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ESTUDIO DE CASO DEL MODELO CLASE INVERTIDA EN UN CURSO DE MECÁNICA DE CUERPOS RÍGIDOS

A CASE STUDY OF THE FLIPPED CLASSROOM MODEL IN A RIGID-BODY MECHANICS COURSE

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RESUMEN

El objetivo de este artículo es presentar una investigación en la que se empleó el método de estudio de caso utilizando un grupo control, para aplicar el modelo de clase invertida en un curso de mecánica de cuerpos rígidos. Los estudiantes del grupo A recibieron el curso con el modelo clase invertida, mientras que el grupo de control B con el método tradicional basado en conferencias magistrales. Este estudio cuali-cuantitativo recolectó información de dos fuentes: calificaciones finales del curso y encuestas a los estudiantes. Como resultado, las calificaciones finales del grupo B fueron significativamente más altas que las del grupo A (p = 0,039). Las calificaciones del grupo B estuvieron relacionadas con el porcentaje de revisiones de las conferencias pregrabadas. En las encuestas, el grupo B calificó positivamente la aplicación del modelo en 8,3±1,4. Concluyendo, que la clase invertida promueve el autoaprendizaje de los estudiantes, por lo que se recomienda en contenidos relacionados con la Física y las Matemáticas.

***Palabras clave**: modelo clase invertida, resolución de problemas, videos educativos*

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ABSTRACT

The objective of this article is to present an investigation in which the case study method was used using a group control, to apply the flipped classroom model in a rigid body mechanics course. The students of the group have received the course with the investment model, while the control group with the traditional method is based on lectures. This qualitative-quantitative study collected information from two sources: final course grades and student surveys. As a result, the final scores of group B were also higher than group A ($p = 0.039$). Group B ratings related to the percentage of pre-recorded conference reviews. In the surveys, group B positively rated the application of the model at 8,3 ± 1,4. In conclusion, that the inverted class promotes student self-learning, which is recommended in the contents related to Physics and Mathematics.

Keywords: *flipped classroom, problem solving, educational videos*

1. INTRODUCTION

Educators and educational researchers have questioned the effectiveness of teaching methods that are entirely lecture-based [1]. Also, students have started to be less tolerant of lecture-style presentations [2], and usually, with this method, they can only retain knowledge and do not understand it. One way to solve these problems is active learning, which is “any instructional method that engages students in the learning process” (p. 1) [3]. This learning is based on student activities, where they are encouraged to think about what they are doing, which promotes the active and constructive process of knowledge [4] [5].

The *flipped classroom* is one of the active learning models. Instructors create a video lecture, screencast or podcast, which allows the student to learn the concepts out of the classroom, freeing up valuable class time for more engaging activities [6]. During class time, students can work through problems, advance concepts, engage in collaborative learning and increase their knowledge retention [2] [7] [8]. Today, the *flipped classroom* model is possible due to three main aspects: students have internet access for viewing web-based instruction in their own time on most university campuses and homes [5]. Also, they are accustomed to using and accepting modern technology [9]. And, educators are interested in maximizing their students learning through innovative practices [10]. If learners view the pre-recorded lectures, before class, there will be more available time in the classroom to use the information addressed in that online lecture. Therefore, contact hours can be devoted to problem-solving, skill development, and gaining a deeper understanding of the subject matter [5].

There are few things in the *flipped classroom* which should be considered. First, instructors may produce quality video instructional and technical. Second, students must have access to internet connection and technology devices where they can watch the video. Also, they will not be able to consult the teacher about the content. And finally, students can be distracted by browsing other web pages. [2] [6]. *Flipped classroom* model has been used in many educational areas, such as medicine [2], engineering [11] [14], business [15], cinema [16], economics [17] [18], language [19], among others. Nevertheless, the model could be adapted easily to multiple disciplines such as textile design, apparel design and construction, interior design, and nutrition [2]. Also, there could be other circumstances for the application of this model that have not been considered yet by researchers [9].

In engineering, the *flipped classroom* was implemented in some mechanic courses but it was not in rigid-body mechanics. Based on that and the satisfactory results worldwide the following two research questions are addressed in this study. First, what is the student's opinion about the flipped classroom model, after experiencing it? And, how does the flipped classroom model influences the students' grades in comparison to the traditional education model? To answer the first question a study group (group A) took a rigid-body mechanics course with the *flipped classroom* model. These students had to review the pre-recorded lectures of every topic before the face-to-face class. In each session, they had to solve some problems and take others as homework. At the end of the course, they answered a blind survey about the education method, in order to know their opinion about it. Otherwise, to answer the second question, their grades were compared with another group (group B) who received the course with the traditional education model.

2. DEVELOPMENT

Within the field of mechanics, the *flipped classroom* model has been implemented in several courses, such as fluid mechanics [11], mechanics of materials [12], dynamic [13] [14] and classic mechanics [14]. In fluid mechanics, two groups of students were considered: those who received the class with the *flipped* model and those who received it with the traditional one. Learners in the first group had to watch videos online before class, participate in in-class problem-solving activities, and complete tests weekly. There was an increase in their score of 7,5 points compared with the traditional method group [11].

In a course of mechanics of materials, 15 students took it with the *flipped classroom* model. Their results were compared with the results of 11 students that took the course with the traditional model. The fifteen students had to review some videos, answer short questions and solve an extra-class task before face-to-face class. In-class, teacher focused on the main concepts of the videos, problem-solving sessions, demonstrations, and tests. Learners who received the course with the model proposed method performed better than the students who received the course with the traditional method [12].

Flipped classroom method was also applied in an online dynamics course, with 680 students from the Massachusetts Institute of Technology. They had to watch videos and solve problems with a guiding document, before exams and tests. The course improved their learning experience and their ability to solve problems [13]. With around 200 students, the *flipped classroom* was applied in classical mechanics. Students had to review or perform, prior to the face-to-face class, several online courses or prepare a topic from books or web pages. In-class, the academic gaps of the subject was covered, through guided discussions and multiple-choice questions. 51% of the students considered that the use of the method was excellent, while, after finishing the course, 54% prefer the *flipped classroom* method that the traditional method [14]. In summary, those investigations reported improvements in grades, increased retention or showed a preference for the method, which suggests that the *flipped classroom* method has additional benefits over the traditional one.

3. METHODOLOGY

Qualitative and quantitative research was proposed in order to answers both study questions. The first one included a groups A survey at the end of the course. This instrument had several questions (open and closed) about their experience with the *flipped classroom* model, pre-recorded lectures, self-learning, problem-solving session and their final comments about it. Otherwise, the quantitative study compared the finals course grades from both groups in order to see if the model helped to get better grades to compare with the traditional model. In order to contextualize Figure 1 shows those educational models applied in the rigid-body mechanic's course.

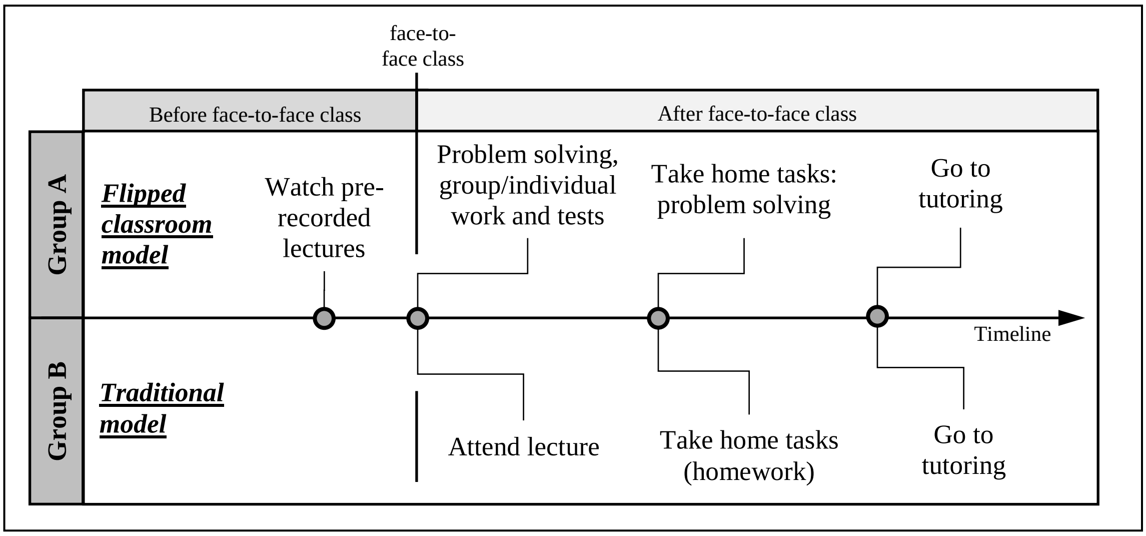

Figure 1. *Chronology of educational models applied in the rigid-body mechanic's course. Source: the author*

As can be seen in Figure 1, students from group A had to watch pre-recorded lectures before the face-to-face class. In-class they worked individually or in a group in problem-solving

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sessions and taking tests. After classes, they did complementary work and went to tutoring if they had questions about the topic and/or problems that they could not solve. Conversely, students from group B did not have any activity before class. So they attended in-class to the lecture and then they had to solve problems and go to tutoring in case they had some questions about the topic. Since group A and B have their own characteristics, details of each of them are described below.

3.1. Group A

3.1.1. Sample size

Group A were students that received the rigid-body mechanic's course with the *flipped classroom* model. This group was a non-probability sample because all students that registered in the course were part of this study. Consisted of undergraduate students (n=75) who enrolled in the course in October 2015 - February 2016 period. They were in the second year of civil engineering at the Universidad Técnica Particular de Loja. Twenty-one of them were women and fifty-five were men.

3.1.2. Course structure

Class structure consisted of 12 topics (week 2-7 and 9-14) as shown in Table 1. Twelve pre-recorded lectures or education videos were made for every topic which lasted from 26 minutes to 2 hours. The videos were digital slide presentations with voiceovers using Microsoft PowerPoint. They were available online throughout the whole course, so students could go back to review them whenever they needed to.

Table 1. *Description of the pre-recorded lectures and number of example problems. Source: the author*

Week	Topic	Duration	Number of example problems		
		hh:mm:ss	In-class	Homework	Total
1	**Introduction**	-	-	-	-
2	Force Vectors	0:59:46	3	9	12
3	Force System Resultants	2:07:38	6	5	11
4	Equilibrium	0:57:46	8	8	16
5	Structural Analysis	0:42:42	3	6	9
6	Structural Analysis (cont.)	0:26:25	4	5	9
7	Cables	0:48:51	2	5	7
8	**Midterm**	-	-	-	-
9	Friction	1:05:12	4	7	11
10	Center of Gravity and Centroid	1:08:59	6	6	12
11	Moments of Inertia	0:40:00	4	10	14
12	Kinematics of a Particle	1:12:15	7	21	28
13	Kinetics of a Particle: Force and Acceleration	1:02:48	8	16	24
14	Kinetics of a Particle: Work and Energy	1:02:32	6	11	17
15	**End of term exam**	-	-	-	-

- There were not any pre-recorded lecture

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Every week they were uploaded in YouTube platform and were shared through the university's Virtual Learning Environment (VLE). Lectures were based mainly on two books: engineering mechanics statics [20] and engineering mechanics dynamics [21]. Table 1 also shows the number of example problems that students had to solve in every topic. The preparation of education videos lasted 16-24 working hours depending on the topic extension and the number of problems that were solved in the video. Video recording took from 01h30 to 02h30 to achieve the desired audio result. In spite of this amount of time, video lectures will be ready for future rigid-body mechanic courses.

3.1.3. Flipped classroom application

Group A watched the pre-recorded lectures before attending a weekly class that lasted four hours. In-class, students did individual or group tasks and problem-solving session conducted by the teacher. Homework was assigned and they had to deliver it by the next class. Final grades were up to 100 points with a minimum is a requisite for passing the course. Random reading tests were taken at the beginning of the class in order to encourage students to watch pre-recorded lectures. Reading test and homework had a weighting factor of 10% of the final course grade. Tests were taken approximately every three weeks to evaluate the student's progress, which counted as 20% of the final grade. Also, approximately every two months, pupils had a midterm exam that scores 60% of the final course grade. Classwork and interaction with the VLE were also included with a weighting factor of 10%.

Additional to the grading procedure mentioned above, two incentives were considered to maximize learning. First, in-class, for every four times that a student solved correctly a given problem, an additional 5% was assigned to that student. Also, for every four errors that they found in the pre-recorded lectures, they could get an additional of 5%. These additional scores allowed some students to reach up to an additional ≈ 9% of the final course grade. The teacher that made the pre-recorded lectures also participated during the face-to-face class. Quizzes and tests lasted 1-2 hr. These evaluation tools had some problems to resolve, and a conceptual part of true and false questions. Weekly tutoring session lasted one hour and was designed to evaluate some of the unsolved homework and the main ideas from the week's material.

3.1.4. Data collection

Two instruments for data collection were used: a survey and final grades records. At the end of the course, students were asked to complete an optional blinded survey about their experience with the implementation of the *flipped classroom* model. Sixty-five students answered that survey. Otherwise, the teacher calculated the student's final course grade to compare with the grades from group B.

3.2. Group B

3.2.1. Sample size

Group B, or control group were students that received the rigid-body mechanic's course with the traditional model lecture-based. This group was also a non-probability sample and consisted of undergraduate students (n=46) who enrolled in the course in April – August 2015 period. This group had 16 women and 30 men. Students were coursing the second year of architecture at the Universidad Técnica Particular de Loja. Students from civil engineering and architecture major cannot be considered the same since they need different skills and knowledge. However, in the second year, civil engineering and architecture has little differences in their curricular subjects.

Also, students already had some contact with the course topics in their school, and they have the same time of adjustment in university life. For those reasons, group A and B can be considered as similar in this study. The number of students in group A was 75 and in this group was 46. Both groups had a total of 121 learners. And other studies in the same field worked with 26-680 students [12] [14]. This means that the sample size of this study is an acceptable number that allows making significant conclusions.

3.2.2. Course structure

The course structure of group B had the same topics as group A. Also the number of example problems was the same and with a similar difficulty level.

3.2.3. Traditional classroom procedure

Group B received a face-to-face lecture for four hours in a weekly class. Also, students did a few individual or group tasks and problem-solving session conducted by the teacher. Furthermore, homework had to be delivered by the next class. Final grades were up to 100 points with a minimum of 70 points to approve the course. The same weighting factors as group A were used to calculate their final grades. The teacher was the same as for group A. Different versions of quizzes and tests were given to the two classes; nonetheless, they were designed with the same difficulty level and duration. The weekly tutoring session also lasted one hour, where students asked for unresolved problems or questions from the lecture.

3.2.4. Data collection

Just their final grades were used as an instrument in order to answer the second research question. Student's final course grades were calculated by the professor. Students from this group were not asked to answer any survey, because, their experience with the traditional teaching method was not being evaluated.

4. RESULTS

This section is divided into three: group A results, group B results, and final course grades results. In the first part, the results of the implementation of the flipped classroom model are shown by using pre-recorded lectures statistics, final course grades, and the relationship between final grades and video reviews. In the second part, final course grades from group B are shown, and in the last part, those grades were compared with the grades from group A. Is it necessary to mention that most results will be presented as mean ± confidence interval (α = 0,05). This interval is obtained with the following equation:

$$CI = Z\left(\frac{\sigma}{\sqrt{n}}\right) \quad (1)$$

Where: CI: confidence interval, Z: standard normal distribution value related to the confidence level that in this case is 1,96 for 95%, σ: standard deviation and n=sample size.

4.1. Group A Results

4.1.1. Pre-recorded lectures

In the survey students rated every pre-recorded lecture on a scale of one to five (five being the highest value and one being the lowest). In Table 2, results of this rating are shown, where most of the educational videos received an acceptable rating over 4,3. In the table also the average numbers of video reviews are shown. On hit counter, YouTube [22] students watch the educational videos on average more than 1,8 times. These statistics consisted of the learner's answer where 34% said they usually watched every video once, 46% watched them twice, and 20% had done it three times or more. This was possible due to pre-recorded lectures were available throughout the course and students were able to watch them more than once.

From Table 2 it also can be seen a reduction in views the week before exams because they were more worried about the exams than the videos. This behavior was also found in another preview research from 2012 [9]. Also, there were some variations in the number of reviews

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during the whole semester, which could be related to the "take home" problems, that is to say, they watched the pre-recorded lectures fewer times when the number of problems was increased and vice-versa. Based on that, for homework activities a maximum of 10 problems per week is recommended. This is consistent with other researchers in the field where they recommended between 5 and 15 per unit [13].

Table 2. *Pre-recorded lecture scores, given by students from group A and the average number of video reviews. Source: the author*

Week	Topic	Score m ± CI	Average number of video reviews**
1	**Introduction**	-	*
2	Force Vectors	4,7 ± 0,1	3,2
3	Force System Resultants	4,7 ± 0,2	3,3
4	Equilibrium	4,6 ± 0,2	3,4
5	Structural Analysis	4,6 ± 0,1	3,0
6	Structural Analysis (cont,)	4,6 ± 0,1	2,6
7	Cables	4,5 ± 0,1	2,0
8	**Midterm**	-	*
9	Friction	4,5 ± 0,2	1,9
10	Center of Gravity and Centroid	4,5 ± 0,2	1,9
11	Moments of Inertia	4,6 ± 0,2	2,5
12	Kinematics of a Particle	4,3 ± 0,3	2,3
13	Kinetics of a Particle: Force and Acceleration	4,4 ± 0,2	2,0
14	Kinetics of a Particle: Work and Energy	4,4 ± 0,3	1,8
15	**End of term exam**	-	*

- Not possible to score, * There were not any video to watch, **According to YouTube statistics [22], m=mean, CI: confidence interval

Besides the relationship between number problems and video reviews, the survey also asked come pre-recorded lectures details as can be seen in Table 3

Table 3. *Results from question-related to pre-recorded lectures reviews. Source: the author*

Questions	Options/answers percentages			
How many pre-recorded lectures did you watch?	All of them	I did not watch 1 or 2	I did not watch 3	I did not watch more than 4
	21,5%	52,4%	13,8%	12,3%
At what time did you watch the pre-recorded lectures?	6-14h00	14-19h00	19-21h00	21-24h00
	20,0%	24,6%	43,0%	12,4%
Usually, when did you review the pre-recorded lectures?	During the day of the class	1 day before class	2 days before class	3 days or more before class
	4,5%	60%	31%	4,5%
How long should the pre-recorded lectures be?	20m-40m	40m-50m	50m-1h	1h-2h
	13,8%	38,5%	35,4%	12,3%

Students watched the pre-recorded lectures as follows: 21,5% of students watched all of them, 52,4% said that they did not watch 1-2 pre-recorded lectures and 26,1% said that they did not watch from 3-5 pre-recorded lectures. On the other hand, 43,0% of the students watched the pre-recorded lectures between 19-21h00; this may be due that during these hours their regular academic activities generally ended. Most learners (60%) watched the videos the day before

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attending class, 31% did it two days before the class, 4,5 % reviewed them three or more days earlier, and 4,5% admitted to having watched them on the day of the session. Regarding the duration of the educational videos, 73,9% felt that they should last between 40 minutes to 1 hour. Previews researchers had considered the duration of 20 min [16], 20-30 min [4], up to 1 hour [9], and others just said: “short videos” [6] [11]. With regard to the devices where students watched the videos, they mostly used a computer (88%) to watch pre-recorded lectures, secondly mobile phone (9,7%), later a TV with an internet connection (1,8%) and few others used tablets (0,5%) [22].

4.1.2. Final course grades

Final course grades for group A were calculated using the weighting factors described before and its results are shown in Table 4.

Table 4. *Final course grades for students from group A. Source: the author*

Final course grades	Number of male students	Number of female students	Total
100-90	2	2	4
89-80	6	2	8
79-70	18	6	24
69-60	7	8	15
59-50	12	1	13
49-40	5	1	6
39-30	2	0	2
29-20	1	1	2
19-10	1	0	1
9-0	0	0	0

From table 4, 36 students approved the course, where 24 of them obtained a final grade between 70-79 points. Women scored an average of 67,9 points and men scored an average of 63,9 points. The average grades of women were higher but not statistically different at 95% confidence level ($p = 0,074$). This analysis was done using Student’s t-test. The final grade average for all students from group A was 65,0 points.

4.1.3. Relationship between final grades and video reviews

Since learners answered that the pre-recorded lectures promoted the constructive process of learning in $4,4 \pm 0.2$ (1 = disagree, 5 = agree), an analysis between final course grades (points) and the percentage of the pre-recorded lectures views (PVW) was performed. This information is drawn in Figure 2.

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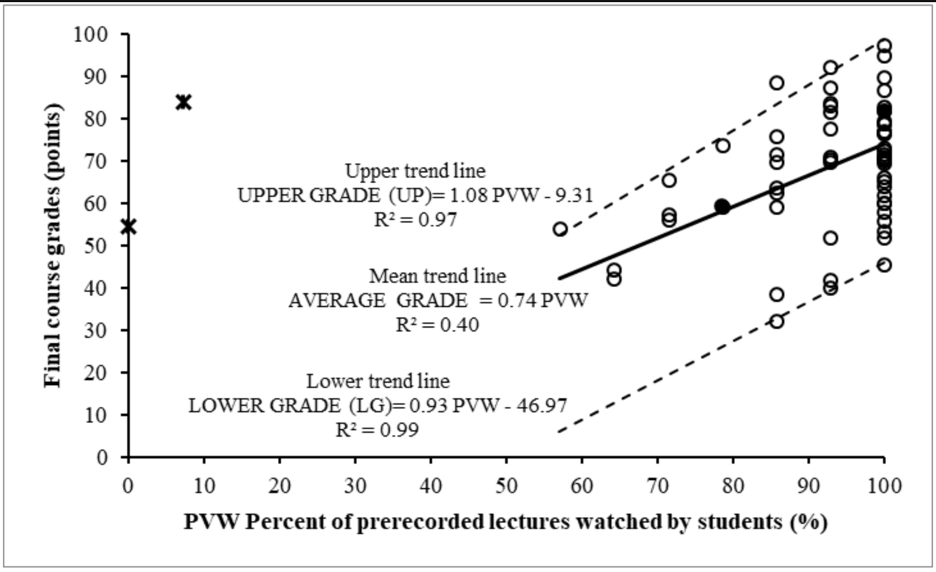

Figure 2. *Relationship between the final course grades and the percentage of pre-recorded lectures watched by students. Source: the author*

In general, Figure 2 shows that the final course grades were higher when the student watched most of the pre-recorded lectures. However, two students are out that trend (see * in Figure 2); one scored 55 points without watching any pre-recorded lectures, and the other scored 84 points watching about 7% of them. This may be caused for several reasons: students may have already attended this course on another occasion, they found the topics easy to understand, or responded to the survey with false information.

So, answers for those two students were eliminated from the data, in order to calibrate some equations. Three linear regressions models were calibrated: average grade (R2 = 0,40), upper grade (R2 = 0,97) and lower grade (R2 = 0.99). The last two equation were calibrated using the most extreme values. Based on these equations, if a student watches 85% of the pre-recorded lectures, then it is likely that his/her final course grade will be: 0,74 (85) = 62,9 points. However, there will be other students that, even though they watch the same percentage of the pre-recorded lectures will get higher or lower grades than that value. These values can be calculated as UG = 1,08 (85) – 9,31 = 82.5 points and LG = 0,93 (85) – 46,97 = 32,1 points, which means that students who have watched 85% of the pre-recorded lectures will obtain final grades between 32,1 to 82,5 points. The standard deviation or the confidence interval in these equations was not used because they have a smaller range than those of the extreme values.

Another preview research from 2015 [11] also calibrated an equation based on a combined final exam and post-concept inventory score. In 2014 some investigators [12] calibrated an equation considering the college GPA, the average pre-quiz score and if it is a control group

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or a treatment group. Anyway, those equations and the equations from Figure 2 should be used as a reference, considering that academic evaluation is a complex field. Also, beyond the range considered they should not be used, since it may lead to inconsistent results. These results should be validated by further studies.

4.2. Group B Results

4.2.1. Final course grades

The final course grades from group B were calculated using the same weighting factor described for group A and its results are shown in Table 5.

Table 5. *Final course grades for students in group B. Source: the author*

Final course grades	Number of male students	Number of female students	Total
100-90	0	0	0
89-80	3	2	5
79-70	4	2	6
69-60	9	4	13
59-50	6	5	11
49-40	4	2	6
39-30	4	1	5
29-20	0	0	0
19-10	0	0	0
9-0	0	0	0

In group B, 11 students approved the course. Women scored an average of 59,5 points while men scored an average of 57,8 points. Again using the Student's t-test, the average grades of women were higher but not statistically different at 95% confidence level (p = 0,537). The average final grade for all students from group B was 58,5 points.

4.3. Final Course Grades Analysis

Group A performed better in the course than group B, the final course grades from both groups are represented in Figure 3. According to this information, 48% approved the course with the *flipped classroom* model compared to 24% with the traditional model. Also, the average final grades from group A was 6,5 points higher than group B. And those grades were statistically different at 95% confidence level (p = 0.000) using student's t-test. In conclusion, the flipped classroom model affected positively their students' grades in comparison with the traditional education model. This statement answers the second research question.

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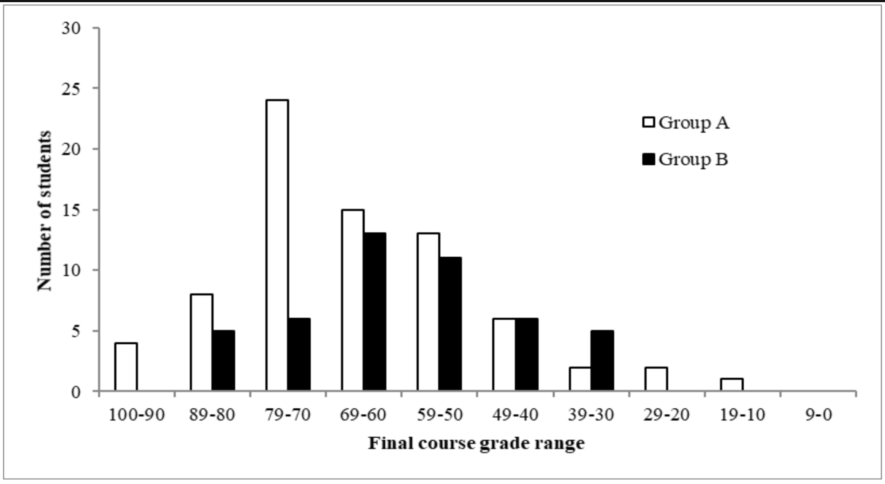

Figure 3. *Final course grades of the two study groups. Source: the author*

Other researchers in the field reported an average of 79 points [14] and 58 points [12] for the flipped classroom model. In both cases, they informed that students who received the course with a flipped classroom model had better results than the traditional educational model, as, in this research was also found. In a fluid mechanic's course were reported similar results, where students got 7,25 points more than students with traditional model [11].

5. CONCLUSIONS

The aim of this article was to show the case study of the flipped classroom model in a course of rigid-body mechanics. This study was looking to answer two questions: what is the student's opinion about the flipped classroom model, after experiencing it? And how does the flipped classroom model influence the students' grades in comparison to the traditional education model? To answer these questions two groups of students were analyzed.

Structure course was planned in order to answer the first research question, where twelve educational videos were prepared for every topic. A blind survey was conducted in group A after the flipped classroom model was implemented. Their results suggest that this model is well received, promoted students self-learning and learners were more aware of their own learning. However certain elements have to be considered in the future: a) pre-recorded lectures should be short, between 40 minutes to 1 hour, and, b) pre-recorded lectures would have fewer reviewers when main exams are coming. So, academic activities at-home s should allow students enough time to review pre-recorded lectures.

In order to answer the second research question, the final course grade was calculated for both groups and compared between them. There was a positive relationship between students' final course grade and the percentage of pre-recorded lectures reviewed. A higher grade was expected when students watched more pre-recorded lectures, and three equations were

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calibrated. Also, the flipped classroom model improved the students' final course grade.

The successful experience in the implementation of this model suggests that could be applied in other courses such as subjects related to Physics and Mathematics. In future works, this should be investigated. This paper covers the existing gap in mechanics courses that used the flipped classroom model. Also, this document provides a general methodological guide about how to implement a flipped classroom model as well as details of pre-recorded lectures, number of example problems and expected results.

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