Engineering Economics Analysis Course – from Flipped Classroom to Distance Teaching

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Abstract

Engineering economic analysis is part of the engineering curriculum for most of the disciplines of the Engineering College at the University of Puerto Rico. Because of the need to have engineers that can perform detailed economic analysis of projects or investment opportunities, problem solving techniques should be used when teaching this course. The experience of the professor teaching engineering economic analysis for over ten (10) years, motivated a significant change on the way the course was being taught. It started with the concept of flipped classroom for about 70% of the course. This teaching technique was proven with regular size groups of approximately thirty (30) students per session and with mega sessions of approximately sixty (60) students. Feedback received from students shows the teaching strategy is working appropriately and students are taking additional knowledge with them. As of this last Spring semester, due to the pandemic affecting the world, classes were moved to distance learning. Transitioning on this course to distance learning represented an extension of the hybrid teaching technique that was been used. This article shows a summary of the lessons learned during this whole process of over two (2) years.

Keywords
Engineering Economic Analysis, Flipped Classroom, Inverted Classroom, Distance Learning

1. Introduction
Engineering economic analysis course is part of the curriculum of the industrial engineering department for undergraduate students at the University of Puerto Rico, Mayagüez campus. The three (3) credit-hours, forty-five (45) contact hours course has also been a required course for electrical and computer engineering undergraduate students for a long time. Recently, this course was included in the chemical engineering curriculum and as of 2019, it is also required for mechanical engineering students. As many engineering courses, a large part of the topics included in the syllabus have a high-level content of mathematics. The extensive use of mathematics made the professor to look for alternatives to teach it in a way increasing the active participation of the students. The professor heard about the flipped or inverted classroom teaching/learning strategy and attended a workshop in campus. That was enough to start planning how to convert partially or completely the engineering economic course. About a year after the workshop, participating of an industrial and system engineering conference, one presentation was about the use of the flipped classroom by a colleague at a different university who was also teaching the engineering economic analysis. He shared the positive results he has obtained in over five years using this concept which helped the professor to identify specific strategies on how to plan the transition of a traditional lecture-oriented course to a flipped classroom course.

The process of transitioning to flipped classroom was started in the Fall 2018 semester using the technique for about 70% of the topics included in the course. Uninterruptedly, the flipped classroom teaching strategy has been used with some variations for four fifteen-weeks semesters and two summer sessions. Results will be shown on the corresponding section of this paper by presenting the grades obtained for the two semesters before starting the transition and a comparison versus the periods since the inverted classroom has been used. The feedback received by most of the students is that they prefer it for this kind of course because they can practice and solve many problems with others and discussed them to clarify questions with their peers and the professor. Having change to this teaching methodology helped to move to a hybrid teaching style during Spring 2020 and to distance learning for the Summer 2020 session due to the pandemic affecting the world. The upcoming semester of Fall 2020 teaching will also be using the distance learning approach.

The following sections of this paper include the review of relevant literature, the methodology used, the analysis of the data and results obtained. This article is finished with conclusions including lessons learned and some recommended future steps.

2. Literature review

Flipped or inverted classroom can be defined as "a new pedagogical method, which employs asynchronous video lectures and practice problems as homework, and active, group-based problem-solving activities in the classroom" or "as an educational technique that consists of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom" (Bishop and Verleger 2013). It involves active, problem-based, and cooperative learning activities. Asynchronous can be defined as not simultaneous or concurrent in time and it usually refers to digital communication (Merriam-Webster 2020). Another author explained that "class becomes the place to work through problems, advance concepts, and engage in collaborative learning" (Tucker 2012). Figure 1 shows a comparison of the general concept of traditional versus flipped classroom.

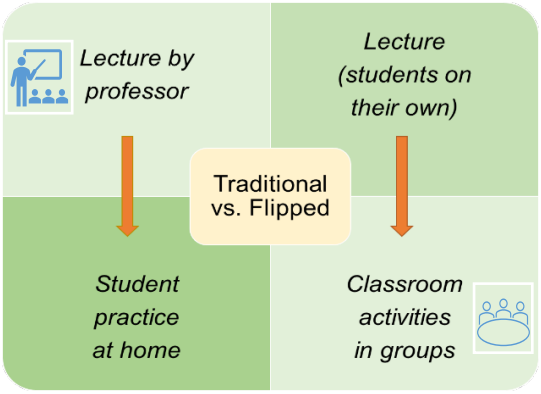

Figure 1: Comparison of traditional versus flipped classroom

The review of relevant literature for this project was divided into three major areas: (1) advantages and disadvantages of converting traditional courses to flipped classrooms, (2) flipped classroom in engineering or technical courses, and (3) instructors perspective about flipped classrooms.

Reviewed literature presents in general more positive results obtained from flipping courses than opportunity areas for improvement. Some of the relevant findings that can help in understanding the advantages of a flipped classroom are explained next. For her first experience with a flipped classroom on an agricultural economics course for freshman, Barkley suggests that it could enhance students' learning and engagement (Barkley 2015). Activities done in class with flipped classrooms provide a more attractive environment for millennials due to their preference for interactive an experiential-learning experiences (Phillips and Trainor 2014). In an Interior Design & Merchandising department they found that "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). In a study where the researchers wanted to investigate the impact to students' emotion by participating in a flipped classroom experience, they found that the students (79% were not from science nor technology) demonstrated to have more positive (i.e. fun) and less negative (i.e. fear) emotions (Jeong et al. 2016). The main advantage identified by a different group of researchers is the students' flexibility to learn from videos (Ramirez et al. 2014).

On the areas for improvement or disadvantages of the inverted classroom, it was found during the literature review step that at a civil engineering course, the researchers concluded that "the lack of immediate feedback may prevent deeper understanding of the material" (Hotel and Garrow 2016). Another group of researchers found that some students did not enjoy the flipped classroom because they preferred working alone and do not like the group learning activities (Roehl et al. 2013). Some disadvantages identified on a study to science, technology, engineering and math (STEM) students are technical problems found related to their internet providers, the lack of instant feedback, and a limited number of examples of solved problems to study (Ramírez et al. 2014). Another important drawback of the inverted classroom found in the literature is that "there is a risk that flipped classroom curriculum approaches may 'wither on the vine' through a lack of pedagogical integrity" (O'Flaherty and Phillips 2015).

Flipped classrooms have been used in courses from many disciplines; some examples include engineering courses, economics, accounting, general science, and textile and apparel design, among many others. It is commonly seen that inverted classrooms applications are related to hybrid or distance learning courses. Some instances that can be mentioned are the following: a one-hour engineering economy course for civil and environmental engineering students (Lavelle et al. 2013), and a civil engineering systems course (where 2/3 of the material was related to engineering economy) for civil and environmental engineering students and a few industrial and systems engineering students (Hotle and Garrow 2016).

From the instructors perspective, to alleviate the additional work while preparing a flipped course, it was found that it is "recommended peer assistance among instructors as valuable support to implement the flipped classroom model in instruction successfully" (Long et al. 2017). Also, effective implementation of the concept is key for the success of the flipped classroom; another researchers found that "while flipped classroom teaching methods offer several advantages to educators, haphazard implementation will almost surely result in disgruntled faculty members or students and a compromised learning environment" (Rotellar and Cain 2016). Another concern found in the literature related to instructors is the "lack of institutional support for flipping classrooms and providing flexible assessment" due to the additional time commitment (Wanner and Palmer 2015).

3. Methodology

To decide how to implement the inverted classroom for the engineering economics course, the professor decided to keep teaching the introductory topics using the traditional style of lecturing and then practicing problems both in class and with assigned problems. This was done because this is a course where the topics and concepts accumulate throughout the semester and it is very important to dominate the basic concepts to be able to build up on previous material. The important topics to cover the basic concepts from the textbook (Newman et al. 2020) are:

- Introduction and making economic decisions
- Estimating engineering costs and benefits and break-even analysis
- Interest and equivalence and time value of money

For this article it is considered that the course was partially flipped with 30% of the topics (mentioned above) discussed as a traditional classroom (i.e. professor offering the lectures) and 70% using the technique of flipped classroom. Usually, there is a quiz or exam related to the basic concepts of the course before moving into the inverted classroom style. The methodology followed to teach engineering economics with the inverted classroom is summarized in Figure 2 and explained in detail in this section of the paper.

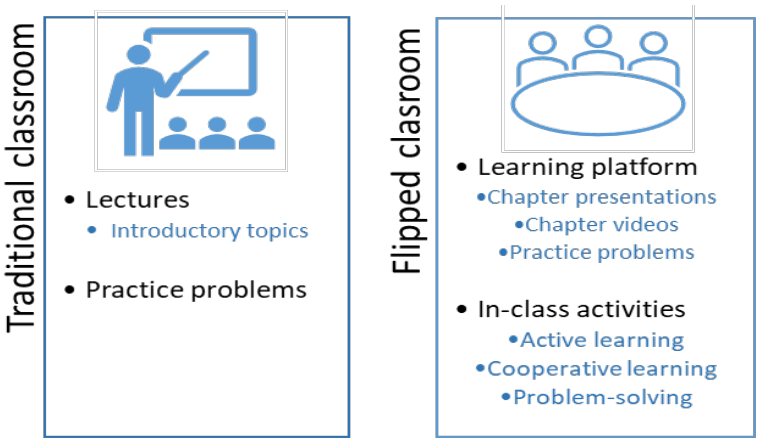

Figure 2: Schematic of the methodology

The courses management system used by the University of Puerto Rico is the open source learning platform called Moodle (Moodle 2020). Therefore, the professor uses Moodle to upload the material needed for the course: course syllabus, chapter presentations, recommended problems, special assignments, grades, etc. Once the flipped classroom was started, videos of the corresponding chapters were prepared explaining the theory concepts and solving example problems. Now the students can access the videos that were uploaded under the corresponding chapter presentation.

Any additional material that may help the students to prepare for in-class activities, is also made available for the students in the platform. Students are required to watch the video before coming into class and they know the order they must follow because it is based on the sequence of the topics included in the syllabus.

In-class activities were created considering active learning and cooperative learning techniques. Specifically, this is achieved with problem-solving sessions in teams. After the students watch each chapter video prior to meeting with the professor, they are prepared to practice the concepts learned by themselves. The class starts verifying students' knowledge about the theory concepts. This is done by summarizing the most relevant concepts from the chapter and answering questions to the students. Once the doubts have been clarified, the professor solves and discusses several examples of the problems related to the lesson of the day with direct interaction with the students. After enough examples have been discussed and all questions have been answered, additional problems are identified and assigned to small group of students (3 or 4) to be solved in teams and later discussed with the class. This process is repeated for approximately eleven to twelve weeks of each semester.

4. Data analysis and results

The analysis of the data consists of the evaluation of the performance of students during the three years that lasted the study and based on their final grades on the course. The first year represents data from the academic year 2017-2018 and it was *before* converting to flipped classroom. The rest of the data is for the two years since the flipped classroom technique is being used; these are the academic years 2018-2019 and 2019-2020. The results were not statistically analyzed because during the three years period, there were too many variables out of the control of the researcher that may have impacted the results obtained. These relevant variables consist of the following:

- *2017-2018*: these two semesters were severely affected by two major hurricanes that directly impacted the island of Puerto Rico
- *Spring 2019*: a mega section of sixty (60) students was offered for the first time
- *Spring 2020*: a significant earthquake and many smaller ones affected the island of Puerto and the COVID-19 pandemic began – a hybrid teaching semester
- *Summer 2020*: the pandemic continued – a distance learning session

A total of 367 students took the engineering economics course with the professor during the three years of the study, 34% or 123 students took the course as a 100% traditional course during the academic year 2017-2018. The remaining 66% represented by 244 students were taught using the flipped classroom technique for the academic years 2018-2019 and 2019-2020. Out of the 367 students, 150 (41%) were from the industrial engineering department and 217 (59%) were from other engineering disciplines. This characteristic was highlighted because industrial engineering is the only discipline within the engineering college that has this course as a pre-requisite for more advanced courses of their bachelor's degree. Additionally, the academic year is another factor that was evaluated to determine if being a junior or a senior may have an impact on the performance of the students. For each semester, the average grade, or the GPA (on a scale with a maximum of 4.0) for the group was calculated for comparison purposes.

Table 1 show the total number of students per semester and the average grade of each group which varies from a minimum of 2.42 to a maximum of 3.52. The minimum GPA happened when the mega section was taught for the first time. It is the impression of the professor that this could have happened due to the minimum amount of time that she had for individual or small group interactions. On the other extreme, the maximum GPA was during an uncommon sort of small summer session allowing the professor and the students to constantly interact helping to improve the active learning experience of the students.

The available data related to the final grade (i.e. A, B, C, D, F) of each student was analyzed and compared based on the following:

- Traditional classroom versus flipped classroom
- Grade distribution per semester – all students (refer to Figure 3)
- Grade distribution per semester – students from industrial engineering versus other engineering disciplines (refer to Figures 4 and 5)
- Grade distribution per semester – juniors versus seniors – all disciplines (refer to Figures 6 and 7)
- Grade distribution per semester – juniors versus seniors – industrial engineering students versus other engineering disciplines (refer to Table 2)

Table 1: Students registered in the engineering economic course

Type of classroom	*Academic year*	*Semester*	*Students*	*Group GPA*
Traditional	2017-2018	Fall	61	2.77
		Spring	62	3.13
Flipped	2018-2019	Fall	29	3.17
		Spring	59	2.42
		Summer	21	3.52
	2019-2020	Fall	58	3.03
		Spring	30	3.40
		Summer	47	2.77

When the distribution of grades for all students who took the engineering economic courses during the three years of the studied period with the researcher, it is observed in Figure 3 a slight trend to improve in grades (considering As and Bs as good grades and Ds and Fs as bad grades) with the flipped classroom. The main exceptions are Spring 2019 when the 60 students' session was offered and Summer 2020 when a 47 students' session was offered with the distance learning mode.

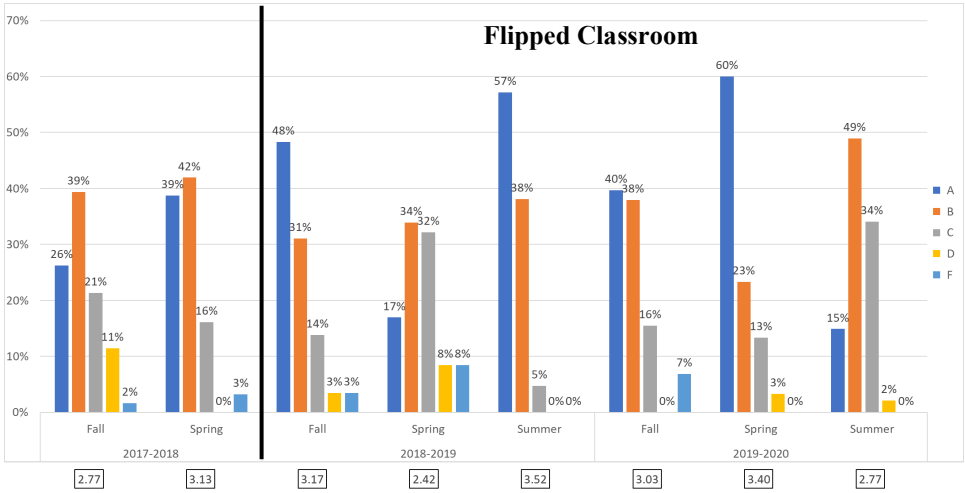

Figure 3: Comparison of the grades of all students

When dividing the results among industrial engineering students (IEs) and other disciplines and doing a similar analysis it is observed on Figure 4 for IEs a better trend than for non-IEs (Figure 5) where the trend is to slightly decrease on their grades.

Analyzing the results graphed on Figure 6 and 7 comparing grades of juniors and seniors of all engineering disciplines, it is almost the norm that the juniors perform better than the seniors. Also, the trend of the grades of the juniors was to improve with the flipped classroom, while the impact the flipped classroom had on the seniors' grades were not particularly noticeable.

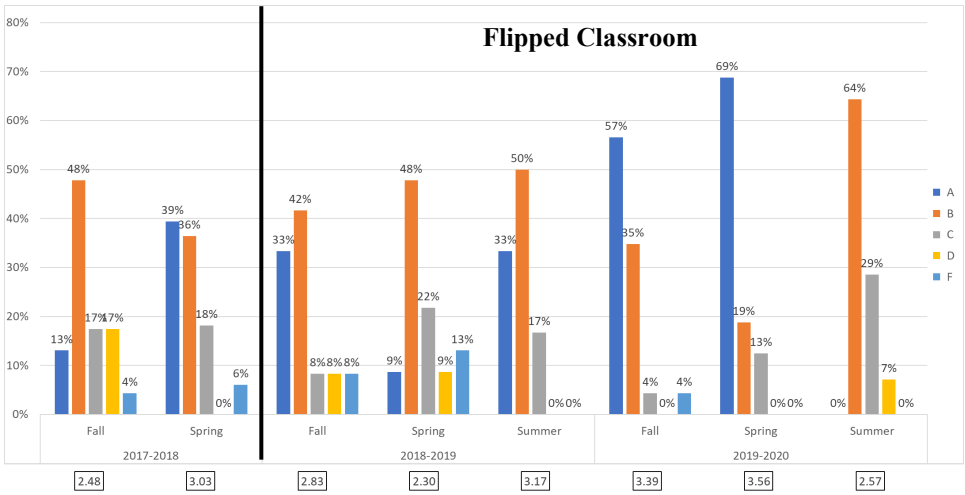

Figure 4: Comparison of the grades of industrial engineering students

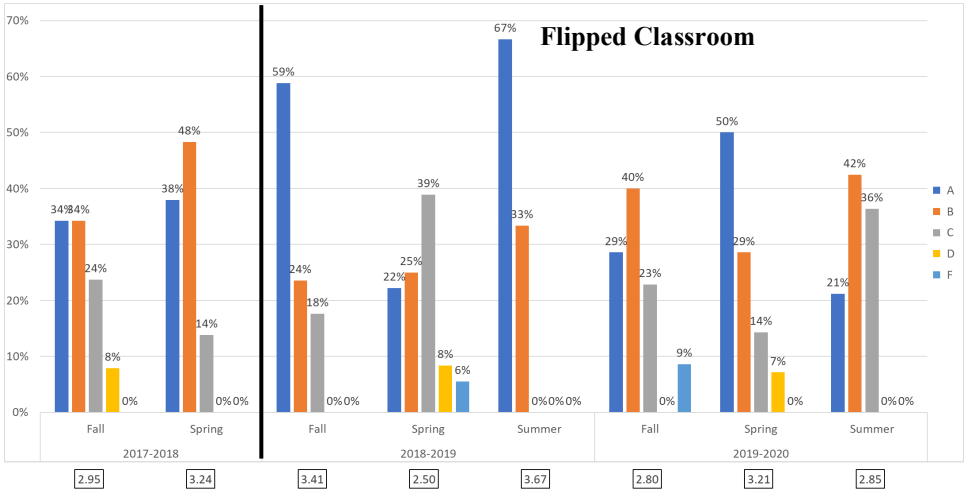

Figure 5: Comparison of the grades of non-industrial engineering students

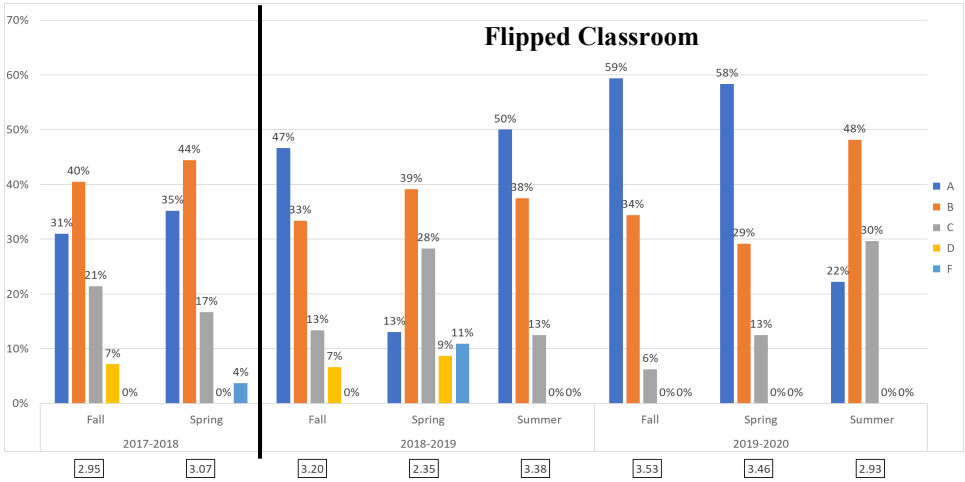

Figure 6: Comparison of the grades of junior students – all disciplines

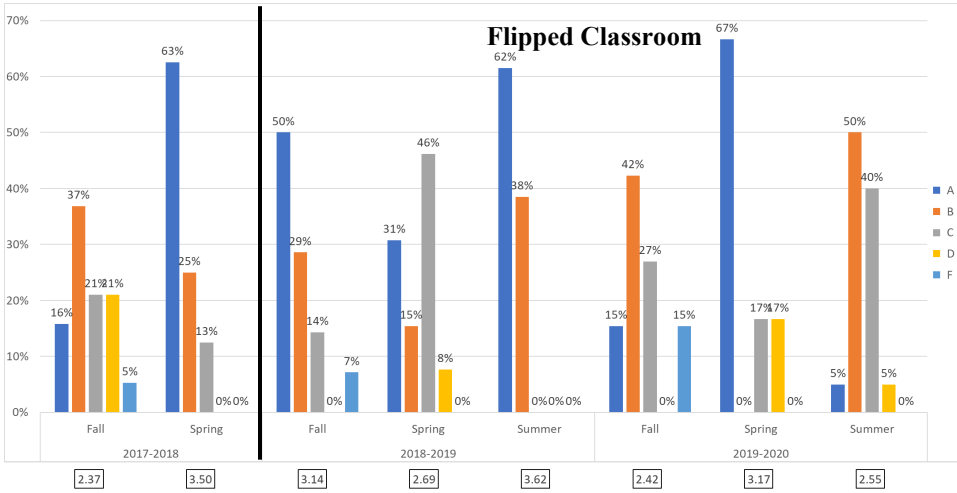

Figure 7: Comparison of the grades of senior students – all disciplines

Additional comparison was made among juniors and seniors dividing them on IEs and non-IEs. When splitting juniors and seniors' students by IEs or non-IEs, it is important to keep in mind that the sample of IEs is smaller by design; it is a smaller department when compared to other engineering departments. The results presented on Table 2 are not conclusive, but some trends can be observed, such as non-IEs juniors have slightly better grades than IEs juniors. Also, the opposite trend can be seen for the senior students because in general, seniors IEs show slightly better performance in this course than their classmates from the other engineering disciplines.

Table 2: Comparison of the juniors and seniors' grades – IEs and non-IEs students

Type of classroom	*Academic year*	*Semester*	***Juniors***				***Seniors***			
			As and Bs		*Ds and Fs*		*As and Bs*		*Ds and Fs*	
			IEs	*Non-IEs*	*IEs*	*Non-IEs*	*IEs*	*Non-IEs*	*IEs*	*Non-IEs*
Traditional	2017-2018	Fall	59%	80%	18%	0%	67%	46%	33%	23%
		Spring	76%	87%	6%	0%	100%	83%	0%	0%
Flipped	2018-2019	Fall	80%	80%	10%	0%	50%	83%	50%	0%
		Spring	60%	46%	25%	16%	33%	50%	0%	10%
		Summer	66%	60%	0%	0%	100%	100%	0%	0%
	2019-2020	Fall	95%	91%	0%	0%	50%	59%	50%	13%
		Spring	87%	88%	0%	0%	100%	60%	0%	20%
		Summer	67%	72%	0%	0%	63%	50%	13%	0%

Relevant details that must be emphasized for all the comparisons made on this section, it the particularities of some of the semesters studied. These are:

- Spring 2019 semester was the 60 students' mega section and the GPA of the group was the lowest at 2.42 out of 4.0. Therefore, for the analysis made of each graph and table or results, this semester was considered to be outside the norm.
- For three of the studied semesters, Fall 2017, Spring 2020, and Summer 2020, the students had the option of soliciting a pass/fail grade; this is not considered in this analysis. It is understood that this consideration may affect the effort the students put on their course during those semesters when extraneous things happened (major hurricanes, earthquakes, and pandemic).
- Spring 2020 semester ended being a hybrid semester and Summer 2020 was a 100% distance learning session due to the pandemic. The preparations done for the inverted classroom since Spring 2019, significantly helped with the transition to a hybrid semester and consequently to a distance learning session.
    - The summer session was taught using the flipped classroom methodology for 100% of the course.

The feedback received by the students throughout this process convinced the professor that the flipped or inverted classroom is definitely the way to continue into the future with the engineering economics course. Students showed high satisfaction in informal surveys done by the professor (not included in this research) in terms of mastering better the material of the course, working in teams to solve problems and on assignments. These in-class activities have allowed them to practice the active learning strategies such as cooperative learning and problem solving. Additionally, the professor has received a lot of constructive feedback to continue improving for the upcoming virtual or presential semesters.

5. Conclusions and Next Steps

The first experience for the professor with the flipped classroom has been very rewarding and encouraging because she has seen the boost in commitment with the course and participation of the students during the class period both in presential classes as in synchronous meetings. At the beginning of the process it represented a lot of additional work for the professor mainly because recording videos was also a first for her. Once she started preparing the course videos, she was constantly motivated because she felt she was developing a whole new experience for her and for the engineering students. And this happened to be with the professor's favorite topic to teach because she sees the multiple application of the course topics for engineers of any discipline in the professional experience as well as in their personal lives.

During the whole process of transitioning to flipped classroom, the professor learned a lot and felt the students' learning process was quite different. Therefore, this article cannot be concluded without pinpointing the lessons learned for the students and for the professor:

- Engineering students really like to use technology on their courses
- Engineering students like to have full control of their time to decide when and how to learn
- Engineering students are being educated to learn by themselves as much as they can
- Most engineering students are willing to do work in small groups
- Most engineering students want to practice real-life scenarios in their courses
- Students preferred the professor to be a facilitator for their education
- Most engineering students do not like the lecturing style of the traditional classrooms
- Many engineering students are precautious when the traditional teaching systems are changed
- The professor learned the difficulties of preparing class materials using technology without being trained
- The professor learned to enjoy even more the "teaching" time while facilitating in-class practices
- The professor felt satisfied when the curiosity of the students to learn more was expanded
- The professor enjoyed having students asking on the applications of the course topics for their personal economic analyses

Several next steps can be identified to give continuity to this effort and promote further learning and improve the course. The professor was recently certified as a virtual educator and is planning on using many of the concepts learned to improve the course. That will start with revising many of the course videos and split them in shorter videos that will work better with the attention span of the students. Also, more relevant data are to be collected to be able to enhance the research done by including statistical analysis and justifications. It will be very interesting to include the gender of the students and evaluate their performances considering that factor and determine if it is relevant. The professor is finishing this research effort completely convinced that active learning techniques are needed, and it is part of her responsibility to help the engineering students to learn them by practicing in class.

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Biography

Mayra I. Méndez-Piñero, PhD, is Professor of the Department of Industrial Engineering at the University of Puerto Rico-Mayagüez Campus. Before joining academia, she worked for over twelve (12) years in a textile manufacturing environment. Her research focuses on using industrial engineering tools to optimize costs, for cost analysis and control, for cost modeling, and engineering economics in multiple applications such as manufacturing of electronics products, renewable energies, health services, higher education, and pharmaceutical industries among others.