FLIPPED CLASSROOM: AN ALTERNATIVE TEACHING METHOD FOR INTRODUCTORY STATISTICS COURSES

By

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From a passive student to an active student. From a teacher-centered education to a student-centered education. The inverted class or flipped classroom is a new teaching method in which, in one of its versions, technology is used to change the direct instruction outside the classroom. In our study the lessons are taught online outside of class through videos, and class time is used in activities that promote a deeper exploration of the topics. These activities give us the opportunity to teach students not only the formulas but the concepts, interpretations and the most useful and important technological tools in statistics. An experiment with two introductory courses in statistics at the University of Puerto Rico at Mayagüez was carried out to determine the effect of a partially flipped classroom on the academic achievement and the attitude towards statistics of the students. In this work, the experiences and results of the implementation of the flipped classroom in our study will be presented.

Resumen del Proyecto Presentado a Escuela Graduada
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CLASE INVERTIDA: UN MÉTODO DE ENSEÑANZA ALTERNATIVO PARA CURSOS INTRODUCTORIOS DE ESTADÍSTICA

Por

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Mayo 2017

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De un estudiante pasivo a un estudiante activo. De una educación centrada en el educador a una educación centrada en el estudiante. La clase invertida es un nuevo método de enseñanza en el cual, en una de sus modalidades, se emplea la tecnología para cambiar la instrucción directa fuera del salón de clases. En nuestro estudio las lecciones se imparten en línea fuera de la clase a través de videos, y el tiempo de la clase se utiliza en actividades que promueven una exploración más profunda de los temas. Estas actividades nos brindan la posibilidad de enseñarles a los estudiantes no tan solo las fórmulas, sino los conceptos, las interpretaciones y las herramientas tecnológicas más útiles e importantes en la estadística. Un experimento con dos cursos introductorios de estadística en la Universidad de Puerto Rico en Mayagüez se llevó a cabo para determinar el efecto de la clase parcialmente invertida en el aprovechamiento académico y la actitud hacia la estadística de los estudiantes. En este trabajo se presentarán las experiencias y los resultados de la implementación de la clase invertida en nuestro estudio.

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LIST OF ABBREVIATIONS

ASA	American Statistical Association.
COR	Correlation.
DB	Binomial Distribution.
ESMA 3015	Elementary Statistics.
ESMA 3101	Applied Statistics I.
ICM	Confidence Intervals for the Mean.
ICP	Confidence Intervals for the Proportion.
MTC	Measures of Central Tendency.
MV	Measures of Variability.
OIIP	Institutional Research and Planning Office.
PHM	Hypothesis Testing for the Mean.
PHP	Hypothesis Testing for a Proportion.
RL	Linear Regression.
TM	Sample Size.
UPRM	University of Puerto Rico in Mayagüez.

Chapter 1
INTRODUCTION

In daily life as well as in scientific articles, people including students, are faced with statistical results. How do they recognize if the information is presented adequately? How do they interpret it? For this, they need to have statistical literacy. But it is not just learning concepts; is to understand them correctly so that they can apply them to daily life. Since after taking statistics courses, several students remain with misconceptions, it has been proposed to redirect instruction so that students are active in reasoning and thinking in what is done rather than memorizing formulas and definitions. Shifting from a passive environment to a more active one, could boost the understanding and retention of what is learned by the students. With the intention of provoke students' conceptual understanding, many statistics instructors have redesigned their courses either by implementing technology or by modifying their teaching and assessment method (delMas et al., 2007).

Now, teaching with the traditional methodology it is becoming a challenge to get Millennial students interested, so that they can understand and learn appropriately to the age. For that reason, it could be investigated if building strong understanding could be achieved increasing the use of technology in the classroom in order to promote active learning. In other words, modify the way of teaching to investigate if students are able to achieve a deeper understanding of statistics and, possibly, improving their academic achievement.

In addition, in 2005, the American Statistical Association (ASA) (American Statistical Association, 2012), endorsed the Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report. In this report, they endorsed the following recommendations to produce statistically educated students:

- √ Teach statistical thinking.
- √ Focus on conceptual understanding.
- √ Integrate real data with a context and a purpose.
- √ Foster active learning.
- √ Use technology to explore concepts and analyze data.
- √ Use assessments to improve and evaluate student learning.

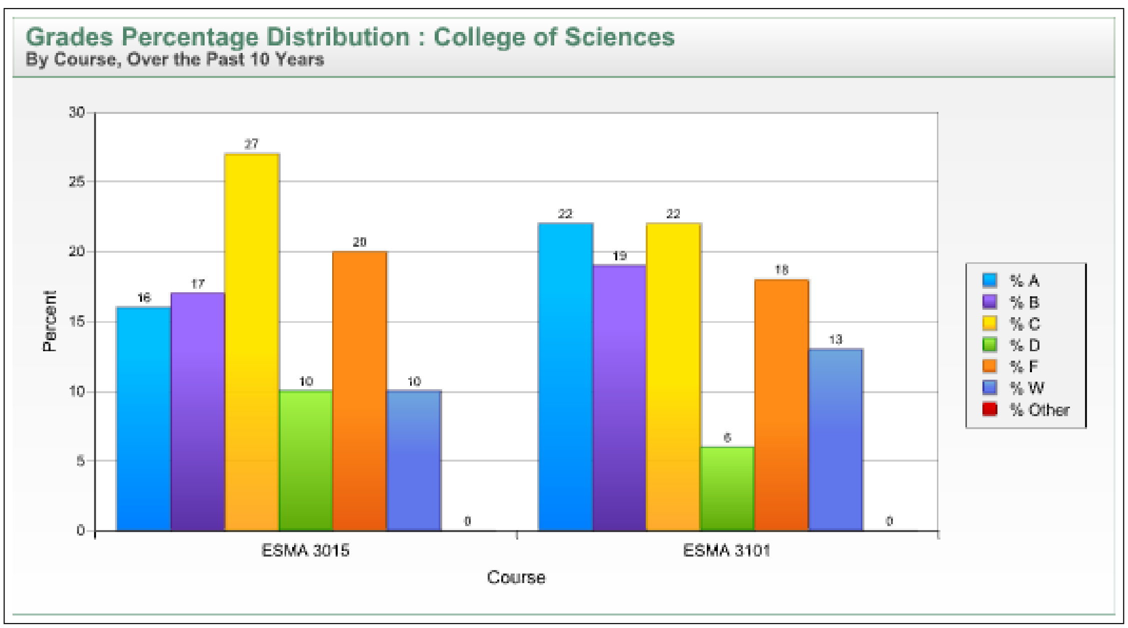
In a traditionally taught class, in which students have a passive learning, is difficult to provoke students' conceptual understanding, to use technology, and to implement the ASA recommendations. This is why, a different way of teaching statistics was sought, leading to the implementation of the flipped classroom.

The inverted class or flipped classroom is a recent teaching method in which what is traditionally taught during the in-class time, is covered outside the classroom, and the exercises and applications that were usually assigned to deepen understanding are now done in the classroom. Lectures are given outside the classroom whether assigning online or textbook readings or using technology such as presentations, screen-casts, or online or self-created videos. The lectures are assigned so that students watch them before arriving to the classroom. In-class time is devoted to the practical exercises or activities that previously were homework or projects. These activities are designed with the objective of improving students' deep understanding of the course topics.

The partially flipped classroom was implemented in introductory statistics courses of the University of Puerto Rico in Mayagüez (UPRM) to determine if it improves students' understanding and, possibly, their academic achievement. This project will focus on the ESMA 3015 (Elementary Statistics) and ESMA 3101 (Applied Statistics I) which are introductory statistics courses of the Department of Mathematical Sciences of the UPRM. The list of topics and the list of programs in the UPRM for which these courses are required or recommended is shown in Appendix A.

The grades percentage distribution of all the courses offered at the UPRM can be found in the Institutional Research and Planning Office (OIIP, for its acronym in Spanish). Specifically, the OIIP shows the grades percentage distribution for the last ten years. As seen in Figure 1, for the past ten years, the failure rate (F's and W's) in both courses is about 30% of students. About 20% of the students enrolled in the ESMA 3015 course earned an F grade, and 10% dropped out of the course. Similarly for ESMA 3101 students, where 18% scored an F grade and 13% dropped out. The grades exhibit a similar distribution in the last five years.

Figure 1–1: Grades distribution by course in the past 10 years.



Source: OIIP, UPRM (https://tinyurl.com/n5fhx3g)

The purpose of this research was to implement a partially flipped classroom methodology in some sessions of the ESMA 3015 and ESMA 3101 courses of the UPRM. Partially flipped classroom means that the methodology was implemented only in some topics of the class, not in all of them. The implementation was done during the academic years 2015-2016 and 2016-2017 to:

- Compare students' attitudes towards statistics before and after the course, whether partially flipped or with traditional instruction.
- Compare students' academic achievement in the partially flipped course with those in the traditional course.
- Evaluate the design of the video lectures.

Chapter 2
LITERATURE REVIEW

To improve students' performance and understanding, it has been proposed that teachers shift from passive teaching, in which the teacher is the center of the class, to active teaching in which the student becomes the center of the class (Roehl et al., 2013). Through active learning, the teacher not only instructs, but focuses on guiding the student through the learning process. The student not only becomes more participatory but ventures into critical thinking, increasing the chances of improving academic achievement. One way to achieve this, would be to implement activities that encourages student performance and reasoning; requiring the application of high-thinking skills from Bloom's taxonomy such as analysis, synthesis, and evaluation (Roehl et al., 2013).

One of the teaching methods that has been proposed for the development of deep and active learning is called the flipped classroom. The flipped classroom is a recent developed teaching method in which, in one of its versions, technology is used to change the direct instruction outside the classroom. There are several definitions or opinions about what should be a flipped classroom. Bishop and Verleger (2013) state that in a flipped classroom, the "events that are traditionally in the classroom now take place outside the classroom and vice versa". Similarly, Missildine et al. (2013) states that the flipped classroom uses "technology to move the classroom lecture to homework status and uses face-to-face classroom time for interactive learning".

How did the flipped classroom emerge? In 2006, Jon Bergmann and Aaron Sams, two chemistry teachers in Colorado noticed that a lot of their students missed school because of sports and activities. A year later, they started recording Power Point lectures using a screencasting software, and posted them online. In this way, the students that were absent could access the video lecture and learn the class material they had missed. But, not only the students that were absent were watching their video lectures. Some students who were in class began to watch them too when reviewing for exams. So, they recorded all their chemistry lectures and conducted the same laboratory experiments that they had always done, and ended up developing the flipped classroom methodology (Bergmann and Sams, 2012).

The inverted class model uses a wide variety of technologies, either during teaching or through the publication of lessons to be studied before class (Roehl et al., 2013). The use of technology could present difficulties for teachers who do not dominate it, but perhaps not so much for students. The millennial generation, being exposed to the technology from such an early age, is characterized by its easy access and mastery (Roehl et al., 2013). Technology is developed so quickly, that it is easier for students to have access to all kinds of information and, academic material is no an exception. Consequently, teachers and books are no longer the only source of such information. This technological environment could lead to both better teaching and improved learning outcomes (Roehl et al., 2013).

The inverted-class methodology allows the teacher to offer immediate help and guidance to students who show difficulty with a concept or activity. Due to an increase in student-teacher interaction, the teacher would now have a greater perception of the students' learning and understanding of information. In addition, the teacher could provide a more difficult task for those students who find it easy to complete an activity (Morgan, 2014). The inverted class provides the opportunity to strengthen both teacher-student, and between-students relationship making teachers more effective and reflective during teaching. (Dove and Dove, 2014).

During the in-class time of a flipped classroom, group work or activities involving the full participation of students are assigned. Activities could include questions about the videos, practice problems, collaborative activities, projects, or any other exercises that promotes a continued student participation. Small-group exercises, case studies, reviewing and critiquing published articles, and working through an entire data analysis process using statistical software are as well included in the individual-based activities. "Small-group activities are critically important pieces of the flipped course" since they promote discussion of the student' responses (Schwartz, 2014). During a group activity, a student might have a misconception about a concept that could be corrected by a peer, reducing the possibility of feeling intimidated about asking the teacher (Schwartz, 2014). "Using class time for active learning versus lecture provides opportunities for greater teacher-to-student mentoring, peer-to-peer collaboration and cross-disciplinary engagement" (Roehl et al., 2013). As has been noted, with this method of instruction, the instructor is no longer the center of the classroom and becomes a guide, while students shift from passive to active learners and become the center of the class.

Minimizing lecture time in class and having students spending the time doing hands-on activities could help them improve their understanding. Schwartz's (2014) students learned concepts "more deeply when there were multiple points of contact for learning". As an illustration, prior the class, students had to watch a video of the class material. During the class, they did an activity that involved active learning and ended with a homework related to the class material (Schwartz, 2014). Spending in-class time doing hands-on activities limits the time to lecture, therefore, the content had to be covered outside the classroom time, giving way to the flipped classroom methodology.

All teaching methods have their disadvantages. One of the disadvantages of the flipped classroom is that students do not necessarily study the lessons before arriving to the classroom. Some students mentioned that "it was easy to get distracted while listening to the video lecture" (Zappe et al., 2009). This could lead to an undesired dynamic within the classroom because students would not be familiar or prepared with the concepts needed to complete the in-class activities. Zappe (2009) used online quizzes to help ensure that the students watched the posted videos, and reviewed the video content at the beginning of the class to help the "transition to the in-class exercises".

Since this methodology presents a radical change in the way of teaching and, some students prefer to work by themselves in the activities, the adaptation process can be a bit complicated for both the teacher and the student. Speaking of the teacher, changing and editing traditional lessons so that they can be published could also be tedious and complicated, and can make a teacher with insufficient technology skills to give up in this methodology (Roehl et al., 2013). Like students, teachers should not give up on this methodology and should let the process of adaptation arise. A major benefit is that this methodology allows teachers and students to learn from each other. Teachers can learn both learning techniques and technological skills, whether sharing or asking for help to other teachers with their lessons or videos. Students could also benefit by observing lessons from different teachers being able to learn a topic from different points of view (Fulton, 2012). This methodology leads students to be more aware of their learning processes than students in the traditional environment (Roehl et al., 2013).

In the research held by Winquist (2014), it was noticed that "the flipped course led to better long term performance than lecture course". Since this methodology allows students to learn at their own pace and to do their homework in the classroom, students feel more confident and likely to ask questions at the precise moment they arise, and do not feel restrained as many other students that learn in traditional settings (Roehl et al., 2013). In the school case, this methodology alleviates the problem of some parents that are unable to help their children with homework (Morgan, 2014). Parents who do not remember or know the concepts to help their children with homework, can observe lessons and learn together with their children (Dove, 2013). It also helps to save money as schools, parents and students would not have to buy as many books to have a good education (Morgan, 2014).

Many teachers decide that videos are the best method for publishing lessons. These videos can be created by other instructors who teach the same course, the same instructor who teaches the course, or even by any expert on the subject. In order for students to have access to their own teachers' class material, instructors post videos or presentations with the lesson content on the Internet. The material is published with sufficient time for students to observe and absorb it before the in-class time. Posting video lessons has several advantages, but the most important benefit of using them, is that "students can rewind, pause, rewatch and skip to sections of the video that they need to specifically review" (Dove, 2013). Videos also allow the students to absorb the material anytime, from anywhere and, and at their own pace even if they have to miss class due to sickness, sporting event or other academic subject (Fulton, 2012).

Although students feel more comfortable when videos are made by their own teacher, "some find it helpful to watch a different teacher's video lesson" (Fulton, 2012). In this way, students could watch a lesson from a different angle providing the opportunity to develop the different modalities of intelligence (Gardner, 1995). By other hand, studies have revealed that students who sit in the front row of the classroom have better academic performance than those who sit in the back. With this flipped methodology, "students have a virtual front-row view of the material", whether video, presentation or reading, providing them the opportunity to improve their academic performance in the subject (Dove, 2013).

Using surveys, teachers have asked for students' opinion regarding the length and the effectiveness of the videos. It was found that, although some students preferred longer video recordings, videos of 10 to 15 minutes length "tended to provide better results" (Schwartz, 2014). Zappe's students also expressed that they preferred videos rather than reading the textbook, and videos of approximately 20 minutes in length (2009). This means that lessons that used to be of about one hour, should be synthesized in such a way that they can be presented in short videos.

Schwartz (2014) implemented this methodology with the help of a teaching assistant (TA) that helped 10 hours a week. The TA provided office hours, held computer labs, and attended classes to assist students while working in the activities (Schwartz, 2014). Roehl (2013) implemented the inverted class in "topics where lectures predominated at the time of instruction". Specifically, the Winquist's (2014) inverted course covered descriptive statistics such as: frequency distributions, central tendency measures, dispersion measures, and statistical assumptions; and inferential statistics such as: hypothesis testing, confidence intervals, ANOVA and correlation.

In most cases, students reflected their reaction to the flipped classroom methodology via comments or surveys. Students' feedback suggests that they felt pride in learning the material by their own and implementing it in active learning activities. Although students "would prefer that only about half the classes be flipped and some use of traditional lectures should be maintained", the active learning exercises and the available project time available in class improved their understanding of the explained concepts (Zappe et al., 2009). Otherwise, students' survey responses of a flipped undergraduate statistic course point out that they "preferred the flipped classroom approach in comparison to previous traditional methods used in their mathematics courses" (Dove, 2013). Furthermore, 95% of Dove's students expressed that they would like to take another flipped course, and that they would recommend it to their peers (Dove and Dove, 2014).

Chapter 3
METHODS AND MATERIALS

3.1 Fall 2015 Term

During the course of Fall 2015 term, an experiment with four sections of the ESMA 3015 course was performed. Two sections were taught by Professor 1 and another two, by Professor 2. Each professor taught one section using the traditional method and the other section using the partially flipped classroom. The methodologies were randomly assigned to each section. Both sections of Professor 1 were in the morning. The traditional section was two hours later than the partially flipped. Each class period of Professor 1 lasted 50 minutes and there were three periods per week. For Professor 2, the meetings of the partially flipped section were in the afternoon, while the traditional ones were in the morning. Each class period of Professor 2 lasted 1.25 hours and there were two periods per week. Each section had capacity for about 55 students and were taught in a classroom with computers. Students enrolled in the course didn't know that they could be part of an experiment at the enrollment time.

At the beginning of the semester students were informed about the flipped classroom methodology. That same day, they were given a consent form approved by the UPRM Committee for the Protection of Human Subjects in Research (CPSHI, for its acronym in Spanish) in which they decided whether researchers could use their grades and opinions as part of the experiment data. Once their consent was obtained, the data was collected anonymously using an identification code since the Family Educational Rights and Privacy Act (FERPA) protects the privacy of student education records. Academic freedom allow professors to use any teaching methodology, therefore, whether the student consented or not, he or she could be part of the partially flipped course (depending on the results of the methodology randomization). In the partially flipped section of Professor 1, 25 students consented to participate and, 39 consented in the traditional class. In the Professor 2 sections, 39 students consented in the partially flipped section while 50 consented in the traditional class.

Days after giving the consent form to the students, the researcher sent them via email the Attitudes Towards Statistics Survey (see Appendix B). That same survey was sent to them at the end of the semester in order to determine if their attitude towards statistics changed (positively or negatively) at the end of the course.

Throughout the semester, the following topics were flipped: central tendency measures (MTC), measures of variability (MV), binomial distribution (DB), correlation (COR) and linear regression (RL). In this approach, the statistical literacy concepts were discussed through videos. For each inverted topic, the researchers created videos of 5 to 15 minutes in length to explain the theoretical content. The original idea was to start each video presenting its objectives and to end with a summary but, after flipping the first two topics, at the end of the videos questions were added related to the discussed topic. Students had to hand in their answers to the questions which counted as extra points in the course, thus, giving an extra incentive to watch the video. To create the videos, a PowerPoint presentation was designed that was then saved in pdf format and the audio was added using the Explain Everything application. After having the video ready, it was uploaded to YouTube and published in the ecourses university platform.

Two days before a flipped topic, the video was published in the course platform and students were notified that the next class was going to be flipped. This way, students had enough time to watch and re-watch the videos before arriving to the classroom. At the beginning of the class, a brief summary of the material presented in the video was given. During in-class time, a teaching assistant attended classes to assist the professor and the students while working in the activities. Students worked with activities related to the topic presented in the videos. The activities were designed to cover the highest levels of Bloom's taxonomy and provided the possibility of teaching students not only the formulas, but the most useful and important concepts, interpretations and technology tools in statistics such as R ©, RStudio ©, Microsoft Excel ©, and Minitab ©. In this semester, only Microsoft Excel and Minitab were used. At the end of each activity, the solutions were published in the course platform.

After each activity, students were supposed to respond to a survey sent by the principal investigator via email to evaluate the video and the activity in their spare time. Because of the survey's length students only filled the survey after flipping the topics of measures of central tendency and measures of variability. The survey included items that asked about how many times they watched the video, its ideal duration and about its quality and its effectiveness. They also evaluated the flipped format by responding whether they preferred this format instead of the traditional one, whether they preferred working in groups and if they could learn at their own pace.

In both the control and experimental groups, students were evaluated with the same partial exams in order to compare their academic achievement using the same instrument. Because the materials used were not fully developed and the investigation group was still going through a learning process about the methodology, the research group was not able to continue working with Professor 2.

3.2 Spring 2016 Term

During the Spring 2016 term, the experiment was repeated with two sections of the ESMA 3015 course and two sections of the ESMA 3101 course. Both ESMA 3015 sections were taught by the same Professor 1 of the previous semester, and both sections of the ESMA 3101 course were taught by a new professor, Professor 3. Each professor taught one section using the traditional method and the other section using the partially flipped classroom. The methodologies were randomly assigned to each section. The ESMA 3015 sections meetings of Professor 1 were in the morning. The partially flipped section was one hour later than the traditional class. Each class period of the ESMA 3015 course lasted 50 minutes and there were three periods per week. For Professor 3, the meetings of the partially flipped section of ESMA 3101 were in the afternoon, while the traditional class was in the early morning. Each class period of the ESMA 3101 lasted 1.25 hours and there were two periods per week. Each section had capacity for about 30 students and were taught in a classroom with computers. Just like in the previous semester, students enrolled in the course didn't know that they could be part of an experiment at the enrollment time.

The procedure for informing the students and asking for their consent was the same as for the previous semester. In the partially flipped section of the ESMA 3015 course, 28 students signed the content as well as 30 students in the traditional class. For ESMA 3101, 28 and 24 students signed the consent in the partially flipped and in the traditional section, respectively.

Days after giving the consent form to the students, the professors sent via email the Attitudes Towards Statistics Survey. That same survey was sent at the end of the semester to determine if the attitude toward statistics changed (positively or negatively) after the course ended.

During this semester, the flipped classroom was implemented in the same topics from the previous semester. The videos used were the same as in the previous semester but with some changes or improvements gained from the experience in the previous semester. The content of the videos was improved in the areas that were identified as difficult for the students in the previous semester. Now, questions were also added at the end of all the videos, for extra points as a strategy to encourage the students to watch the videos.

Simultaneously, activities were edited and improved. Some became longer, others, shorter, and the instructions or procedures that students had to perform when using a statistical program (if any) were explained in detail. The way questions were asked was improved in the items in which the students in the previous semester presented greater difficulty. The statistical software used were RStudio and Microsoft Excel, but mainly RStudio.

After each activity, students answered a survey sent by the professors via email about the video they just watched. To avoid overwhelming students with long surveys, the survey was changed to include only two questions: how many times did they watch the video, and whether or not they took notes while watching it.

In both the control and experimental groups of ESMA 3015, students were evaluated with the same partial exams in order to compare their academic achievement using the same instrument. Also, in each section, the professors gave the same number of bonus points for their participation in the study, which included points for completing the corresponding surveys. The groups of the ESMA 3101 course worked in a similar way.

3.3 Fall 2016 Term

During the Fall 2016 term the experiment was only performed with 2 sections of ESMA 3015. Both sections were taught by the same Professor 1 from the previous semesters. The methodologies were randomly assigned to each section. The sections meetings were in the morning. The partially flipped section was one hour later than the traditional class. Each class period lasted 50 minutes and there were three class meetings per week. Each section had capacity for about 30 students and were taught in a classroom with computers. Just like the previous semesters, students enrolled in the course didn't know that they could be part of an experiment at the enrollment time.

The procedure for informing the students and asking them for their consent was the same as for the previous semesters. In the partially flipped section of the ESMA 3015 course, 28 students signed the consent while 29 students signed in the traditional class.

The same day the consent form was delivered, students completed the Attitudes Toward Statistics Survey in the classroom. That same survey was completed at the end of the semester in the classroom to determine if the attitude toward statistics changed (positively or negatively) after completing the course.

Unlike the previous semesters, the section of the experimental group was flipped in a block of consecutive topics at the end of the semester, and not only in certain sporadic topics during the semester as suggested by Donna McGregor, Pamela Mills and Gustavo López. They were the speakers of the talk "Flipping out in Chemistry" at the UPRM and provided a description of the course structure, reported on student outcomes and shared faculty stories about how the model has transformed their own thinking about teaching and learning at both Hunter and Lehman Colleges. The speakers mentioned that it takes some time for the students to become familiar with the methodology and to understand the importance of watching the videos. This way there was continuity in the methodology leading the students to have a better process of adaptation. The following topics were flipped: confidence intervals for the mean (ICM) and for the proportion (ICP), sample size (TM), hypothesis testing for the mean (PHM) and for the proportion (PHP), correlation (COR), and linear regression (RL).

Since there were topics that had not been flipped before, new videos were created applying all that had been learned from the previous semesters. For the correlation and linear regression topics, the videos of the previous semester were used. As in previous semesters, the videos started showing the objectives, then an example problem related to the topic and, as the solution was presented, the theory and formulas or RStudio output required was explained. All videos ended with a summary and questions that students had to answer and hand in in the next class.

Like the videos, activities for the new topics were also developed. As an opening exercise, the statistical analysis presented in the video was done. In this way, students practiced how to load up data to RStudio and to obtain the output shown in the video. For confidence intervals, only one video was created on confidence intervals for the mean of a population. One activity was done for confidence intervals for the mean and, another activity for confidence intervals for the proportion. Similarly, was done for the topic of hypothesis testing. The statistical software used was RStudio, especially the R Commander library. This library provides graphical user interface (GUI) that makes it easier the use of R to the students.

Prior to each activity, students answered in the classroom a survey about the video they just watched. This was the same survey used in the previous semester that only had two questions: how many times did they watch the video, and whether or not they took notes while watching it. Some activities lasted a day and a half, or two days. After all students completed it, the professor took time to discuss the activity.

As part of the course evaluation, in both sections of ESMA 3015, weekly quizzes were given on the topics that were taught the previous week. In both the control and experimental groups of ESMA 3015, students were evaluated with the same quizzes and partial exams in order to compare their academic achievement using the same instrument. In addition, in each section, the professor gave the same number of bonus points for their participation in the study which included points for completing the corresponding surveys.

3.4 Term Comparison

The design of the experiment per semester is shown in Table 3–1. During the first two terms, the experiment was done in four sections of statistics courses but, in Fall 2015, Professor 2 withdrew from the experiment. Professor 1 participated by teaching ESMA 3015 during the three semesters of the study. The number of participants per section varies between 24 and 50 students.

Table 3–1: Experiment design and participants per course section

Term	**Control (Traditional Method)**	n_C	**Experimental (Partially Flipped)**	n_E
Fall 2015	ESMA 3015 (Professor 1)	50	ESMA 3015 (Professor 1)	39
	ESMA 3015 (Professor 2*)	39	ESMA 3015 (Professor 2*)	25
Spring 2016	ESMA 3015 (Professor 1)	30	ESMA 3015 (Professor 1)	28
	ESMA 3101 (Professor 3)	24	ESMA 3101 (Professor 3)	28
Fall 2016	ESMA 3015 (Professor 1)	29	ESMA 3015 (Professor 1)	28

*Professor 2 withdrew from the experiment at mid-semester.

The list topics taught using the partially flipped classroom is shown in Table 3–2 by semester. Besides, the table shows the number of videos and surveys given per semester. During the first two semesters, the flip was made in non consecutive topics while in Fall 2016 was made in a block of consecutive topics at the end of the semester. During the Spring 2016, the topics were the same as in the Fall 2015, except for confidence intervals. Throughout the Fall 2016, videos were created for the new topics applying what was learned in the previous semester. Although there were two topics with no videos, all topics had in-class activities.

Table 3–2: List of flipped topics through the different terms

Term	**Topics**	**Video Created**		**Video Survey**	
		Yes	**No**	**Yes**	**No**
Fall 2015	Measures of Central Tendency (MTC)	x		x	
	Measures of Variability (MV)	x		x	
	Binomial Distribution (DB)	x			x
	Correlation (COR)	x			x
	Linear regression (RL)	x			x
Spring 2016	Measures of Central Tendency (MTC)	x		x	
	Measures of Variability (MV)	x		x	
	Binomial Distribution (DB)	x		x	
	Correlation (COR)	x		x	
	Linear Regression (RL)	x		x	
Fall 2016	Confidence Intervals for the Mean (ICM)	x		x	
	Confidence Intervals for Proportions (ICP)		x		x
	Sample Size (TM)	x		x	
	Hypothesis Testing for One Mean (PHM)	x		x	
	Hypothesis Testing for One Proportion (PHP)		x		x
	Correlation (COR)	x		x	
	Linear Regression (RL)	x		x	

3.5 Materials

The links of the videos used for the flipped topics in the Fall 2016 term are the following:

- Confidence intervals: https://youtu.be/6_Zxgc2bCg4
- Hypothesis Testing: https://youtu.be/gsFwecDCxGw
- Sample size: https://youtu.be/g3jVN6GZt1o
- Correlation: https://youtu.be/ctNnvpqD7-U
- Linear regression: https://youtu.be/UgR7sDKW06k

The activity for Confidence Intervals for the mean is included in Appendix D.

Chapter 4
RESULTS

Throughout this section, results will be presented regarding the students' attitudes toward statistics, the videos used for lecturing, the activities, and the students' academic achievement. Table 4–1 shows the semesters for which data was obtained on each one of this categories. Regarding students' attitudes towards statistics, only the results of Fall 2016 term will be presented, since in Fall 2015 and Spring 2016 the students answered the surveys in their spare time, and there was a lot of missing data. For videos and activities, results for the three terms will be presented, and with respect to students' academic achievement, results will only be presented for Fall 2016 since this data was not collected for the previous semesters.

Table 4–1: Results presented per term

	Term		
	Fall 2015	Spring 2016	Fall 2016
Survey of Attitudes Towards Statistics			x
Videos	x	x	x
Activities	x	x	x
Students' Academic Achievement			x

4.1 Students' Attitudes Towards Statistics

At the beginning and at the end of the Fall 2016 term, students were asked to fill out the Attitudes Towards Statistics Survey (see Appendix B) about their agreement on a five-point Likert scale regarding their attitude towards statistics. This survey has 25 items that can be categorized in five dimensions: utility, anxiety, confidence, pleasantness, and motivation.

The utility dimension refers to how much a person values statistics and includes the items 1, 6, 11, 20, and 21. The anxiety dimension refers to the feeling of anxiety that the person manifests when facing statistics and includes the items 2, 7, 12, 17, and 22. The confidence dimension demonstrates the self-confidence and security of the person when practicing with statistics and includes the items 3, 8, 13, 18, and 23. The pleasantness dimension refers to the aspect of pleasure or enjoyment provoked by statistical work and includes the items 4, 9, 14, 19, and 24. Finally, the motivation dimension is interpreted as the motivation that the student feels towards the study of statistics and includes the items 5, 10, 15, 16, and 25.

The mean and sum of the scores in each dimension at the beginning (pre) and at the end of the semester (post) are shown in Table 4–2, classified by the partially flipped and the traditional methodology. Items of the anxiety and motivation dimensions are redacted in a negative sense. Since not all the items are written in the same sense, they have all been codified so that a higher score is associated with a more positive attitude. For example, in these two dimensions, a 5 means that they were in completely disagreement with the negative statement towards statistics. Hence, the higher the mean, more positive their attitude. On the other hand, a negative difference (Post-Pre) means that, in that dimension, there was a negative change in students' attitudes towards statistics. Only two dimensions changed positively: anxiety and pleasantness in the traditional setting. It is worth noticing that, although pleasantness scores are low, utility scores are higher. Thus, students seemed to perceive the utility of statistics.

To test if the differences were statistically significant, for each survey dimension, a 2×2 mixed ANOVA was carried out to compare students' attitudes towards statistics before and after completing the course and, students' attitudes between the traditional and the partially flipped methodology. The 2×2 mixed design consists of one within-subject variable (time), with two levels (pre and post survey), and one between-subject variable (methodology), with two levels (partially flipped and traditional). In order for the ANOVA results of this design to be valid, for each dimension, it was verified that: the observations were independent, the distribution of the residuals were normal, and, the populations had equal variance (homogeneity of variance). The ANOVA statistics results in Table 4–2 show that, in each survey dimension, the time × methodology interaction effects and both main effects time and methodology were not statistically significant. In fact, anxiety and pleasantness were the only dimensions that increased from pre to post semester and, those increments only happened in the traditional section but, as previously stated, were not statistically significant.

Table 4–2: Summary statistics and 2×2 mixed ANOVA results for the attitude towards statistics survey, Fall 2016

Survey Dimension	**Time of Survey**	**Partially Flipped**		**Traditional**		**ANOVA Statistics**		
		Sum	**Mean**	**Sum**	**Mean**	**Factor**	**t-value**	**p-value**
Utility	Pre	18.72	3.74	18.82	3.76	Time	0.176371	0.8605
	Post	17.46	3.49	17.75	3.55	Method	1.309981	0.2021
	Difference	**-1.26**	**-0.25**	**-1.07**	**-0.21**	Interaction	0.084696	0.9332
Anxiety	Pre	16.12	3.22	15.46	3.09	Time	0.000948	0.9992
	Post	15.73	3.15	16.21	3.24	Method	0.530004	0.6008
	Difference	**-0.39**	–0.07	**0.75**	**0.15**	Interaction	0.868763	0.3932
Confidence	Pre	17.20	3.44	17.00	3.40	Time	-1.062410	0.2915
	Post	16.88	3.38	16.33	3.27	Method	0.625171	0.5375
	Difference	**-0.32**	**-0.06**	**-0.67**	**-0.13**	Interaction	0.742722	0.4646
Pleasantness	Pre	13.36	2.67	13.46	2.69	Time	0.187651	0.8517
	Post	13.31	2.66	13.62	2.73	Method	-0.487697	0.6300
	Difference	**-0.05**	**-0.01**	**0.16**	**0.04**	Interaction	0.074672	0.9411
Motivation	Pre	16.96	3.39	17.00	3.40	Time	0.445108	0.6575
	Post	15.65	3.13	16.38	3.27	Method	1.314534	0.2006
	Difference	**-1.31**	**-0.26**	**-0.62**	**-0.13**	Interaction	-0.281984	0.7803
All dimensions	Pre	82.36	3.29	81.75	3.27	Time	-0.097868	0.9223
	Post	79.04	3.16	80.29	3.21	Method	0.940895	0.3558
	Difference	**-3.32**	**-0.13**	**-1.46**	**-0.06**	Interaction	-0.037528	0.9704

Partially Flipped Pre (n=25), Partially Flipped Post (n=26), Traditional Pre (n=28), Traditional Post (n=24).

Although there was no statistically significant change in students' attitudes towards statistics, most of them showed great interest and positivity towards the flipped methodology. When asked if they would take another partially flipped class, 75% of them answered yes. Several students commented about the change in the course dynamics by saying the following (with some orthographic corrections): "*El método de flip classroom me pareció una buena experiencia ya que fomenta el trabajo en grupo y sale de la rutina de ser una clase de sentarse a escuchar a una más dinámica*". Other students commented positively on the flipped methodology: "*Considero que este método, al menos en mi caso, resultó ser uno muy eficaz. Logré comprender mejor que si hubiese sido el método monótono de dar clase. Los videos y el que haya sido la misma profesora la que explica mediante ejemplos, me dio la flexibilidad de poder verlos la cantidad de veces que fuese necesario para comprender el tema dado*" while others said that: "*En una clase que no es mi dominio, es tedioso*". Overall, the comments were very positive.

4.2 Video Survey

Table 4–3 shows results on how many times the student self-reported watching the videos. The alternatives were never, once, twice and more than twice. Also in the table, results on whether or not they took notes while watching the videos. The results are shown per activity. As mentioned before, in the Fall 2015 semester only two video surveys were given. Students completed surveys for the measures of central tendency (MTC) and measures of variability (MV) videos. The 97.7% and 89.7% of the participating students watched the videos of MTC and MV, respectively. However, about half of the students took notes in both videos. The following results were also obtained from this survey:

- About 83% of the students reported that the videos had a good quality and accessibility.

- Around 76% considered that the videos should last between 7 and 15 minutes.
- Approximately 60% of the students felt prepared to complete the activity after watching the video.
- Between 69% and 77% of the students reported that it should be continued to use video lectures.
- More than 78% said that they should be reviewed before starting the activity.
- Approximately 74% of the students reported that they would take another partially flipped course.

Focusing on the Spring 2016 term, 100% of students self-reported watching the videos in the ESMA 3015 course. For the ESMA 3101 course, about 95% of the students watched the videos, with the topics of correlation (COR) and linear regression (RL) being the videos with the highest percentage that were not seen by the students. In this semester, both the COR and RL were carried out on the last day of the term. This may indicate that, the last day of school, is not a good day to do a flipped topic. More students decided to take notes while watching the videos, around 53% and 71% in ESMA 3015, and around 40% and 71% in ESMA 3101, compared to the previous semester (about 43% and 54%).

On the other hand, in the Fall 2016 term there were seven activities but five videos, that is, seven topics were taught using the flipped format but five videos were created. For the activities on confidence intervals for the proportion and hypothesis test for the proportion, the videos that were created for the mean were used, since the videos explained the concepts needed to perform the activities for the proportion. Note that about 98% of the students watched all the videos and about 70% of the students took notes. This increase of students that self-reported watching the videos and taking notes could be due to the continuity of the topics that were inverted or because students realized that lecture was not going to be done in the

Table 4–3: Percentage of students that watched or took notes in each video

Semester	Course	Activity	Q1: How many times did you watch the video?				Q2: Did you take notes?		n
			Never	Once	Twice	More than twice	Yes	No	
Fall 2015	**ESMA 3015**	**MTC**	2.3	53.5	34.9	9.3	42.9	57.1	43, 42*
		MV	10.3	34.5	41.1	13.8	53.8	46.2	29, 26*
Spring 2016	**ESMA 3015**	**MTC**	0.0	40.0	45.0	15.0	65.0	35.0	20
		MV	0.0	50.0	37.5	12.5	70.8	29.2	24
		DB	0.0	57.9	15.8	26.3	52.6	47.4	19
		COR	NA	NA	NA	NA	NA	NA	NA
		RL	NA	NA	NA	NA	NA	NA	NA
	ESMA 3101	**MTC**	0.0	69.6	26.1	4.4	39.1	60.9	23
		MV	0.0	23.5	58.8	17.7	64.7	35.3	17
		DB	4.0	40.0	28.0	28.0	70.8	29.2	25, 24*
		COR	11.8	58.8	29.4	0.0	53.3	46.7	17, 15*
		RL	11.8	58.8	17.7	11.8	53.3	46.7	17, 15*
Fall 2016	**ESMA 3015**	**ICM**	0.0	46.2	34.6	19.2	61.5	38.5	26
		ICP	NS	NS	NS	NS	NS	NS	NS
		TM	0.0	37.0	44.4	18.5	74.1	25.9	27
		PHM	4.0	44.0	44.0	8.0	79.2	20.8	25, 24*
		PHP	NS	NS	NS	NS	NS	NS	NS
		COR	4.2	58.3	20.8	16.7	65.2	34.8	24, 23*
		RL	0.0	51.9	40.7	7.4	70.4	29.6	27

*Students who answered Never in Q1 are discarded; NA: Data no available; NS: No survey was administered. For the activities abbreviations, see the list of abbreviations on page ix

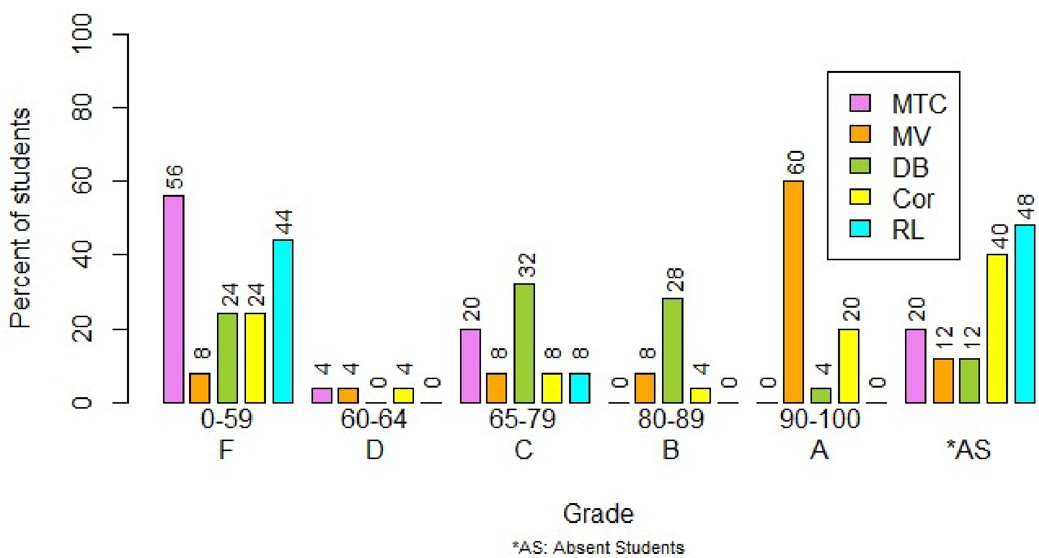
classroom. Therefore, to keep up with the class material, they had to watch the videos and take notes as if the professor was lecturing. Observing this result, it could be recommended to flip a block of consecutive topics rather than spread topics in the semester. In general it can be observed that, in all semesters, there are more students who watch the videos only once and fewer students who never watch them. Additionally, the majority of the students took notes while watching videos.

4.3 Activities

Although the activities were not part of the students' assessment in the ESMA 3015 and ESMA 3101 courses they were graded to determine their performance and the most challenging questions in each of them. Each activity question was graded as correct or incorrect, i.e., there were no partial points. The statistical skills that are assessed in each activity are described in Appendix C.

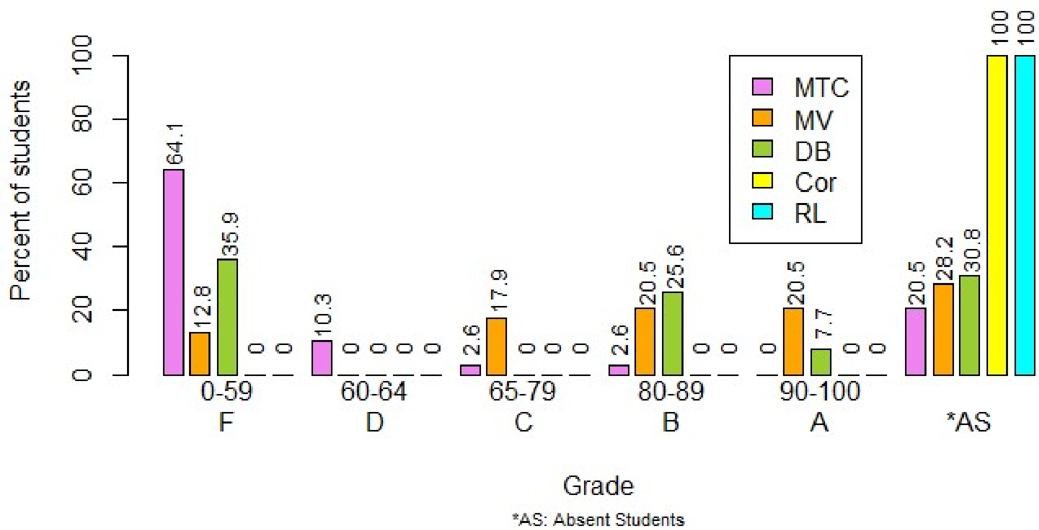
During Fall 2015, as seen in Figure 4–1, the activity in which students of Professor 1 performed better, was in the measures of variability (MV), in which 60% scored between 90% and 100%. In this activity, two data sets were provided and they had to verify which one had greater variability using the range, the variance, the standard deviation, and the coefficient of variation. In addition, they had to observe several histograms and order them from greater to less variability using the amplitude and the variance measures.

Figure 4–1: Scores distribution per activity, ESMA 3015, Fall 2015, Professor 1



The opposite occurred in the activity of measures of central tendency (MTC), where 56% of the students scored between 0% y 59%. Most of them failed interpreting the mean (80%) and the median (70%) of a data set, and establishing the relationship between these measures as the shape of the distribution changes (80%). In the activities of correlation (COR) and linear regression (RL) there was a lot of absenteeism, with 40% and 48% of the students, respectively. These topics were taught in the last days of the semester. In addition, in RL 44% of the students scored between 0% y 59%, failing to interpret the slope and the intercept of a linear model (about 92% and 84%, respectively). In the binomial distribution activity (DB), 32% of the students scored between 80% and 100%. In this activity, they had to verify the assumptions of the binomial experiment, calculate or estimate probabilities, and describe the change of the distribution shape as the probability of success changes.

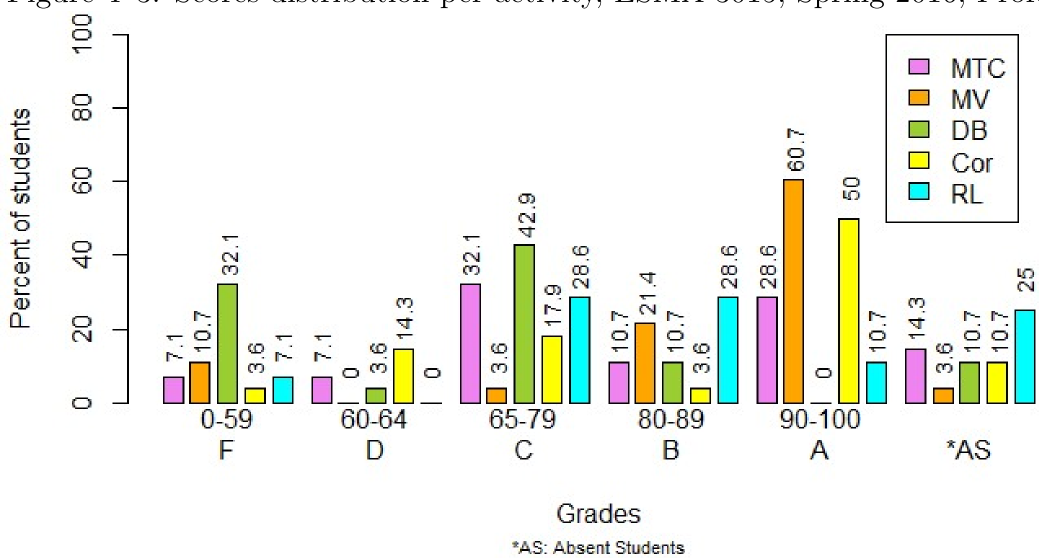
Figure 4–2: Scores distribution per activity, ESMA 3015, Fall 2015, Professor 2



Professor 2, only did three activities: MTC, MV, and DB. Figure 4–2 shows that, in a similar way as Professor 1, 64% of the students scored between 0% and 59% in the activity of MTC. About 93% and 80% of the students failed interpreting the mean and the median of a data set, respectively. However, in the MV activity, students didn't performed as well as Professor 1 students. 20.6% of the students scored between 90% and 100%. In the DB activity, around 33% of the students scored between 80% and 100%.

For Spring 2016, since all activities were revised and improved, there was a great improvement in student scores in both courses. For ESMA 3015 (see Figure 4–3), the activity with poorest student's performance was DB, with about 30% scoring between 0% and 59%. No student scored between 90% and 100%; approximately 43% scored between 65% and 79%. Like the previous semester, the best activity for students, in terms of scores, was MV, then COR. Around 60% and 50% of the students scored between 90% and 100%. In the RL activity, in comparison with the previous semester, students obtained better scores, but there was also a lot of absenteeism (25%). In the MTC activity, the item in which students had to establish the relationship between the mean and the median as the distribution shape changed was redesigned. Now, they had to estimate the median, and then indicate if the mean was less, equal or greater. There was some improvement, but students still failed to interpret the mean and median of a data set. Overall, most students scored between 65% and 100% in all activities, except in DB.

Figure 4–3: Scores distribution per activity, ESMA 3015, Spring 2016, Professor 1



Students in ESMA 3101, as seen in Figure 4–4, scored better than students in ESMA 3015 in the DB activity, where 81.4% scored between 65% and 100%. As in previous semesters, the best activity for students was MV, where 63% scored between 90% and 100%. However, there was much more absenteeism in COR and RL activities compared to ESMA 3015 with around 33% and 37% of the students, respectively. In this course, these subjects are also taught in the last days of the semester.

Finally, in Fall 2016 (see Figure 4–5), in the linear regression activity (RL), 67.9% of the students scored between 0% and 59%. In this activity, the vast majority of students failed interpreting the slope and the intercept of the regression equation using confidence intervals, making interval estimates, and extrapolating. It should be noted that, in the topics of correlation (COR) and linear regression, the videos and activities from the previous semester were used, which were not adapted to the use of R Commander. The correlation activity did not involve the use of RStudio, however, the linear regression activity did. For this last one, additional instructions were written explaining the necessary process to complete the activity using R Commander.

In Figure 4–6, it can be seen that, in comparison with confidence intervals for the mean (ICM), students obtained better scores in confidence intervals for the proportion (ICP) which followed the activity of confidence intervals for the mean. The same thing happened with the topics of hypothesis testing (PHM and PHP). This might have happened because the main concepts and interpretation were covered in the first activity and students had already practiced and digested most of the theory

Figure 4–4: Scores distribution per activity, ESMA 3101, Spring 2016, Professor 3

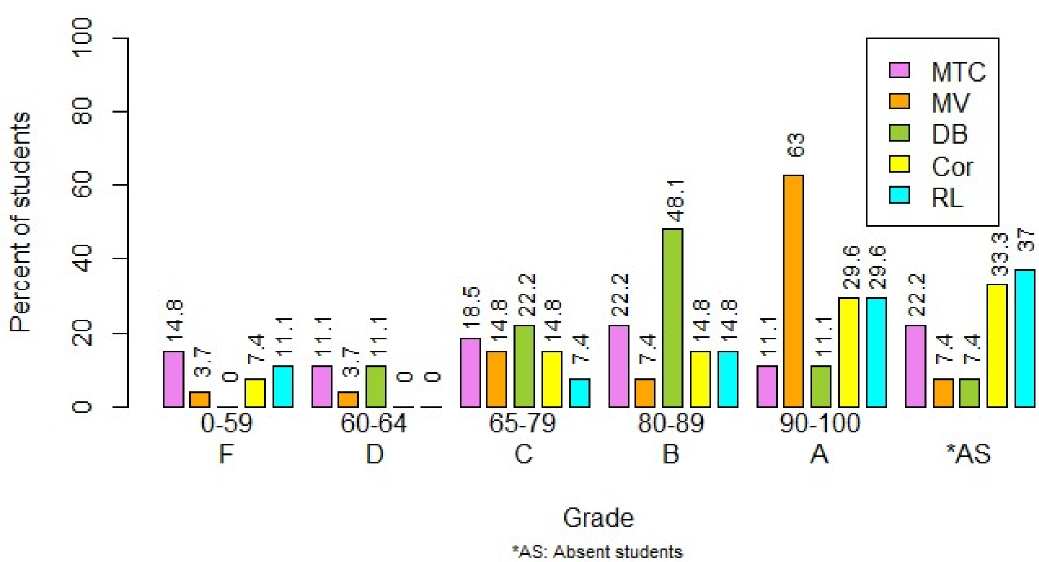
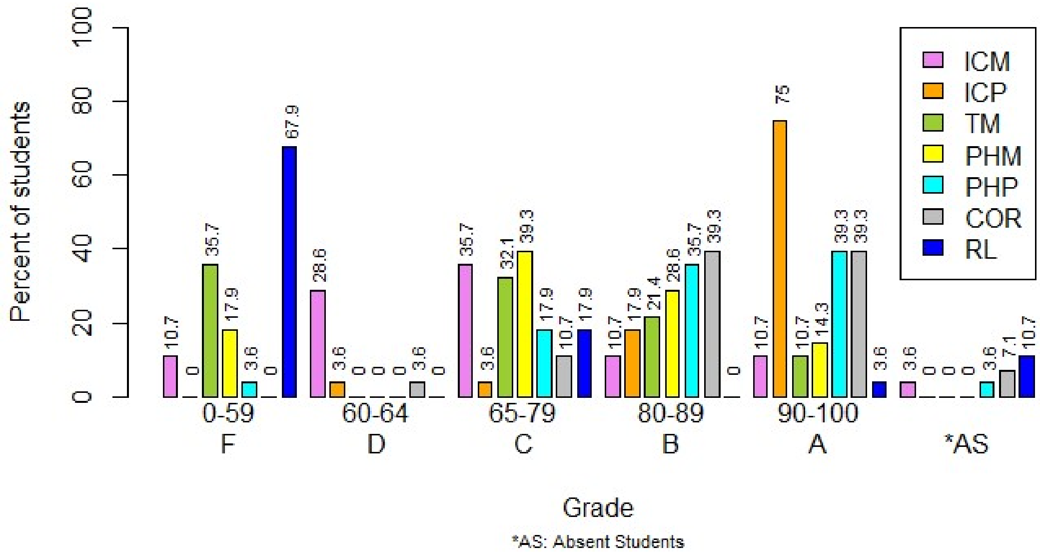
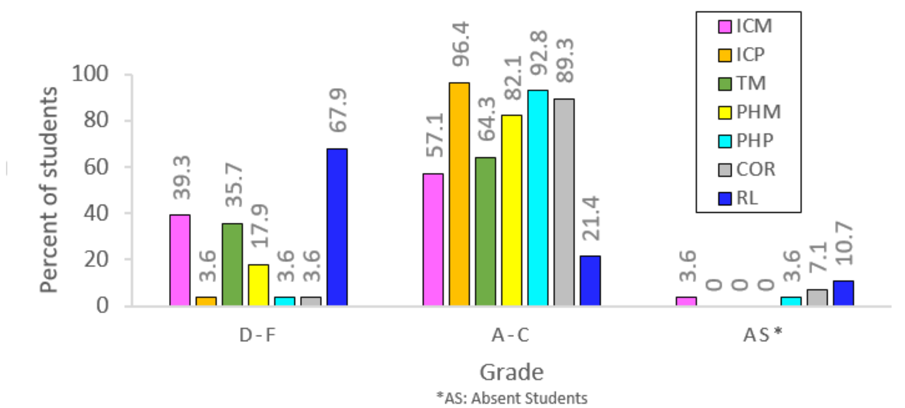


Figure 4–5: Scores distribution per activity, ESMA 3015, Fall 2016, Professor 1



needed to perform such activities. In these activities, students discovered that the differences were the type of variable, the assumptions and the menu in RStudio.

Figure 4–6: Scores distribution per activity grouped by A-C and D-F, ESMA 3015, Fall 2016, Professor 1



In the correlation activity almost no doubts emerged from the students, perhaps because it was the most visual of all. In this, students visually estimated the correlation coefficient in several graphs and, about 90% of the students scored between 65% and 100% (A-C).

4.4 Students' Academic Achievement

During the Fall 2016 term, several data was collected regarding student scores. Students' final grade of the course was obtained as well as the score obtained in the items of the flipped topics in the exams and the score of quizzes of the flipped topics. The topic of confidence intervals was evaluated in exam 3, in the final exam and in a quiz. Sample size and hypothesis testing topics were evaluated in the final exam and in quizzes (one quiz for sample size and another for hypothesis testing). Finally, the correlation and linear regression topics were only evaluated in the final exam.

For the topics of confidence intervals, there was a possible maximum score of 27 points on exam 3 and, 14 points on the final exam. For the topics of sample size, hypothesis testing, correlation and linear regression there was a total of 10, 29, 2 and 9 points, respectively in the final exam. Since quizzes were online, they were automatically corrected based on 100 points.

Table 4–4 shows the average of the scores obtained by the students in the assessments (Topics in Exam 3, Topics in Final Exam and Topics in Quizzes); by topic (IC, TM, PH, COR, RL) and in the final grade, in both methodologies. For Topics in Quizzes* and RL*, t-tests were done to determine if there was a statistically significant difference in student percentages between methodology. For the others, a Wilcoxon Rank Sum Tests was made with the same purpose. Although statistically significant differences between the traditional and partially flipped methodology were not found, mean scores tend to be higher in the flipped classroom than those in the traditional one.

Table 4–4: Average of students' scores, Fall 2016

Students scores in	**Partially Flipped**	**Traditional**	***p-value***
Final Grade	80.42	81.03	0.64
Topics in Exam 3	69.01	66.28	0.7621
Topics in Final Exam	77.12	72.83	0.9789
Topics in Quizzes*	51.79	57.35	0.2502
IC	71.02	66.81	0.8518
TM	67.78	73.93	0.0776
PH	67.16	62.75	0.499
COR	90.74	84.62	0.3103
RL*	59.67	58.75	0.881

*A Welch Two Sample t-test was conducted.

Chapter 5
CONCLUSIONS AND DISCUSSION

5.1 Conclusions

A lot was learned during the partially flipped experiment in the ESMA 3015 and ESMA 3101 courses of the University of Puerto Rico in Mayagüez. It was found that, although there was not statistically significant difference in the participants' attitudes towards statistics between the partially flipped classroom and the traditional method, the students embraced the partially flipped methodology with enthusiasm and seemed to perceive the utility of statistics.

Although statistically significant differences were not found between the traditional and partially flipped methodology in the various types of performance assessments that were used, mean assessment scores tend to be higher in the flipped classroom than those in the traditional one.

In this study, most students reported watching the videos, over time more of them took notes while watching the video, and felt prepared to complete the in-class activities. Around 76% of the students considered that the video lectures should last between 7 and 15 minutes, and that the video should be briefly discussed before starting the in-class activity. Finally, most of them (74%) reported that they would take another partially flipped course during their undergraduate studies.

If a partially flipped classroom will be implemented, it is recommended that the topics selected are in a block of consecutive topics to allow students to get used to the method and connect ideas across activities.

5.2 What was Learned about the Flipped Classroom?

The implementation of the flipped classroom is not as easy as it seems. Just as it takes time for students to adapt, it also takes time for teachers to redesign their courses. The flipped classroom is not just about recording video lectures and letting students learn on their own. The flipped classroom is much more than that, with the potential to redefine what is taught and how it is taught. It takes a lot of time and thought to decide what to teach in the videos, and how the video content is going to be used to work in the in-class activity. The following are some of the most important learnings.

5.2.1 Videos

- Video lectures should be carefully designed with main learning objectives in mind.
- Detailed scripts must be written before recording the videos.
- Their length should be between 7 and 15 minutes.
- Statistical content should be kept at low cognitive levels of Bloom's Taxonomy.
- Video content should be focused on concepts rather than formulas.
- Questions should be included at the end of the videos to encourage students to watch the videos.
- Videos should be made available to the students at least two days before the in-class activity.
- Animated videos created using software such as GoAnimate may be preferable over voice recording videos created with software such as Explain Everything or Power Point.

5.2.2 In-class activities

- Activities should be designed following the ASA guidelines contained in the GAISE Report.
- Activities should be carefully designed with main learning objectives in mind.
- The tasks in the activities should be ordered from low-level to high-level difficulty.
- Videos should be briefly discussed before starting the activity.
- Reproducing statistical outputs shown in the videos should be included as part of the activity as a tool to introduce the use of statistical software.
- Activities should allow time to have good in-class group discussions.
- Statistical content must be focused on higher levels of Bloom's Taxonomy.
- The focus should be on concepts rather than formulas.

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APPENDICES

Appendix A
ESMA 3015 AND ESMA 3101: PROGRAMS AND LIST OF TOPICS

Table A–1: List of programs where ESMA 3015 and ESMA 3101 are required or recommended, and the list of topics covered in these courses

Course	**ESMA 3015**	**ESMA 3101**
Required for bachelors in:	Hispanic Studies Nursing Physical Education* Political Sciences* Social Sciences Sociology	Agribusiness Agricultural Economics Economics Industrial Microbiology Physical Education* Political Sciences* Pre-Medical Studies Psychology
Recommended for bachelors in:	Comparative Literature* English French Language and Literature* History* Plastic Arts* Theory of Art*	Biology Comparative Literature* French Language and Literature* History* Plastic Arts* Theory of Art*
Topics	Nature and Meaning of Statistics, Elements of Probability, Normal Distribution, Binomial Distribution, Organization of Data, Measures of Location Measures of Variability, Statistical Inference, Simple Regression, Correlation, Statistical Analysis through Computers.	Methods of Applied Statistics, Descriptive Statistics, Probability, Random Variables, Probability Distributions, Statistical Analysis through Computers.

*Students can choose between ESMA 3015 or ESMA 3101.

Appendix B
SURVEY OF ATTITUDES TOWARDS STATISTICS

INSTRUCCIONES

En la siguiente sección hay una serie de afirmaciones. Éstas han sido elaboradas de forma que te permitan indicar hasta qué punto estás de acuerdo o en desacuerdo con las ideas ahí expresadas. Seleccione uno de los cinco números según tu grado de acuerdo o de desacuerdo con la afirmación correspondiente.

1 Totalmente en desacuerdo (TD)

2 En desacuerdo (D)

3 Neutral, ni en acuerdo ni en desacuerdo (N)

4 De acuerdo (A)

5 Totalmente en acuerdo (TA)

		TD	D	N	A	TA
1.	Considero la estadística como una materia muy necesaria en la carrera.	1	2	3	4	5
2.	La asignatura de estadística se me da bastante mal.	1	2	3	4	5
3.	El estudiar o trabajar con la estadística no me asusta en absoluto.	1	2	3	4	5
4.	El utilizar la estadística es una diversión para mí.	1	2	3	4	5

5.	La estadística es demasiado teórica como para ser de utilidad práctica para el profesional medio.	1	2	3	4	5
6.	Quiero llegar a tener un conocimiento más profundo de la estadística.	1	2	3	4	5
7.	La estadística es una de las asignaturas que más temo.	1	2	3	4	5
8.	Tengo confianza en mí mismo/a cuando me enfrento a un problema de estadística.	1	2	3	4	5
9.	Me divierte hablar con otros de estadística.	1	2	3	4	5
10.	La estadística puede ser útil para el que se dedique a la investigación pero no para el profesional medio.	1	2	3	4	5
11.	Saber utilizar la estadística incrementaría mis posibilidades de trabajo.	1	2	3	4	5
12.	Cuando me enfrento a un problema de estadística me siento incapaz de pensar con claridad.	1	2	3	4	5
13.	Estoy calmado/a y tranquilo/a cuando me enfrento a un problema de estadística.	1	2	3	4	5
14.	La estadística es agradable y estimulante para mí.	1	2	3	4	5
15.	Espero tener que utilizar poco la estadística en mi vida profesional.	1	2	3	4	5
16.	Para el desarrollo profesional de nuestra carrera considero que existen otras asignaturas más importantes que la estadística.	1	2	3	4	5
17.	Trabajar con la estadística hace que me sienta muy nervioso/a.	1	2	3	4	5

18.	No me altero cuando tengo que trabajar en problemas de estadística.	1	2	3	4	5
19.	Me gustaría tener una ocupación en la cual tuviera que resolver problemas de estadística.	1	2	3	4	5
20.	Me provoca una gran satisfacción el llegar a resolver problemas de estadística.	1	2	3	4	5
21.	Para el desarrollo profesional de mu carrera una de las asignaturas más importantes que ha de estudiarse es la estadística.	1	2	3	4	5
22.	La estadística hace que me sienta incómodo/a y nervioso/a.	1	2	3	4	5
23.	Si me lo propusiera creo que llegaría a dominar bien la estadística.	1	2	3	4	5
24.	Si tuviera oportunidad me inscribiría en más cursos de estadística de los que son obligatorios.	1	2	3	4	5
25.	La materia que se imparte en las clases de estadística es muy poco interesante.	1	2	3	4	5

Appendix C
STATISTICAL SKILLS ASSESSED IN EACH ACTIVITY

The following is a list of the statistical skills assessed in each activity. The skills that have the *, †, and ‡ symbols are assessed in the Fall 2015, Spring 2016 and, Fall 2016 terms, respectively.

Measures of Central Tendency (MTC)

- Calculate the mean and the median of a data set.*
- Interpret the mean of a data set.*
- Interpret the median of a data set.*
- Estimate the mean of several distributions.*
- Estimate the median of several distributions.*†
- Observing several distributions, indicate whether the mean is greater, equal or less than the median.†
- Establish the relationship between the mean and the median as the shape of the distribution changes.*†
- Determine the best measure to analyze a data set.*
- Indicate how the outliers can affect the different measures.*†
- Calculate the mean using RStudio†

Measures of Variability (MV)

- Calculate the measures of variability (amplitude, variance, standard deviation and coefficient of variation).*†
- Order histograms from highest to lowest variability using the variance.*†
- Order histograms from highest to lowest variability using the amplitude.*†

Binomial Distribution (DB)

- Establish the assumptions of a binomial experiment.*†
- Estimate probabilities using a graph of a distribution.*†
- Estimate the mean of a distribution using a graph.*†
- Interpret the mean of the distribution.*†
- Calculate probabilities by hand*† and using Minitab* or RStudio.†
- Calculate the mean of the distribution.*†
- Describe the change of the distribution shape as the probability of success changes.*†
- Calculate proportions using RStudio.†

Confidence Intervals for the mean (ICM)

- Calculate confidence intervals using RStudio.‡
- Make the practical interpretation of a confidence interval.‡
- Make the probabilistic interpretation of a confidence interval.‡
- Verify the assumptions before constructing a confidence interval.‡
- Determine if the interval contains the population mean.‡

Confidence Intervals for the Proportion (ICP)

- Calculate proportions.‡
- Determine the type of variable needed to construct a confidence interval for the proportion.‡

- Calculate a confidence interval for the proportion using RStudio.‡
- Make the practical interpretation of a confidence interval for the proportion.‡
- Determine if the interval contains the population proportion.‡
- Verify the assumptions before constructing confidence interval for the proportion.‡

Sample Size (TM)

- Calculate the sample size needed given an margin of error and a confidence level.‡
- Establish the relationship between the sample size and the margin of error.‡
- Interpret plots considering the margin of error.‡

Hypothesis Testing for the Mean (PHM)

- Verify the assumptions before conducting a hypothesis test.‡
- Conduct a hypothesis test using RStudio.‡
- Establish the level of significance.‡
- Identify the p-value in the output.‡
- Make conclusions.‡
- Establish the null and the alternative hypothesis.‡
- Define the parameter of interest.‡
- Graph the p-value.‡

Hypothesis Testing for the Proportion (PHP)

- Determine the type of variable needed to make a hypothesis test for a proportion.‡
- Define the parameter of interest.‡
- Establish the null and the alternative hypothesis.‡
- Establish the level of significance.‡
- Calculate proportions.‡
- RMake conclusions.‡

- Verify the assumptions before conducting a hypothesis test for the proportion.‡

Correlation (COR)

- Determine which graph is more appropriate to plot the relationship between two quantitative variables.*†‡
- Describe the correlation between two quantitative variables.*†‡
- Estimate the Pearson correlation coefficient using a graph.*†‡
- Understand the correlation doesn't imply causation.*†‡
- Calculate the Pearson correlation coefficient using Excel.*

Linear Regression (RL)

- Make a scatter-plot using Excel* or RStudio.†‡
- Fit a linear regression model in Excel* or RStudio.†‡
- Identify the slope of the linear model.*†‡
- Interpret the slope of the linear model.*†‡
- Identify the intercept of the linear model.*†‡
- Interpret the intercept of the linear model.*†‡
- Make point estimation* or interval estimation.†‡
- Identify the drawbacks when extrapolating.*†‡

Appendix D
ACTIVITY OF CONFIDENCE INTERVALS FOR THE MEAN

Actividad: Intervalos de Confianza para el Promedio

Nombre:______________________________ Sección: __________ Fecha: __________

1. Veamos cómo se calculó el intervalo de confianza del 95 % para el promedio para la primera muestra aleatoria de 15 botellas de malta que se presentó en el video. El conjunto de datos (en onzas) se muestra a continuación:

7.0	6.8	7.0	6.7	7.3	6.7	6.9	7.2	7.4	6.8	7.1	7.0	6.8	7.1	6.9

Para crear los datos:

- Abrir Excel y escribir los datos tal y como se muestra en la Figura 1. Una vez tenga los 15 datos en Excel, guarde el archivo en el Desktop con el nombre `Malta` usando el menú **File**, **Save**, **Computer** y **Desktop**.

Figura 1: Malta.

	A
1	Malta
2	7
3	6.8
4	7
5	6.7
6	7.3
7	6.7
8	6.9
9	7.2
10	7.4
11	6.8
12	7.1
13	7
14	6.8
15	7.1
16	6.9

Para importar los datos:

- Abrir RStudio y ejecutar el comando `library(Rcmdr)`.
- Una vez en R Commander, hacer click en: **Data** → **Import data** → **from Excel file...** Entrar el nombre del conjunto de datos: `Malta` y hacer click en **Ok**. Buscar el archivo `Malta` de Excel que guardó en el Desktop, escogerlo y oprimir **Open**.

Para verificar los supuestos:

- Constrya un boxplot usando el menú **Graphs** → **Boxplot...** Seleccione la variable `Malta` y oprima **OK**. Observe y analice la gráfica en RStudio.
- Constrya un gráfico de normalidad usando el menú **Graphs** → **Quantile-comparison plot...** Seleccione la variable `Malta` y oprima **OK**. Observe y analice la gráfica en RStudio.

Para construir el intervalo de confianza:

- Hacer click en **Statistics** → **Means** → **Single-simple t-test...** Verificar que la variable escogida sea `Malta`, que el nivel de confianza sea 0.95 y hacer click en **Ok**. Observar el output en RStudio (no en la ventana de R Commander)

a) Escriba el promedio del contenido de las botellas de malta.

b) Escriba el intervalo de confianza del 95 % del promedio del contenido de las botellas de malta.

c) Indique la interpretación práctica de este intervalo.

2. María y Luis desean estimar el promedio de ventas de comida por día que se producen en un *food truck*. Entre los dos evaluaron al azar las ventas que se realizaron durante 30 días. Luis reportó que en promedio las ventas de comida llegan a \$700 por día y María reportó que el promedio de ventas de comida por día que se produce en el *food truck* está entre \$587.99 y \$812.01 con un 95 % de confianza. ¿Cuál de los dos, Luis o María, reportó de forma adecuada sus resultados? **Justifique su respuesta.**

3. Suponga que la población de Puerto Rico tiene 100 habitantes y que en la funda provista tenemos la esperanza de vida para cada uno de estos habitantes. El interés es estimar la esperanza promedio de vida de esta población. Como no puede mirar los 100 datos, entonces tome una muestra aleatoria de tamaño 10. Introduzca los datos obtenidos en Excel y calcule el intervalo de confianza del 95 %, tal como lo hizo en el Problema 1. Anótelo en la tabla que se provee abajo e indique la interpretación práctica de este intervalo.

IC de 95 %	Interpretación práctica

4. Escriba una marca de cotejo ($\surd$) en los supuestos que se deben cumplir antes de usar la fórmula para construir intervalos de confianza para el promedio. (Marque todas las que apliquen.)

   ☐ La muestra es aleatoria.

   ☐ La muestra no tiene valores atípicos.

   ☐ La distribución de la esperanza de vida es normal o el tamaño de muestra es lo suficientemente grande.

5. La esperanza de vida promedio de esta población es de 74.2 años con una desviación estándar de 4.37 años. (En este problema conocemos el promedio y la desviación estándar porque tenemos los datos de la población. En la práctica este no sería el caso y es justamente el promedio o la desviación estándar de la población lo que tal vez se desea estimar.)

   a) Indique si la esperanza de vida promedio de la población está en el intervalo que construyó.

   b) De los intervalos construidos en clase, ¿cuántos de ellos incluyen el promedio poblacional?

   c) De los intervalos construidos en clase, ¿qué porciento de ellos incluyen el promedio poblacional?

   d) ¿Es este porciento similar al nivel de confianza? Sí __________ No __________

   e) **Observe la simulación que presentará el profesor.**

   Note que no todos los intervalos contienen el promedio de la población, pero más intervalos lo contienen. En la práctica usted hace el estudio una sola vez y calcula **solamente un** intervalo de confianza. ¿Este intervalo de confianza que calcularía contiene el promedio de la población?

   Sí __________ No __________ No se sabe __________

   f) Cuando se construye un intervalo de confianza para el promedio de la población: (Marque todas las que apliquen.)

   ☐ no se sabe si este intervalo contiene el promedio poblacional.

   ☐ de todos los intervalos posibles con el mismo nivel de confianza, hay muchos más intervalos de confianza que contienen el promedio poblacional.

   ☐ la probabilidad de que haya construido un intervalo de confianza que contenga el promedio poblacional está a su favor.

6. Suponga que lee el siguiente resultado estadístico en un artículo científico: "Basado en un estudio epidemiológico con una muestra aleatoria de mujeres embarazadas, se reportó que el nivel promedio de glucosa en la sangre de estas mujeres fue de 110 mg/cc (Intervalo de confianza del 95 %: [106.08,113.92])."

   a) ¿A qué promedio se refiere el 110 mg/cc?
   __________ Nivel promedio de glucosa de la población
   __________ Nivel promedio de glucosa de la muestra

   b) ¿Se encuentra el nivel promedio de glucosa de la población de mujeres embarazadas en este intervalo?

   c) Interprete el intervalo de confianza.

Appendix E
APPROVAL OF THE CPSHI OF THE UPRM

Comité para la Protección de los Seres Humanos en la Investigación
CPSHI/IRB 00002053
Universidad de Puerto Rico – Recinto Universitario de Mayagüez
Decanato de Asuntos Académicos
Call Box 9000
Mayagüez, PR 00681-9000

24 de junio de 2015

Yareliz Román Traverso
Ciencias Matemáticas
PO Box 413
Aguada, PR 00602

Estimada estudiante:

El Comité para la Protección de los Seres Humanos en la Investigación (CPSHI) ha considerado su Solicitud de Revisión y demás documentos sometidos para el estudio titulado *Alternative Teaching Method for Introductory Statistic Courses (# Protocolo 20150603).*

El CPSHI considera que este estudio no supera el nivel mínimo de riesgo y que cualifica, bajo la categoría 1 del 45 CFR 46.110, para un proceso exento de aprobación.

Cualquier cambio al protocolo o a la metodología deberá ser revisado y aprobado por el CPSHI antes de su implantación. El CPSHI deberá ser informado de inmediato de cualquier efecto adverso o problema inesperado que surgiera con relación al riesgo de los seres humanos, de cualquier queja sobre esta investigación y de cualquier violación a la confidencialidad de los participantes.

Cordialmente,

Dr. Rafael A. Boglio Martínez

Dr. Rafael A. Boglio Martínez
Presidente
CPSHI/IRB
UPR – RUM

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