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The Impact of Non-Traditional Teaching on Students' Performance and Perceptions in a Structural Engineering Course*

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The Civil Engineering program at Universidad de los Andes, Colombia, redesigned its Structural analysis course to exploit the advantages of blended and flipped learning. The process focused on connecting the civil engineering education to professional practice throughout virtual field visits, hands-on activities, and real-world assignments and examinations. To evaluate the effects of the redesign on the student's learning experience, we conducted a multiphase mixed methods research (N = 329), which confirmed a positive impact on students' perceptions of their learning experience. Students value the greater availability of resources, considered to be a key factor to improve their learning. The redesign also promoted a greater interaction between peers and professors around problems closely related to professional engineering practice. Although we observed a lower final grade average, further analysis confirmed an increase in examinations difficulty and performance improvements when reviewing control test questions. Overall, the redesign had a positive influence on students and instructors by merging real-world problems with the classroom experience.

Keywords: blended learning; performance; student perception; learning environment; mixed methods research

1. Introduction

Structural Analysis is one of the core courses in Civil Engineering undergraduate programs around the world. It is usually taken halfway through the program and it teaches students to idealize real structures into mathematical models that allow a quantitative assessment of the effects of external loads. This is the first step in the design of new or the evaluation of existing structures, a common task for structural engineers. To acquire these skills, students need to understand difficult and abstract concepts that are hard to visualize using a traditional face-to-face teaching approach – a common problem in engineering classes. Considering this issue, the Dean of the School of Engineering at Universidad de los Andes in Bogotá, Colombia supported a complete redesign of the Structural Analysis course with the goal of incorporating active learning and learning technologies. From 2014, the course professors – guided by pedagogical, technology, and assessment advisers – redesigned the course. Initially, they implemented a first version on Fall 2015 with only two out of the five course modules redesigned. By Spring 2016, a fully reshaped version was deployed.

The original learning methodology of the Structural Analysis course was a traditional face-to-face passive approach comprised by three main moments. First, students met with the instructor twice a week in periods of 1.5 hours to receive class lecture; second, students met with a course assistant for a complementary 1.5-hour class focused on solving practical analysis problems; and third, students conducted one laboratory session per week using small-scale physical models or a commercial structural analysis software.

The course redesign focused on three major challenges that the traditional course failed to overcome: (1) the large amount of content from prerequisite courses reviewed during class time to ensure a similar conceptual knowledge base for all students; (2) the limited amount of class time available for students to solve real-world problems with instructor guidance; and (3) the students' tendency to overemphasize the importance of mathematical procedures over the interpretation of results and practical implications. Given these

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challenges, the new course opted for a flipped learning methodology than evolved to a full blended learning methodology. The redesign kept the laboratories that use small-scale physical models since they prompt the students to contrast theory with reality, a fundamental component for motivation and creativity [1–3]. The redesigned course gives students a more active role in their learning process by making them accountable for studying fundamental concepts before class. Therefore, the instructor has more time to focus on real-world engineering problems that require – in addition to mathematical dexterity – a careful interpretation of the results. This new approach requires recording video clips that serve as study guides to reduce class time. The initial implementation of the course employed a flipped classroom methodology that incorporated concepts of active learning, but kept the same number of hours of face-to-face interaction between the students and instructors or teaching assistants. When the model evolved to a blended methodology, the old face-to-face software laboratories were replaced by virtual sessions, and the complementary classes were replaced by optional office hours for students. This led to a 30% reduction of instructor-student face-to-face time compared to the traditional and flipped classroom course.

A detailed description of the redesigned course and an evaluation of its effects on students' perception of the course and academic performance, can be found in [4]. These authors conducted an analysis of the impact of the course redesign by evaluating data from a survey given to students in Fall 2015 and Spring 2016, responses of a focus group, and students' final grades. Surveys from Fall 2015 revealed that student satisfaction with the course increased from 84.5% in its traditional form to 95% in the redesigned form. These results revealed that students had a positive appraisal of the course redesign. Also, in a survey from the Spring 2016 course (which was taught entirely with a blended methodology), 52.7% of participants reported their learning process to be excellent and 39.8% reported it to be good. The results from the focus group study presented, confirmed these results. Despite this, no improvement in students' final grades was found after the redesign [4]. In fact, student during Fall 2015 had the highest failing rate in the course's history; the authors suggested that the decrease in performance was due to the fact that more complex application problems were included in take-home assignments and exams. This hypothesis was not further evaluated by [4].

This mixed methods study was conducted to address the aforementioned hypothesis and to further understand the effects of the teaching method redesign on student learning. To this end, we collected data from the following Structural Analysis courses: Spring 2014 (taught traditionally), Fall 2015 (three modules taught traditionally, two modules taught using flipped classroom), and Spring 2016 (taught using a blended teaching method, instructor-student face-to-face time had been reduced by 30%). Each cohort had a total of five modules; Table 1 shows the teaching methods and the number of modules that were used.

Table 1. Cohort number of modules by cohort and teaching method

Cohort	Teaching method		
	Traditional	Flipped Classroom	Blended
Spring 2014	5	–	–
Fall 2015	3	2	–
Spring 2016	–	–	5

The research design for this study has two main strands: one by analyzing students' perceptions through surveys conducted during the redesigned process, and another by analyzing students' performance using their class grades.

Academic performance was reviewed by analyzing students' grades on assignments, midterms, and final exams from the structural analysis courses. Additionally, midterm and final exams difficulty was categorized using a self-developed rubric. Finally, equivalent questions within midterm and final exams were identified, and statistically compared to detect changes in performance directly related to the teaching method redesign. Particularly, in the Colombian context, there is no grade inflation, and in the university level, grades range between 0 to 5, being 3 the passing grade.

Regarding students' perceptions, qualitative data from an open-ended survey question was coded to identify additional variables that affect students' learning experience. This data was quantified, confirming a set of variables that highlight the importance of students' perceptions of their learning experience, such as, perception of teaching method and level of content difficulty.

2. Theoretical Framework

The concept of a 'learning environment' refers to all the available resources in which learning happens. These resources include the roles and interactions between instructors and students, as well as the material and intellectual resources that are offered in a specific space and time. According to Vygotsky [5], learning is a process of collective construction in which the interactions between individuals are key intermediaries. These interactions are an element of the learning environment where participation occurs in diverse ways [6]. For example, peer interactions can be informal, such as when students voluntarily create study groups and support each other in carrying out tasks and workshops. Likewise, the traditional learning environment encourages student-instructor interactions during lectures where communication occurs mainly unidirectionally from instructor to students. In laboratories, the role of the student is more active, and in projects the instructor acts as an advisor returning the agency of the learning process to students [1, 2, 7, 8].

Structural Analysis courses are an excellent example of a multifaceted learning environment because they require creating diverse spaces for interaction between students, who must collaborate on group projects and laboratories. Also, the course fosters opportunities for interaction between students and instructors, which allows for theoretical problems to become practical by means of activities and projects based on real life situations. This creates an ideal setting to use flipped or blended learning methods that empower students to take a more active role in their learning process [9]. The main concept is to shift the presentation of theoretical concepts from face-to-face class time to off-class with the support of different resources (mainly video or audio). This shift of activities frees class time that can be used to address questions about the material, solve real-world problems, and hold application discussions [9–11]. Flipped and blended pedagogies stand in opposition to the traditional teaching approach where time within the classroom is used mainly by the instructor to present the theoretical concepts of the course [11].

Material and intellectual resources also play a crucial role in the development of a learning environment. Material resources, such as field trips, videos, or in class activities, may promote diverse forms of interactions; therefore, students can play a central role as builders of their learning process [12, 13]. For instance, Material resources – like class video-clips – allow the professor to trust the student with their first contact with the material in the moment that is more convenient for the student. Such Material resources make more dynamic the way in which students receive knowledge and build from it, as it gives meaning to the intellectual resource [14]. For example, when two individuals exchange experiences between themselves, the intellectual resource of the expert can exist through a material resource (for example, a book) or through the instructor who offers the knowledge. Likewise, intellectual resources allow for the construction of knowledge by generating cognitive conflicts that allow the learner to accommodate and create new reasoning structures [15]. When the intellectual resource is offered by an interaction with peers or an instructor, it provides a different point of view that allows the learner to generate cognitive conflicts by creating a dialogue that promotes the collaborative construction of knowledge [15].

Deep and lasting learning only occurs when a true understanding of the topic takes place [14]. According to Perkins [16], understanding is the ability to think and act with flexibility based on what one knows. Nonetheless, understanding is not the same as knowledge. According to Graffam [14], knowledge can exist without the need for reflection and meta-cognition; however, understanding implies both new content, novel skills and fresh thinking habits that allow connecting previous knowledge with original ones [17].

Assessing student understanding involves evaluating what students know (content), their know-how (skills and abilities) and how they do it (attitudes and habits of thinking); it basically means to evaluate who is competent enough. To make this assessment possible, performance must be evaluated by observing what the student can do [18, 19].

The evaluation of performance must also be accompanied by the measurement of students' perception of their learning experience since perceptions have been found to have an influence on the learning processes and performance [20, 21]. Students' perceptions of their learning environment are an important indicator of personal learning and development since perceptions may show students' commitment with their learning process [22].

Performance is also influenced by the difficulty of evaluation or the complexity in the level of cognitive process it requires as proposed by Bloom's taxonomy [23]. This taxonomy, modified by Anderson and Krathwohl [24], contemplates six learning levels: (1) remember: the student can recite the memorized information; (2) understand: the student can explain a concept in her own words; (3) apply: the student uses the concept in a specific situation; (4) analyze: the student can separate the concept into parts in order to understand its structure, (5) evaluate: the student makes value judgments about the concept; and (6) create: the student unites the parts that make up the concept to form a whole that builds a new point of view.

The modified Bloom's taxonomy's learning levels can be used to assess understanding and performance. Student's performance is positively affected by the level of learning required and the type of knowledge that dominates, which may be declarative, procedural, schematic, or strategic [19]. Declarative knowledge describes what to do, procedural knowledge involves how to do it, schematic knowledge allows understanding why to do it, and strategic knowledge refers to identifying who, when and where knowledge is applied. This classification of knowledge enables to consider the cognitive tools required by the student to solve the designed assessment and its influence on which knowledge is used and its effect on student performance [19].

According to Biggs' 3P model [25], the learning process occurs through the interaction between the learning environment and the student's characteristics, the approach to student learning, and the results of learning. Biggs' proposal states that there is a direct influence between the learning outcomes and the perceptions that students have about their learning experience, defined by the teaching methods, academic load, and curricular structure. According to Lizzio et al. [26], student's perception of their learning environment affects their performance, so changes in the former can affect the latter. In addition, the authors identify a direct relationship between a positive perception of the learning experience and better academic achievement and qualitative learning outcomes. Furthermore, a negative perception of academic load and evaluation promotes superficial approaches to learning with a consequent effect on academic performance [26].

Academic grades are typically used as performance indicators that demonstrate the knowledge acquired [27]. Grades are a form of evaluation that depends on what students are able to prove, beyond presenting an adequate understanding about what is being learned by students [28]. Hence, in order to determine the influence of different types of teaching methods used in the classroom, it is important to assess performance by reviewing students grades as well as their perceptions of their learning environment. In this context, Zimmerman [29] states that student learning assessments require evaluation strategies that integrate both, the grades as well as students' perceptions as performance indicators. According to Gibbs and Simpson [27], the evaluation system strongly influences the students' performance and the overall learning process. Likewise, Vaessen et al., [30], regard evaluation as a process that allows learning to improve.

Other situations may affect students' performance. For example, several studies presented by Cassady and Johnson [31] consider the cognitive component of evaluation anxiety as a major factor associated with drops in performance. Similarly, Chapell et al. [32] conclude that anxiety before the evaluation is one cause of low performance in both, undergraduate and graduate students.

3. Presentation of the Research Question

3.1 Main Objective

How does the redesign from traditional to blended and flipped teaching methods influence civil engineering students' performance and perceptions in a structural analysis course?

3.2 Specific Objectives

1. Establish if students' grades in final exam, midterm and other assignments differ depending on the teaching method.
2. Identify if the differences on students' performance between semesters are related with changes on exam difficulty level.
3. Identify students' perceptions related to the teaching methods.

4. Presentation of the Research Design

The research used a multiphase mixed methods design [33] with two main strands: academic performance and students' perceptions. The first strand focused on academic performance by evaluating different assessment grades as well as identifying variations on midterm and final exam levels of difficulty. The second strand highlighted students' perceptions after the changes on the teaching method. This approach allows a more comprehensive understanding of the effects of the redesign since it evaluates, from an iterative qualitative and quantitative perspective, the effects of using a new teaching method. Furthermore, a wider number of variables can be evaluated and consequently a clearer picture of students' learning experience can be reconstructed. This process uncovers the changes in students' grades while the course progresses, and links those changes to possible factors, providing a comprehensive picture of the research problem.

A purposive critical case sampling scheme was used as a tool to comprehend the changes on students learning experiences [34]. Since the course redesign was executed in stages during a two-year period, we selected three cohorts for this study: (1) Spring 2014, when the course was taught in a completely traditional form; (2) Fall 2015, when some modules were flipped classroom and others traditional; and (3) Spring 2016, when the course became blended (See Table 1). Three different methods for collecting and analyzing data were used: (1) a quantitative analysis of course grades; (2) a qualitative and quantitative analysis of an open-ended survey about students' perceptions of their learning process and course resources; and (3) a qualitative and quantitative case analysis of the midterm and final exams. The entire research design is summarized in Fig. 1. All the quantitative analyses were conducted on IBM SPSS Statistics software, while the qualitative analyses were conducted directly on the artifacts and systematized on Excel software.

4.1 *Strand 1 – Academic Performance*

The first comparison performed by Reyes et al. [4] was conducted between students' passing rates for cohorts before (Spring 2014), during (Fall 2015), and after (Spring 2016) the teaching method redesign. The same sample was used for the present study, which included the full academic records of 329 undergraduate students who enrolled in the Structural Analysis course during those cohorts. The sample was organized in three groups based on the type of teaching method used during the semester they took the class: 30.1% (n = 99) belonged to Spring 2014, 35.6% (n = 118) to Fall 2015, and 34% (n = 112) to Spring 2016. The sample was predominantly male (n = 240, 72.9%).

This strand comprised two phases (see 1 and 3 in Fig. 1): a quantitative analysis of students' grades (1 in Fig. 1), and an exploratory sequential design

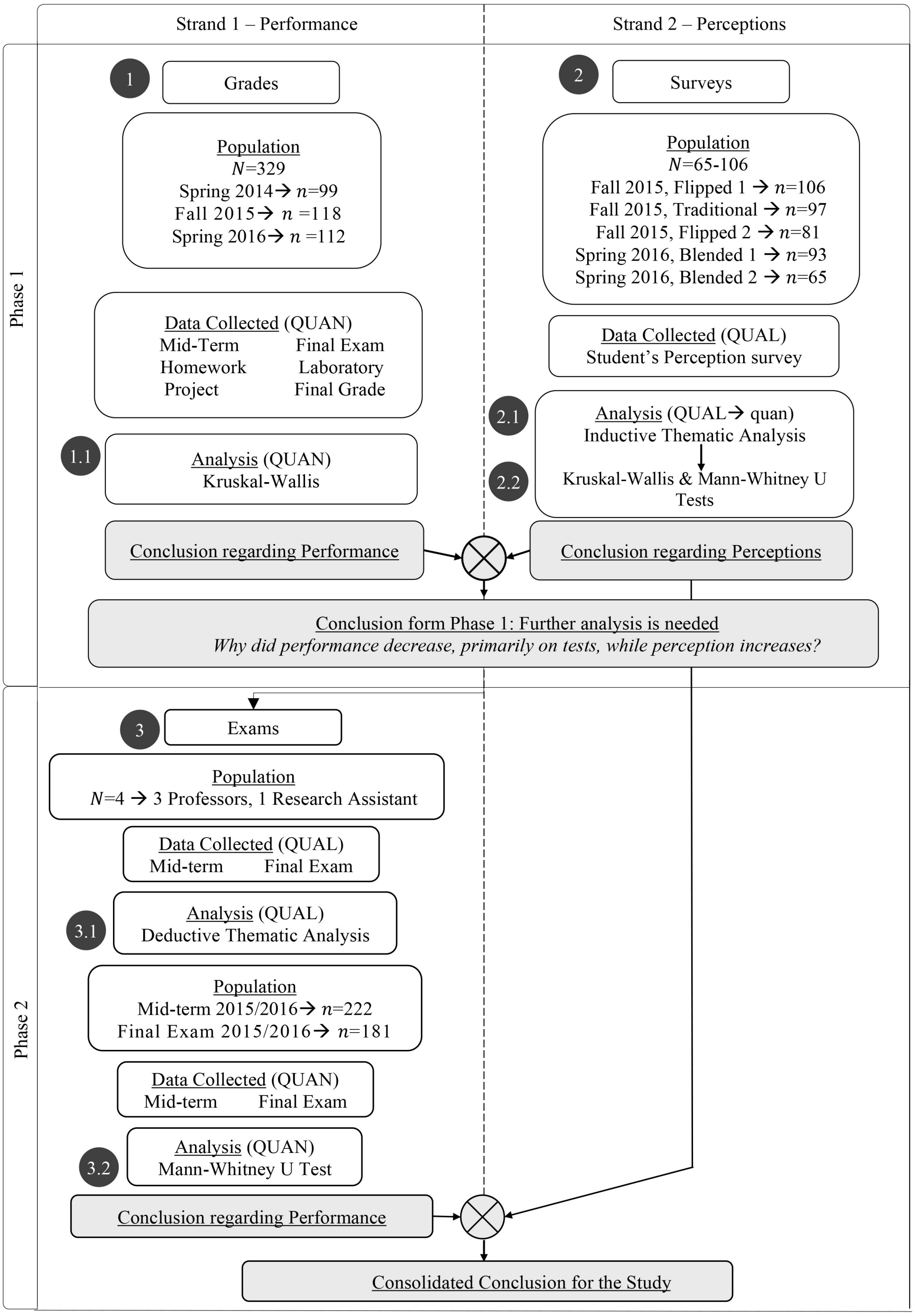

Fig. 1. Research design diagram.

Table 2. Teaching method comparison

Exam	Number of control questions	Fall 2015	Spring 2016
Midterm	3	Traditional	Blended
Midterm	3	Flipped Classroom	Blended
Final	2	Traditional	Blended
Final	4	Flipped Classroom	Blended
Total	12	–	–

(QUAL → QUAN) of exam level difficulty (3 in Fig. 1). For the first phase, a quantitative analysis of students' grades was conducted for descriptive and comparative statistics of performance (1.1 in Fig. 1), using a Kruskal-Wallis analysis with data from the midterm exam, final exam, homework assignments, in-class laboratories, and final project. For the second phase, the exploratory sequential design (3 in Fig. 1) [33] was conducted for understanding the change of grades within cohorts, due to changes in exam's difficulty, and how these changes affected students' performance.

The qualitative analysis of changes in assessments through cohorts (3.1 in Fig. 1) involved a team of three professors (two of which taught the class and an additional expert on engineering education), as well as a research assistant. This team solved the midterm and final exams for all three semesters in a controlled environment where the amount of time needed to solve each test question was noted. Also, the team filled a rubric, to classify each test question according to Bloom's taxonomy of cognitive processes [23] and assessed the type of knowledge required by the student [19].

For the six midterm exam questions, the following comparisons were possible: traditional against blended classroom (3 questions) and Flipped classroom against blended (3 questions) for a total sample of N = 222 (n = 114 from Fall 2015, and n = 108 from Spring 2016). For the final exam, four questions were equivalent between the blended and flipped classroom cohorts, and two questions were equivalent between the blended and traditional cohorts. This repetition of equivalent questions between cohorts allowed us to statistically compare students' performance between teaching methods, controlling for exam difficulty. The total sample was N = 181 (n = 75 from Fall 2015, and n = 106 from Spring 2016). For both exams, the grade assigned for each test question ranged between 0.0 and 4.0.

4.2 Strand 2 – Students' Perceptions

In addition, the study shows an analysis of data on students' perceptions about the teaching method redesign (2 in Fig. 1). This sample was chosen by convenience since data was collected from a series of not compulsory surveys given to students; hence, the data only considered students that answered the surveys [34]. Five surveys were conducted between Fall 2015 and Spring 2016. Surveys were administered after laps of one to two modules, throughout the cohort aiming to have the same student population evaluating both teaching methods, the traditional and flipped classrooms, which were administered on Spring 2015. Surveys for Spring 2016 refer only to perceptions about the Blended teaching method. Table 3 summarizes the cohort, module number, teaching method, and response rate for the five surveys. Note that surveys were only administered during two cohorts, whereas the grades collected belong to three separate cohorts (Spring 2014, Fall 2015 and Spring 2016).

The survey instrument asked about the quality of the new learning resources implemented (videoclips and handouts), the feasibility of the proposed activities, and the interaction between peers and professors encouraged by the teaching methodology. Furthermore, students were asked the following open-ended question: How would you assess your learning process for _______? (where _______ is filled-in with the content regarding to the specific module). All close-ended questions were previously analyzed [4], while the open-ended question responses are analyzed in this article. Aligned with Braun and Clarke [35], responses were qualitatively coded using thematic analysis (2.1 in Fig. 1) for identifying category patterns. Afterwards, a set of quantitative data was derived from the first qualitative coding of students' perceptions (2.2 in Fig. 1) and results were analyzed using Mann-Whitney U test and Kruskal-Wallis statistics.

Table 3. Survey characteristics

Survey	Cohort	Module	Teaching method	Students Surveyed
1	Fall 2015	1	Flipped classroom	106/119 (89%)
2	Fall 2015	2 and 3	Traditional	97/113 (83%)
3	Fall 2015	4	Flipped classroom	81/113 (72%)
4	Spring 2016	1 and 2	Blended	93/114 (82%)
5	Spring 2016	3 and 4	Blended	65/114 (57%)

5. Results: Mapping Students' Learning Experience

The following findings gather the research efforts to understand better the effects of the course redesign on student learning experience. For statistical analysis, the following convention was used for p-values: $p \leq 0.001$ refers to statistically highly significant; $0.001 < p \leq 0.01$ refers to very significant; $0.01 < p \leq 0.05$ refers to statistically significant and $0.05 \leq p < 0.1$ identifies a trend.

5.1 Phase 1. Strand 1 – Academic Performance

Quantitative Comparative Results (1.1 in Fig. 1) Quantitative descriptive statistics were used to analyze the distribution of grades. Since the purpose of the research is to understand the effects of the course redesign on students' learning experience, the type of teaching method was used as the independent variable, while grades were used as measure for the dependent variable, the performance.

Table 4 reports the calculated means and standard deviations for the independent variable (teaching method named by the cohort the student attended) and the dependent variable (students' grade for each type of assessments and final grade for the course). The mean grade of most assessments decreased from Spring 2014 to Fall 2015. Spring 2016 showed a slight increase in half of the assessments (midterm exam, homework and project) in relation to Fall 2015, but the final grade average (as well as the final exam and laboratory grade averages) still decreased.

Skewness and kurtosis assessments were used to determine normality of data. A ratio between mean values and standard deviation of Kurtosis and Skewness greater than 3 were considered non-normal [36], therefore no normality was assumed.

Results revealed the following differences between the three teaching method types, used during each cohort. For the midterm exam, there are no significant differences between Fall 2015 and Spring 2016 (p = 0.74, M_{Fall} 2015 = 2.97, M_{Spring} 2016 = 2.99); whilst between both of this cohorts and the traditional teaching method (Spring 2014) the differences were highly significant (p < 0.001, M_{Spring} 2014 = 3.61). Regarding the final exam, all comparisons showed a highly significant difference (p < 0.001) with a mean value higher for the traditional method cohort (M_{Spring} 2014 = 3.43) and decrease in grade with each subsequent cohort assessed (M_{Fall} 2015 = 2.94, M_{Spring} 2016 = 2.57). It is worth noticing that only cohort of Spring 2014, on average, pass the midterm and final exam (passing grade is 3 over 5).

The homework, a less traditional assessment artifact, revealed no significant differences in grades between cohorts (p = 0.20). Laboratory and project grades, a more collaborative type of assessment, showed a lower performance in Spring 2014 compared to the latter cohorts (Project-M_{Spring} 2014 = 4.12, Lab-M_{Spring} 2014 = 4.30), compared to Fall 2015 (Project-M_{Fall} 2015 = 4.10, p = 0.03; Lab-M_{Fall} 2015 = 4.46, p < 0.001) and Spring 2016 (Project-M_{Spring} 2016 = 4.21, p < 0.01; Lab-M_{Spring} 2016 = 4.38, p < 0.001). This shows a contrast between traditional against flipped/ blended teaching method correspondingly, but no differences between flipped and blended teaching methods. Lastly, the course final grade corroborated that no differences (p = 0.16) exist between flipped classroom (M_{Fall} 2015 = 3.48) and blended learning (M_{Spring} 2016 = 3.39), but there is a statistically significant difference between these two cohorts and Spring 2014 (M = 3.76, p < 0.001), in which students had a higher performance. In summary, there is a coherence between type of assessment and type of teaching method, which is that students performed higher in the midterm and final exam during Spring 2014 (taught traditionally), while students did better in project and laboratory assessments during Fall 2015 and Spring 2016 (taught using Flipped/Blended). Since the midterm and final exams grades accounted for 55% of the course final grade, those have a greater impact on students' final grade than other assessments used during the course.

Table 4. Descriptive statistics

Cohort		Midterm	Final Exam	Homework	Project	Laboratory	Final Grade
Spring 2014 (Traditional) n = 99	Mean	3.61	3.43	3.85	4.12	4.30	3.76
	Std. Deviation	0.70	0.62	0.43	0.66	0.24	0.36
Fall 2015 (Traditional and Flipped classroom) n = 118	Mean	2.97	2.94	3.62	4.10	4.46	3.48
	Std. Deviation	0.79	1.01	0.89	1.07	0.68	0.71
Spring 2016 (Blended) n = 112	Mean	2.99	2.57	3.74	4.21	4.38	3.39
	Std. Deviation	0.79	0.84	0.85	1.04	0.73	0.72
Total N = 329	Mean	3.17	2.97	3.74	4.15	4.39	3.43
	Std. Deviation	0.82	0.91	0.77	0.96	0.61	0.70

5.2 Phase 1. Strand 2 – Students' Perceptions Qualitative Results (2.1 in Fig. 1)

The following coding categories resulted from the qualitative analysis of the open-ended answers from surveys given to students during different modules for Fall 2015 and Spring 2016. Results revealed six categories of positive perception and two categories of negative perception of the learning experience.

5.2.1 Positive Perception Categories

5.2.1.1 Teaching Quality

Regarding the quality of the instructors throughout the course, the most relevant qualities highlighted by students are the clarity with which the professors explain and give examples of the content. Special mention was given to the precise answer to questions, and how well they can keep students interested, motivated, and focused during class. Responses belonging to this category were present in surveys for all three teaching methods but appeared most often for the traditional modules where the instructor has a leading role in the learning experience.

5.2.1.2 Good Methodology that Facilitates Learning

For all three teaching methods, a similar proportion of responses revealed that students recognize that the teaching method contributes to their own learning. For example, the following was a typical answer: "I think the method that is being used is very good for learning this subject because it allows the student to have clarity on the topics that are being talked about". This category indicates a positive perception towards the contribution of different activities and resources to the students' learning experience.

5.2.1.3 Chosen Examples Facilitate Content Understanding

The qualitative coding of all surveys showed that students highlighted how the examples used throughout the course contributed to their learning. Students stated that when case studies were used as examples, these complemented theoretical content by allowing them to practice the different topics in the context of professional practice. Students' answers referred to examples as activities done prior to lectures through which they could review and prepare class content.

5.2.1.4 High-Quality Videos Facilitate Content Understanding

According to student testimonies for both, flipped classroom and blended teaching methods, evidence showed that videos were instrumental to improve the understanding of class topics. Students' answers coded in this category indicate that videos with high visual quality and more examples are more efficient than simpler and shorter videos. A typical student answer was: "It is very easy to understand the concepts since they are offered in a more graphic and visual way through the videos.". Note that the greatest reply ratio was observed for the first module of Fall 2015, perhaps because this was the first time that students experienced an alternative teaching method.

5.2.1.5 Pre-Class Activities Allows for Better Use of Face-To-Face Lecture

According to students, preparing classes in advance promotes faster-paced lectures and encourages participation. Likewise, it allows lectures to be focused on the most challenging parts of the content, solving exercises, and answer students' questions. This category is related to the previous one (video quality); however, it focuses on course topic preparation instead of video quality.

5.2.1.6 Learning Resources Allow Students to Learn at Their Own Pace

This category compiles students' answers about the effectiveness of the various resources to allow them to learn at their own pace. Students highlighted the importance of having learning resources (especially videos) available on demand. This allowed students to access explanations and examples as many times as they wished and whenever they considered it appropriate.

5.2.2 Negative Perception Categories

5.2.2.1 Inability to Understand Complex Content

According to several testimonies, not all topics were entirely clear by the end of lecture. This perception was most common for the higher complexity modules (the last two). Students said that this may be because a combination of insufficient explanation by the instructor, and lack of examples. Some students stated that the time to solve complex examples during class was not enough, which hampered comprehension of harder topics. Students felt that in-class examples and problems were too simple and did not reflect the complexity of applied engineering problems like those included in homework assignments or exams. As the semester went on, more students gave responses belonging to this category, revealing a relation between the content complexity and the students' negative perceptions of their learning experience. Responses belonging to this category were present in surveys for all three teaching methods.

5.2.2.2 The Absence of Videos Hinders the Learning Process

For modules using the traditional approach – without videos – students notice that most of the class time is spent presenting content rather than addressing questions or solving problems. Also, by comparing answers for modules with videos and modules without videos, it is evident that students struggle to understand new topics when there are no videos available since they could only hear once the instructor explanation.

5.2.3 Quantitative Results – Evaluating Perception (2.2 in Fig. 1)

In order to conduct a descriptive statistical analysis on students' perceptions, a quantification of open-ended answers from surveys collected in Fall 2015 (traditional and flipped classroom) and Spring 2016 (blended) was performed. The teaching method was selected as the independent variable, and students' perception of the teaching method as the dependent variable (qualitative codes quantified as very positive = 3, positive = 2, neutral = 1, and negative = 0). To determine normality of data distribution skewness and kurtosis was assessed. For at least one teaching method the ratio, between skewness average and standard deviation values were above 3, therefore no normality was assumed. Nonparametric Kruskal-Wallis and Mann-Whitney U tests were applied for correlating positive/negative perceptions with teaching method. The teaching method perceived as the most positive one was the flipped (on average half occurrences were very positive and half were positive), followed by blended (on average 2/3 of occurrences were positive and the rest were very positive) and traditional (on average all occurrences were positive) as shown in Table 5.

Both redesigned teaching methods obtained statistically more positive perceptions than the traditional teaching method ($p < 0.001$ for flipped, $p = 0.04$ for blended). There are no significant differences in perceptions between flipped and blended teaching methods, but a trend with more positive perceptions towards the flipped was shown ($p = 0.06$). It is worth noticing that those students who participated in the flipped teaching method also participated in the traditional one (Fall 2015); thus, the same population could contrast both alternatives, allowing a unique appreciation of the benefits of the redesign. Conversely, those students who participated in the blended teaching method (Spring 2016) only experienced one method design (see Table 1). Meanwhile, the comparison between cohorts, consolidating traditional and flipped teaching methods in one group (Fall 2015) and blended in other group (Spring 2016), showed no significant difference ($p > 0.05$).

Although the students' perceptions were significantly different, all teaching methods were assessed with positive perceptions (there is no difference between quantified categories of the open-ended questions). However, results from the closed-ended survey questions [4], support this finding, showing that redesign teaching methods were perceived more positively by students (see Fig. 2).

Table 5. Descriptive statistics of quantified data from surveys

		Teaching method		
		Traditional	**Flipped Classroom**	**Blended**
Cohort	n	97	187	158
Fall 2015	Mean	2.09	2.48	–
	Std. Deviation	0.69	0.55	–
Spring 2016	Mean	–	–	2.30
	Std. Deviation	–	–	0.67

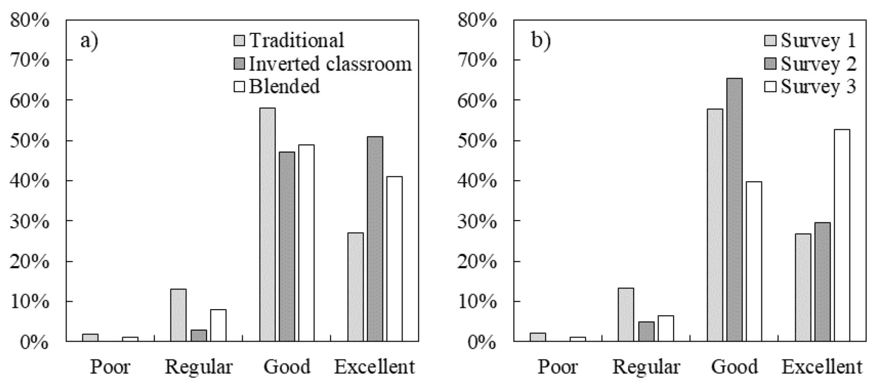

Fig. 2. Students' perceptions between teaching methods a) Open-ended question quantified and b) Closed-ended questions adapted from [4].

5.3 Phase 2. Strand 1 – Academic Performance

After the triangulation of performance and perception strands, no conclusive results could be achieved. Although, perception strand showed a student preference for redesigned teaching methods, aligned width previous analyses [4], the performance strand showed a two-folded result. Students that performed higher in more traditional assessments (midterm and final exams) were taught only using the traditional teaching method, while students that performed higher in less traditional assessments (laboratories and projects) were taught using the redesigned teaching methods. Because of these differences in student's performance, and to possible changes in exam difficulty, the researcher group decided to study the data further, during a second phase, focusing on reviewing midterm and final exams difficulty.

5.3.1 Exploratory Qualitative Results (3.1 in Fig. 1)

For the exploratory sequential phase, a qualitative data analysis was used to assess the difficulty of the midterm and final exams, based on four factors: (1) level of cognitive process per question, (2) type of knowledge per question, (3) number of questions per exam, and (4) time required to solve the exam. Higher levels of cognitive process, more diverse type of knowledge used, higher number of questions included, and longer time needed to solve the exam means that the assessment has higher level of difficulty.

Findings showed that the higher cognitive process assessed in Spring 2014 and Fall 2015 midterms and final exams was *analyze*, according to Bloom's taxonomy [23], while in Spring 2016 was *evaluate.* For midterm, the number of questions increased in each cohort; in fact, they almost triplicated between 2014 and 2015. Fig. 3 shows all response distributions.

For midterm and final exams during Spring 2014 and Fall 2015, the same type of procedural and conceptual knowledge was required in order to solve the test questions. However, final exam of Fall 2015 was found to require more conceptual knowledge than final exam of Spring 2014 proportionally. Finally, Spring 2016 assessed more type of knowledges than previous cohorts, in fact the midterm assessed all type of knowledges. Results can be found on Fig. 4.

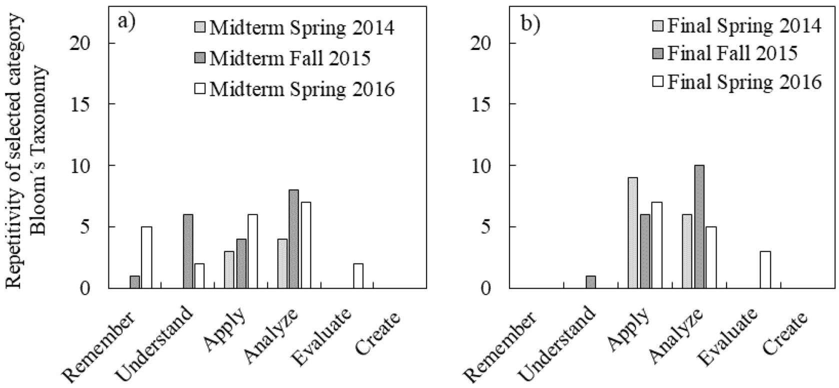

Fig. 3. Distribution of (a) midterm and (b) final exam questions according to Bloom's taxonomy.

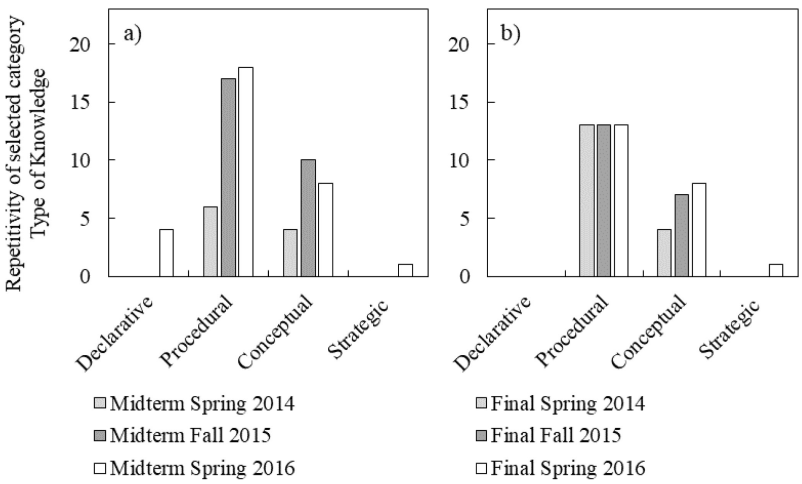

Fig. 4. Distribution of (a) midterm and (b) final exam questions by type of knowledge.

Table 6. Time, in minutes, to solve exam

Semester	Midterm exam (Minutes)	Final exam (Minutes)
Spring 2014	53	78
Fall 2015	101	125
Spring 2016	45	52

The amount of time required for the team to solve each test was recorded. Results can be observed in Table 6. Exams from Fall 2015 took considerably longer to solve. This large difference in test questions responds to a redesign of the midterm format in which instead of asking a few long problems, each problem was split in several smaller questions to target each concept individually. The final exams had all the same number of test questions. A considerable increase in exam difficulty from Spring 2014 to Fall 2015 was found by Reyes [4], leading to a considerable reduction in the exam's length for Spring 2016. In conclusion, Exams in Fall 2015 were considerably more difficult than those conducted in Spring 2014 due three factors, the time required for completing the exam, the number of questions (for midterm), and the higher proportion of cognitive process level assessed (for final exam). Likewise, in Spring 2016 the raise in level difficulty was related to also three factors: number of questions, more diversity of type of knowledge assessed, and the requirement of higher cognitive processes.

In spite of the differences in exam difficulty, for all cohorts, professors provided a range of resources for students (see Fig. 5) to prepare for each test question on the midterm and final exam (classroom hours, videos, office hours with the professor, laboratory, project, and homework). Students' used a broader array of resources after the course redesign because of the videos being included.

These issues support the need of further analysis due to the inconsistencies found in results from performance and perceptions in phase 1. It was crucial to evaluate further the exam's difficulty to allow a proper comparison of the students' performance on each semester to infer the effects of each teaching method.

5.3.2 Exploratory Quantitative Results (3.2 in Fig. 1)

In order to control for exam difficulty, questions assessing equivalent content with the same level of difficulty were identified as control test questions and statistically compared between Fall 2015 and Spring 2016 cohorts.

Table 7 and 8 summarize the teaching method comparison, the cognitive process used, the type of knowledge assessed, and the content topic for each control test question.

To determine normality of data distribution skewness and kurtosis were calculated. Because 10 out of 12 test questions returned kurtosis ratios between average and standard deviation values above 3, no normality was assumed. Nonparametric Mann-Whitney U tests were applied for contrasting corresponding questions between exams. Fig. 6 shows the mean grade differences for the twelve control test questions found. This Figure shows the average grade per question (range between 0 and 4) for each exam, categorized by cohort.

On the midterm exam, 5 out of 6 questions were significantly different form Fall 2015 to Spring 2016. From the 5 questions, students performed higher in 4 questions during Spring 2016, with a

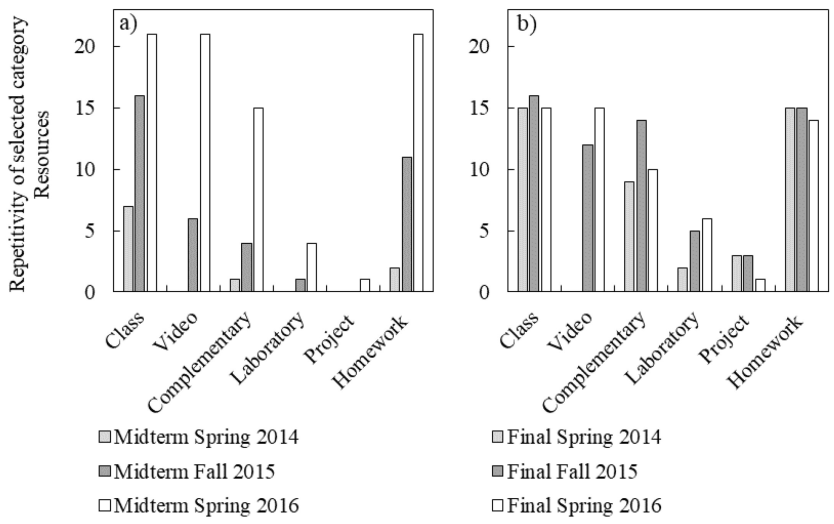

Fig. 5. Learning resources available for (a) midterm and (b) final exams.

Table 7. Control test question summary for the midterm exam questions

Midterm Question	Teaching method		Type of knowledge	Cognitive process	Topic
	Fall 2015	Spring 2016			
1	Flipped Classroom	Blended	Procedural	Apply	Floor systems
2	Flipped Classroom	Blended	Procedural	Understand	Seismic forces
3	Flipped Classroom	Blended	Procedural	Apply	Wind forces
4	Traditional	Blended	Procedural - Conceptual	Analyze	Statics
5	Traditional	Blended	Procedural - Conceptual	Analyze	Statics
6	Traditional	Blended	Procedural - Conceptual	Analyze	Statics

Table 8. Control test question summary for the final exam questions

Final Question	Teaching method		Type of knowledge	Cognitive process	Topic
	Fall 2015	Spring 2016			
1	Flipped Classroom	Blended	Conceptual	Evaluate	Stiffness matrix
2	Flipped Classroom	Blended	Procedural - Conceptual	Analyze	Stiffness matrix
3	Flipped Classroom	Blended	Procedural - Conceptual	Analyze	Stiffness matrix
4	Flipped Classroom	Blended	Procedural	Analyze	Stiffness matrix
5	Traditional	Blended	Conceptual	Analyze	Statics
6	Traditional	Blended	Procedural	Analyze	Wilbur's Method

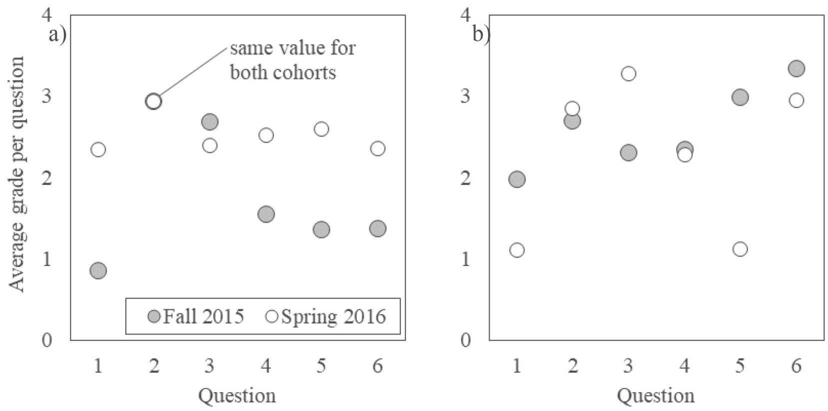

Fig. 6. Average grade per question (range between 0 and 4) for each exam, categorized by cohort for (a) midterm and (b) final exams.

grade difference of 1.2 in grade average and a range of 1.0–1.5 ($p < 0.001$). These questions compared traditional and flipped teaching methods against blended, always showing higher grades in the cohort taught using blended teaching method. The question in which students performed higher in Fall 2015, compared the flipped against the blended teaching methods (both are part of the redesign) with a grade difference of 0.3, this means 7.5% higher grade ($p = 0.01$). These results reveal an improvement in midterm grades after the teaching method shift to blended learning (Table 7). In fact, students' performance was significantly lower in those topics taught with a traditional teaching method.

On the final exam, however, only three questions showed a significant difference between Fall 2015 and Spring 2016. Each of those questions showed that students performed better in each of the three methods ($p < 0.001$); that is, students' grades were higher in question 1 (grade difference of 0.9) that is related to flipped, in question 3 (grade difference of 1.0) that is related to blended, and in question 5 (grade difference of 1.9) that is related to traditional. Comparing teaching methods, there is not a conclusive result about student's performance changes for the final exam, related to the teaching method used (traditional vs. flipped vs. blended).

When reviewing the effect of the type of redesign – traditional vs. blended and flipped vs. blended – this research is not conclusive about differences on students' performance between flipped and blended teaching methods. In fact, this comparison was analyzed in 7 of the 12 control test questions. No statistical difference was shown in 3 questions, while higher grades were obtained in 2 questions related to flipped, and in 2 questions related to blended. In contrast, 5 of the 12 questions compared the traditional and blended teaching methods. No statistical difference was shown in 1 question, while higher grades were obtained in 3 questions related to blended. There was only one question where the traditional teaching method had higher grades; it is worth noticing that this was the largest difference between grades (almost 50% of the grade). Nonetheless, in general, students' performance on the control test questions was better for those that took the class with any redesign than those that had the traditional method.

6. Discussion

In a continuous effort to improve student learning, the Engineering Faculty at Universidad de los Andes had undertaken a project to design core engineering classes. They want their civil engineering courses to integrate new technology-aided teaching methods, that improve students' learning experience by making more efficient the in-class time and addressing more complex problems that are closer real-world situations and therefore to professional practice. In order to assess the effects of teaching method redesign, professors are required to evaluate multiple factors at once (not only students' grades), which can be challenging.

To address this challenge, a mixed methods research approach was chosen since collecting qualitative and quantitative information allows to evaluate students' performance and perceptions for understanding the learning experience in a holistic way. This method honors students' voices as an integral part of the learning experience. Meanwhile, mixed methods results provide deep explanations of the effects of the large number of variables that impact students' grades. Aligned with factors identified by previous studies [6, 9, 10, 12, 14, 20–22], in this research, we have compared each teaching method, by analyzing the following variables: interactions between the students and instructors, the material and intellectual resources available, assessment instruments, student performance measured by grades, and students' perception of their learning experience.

6.1 Beyond Grades as Performance Indicator

The approach performed by [4] for evaluating the redesign of the Structural Analysis course consisted in comparing final grades from courses with a different teaching method (Spring 2014, Fall 2015, and Spring 2016). However, the comparison of final grades showed a decrease in performance, demanding a more profound analysis in order to determine the effects of the redesign. Particularly since the surveys showed that students believed the new teaching methods improved their comprehension of the content.

Previous studies have shown that measuring student performance should contemplate not only students' grades but also the factors that affect them [21, 22, 24]. Grades depend on what students can do beyond presenting a proper understanding of what they learned [37] and therefore provide only an incomplete picture of the learning experience. The present multiphase mixed methods research supports these findings.

There are multiple reasons why grades can decrease. The grade data analyzed allowed researchers to map what happened with students' grades in relation to the various resources used to assess student learning. On the one hand, there was an increase in course assessment difficulty. For instance, exams test questions after the course redesign were found to require a wider diversity of cognitive processes and more types of knowledge were assessed. A detailed analysis of the level of learning [24] and types of knowledge [19] required to solve the exams was performed, as well as a comparison using control test questions that were assessing equivalent content and level of difficulty across teaching methods. This study confirmed that exam difficulty had indeed increased overall, but students' grades improved for the control test questions after the course redesign. One reason for the increased test difficulty may be the creation of a more demanding learning space given that professors were also being transformed by the commitment required to completely change a teaching method. This hypothesis regarding the change of the instructors is of interest for further evaluation. Furthermore, the increment of difficulty has been identified as a cause of student anxiety, which may hinders students' performance [31].

On the other hand, results showed an improvement on grades for assessments that required more interaction between peers and instructors. Detailed analysis of assessment grades suggests that the more collaborative the assessment is, the higher the performance is for those students who were taught in a redesigned learning method. This result may be explained by the changes of the dynamics in the classroom caused by the new pedagogy (namely, its emphasis on a classroom learning experience dedicated to addressing students' questions and analyzing examples rather than reviewing theoretical concepts) positively impacting the interactions that occur inside and outside of the classroom. However, these performance changes have a less predominant influence on the final grade. As a result, these positive effects on performance were not reflected in the analysis performed by [4].

Supporting this research premise that using the final grade as a unique evaluation tool for measuring students' performance is not determinant to decide upon the possible positive impacts that a change of teaching methods has on the students' learning experience. According to Lizzio et al. [26], final grades are a weak measure of students' learning compared to the effect that students' perception of the learning environment has on understanding the interactions required for learning of more complex topics, such as the abstraction required to adequately perform on the structural analysis course evaluated.

6.2 A Successful Learning Experience Based on Students' Perceptions

Results from the survey qualitative analysis demonstrate the importance that students give to the use of videos as a new resource during the modules taught as flipped classroom or blended learning. Students identified three main reasons: high-quality videos facilitate understanding course content, pre-class activities improve the instructor-students' interaction during class, and the availability of learning resources allowed students to go at their own pace. Accordingly, Bergmann and Sams [38] suggests three reasons for using videos as learning resources in their courses, including: (1) they give greater flexibility to students to decide when to work with the contents of the course; (2) they allow instructors to give students personalized attention and focus on those who are struggling with the subject; and (3) they increase interactions between students as well as between students and instructor. Alternatively, the absence of videos during the traditional module was perceived as an obstacle for learning. Furthermore, students' perception of their learning experience was negatively affected by the content complexity, fast-paced teaching, or lack of examples. These findings are important to improve students' learning experience since novel knowledge is acquired when lectures are more practical than theoretical [17].

Results of the quantitative analysis of students' perceptions, confirm that the inclusion of new resources related to the new teaching method was considered a positive influence on students' learning experience. Although, results from the exploratory qualitative phase showed a preference for the flipped classroom, this preference (compared to blended) is only a statistical trend and may be explained because students from Fall 2015 were able to compare between teaching methods, while students who took the course during Spring 2016 only studied under the blended teaching method. Additionally, from the sequential quantitative results of students' perceptions, we conclude that the teaching method used has an influence on students' perception. This was confirmed since there were no statistically significant differences between years; instead, they occurred for the different type of teaching methods analyzed.

Two more variables were found to motivate a positive perception of the learning experience: teaching quality, and examples used to further explain theoretical concepts. Teaching quality is considered in all types of teaching methods as important for the learning experience, but it was particularly salient for the traditional modules reviewed. According to these results, all teaching methods benefit when class examples had enough time to be developed during class and include real-world problems. Our results confirm that higher diversity of resources is recognized by students as an enhancement of any type of learning experience.

7. Conclusions

The mixed-method approach in this study enables an in-depth research on non-traditional teaching methods. In accordance with previous research, the performance strand during the first phase of analysis in this study shows no difference, or even a reduction, on student's performance from cohorts taught with non-traditional methods compared to cohorts taught with traditional methods. However, considering performance and perception together and mixing statistic with qualitative analyses, uncovered measurable performance improvements when controlling for test difficulty.

The results of the present study demonstrate that going from a traditional to a more technology-aided teaching method, such as blended and flipped, improves the learning environment for students. This is accomplished by increasing resource availability and enabling a more interactive learning experience, both of which give students lasting learning opportunities. This resource availability allows students to choose their learning pace and focus therefore may let them perceive the learning experience more positively. Furthermore, a more interactive relationship with the professor and a more collaborative environment were found to be positive influences on students' performance shown by an increase in grades for assessment tools that promote that kind of learning experience.

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