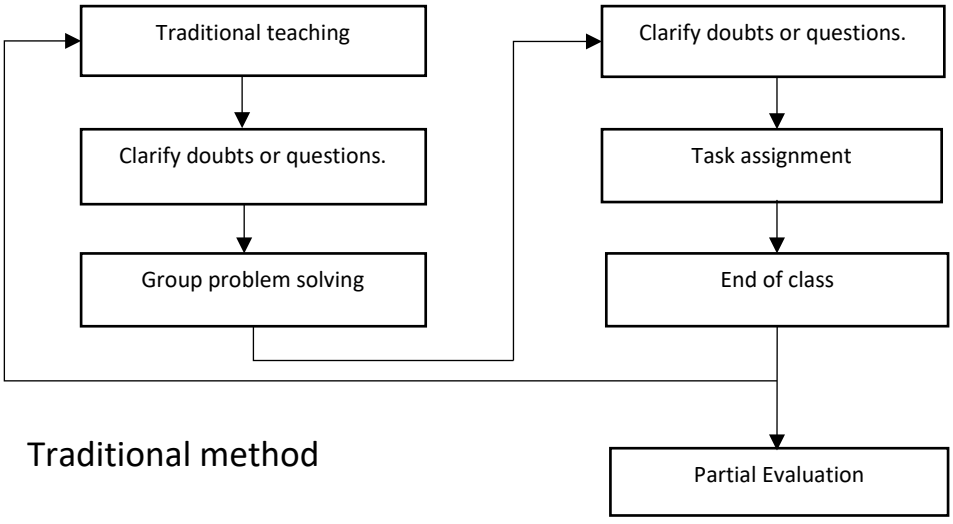

Figure 1. Methodology used in a traditional class.

In the second period of 5 weeks, again in this control group, the flipped classroom didactics were implemented as shown in Figure 2. According to this methodology, prior to the face-to-face session, the students reviewed and studied a video of the topic to be discussed in the face-to-face session, after that, they carried out a control assessment. Then, during the face-to-face session, we worked with the review or homework exercises in a collaborative and/or individual way with the supervision and support of the teacher. At the end of the period, a new partial evaluation of knowledge was carried out to measure their academic performance.

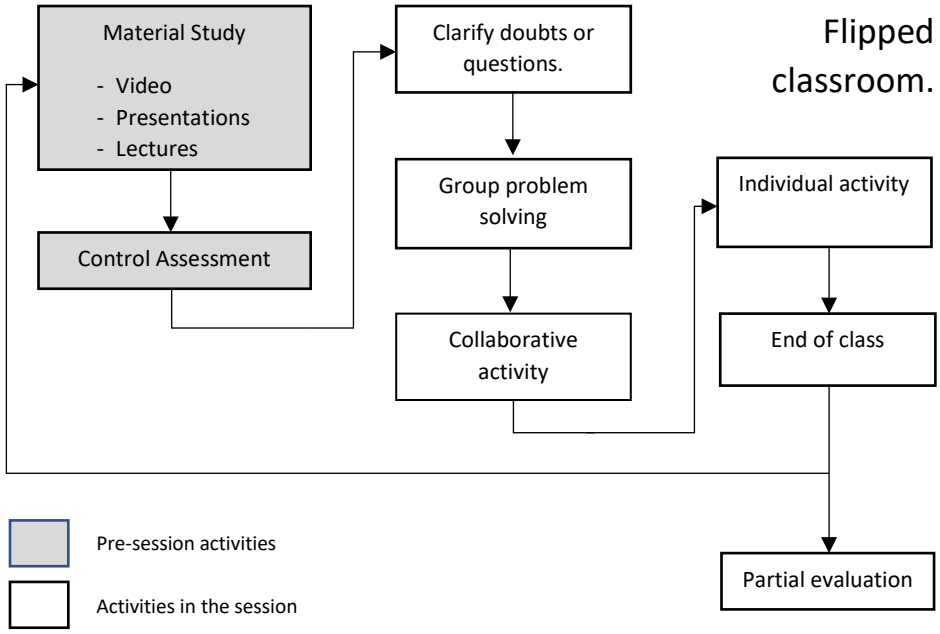

Figure 2. Flipped classroom methodology.

On the other hand, the experimental group worked with the flipped classroom methodology during the two 5-week periods. They studied the material in the video before each session and worked collaboratively during the face-to-face sessions. Similarly, we carried out partial evaluations of knowledge at the end of each of the periods. This flipped classroom methodology was the same as that applied to the *control* group according to the procedure shown in Figure 2.

At the end of the 10 weeks of analysis, in addition to the partial evaluations of knowledge presented at the end of each period, both groups presented an argumentative evaluation, which served to have a measure of the development of their argumentative ability. Figure 3 shows the methodology used in each of the groups according to the period of study.

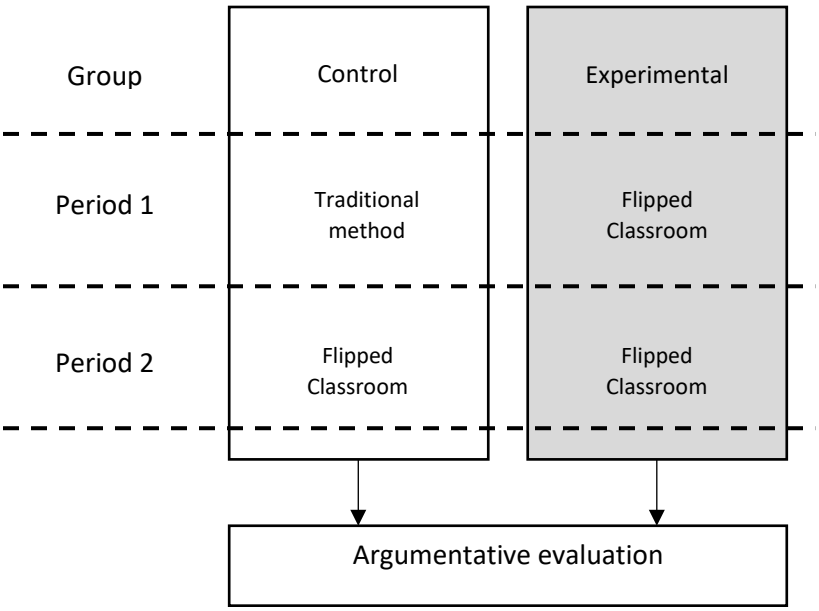

Figure 3. Methodology used in each study group.

Discussion of Results

Three main variables were recorded for each of the groups: the score of a first partial evaluation performed in the 5th week of classes, the score of a second partial evaluation performed in the 10th week of classes, and the score of an argumentative evaluation performed at the end of the course. In the Tecnologico de Monterrey, the passing score of any evaluation is considered to be 70 out of 100.

The scores at the end of the 5th week present a strong bias towards failing marks, as shown in Figure 4. In the control group, 92% of the students received a score below the 70 mark. Similarly, 68% of the students in the experimental group received a failing mark. Moreover, even the experimental group present a higher average score in the evaluation, the difference is not statistically significant, as it can be seen in the one tailed hypothesis test in Table 1, where the null hypothesis stands for a difference of means equal to zero, and an alternative hypothesis of the experimental group to have a higher average mark than the control group.

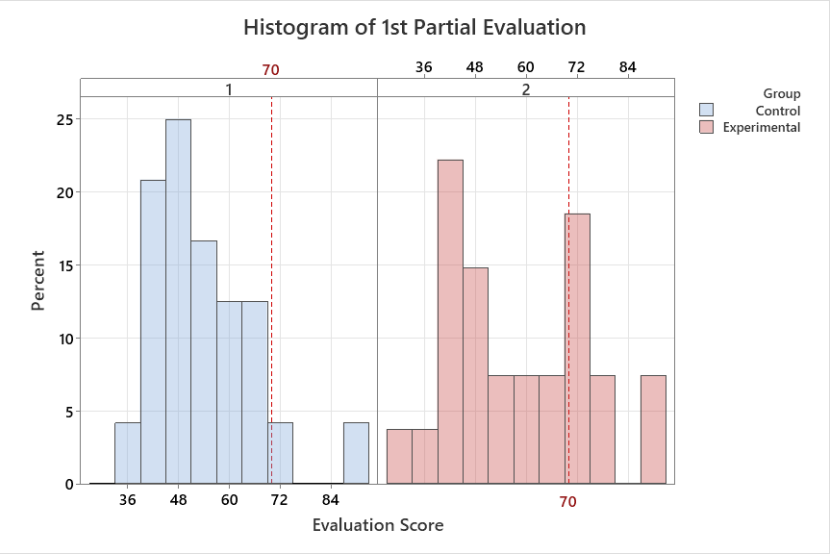

Figure 4. Histogram of 1st Partial evaluation.

Table 1 Hypothesis test for difference of means in 1st Partial evaluation.

Group	Mean	95% CI for difference	P value
Control	53.5	(-12.30, 4.05)	0.315
Experimental	57.6		

Similarly, to the results in the first partial evaluation, results after 10 weeks of classes do not show a significant difference between the experimental and the control group, as shown in Figure 5 and in Table 2. It is important to notice that the objective of each evaluation was to measure procedural skills of students, which implies algorithm recognition and operational performance. These results cannot support therefore any improvement in the aforementioned concepts, with equal results among the control group and the experimental group.

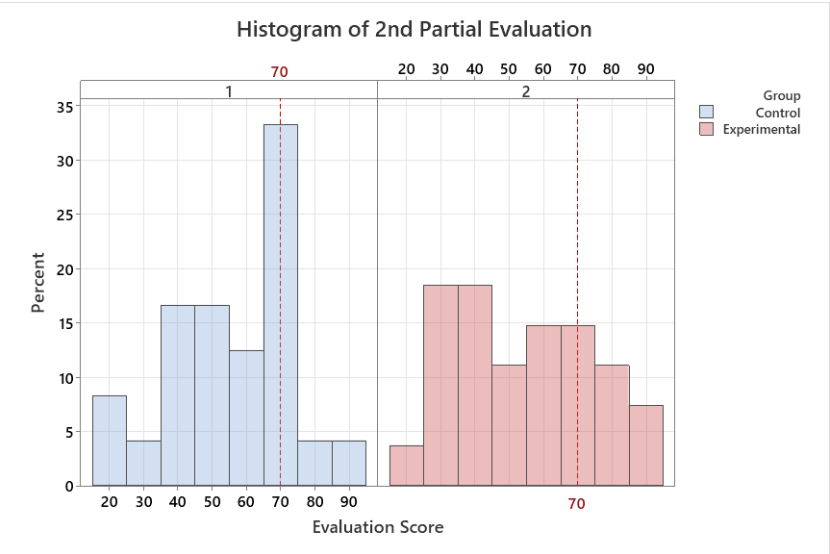

Figure 5 Histogram of 2nd Partial evaluation.

Table 2 Hypothesis test for difference of means in 2nd Partial Evaluation

Group	Mean	95% CI for difference	P value
Control	54.8	(-8.85, 12.50)	0.732
Experimental	53.0		

On the other hand, the argumentative evaluation was intended to measure the degree at which a student comprehend the underlying concepts to model a static system, and the ability to explain them based in scientific foundations. The obtained results show a statistically significant difference between the scores of the experimental group with respect to the control group. As seen in Figure 6, 89% of the student in the experimental group received an approving mark, while only 29% of the control group did.

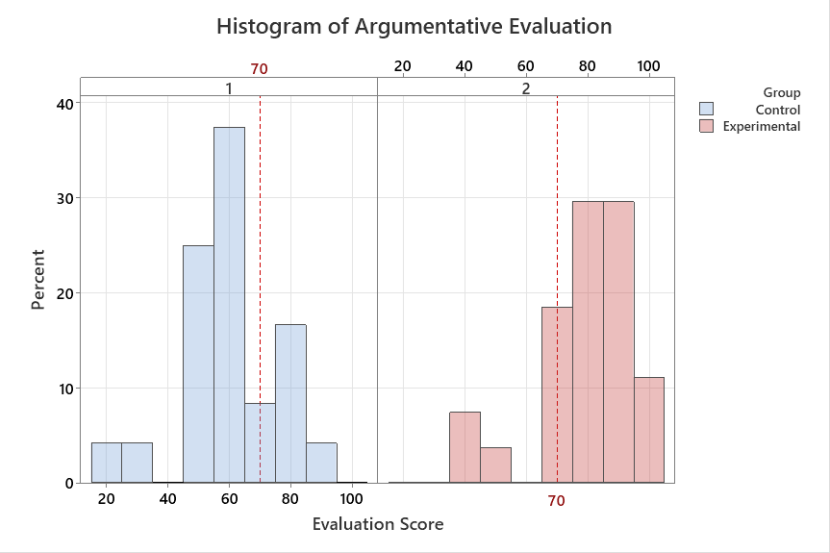

Figure 6 Histogram of Argumentative evaluation.

The one tailed hypothesis test shown in Table 3 confirms a significant difference of means between both groups. These results may imply that students exposed to the proposed Blended Learning methodology developed a better foundational comprehension of the course, allowing them to represent phenomena of static analysis in a better and more scientifically based approach.

Table 3 Hypothesis test for difference of means in Argumentative Evaluation.

Group	Mean	95% CI for difference	P value
Control	60.5	(-28.19, -10.35)	0.000
Experimental	79.7		

Conclusions

The development of this study shows that the flipped classroom methodology has a significant impact on the development of argumentative skills in students; It shows that students who worked with this methodology during the two study periods perform better in their argumentative evaluation. On the other hand, when analyzing the academic performance of the

two groups, control and experimental, during the two study periods, there is no significant impact of this methodology on their learning, since both groups present statistically equal results.

With these results, it can be implied that the flipped classroom methodology allows generating an environment conducive to meaningful learning, allowing students to truly understand the concepts underlying static equilibrium analysis, allowing them to develop their argumentative skills; but it does not necessarily impact practical and theoretical evaluations.

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