Flipped classroom experiences and their impact on engineering students’ attitudes towards university-level mathematics

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ABSTRACT

This paper analyzes the impact of a Course Transformation process based on a Flipped Classroom strategy on Chilean Engineering students’ attitudes toward university-level mathematics. The Attitudes Toward Mathematics Inventory (ATMI) questionnaire was applied as both pre- and post-test to 76 students in three mathematics courses (Calculus I, Calculus II and Elements of Algebra for Computing) at Universidad Católica de Temuco’s Faculty of Engineering which adopted a flipped classroom method. The results showed a significant positive change in the perceived value of mathematics in the four ATMI categories (P < 0.05) with different effect sizes after the implementation of the flipped classroom and active learning strategies. The results suggest that the implementation of transformed courses using a Flipped Classroom method has a positive effect on students’ attitudes toward Mathematics, especially in those who come from families with lower economical income.

Introduction

Over the last two decades there has been growing interest in conducting applied research of teaching innovation processes in higher education, especially in the Science, Technology, Engineering and Mathematics (STEM) areas (Chasteen, Perkins, Beale, Pollock, & Wieman, 2011; Chasteen, Pollock, Pepper, & Perkins, 2012; Crouch & Mazur, 2001; de Araujo, Otten, & Birisci, 2017; Reid, 2016; Rein & Brookes, 2015). This is mainly due to poor learning results that have been identified in courses which use a traditional lecture approach as the main teaching strategy (Chasteen et al., 2012), which has raised questions about its use and foster change towards active learning in the STEM fields (Freeman et al., 2014).

As a result of these findings, the pedagogical changes in university STEM courses often involve a methodological approach that aims to center the educational process on the students following the principles of socio-constructivism (Piaget, 1926; Vygotsky, 1978), through active learning strategies such as the flipped classroom (Bergmann & Sams, 2012).
Chile has also been part of this endeavor. The Chilean Ministry of Education (MINEDUC) has developed a series of policies and STEM projects aimed at improving learning results and other indicators such as retention, equity of access and on time graduation (MINEDUC, 2014). As a result, several universities in the country have developed new approaches to improve STEM education to contribute to the goals of MINEDUC which, at the same time, seek to reach national economic development (OECD, 2017).

The Center for Teaching Development and innovation at Universidad Católica de Temuco, in Chile, has developed a course transformation model aimed at improving students’ learning results and attitudes towards undergraduate STEM courses. These courses have traditionally been characterized by high failure rates and low students’ satisfaction levels. The model considers the students’ learning needs in the context of a competency based higher education institution and considering high levels of socio-academic vulnerability of students (family income, University Selection Test scores, habitational conditions, etc.). This model is based on implementing student-centered teaching/learning activities, with a special focus on developing competencies related to problem solving, research, and on connecting the pedagogical process to real-world situations (Moya, Turra, & Chalmers, 2018). The learning activities have to be contextualized to the engineering work environment, so students can demonstrate competencies which will be relevant to their future jobs during their undergraduate courses.

As stated before, the aim of this model is to contribute to students’ learning considering the special conditions (competency-based model and students’ socio-academic background) in which the educational process at Universidad Católica de Temuco is developed. The model considers pedagogical accompaniment for Faculty which is done by including a pedagogical consultant from the Center for Teaching Development and innovation and it also considers the help from learning Assistants whose role is to accompany students throughout the implementation of the redesigned syllabus. The course transformation model considers three stages; diagnostic/design, implementation and evaluation.

During its first stage, the model considers a diagnosis of the conditions under which the courses are to be implemented. This involves characterizing the students (number in each course, academic background, learning characteristics, access to resources, etc.), and the types of learning activities, evaluation mechanisms and other aspects of the course declared on the current syllabus. After characterizing these conditions, faculty evaluate the most suitable teaching, learning and evaluation methodologies for each particular course considering the diagnostic information and the educational model of the institution. This is the information considered to develop the new syllabus of the course.

The implementation phase starts after the new course design is completed. During this stage, the students and faculty are closely accompanied by the learning assistants and pedagogical consultants. Once the new strategies have been implemented, the effectiveness of the course transformation is assessed based on an impact evaluation framework that includes the incidence of the transformation in faculty, students and the institution (Moya et al., 2018).

The course transformation model is based on the general principles of the ADDIE model (Analysis, Design, Develop, Implement, Evaluate) (Morrison, Ross, & Kemp, 2007). However, one of the differences deals with the design phase which is not time-fixed. This
means the design phase can extend to the implementation phase so as to respond to issues that may again prevent some learning issues during the current implementation. This flexibility is also present in what the ADDIE model considers as ‘develop’ phase, because the course transformation model allows ongoing development of material during the implementation phase as well. Perhaps one of the most important differences deals with accompaniment because the model used at Universidad Católica de Temuco declares explicitly the accompaniment of pedagogical consultants and learning assistants throughout the process. Furthermore, the impact evaluation principles (Moya et al., 2018) consider that the evaluation phase goes far beyond the evaluation of the course itself, but it seeks to identify the impact of the transformation in faculty themselves, students and the institution. The evaluation contributes to a continuous improvement in the teaching practices (self-improvement) based on the data obtained from this process (Peña-Ayala, 2018).

The basic principles of the course transformation model are to align and redesign the entire course (Fink, 2003), considering new learning results, new teaching methodologies and new evaluation processes based on performance observation. At the same time, it orients the evaluation of the changes themselves towards the impact they have in the three actors mentioned before; faculty, students and the institution.

Another basic principle is the promotion of active learning, which leads to less direct intervention by the teacher and greater interactivity between the students. It is particularly important that pedagogical decision-making be supported by concrete evidence obtained from the teaching/learning process, so that attitudes towards the discipline and individual and group learning is maximized. This will also help assess the learning gains, attitudes and other opportunities, as well as the challenges facing the education process (The National Center for Academic Transformation, 2014).

In the next section, some relevant literature on course transformation and Faculty Learning communities in Higher Education Mathematics will be presented. This will be followed by the presentation of the methodology of the study, which include a description of the changes (transformation) of the courses which are part of the design. Finally, we will present the results, discussion and conclusions of the study.

**Literature review**

The literature related to course transformation models and their implementation is rather limited. Chasteen et al. (2012) found that students who take transformed courses obtain greater learning gains than those in traditional courses, especially in terms of conceptual understanding and problem solving. Gender gaps also diminished, as learning results were found to be comparable between males and females. Rein and Brookes (2015) state that one of the advantages of course transformation is the greater satisfaction with the course reported by the students. The experiences connected to course transformation (Chasteen et al., 2012; Pollock & Finkelstein, 2008; Rein & Brookes, 2015; Wieman & Perkins, 2005), have a focus on active learning, and the course redesign has been based on constructive alignment (Fink, 2003).

Despite the few experiences reported as ‘course transformation’, there are plenty of experiences reported in the last 10 years related to the implementation of active learning strategies and its impact. Kay and Kletskin (2012), studied the redesign of a pre-calculus course with the use of video podcasts (n = 288). The results of this
experience show significant positive changes in the results of a pre-post-test which included five categories of knowledge. Additionally, this study also reports a general positive attitude towards the methodology, especially in terms of its usefulness. Similar results were obtained by Jungić, Kaur, Mulholland, and Xin (2015) after the redesign of three large enrolment first year Calculus courses using the flipped classroom method. Their results show consistent student positive satisfaction in several areas of the teaching/learning process. The study of Julian (2017), reports the experience of a course redesign (Quantitative reasoning) using a project-based methodology. After the implementation of the new course, students demonstrate positive changes in their attitudes toward mathematics and mathematics achievement when compared to a control group. These results have been consistent in experiences of course re-design based on the implementation of active learning strategies (Freeman et al., 2014; Hodges & Kim, 2013; Love, Hodge, Grandgenett, & Swift, 2014; McGivney-Burelle & Xue, 2013; Strayer, 2012).

Among the different active learning experiences reported in the literature, the flipped classroom has been one of the most commonly discussed during the last decade (Reid, 2016). This strategy is characterized by delivering instructional content outside of the classroom, which implies more autonomous work on the part of the students, while classroom activities are dedicated to the interactive resolution of problems or to developing in-class group projects (Bergmann & Sams, 2012). Usually, the delivery of instructional content involves educational videos, as well as automated assessment or grading, which are complemented with in-class project/problem-based learning. It is expected that those activities which require less involvement on the part of the student be undertaken in the student’s own time and without direct intervention by the teacher, while those activities that require greater involvement and complex competences are carried out under the guidance of the teacher (Abeysekera & Dawson, 2015).

The studies have noted the advantages of implementing the flipped classroom approach in terms of ensuring learning (Biggs, 2007) as failure and dropout rates tend to diminish while students’ satisfaction with the course increases (Reid, 2016; Ryan & Reid, 2016; Trogden, 2015).

Specifically, the results obtained after the implementation of the flipped classroom in mathematics courses are similar. According to Lopes and Soares (2018), students enrolled in a flipped Financial mathematics course obtain better overall results than those enrolled in the traditional version of the course. These authors highlight that the flipped classroom model ‘led to an increase of students’ motivation and interest for studying Financial Mathematics. Furthermore, it has a positive impact on students’ determination and autonomy’ (Lopes & Soares, 2018, p. 111). In general, the mathematics and science education literature indicate that the flipped classroom leads to higher satisfaction levels due to the characteristics active learning, collaboration between students, closeness with the teacher and ease of learning through educational videos (Jungić et al., 2015; Love et al., 2014; McGivney-Burelle & Xue, 2013; Strayer, 2012).

The current needs for improvement in STEM courses in the context of the study, the evidence supporting active learning methodologies such as the flipped classroom influence in students’ motivation and attitudes towards STEM disciplines and the fact that, in particular, no studies were found, undertaken in Chile which includes socio-economic status as a variable raise the questions; how does
the implementation of a higher education mathematics course based on the flipped classroom influence the attitudes towards the discipline? What are the differences of this influence in students’ that come from families with different socio-economic levels?

**Method**

**Population and sample**

The implementation of a course transformation process in three first- and second-year undergraduate mathematics courses at Universidad Católica de Temuco's Faculty of Engineering was the focus of this study. The Attitudes Toward Mathematics Inventory (ATMI) questionnaire was answered by 76 students (F = 20 F, M = 56) in three courses: Calculus I (N = 28), Calculus II (N = 31) and Elements of Algebra for Computing (N = 17) as seen in Figure 1.

The students, in general, come from families with low economic income (distributed in deciles, decile 1 = lowest income, decile 10 = highest income), and their results in the University Selection Test (Prueba de Selección Universitaria, PSU in Spanish) are considered low. Table 1 shows the distribution of students considering the decile

![Student distribution in courses](image)

**Figure 1.** Distribution of students across the different courses.

| Decile | Percentage |
|--------|------------|
| 1      | 0%         |
| 2      | 1.7%       |
| 3      | 1.7%       |
| 4      | 59.3%      |
| 5      | 8.5%       |
| 6      | 5.1%       |
| 7      | 3.4%       |
| 8      | 8.5%       |
| 9      | 11.8%      |

**Table 1.** Students distribution in terms of decile (family income).
The PSU has 850 maximus points, the average obtained by the students represents an approximated 38% of correct answers in the case of the mathematics section (DEMRE, 2018).

The analysis was conducted using Fennema and Sherman (1976) methodology, used by Cooper (2013). The teacher of each course administered the instrument pre- and post-test (at the beginning and end of the academic semester). The questionnaire was administered to 100% of the students in the three courses.

**Instrument**

A version of the ATMI (Cooper, 2013; Mohamed & Waheed, 2011) originally developed by Fennema and Sherman (1976) was used. This inventory has been validated (Cronbach’s alpha, .798) for evaluating students’ attitudes towards mathematics courses in four categories: 1) Personal confidence toward the (mathematics) subject matter; 2) Usefulness of the subject’s content; 3) Perception of the subject matter as basically a male domain; and 4) Perception of the teacher’s attitudes (P). The original version of this instrument consisted of 9 subscales (Fennema & Sherman, 1976), the version used by Mohamed and Waheed (2011) considered only the four subdimensions mentioned before. All the subscales of the original version have been widely used in different contexts to measure students’ attitudes towards mathematics (Tapia & Marsh, 2004).

The instrument consists of 47 statements (24 positive and 23 negative) which are evaluated using a Likert scale (1 strongly disagree to 5 strongly agree). Table 2 lists the statements grouped per category.

**Context**

The study was conducted at Universidad Católica de Temuco, Araucanía Region, Chile. The Araucanía Region is characterized by high levels of poverty and students from rural backgrounds, as well as low test scores in standard Chilean and international tests in science and mathematics (Agencia Calidad de la Educación de Chile, 2015a, 2015; OCDE, 2016). Over twenty-seven percent (27.6%) of the university’s students are ethnic Mapuche (the main ethnic minority in the Araucanía Region). These characteristics are highly relevant when choosing the most adequate teaching strategies to be used in transformed mathematics courses. Multiple studies have shown that socio-economic conditions affect the academic results achieved by students when pedagogical changes are implemented to promote active learning (Reid, 2016; Ryan & Reid, 2016; Trogden, 2015).

In this context, the university has developed a course transformation model involving the implementation of learning activities that aims at providing the students with better learning opportunities. The model involves three phases spanning two academic semesters. An abbreviated description of the model is presented in Table 3.

The diagnostics of the situational factors, understood as the circumstances that may affect the teaching and learning (class size, student and teachers background, expectations of the course, contribution to curriculum, nature of the subject, etc.) showed, for example, that students dedicated little time for academic purposes outside their classes (less than 1 hour a week), they used technology mainly for entertainment purposes (more than 5 hours a week), did not enjoy the library and study places as they foster individual work. It was also possible to conclude that faculty had a teacher-focused
Table 2. Statements of the Attitudes Toward Mathematics Inventory (ATMI).

| Personal confidence about the subject matter | Usefulness of the subject's content | Perception of teacher's attitudes |
|---------------------------------------------|-----------------------------------|----------------------------------|
| I am sure that I can learn math.            | Knowing mathematics will help me earn a living. |
| I don’t think I could do advanced math.     | Math will not be important to me in my life’s work. |
| Math is hard for me.                        | I’ll need mathematics for my future work. |
| I am sure of myself when I do math.         | I don’t expect to use much math when I get out of school. |
| I’m not the type to do well in math.        | Math is a worthwhile, necessary subject. |
| Math has been my worst subject.             | Taking math is a waste of time. |
| I think I could handle more difficult math. | I will use mathematics in many ways as an adult. |
| Most subjects I can handle OK, but I just can’t do a good job with math. | I see mathematics as something I won’t use very often when I get out of high school. |
| I can get good grades in math.              | I’ll need a good understanding of math for my future work. |
| I know I can do well in math.               | Doing well in math is not important for my future. |
| I am sure I could do advanced work in math. | Math is not important for my life. |
| I’m no good in math.                        | I study math because I know how useful it is. |
| Subject matter is perceived as a male domain | Usefulness of the subject’s content | Perception of teacher’s attitudes |
| Males are not naturally better than females in math. | Subject matter is perceived as a male domain | My teachers have been interested in my progress in math. |
| It’s hard to believe a female could be a genius in mathematics. | Usefulness of the subject’s content | Getting a teacher to take me seriously in math is a problem. |
| When a woman has to solve a math problem, she should ask a man for help. | Subject matter is perceived as a male domain | I would talk to my math teachers about a career that uses math. |
| Women can do just as well as men in math.   | Usefulness of the subject’s content | It’s hard to get math teachers to respect me. |
| I would have more faith in the answer for a math problem solved by a man than a woman. | Subject matter is perceived as a male domain | My teachers have encouraged me to study more math. |
| Women who enjoy studying math are a little strange. | Usefulness of the subject’s content | I have a hard time getting teachers to talk seriously with me about math. |
| Females are as good as males in geometry.   | Subject matter is perceived as a male domain | My teachers think advanced math will be a waste of time for me. |
| Women certainly are smart enough to do well in math. | Usefulness of the subject’s content | I feel that math teachers ignore me when I try to talk about something serious. |
| I would expect a woman mathematician to be a forceful type of person. | Subject matter is perceived as a male domain | My teachers want me to take all the math I can. |
| Studying math is just as good for women as for men. | Usefulness of the subject’s content | My teachers would not take me seriously if I told them I was interested in a career in science and mathematics. |
| I would trust a female just as much as I would trust a male to solve important math problems. | Subject matter is perceived as a male domain | Math teachers have made me feel I have the ability to go on in mathematics. |
| I’m no good in math.                        | Usefulness of the subject’s content | My teachers think I’m the kind of person who could do well in math. |
approach to teaching after the use of the Approaches to Teaching Inventory (Trigwell & Prosser, 2004). After the diagnosis of the three mathematics courses, it was decided that it was critical to: 1) bolster students’ capacity for autonomous work; 2) provide ample in-class opportunities for the students to demonstrate their learning outcomes; and 3) promote collaborative work among peers. With these goals in mind, the flipped classroom model (Bergmann & Sams, 2012) was implemented in the three courses, supported by additional strategies aimed at promoting collaborative work by allocating teachers’ assistants, and choosing activities involving specific methodologies, such as Problem Based Learning. This in-depth analysis made it possible to develop a new course-planning approach as well as new teaching materials, and to successfully implement the planned activities. To illustrate, Table 4 lists the main changes implemented in the Calculus I course from the course as previously taught.

The Calculus I course uses 1 or 2 videos, with a maximum duration of 8 minutes, during the students’ autonomous time before the face-to-face session to introduce the topic of the class. These videos are complemented with brief questionnaires or a short research activity which allows the teacher to monitor students’ comprehension of the contents. The duration of the autonomous activities may vary, but it does not require more than 2 hours. The first activity of the class involves the discussion of the online activities. Normally, after students have had the chance to ask questions and corroborate some of their ideas, the teacher presents a problematic situation that can be solve using different mathematical procedures. The students in groups analyze the problem, discuss the implications of the data presented and reach some conclusions on how to solve it. They present the solution(s) they have encountered and the rationale they used to find it (them). If there are no special individual remarks, the teacher will provide a general feedback to the class, and will introduce the following autonomous activities.

In the case of the course Calculus II, the situation was similar. As in the previous course, Calculus II was also redesigned based on the flipped classroom approach (Table 5). A typical week in this course starts similarly to the Calculus I course. Students are asked to watch 1 or 2 videos (no longer than 10 minutes each) and answer to an online questionnaire which allows the teacher to monitor their comprehension. In class, the first activity is also aimed at checking students’ comprehension of the topics of the videos/
questionnaires by fostering student discussion. The teacher may answer questions, but the main task is to see if other students can provide the answers their classmates are looking for. Then, the teacher gives students a handout with a specific engineering situation they need to research, so as to finally (at the end of a few sessions) provide a design a solution. In between the sessions, the teacher uploads new videos students may use to help them find a or several solutions to the situation. Topics are closed when all the groups have presented their designs. The general details of the Calculus II redesign are described in Table 5.

The course Elements of Algebra for Computing, as well as the other two courses, eliminated the 'lecture' component of the course, and replaced it with educational videos developed by the course's teacher. This course also starts a typical week with video observation. One difference with the other two courses is that Calculus I and II use videos that can be made by the teacher, assistant or from other online sources. The videos used in the Elements of Algebra for Computing are only teacher-made. Students usually watch 1 or 2 videos (between 6 to 15 minutes) and have to solve some exercises and/or do some research activities before the class. At the beginning of each week the teacher fosters students' discussion and provides insight of the different topics covered in the videos. Then, students are presented with a written problem (based on the videos) that they have to solve individually. This activity is usually evaluated. This helps the teacher to ensure students autonomous work, as this is a first-year mathematics course. The other sessions of the week include group and individual problem-solving which can be presented orally or in a written form. The role of the teacher is to mediate students' collaborative work and ask questions that may provide insight into

Table 4. Comparison between the traditional course Calculus I and the innovated course.

| Description of traditional course | Description of course with innovations |
|----------------------------------|----------------------------------------|
| **General objective:** | a) Using derivation techniques to analyze micro-economic data, in order to provide novel responses to market requirements. |
| At the end of the course the student will be familiar with, and will be capable of applying the theoretical aspects of Differential Calculus to solve applied problems. | b) Solving optimization problems in a business context, and proposing creative options for decision making. |
| **Specific objectives** | a) Creativity and innovation (generic) |
| 1. Understand the concept of limit of a function and calculate the limits of functions. | b) Solving problems in economics (specific) |
| 2. Distinguish between continuous and discontinuous functions. | **Contents** |
| 3. Calculate derivatives of functions | a) Algebra of limits and properties |
| 4. Apply derivatives in problem solving. | b) Definition of derivatives |
| 5. Use specialized software to verify aspects of operations performed to solve problems in Differential Calculus. | c) Rules of the derivative |
| **Contents** | **Main teaching/learning strategies** |
| a) Limit of real-valued functions | a) Flipped classroom (autonomous and in-class) |
| b) Derivative of a function. | b) Group and individual Problem-based learning (in-class) |
| c) Application of the derivatives of a function. | c) Peer learning (in-class and autonomous) |
| **Main teaching/learning strategies** | d) Case studies |
| a) Traditional lecture to present and explain concepts (in-class) | **Evaluation** |
| b) Problem solving | Learning achievement 1 |
| c) Working in the computer lab to solve exercises related to the subject matter. | a) Written test focused on content-1 (10%) |
| d) Individual practice. | b) Written test focused on content-2 (10%) |
| **Evaluation** | c) Exercises (10%) |
| **Summative** | **Learning achievement 2** |
| Written test 1 (25%) | a) Written test focused on content-1 (10%) |
| Written test 2 (25%) | b) Written test focused on content-2 (10%) |
| Written test 3 (25%) | c) Exercises (10%) |
| Short tests and written assignments (25%) | b) Comprehensive performance evaluation (20%) |
| Learning achievements: | **Contents** |
| a) Using derivation techniques to analyze micro-economic data, in order to provide novel responses to market requirements. | a) Algebra of limits and properties |
| b) Solving optimization problems in a business context, and proposing creative options for decision making. | b) Definition of derivatives |
| c) Rules of the derivative | c) Rules of the derivative |
| **Main teaching/learning strategies** | a) Flipped classroom (autonomous and in-class) |
| a) Flipped classroom (autonomous and in-class) | b) Group and individual Problem-based learning (in-class) |
| b) Group and individual Problem-based learning (in-class) | c) Peer learning (in-class and autonomous) |
| c) Peer learning (in-class and autonomous) | d) Case studies |
| d) Case studies | **Evaluation** |
| Learning achievement 1 | Learning achievement 1 |
| a) Written test focused on content-1 (10%) | a) Written test focused on content-1 (10%) |
| b) Written test focused on content-2 (10%) | b) Written test focused on content-2 (10%) |
| c) Exercises (10%) | c) Exercises (10%) |
| **Learning achievement 2** | b) Comprehensive performance evaluation (20%) |
| a) Written test focused on content-1 (10%) | Learning achievement 2 |
| b) Written test focused on content-2 (10%) | a) Written test focused on content-1 (10%) |
| c) Exercises (10%) | b) Written test focused on content-2 (10%) |
| b) Comprehensive performance evaluation (20%) | c) Exercises (10%) |
| **Learning achievement 2** | b) Comprehensive performance evaluation (20%) |
a possible solution of the problem. During the last session of the week, the teacher presents the autonomous activities of the following week. Table 6 presents a general description of the traditional and re-design version of the course.

Applying the flipped classroom approach involved implementing new plans of course activities to be performed independently by the student, and also in-class with the teacher (Bergmann & Sams, 2012). The three courses employed educational videos and automatic evaluations aimed at verifying the student’s understanding of concepts presented in the videos seen during autonomous work. In-class time was employed for problem solving using the peer-learning approach and other active learning methodologies. Figure 2 summarizes the main methodological changes of the courses and shows the flow of the teaching strategies in the new designs.
Data collection and analysis procedure

In order to perform statistical analysis of the answers to the ATMI, a score of 5 to 1 was assigned to the positive statements, while the negative statements received a score from 1 to 5 (Cooper, 2013; Fennema & Sherman, 1976; Mohamed & Waheed, 2011). This means that in the positive statements such as ‘I am sure of myself when I do math’ a 5 evaluation corresponds to the highest positive attitude, whereas in a negative connotation statement such as ‘It’s hard to get math teachers to respect me’ the same evaluation (5) represents the highest negative attitude. During the analysis phase, the scores of the later statements (negative connotation) were inverted, so 5 represents the highest positive attitude and 1 the highest negative attitude in all positive and negative statements.

Statistical procedures were applied to the scores which were organized in different data bases (general/per gender/per course) with a Kolmogorov-Smirnov alpha value under .05 to
check normality. Student’s t-test for parametric samples and the Wilcoxon test (sum-rank) for related non-parametric samples were used in order to establish the significance (p-value) of the differences between the pre- and post-test results. These procedures were performed using the Statistical Package for the Social Sciences (SPSS) software. Averages (means) and variance were also calculated per question in both the pre- and post-tests in order to determine whether the differences between the two tests could be considered positive or negative, to evaluate the variation of the answers, and to determine either the increase or decrease of the means per category. Additionally, the t value for each t-student procedure (for parametric samples only) will be reported, and the Cohen’s effect size was calculated for all the samples. The pre- and post-test comparison considered the same students in both tests. The results need to be understood with this last limitation, since there are no control groups or other references other than literature.

Results

Significant differences were detected in the entire instrument and per dimension between the results of pre-test and post-test. There is a positive significant difference in the overall results of the post-test corresponding to .38 points and a size effect (.942) considered large. This size effect and significant statistical difference, considering the limitations of the sample size and design, mean that course transformation influences positively student’s attitudes towards university mathematics and that these results are likely to be repeated in similar studies. Table 7 synthesizes the global results of the comparison post/pre-test considering the entire sample of students, the gender segments and the dimensions of the instrument.
As seen in Table 7, each dimension of the instrument had a significant positive increase in the results of the post-test, however the size effect of each one of them varies. The category Perception of mathematics as a basically male domain presented the greatest change (.78 points) and has the biggest size effect compared to the other dimensions, which means students changed their perception regarding the male stereotype of the mathematics discipline into a more balanced perspective (not a female/male domain). Even though this result may have different interpretations is it likely that this reflects a cultural issue connected to the career choices and expectations of man and women. The Personal Confidence and Teachers’ attitudes dimensions also had a statistically significant difference; however, their size effect can be classified as ‘medium’. There is a positive change after the implementation of the new courses in these two categories which may relate to the new role students and teachers perform in the context of the Flipped Classroom and the complementary active learning strategies.

A different situation occurs when contrasting the ‘Usefulness of course contents’ results. The test shows a statistical significance difference; however, the size effect is small. This can be explained in terms of the changes implemented in the courses, as the main focus is on methodological issues rather than content itself. This is a useful indication to consider in future analysis of the three courses.

The gender segments have a significant difference in the comparison post/pre-test and the size effect of both groups (female and male) are large (higher than .8). Overall, the results per gender are similar, however the pre-test mean of the female segment is lower than the male segment in the same test (F = 3.56 M = 3.71), and the post-test mean for both groups is the same (4.06). This means women had a less positive attitude towards mathematics before their university studies. The course transformation, in this case, helps to homogenize their attitudes towards the discipline.

### Course analysis

In the Elements of Algebra for Computing course, only overall data for males was evaluated, as the number of females was insufficient for a valid sample. The results indicate no significant differences in the pre- and post-test valuations (t-Student P < 0.05) for both the overall and the male segment in this course. The post/pre-test analysis for the entire class (per statement) showed significant differences (Wilcoxon, P < 0.05) in two statements in the category Personal confidence and five statements involving Perception of mathematics as a basically male domain.

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**Table 7.** Global, gender and subdimension pre and posttest mean results, p-value and size effect.

| / | Pre-test mean | Post-test mean | p-value | Size effect (d-value) |
|---|---------------|---------------|---------|-----------------------|
| Personal confidence | 3.81 | 4.18 | .000 | .618 |
| Usefulness of the subject’s content | 3.78 | 3.99 | .013 | .321 |
| Perception of mathematics as a basically male domain | 3.65 | 4.43 | .000 | 1.240 |
| Teacher’s attitudes | 3.46 | 3.74 | .003 | .513 |
| Overall | 3.68 | 4.06 | .000 | .942 |
| Females | 3.56 | 4.06 | .002 | 1.119 |
| Males | 3.71 | 4.06 | .000 | .875 |

Perception of value for each subdimension in a Likert scale from 1 to 5, N = 76 (Male = 56; Female = 20)
In the Calculus I and II courses there were significant changes in the global and gender comparison when using Students’ t-test. Table 8 shows these results for the three courses.

As seen in Table 8, the only course with a smaller size effect in the pre/post-test comparison corresponds to the Algebra course which means the difference is not noticeable, hence the course transformation did not have a significant impact in students’ attitudes towards the subject. This result (d-value .2276) confirms the statistical difference (p-value). The Algebra for computing course is the only first year, first semester course.

The size effect of both, Calculus I and II, confirms the statistical difference of the post/pre-test comparison (d-value over 1). Different from the results of the Algebra course, there is a notorious impact in the students’ attitudes after the implementation of the new version of the courses. These results are similar to the female and male segments.

**Decile segments analysis**

The global sample was divided into 2 groups, deciles 1–5 and decile 6–10, based on the Ministry of Education information and the post/pre-test results were contrasted. The results show that there is a significant positive impact in students’ attitudes in both groups after the course. Table 9 shows the pre/post-test means, the p and t-value (t-student) and the size effect for each group.

There are large size effects in both groups (over .8), however the effect is more notorious in the group with lower family income. This group obtained a lower mean score in the pre-test and their post-test results are higher than the decile 6–10 group. This means that the lower decile group is more affected by the course transformation than its counterpart.

**Discussion**

The results of this study indicate that students’ attitudes toward mathematics have undergone significant changes after the transformation of mathematics courses and the implementation of the flipped classroom approach designed to provide better opportunities for

| Table 8. Global and gender segments result in each transformed course. |
|---|---|---|---|---|
| Elements of Algebra for Computing | Pre-test mean | Post-test mean | p-value | t-value | Size effect (d-value) |
| Males | 3.6 | 3.7 | .328 | 1.011 | .276 |
| Females | 3.6 | 3.7 | .328 | 1.011 | .276 |
| Calculus I global | 3.5 | 4.1 | .001 | 4.373 | 1.337 |
| Males | 3.6 | 4.1 | .001 | 4.373 | 1.337 |
| Females | 3.6 | 4.1 | .001 | 4.373 | 1.337 |
| Calculus II overall | 3.7 | 4.2 | .000 | 5.647 | 1.365 |
| Males | 3.7 | 4.2 | .000 | 5.647 | 1.365 |
| Females | 3.7 | 4.2 | .000 | 5.647 | 1.365 |

Results for each category in a Likert scale from 1 to 5, N = 76 (Males = 56; Females = 20) (t-Student *Wilcoxon)

| Table 9. Results by family income (decile) classification. |
|---|---|---|---|---|
| Decile 1–5 (low family income) | Pre-test mean | Post-test mean | p-value | t-value | d-value |
| | 3.589 | 4.063 | .000 | 5.390 | 1.214 |
| Decile 6–10 (higher Family income) | 3.708 | 4.061 | .000 | 4.389 | 0.837 |
deep learning and increase student engagement (Bergmann & Sams, 2012). Although these results cannot be generalized due to the lack of control groups and the small size of the sample in this study, nevertheless, a trend in terms of the relationship between course transformation and students’ attitudes has been identified.

Similar studies in science and mathematics courses at an international level have reported improvements in the attitudes of the students towards STEM disciplines after the implementation of pedagogical changes (Kay & Kletskin, 2012) as well as improvements in terms of students’ satisfaction in various aspects of educational work (Jungić et al., 2015; Love et al., 2014; McGivney-Burelle & Xue, 2013; Strayer, 2012). Similarly, Julian (2017) found significant differences in students’ attitudes after the implementation of a project-based course, compared to the control group that followed a traditional course. The results obtained by Hodges and Kim (2013) also show significant changes in this area after the implementation of a motivational model, compared to a control group.

Different studies that have analyzed students’ attitudes toward different courses after the implementation of learning experiences based on the flipped classroom have obtained results similar to those of the present work. As an example, the results reported by Lopes and Soares (2018) show that there is a positive impact in students’ motivation and interest towards a flipped version of a financial mathematics course in comparison to the responses provided by students enrolled in a traditional version of it. These positive changes in satisfaction and attitudes levels have been attributed to the role-changes that take place on the part of both students and teachers inside and outside the classroom: the teacher becomes a facilitator of complex learning activities during in-class time, while flexible learning opportunities are available outside of the classroom in the form of educational videos (Cheng, Ka Ho Lee, Chang, & Yang, 2017; Jungić et al., 2015; Love et al., 2014; McGivney-Burelle & Xue, 2013; Reid, 2016; Ryan & Reid, 2016; Trogden, 2015).

In terms of gender differences, it was found in the courses Calculus I and Calculus II that there were significant differences on the part of both males and females in their attitudes toward mathematics after the implementation of course transformation approach. This gender comparison was not made in the case of the course Elements of Algebra for Computing, as there was only one female student in that course. The literature is not conclusive in this aspect. Köğce, Yıldız, Aydınlı, and Altındağ (2009), Mohamed and Waheed (2011), Mohd, Mahmood, and Ismail (2011), Nicolaidou and Philippou (2003) and Sarouphim and Chartouny (2017) have reported similar results after analyzing males’ and females’ attitudes toward mathematics in various educational contexts. For example, Mohamed and Waheed (2011) carried out a study involving 200 high-school students, using an instrument based on the developed by Fennema and Sherman (1976). Their results indicate there are no significant differences in the attitudes reported by males and females. However, according to Lee and Anderson (2015), there is a clear trend showing that male students express more positive attitudes toward mathematics compared to females. It may be inferred that females are less confident, suffer higher anxiety levels, have a weaker self-image, and are influenced by the gender stereotype that considers mathematics as a male domain. Similar results were obtained by Frenzel, Pekrun, and Goetz (2007), who attributed this gender
difference to women’s belief that females do not excel in mathematics, and a high subjective perception of value of what it means to be successful in mathematics.

Another relevant result deals with the difference found between the results of the pre- and post-tests in the category on male predominance in mathematics. The pre-test results in this category reveal a good appreciation of females’ role, while in the post-test results this trend is intensified, which means that there is a more gender-neutral perspective after the implementation of the courses. The literature has reported similar results. Kloosterman, Tassell, Ponniah, and Essex (2008) conducted a study involving 487 high-school students, focused on the perception of male predominance and using the instrument developed by Fennema and Sherman (1976). The researchers concluded that mathematics is perceived as a gender-neutral domain, and females held this opinion most strongly. Similar results were obtained by Forgasz, Leder, and Kloosterman (2004) and in the present study.

In the case of the overall results per course, only one course failed to show significant differences between the pre-test and the post-test results. This was the only first year, first semester course.

The results of the study, as well as the characteristics which reveal the socio-academic vulnerability of the students of the mathematics courses, are generally similar to those reported by Reid (2016), Ryan and Reid (2016) and Trogden (2015). These studies highlight the learning gains and the satisfaction levels of socio-academically vulnerable students after implementation of courses based on the flipped classroom model. The results of the present study show that students that come from socio-economical vulnerable families are more influenced by the pedagogical changes than those that come from families with higher incomes. This is an interesting aspect that needs to be further developed so as to confirm (or not) the results and/or to deepen in its implications.

Conclusions

The types of teaching activities and the role taken by the teacher and students working with active learning strategies, such as the flipped classroom, have an effect on students’ attitudes toward mathematics. This indicates that students’ attitudes can be influenced by the different teaching methods used at a university level. Transitioning towards a more student-centered teaching approach favors students’ attitudes towards mathematics positively, specially of those students that come from families with less access to resources (deciles 1–5). However, considering the limitations of this study, this needs to be further studied.

Another important aspect deals with the small effect produced in the category ‘Usefulness of the subject’s content’. This provides a relevant indication for the teachers and future analysis of the course as this specific transformation did not analyze in depth the role and the implications of the courses’ contents.

Even though the category related to male predominance in mathematics underwent the greatest positive change after implementation of student-centered learning methodologies, which reflects a more gender-neutral perspective, this information only helps us to confirm the necessity of active learning strategies as a tool to provide learning and learning demonstration opportunities for all. Course transformation help students to have more realistic ideas about their own skills.
There were no differences in the attitudes expressed by the males and females in the post-tests, with the exception of the course Elements of Algebra for Computing, in which the comparison could not be made. However, as there was a difference in the pre-test, we may infer that females’ and males’ attitudes toward university-level mathematics tend to homogenize after the implementation of teaching innovations based on the flipped classroom. This, and the results shown in the previous paragraph, shows a trend in terms of considering active learning as a tool that allows every student to learn.

Changing from a teacher-centered educational process to a student-centered approach, jointly with the changes brought about by course transformation would seem to have had an impact on several aspects of students’ learning process. However, it is necessary to conduct similar studies with larger samples of students and considering control groups to contrast the results.

The similarities between students’ initial socio-economic and academic characteristics reported in this work and in other published studies suggest the possibility of conducting research on the effects of teaching strategies based on active learning on disadvantaged students.

Finally, this work focuses only on changes in attitudes toward mathematics. Future studies could focus on general attitudes towards learning, academic self-efficacy, self-regulation in learning and other aspects which may benefit from the student-centered approach.

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References
Abeysekera, L., & Dawson, P. (2015). Motivation and cognitive load in the flipped classroom: Definition, rationale and a call for research. *Higher Education Research and Development, 34* (1), 1–14. doi:10.1080/07294360.2014.934336
Agencia Calidad de la Educación de Chile. (2015). Resultados TIMSS 2011 Chile. Estudio Internacional de Tendencias en Matemática y Ciencias. Retrieved from http://archivos.agenciaeducacion.cl/TIMMS_presentacion_BAJA.pdf
Agencia Calidad de la Educación de Chile. (2015a). Resultados educativos 2015: IX Región de la Araucanía. Retrieved from http://archivos.agenciaeducacion.cl/Araucania.pdf
Bergmann, J., & Sams, A. (2012). *Flip your classroom reach every student in every class every day.* Get Abstract Compressed Knowledge. doi:10.1111/teth.12165
Biggs, J. (2007). Teaching for quality learning at university third edition teaching for quality learning at university. Higher Education, 9, 165–203. doi:10.1016/j.ectp.2007.09.003
Chasteen, B.S.V., Perkins, K.K., Beale, P.D., Pollock, S.J., & Wieman, C.E. (2011). A thoughtful approach to instruction: Course transformation for the rest of US. Journal of College Science Teaching, 40(4), 24–30.
Chasteen, S.V., Pollock, S.J., Pepper, R.E., & Perkins, K.K. (2012). Transforming the junior level: Outcomes from instruction and research in E&M. Physical Review Special Topics - Physics Education Research, 8(2). doi:10.1103/PhysRevSTPER.8.020107
Cheng, X., Ka Ho Lee, K., Chang, E.Y., & Yang, X. (2017). The “flipped classroom” approach: Stimulating positive learning attitudes and improving mastery of histology among medical students. Anatomical Sciences Education, 10(4), 317–327. doi:10.1002/ase.1664
Cooper, I. (2013). The waiting time: Student perceptions of gender bias in middle school mathematics. Victoria, Canada: University of Victoria.
Crouch, C.H., & Mazur, E. (2001). Peer instruction: Ten years of experience and results. American Journal of Physics, 69(9), 970–977. doi:10.1119/1.1374249
de Araujo, Z., Otten, S., & Birisci, S. (2017). Mathematics teachers’ motivations for, conceptions of, and experiences with flipped instruction. Teaching and Teacher Education, 62, 60–70. doi:10.1016/j.tate.2016.11.006
DEMRE. (2018, October 11). Tabla de Transformación de Puntajes - Proceso de Admisión 2018. In DEMRE, Retrieved from https://psu.demre.cl/proceso-admision/factores-seleccion/tabla-transformacion-puntajes-mat-p2018
Fennema, E., & Sherman, J.A. (1976). Fennema-Sherman mathematics attitudes scales: Instruments designed to measure attitudes toward the learning of mathematics by females and males. Source: Journal for Research in Mathematics Education, 7(5), 324–326. doi:10.2307/748467
Fink, L.D. (2003). Creating significant learning experiences: An integrated approach to designing college courses. San Francisco: Wiley.
Forgasz, H.J., Leder, G.C., & Kloosterman, P. (2004). New perspectives on the gender stereotyping of mathematics. Mathematical Thinking and Learning, 6(4), 389–420. doi:10.1207/s15327833mtl0604_2
Freeman, S., Eddy, S.L., Mcdonough, M., Smith, M.K., Okoroafor, N., Jordt, H., & Wenderoth, M.P. (2014). Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences, 111(23), 8410–8415. doi:10.1073/pnas.1319030111
Frenzel, A.C., Pekrun, R., & Goetz, T. (2007). Girls and mathematics- A “hopeless” issue? A control–Value approach to gender differences in emotions towards mathematics. European Journal of Psychology of Education, 22, 497–514. doi:10.1007/BF03173468
 Hodges, C.B., & Kim, C. (2013). Improving college students’ attitudes toward mathematics. TechTrends, 57(4), 59–66. doi:10.1007/s11528-013-0679-4
Instituto Nacional de Estadísticas. (2017). Encuesta Suplementaria de Ingresos 2010–2015 (pp. 1–28). Santiago, Chile. Rep. INE.
 Julian, P. (2017). The effects of a project-based course on students ’Attitudes toward mathematics and students ’Achievement at a two-year college. The Mathematics Enthusiast, 14(1), 508–516.
Jungič, V., Kaur, H., Mulholland, J., & Xin, C. (2015). On flipping the classroom in large first year calculus courses. International Journal of Mathematical Education in Science and Technology, 46(4), 508–520. doi:10.1080/0020739X.2014.990529
Kay, R., & Kletskin, I. (2012). Evaluating the use of problem-based video podcasts to teach mathematics in higher education. Computers Y Education, 59(1), 619–627. doi:10.1016/j.compedu.2012.03.007
Kloosterman, P., Tassell, J., Ponniah, A.G., & Essex, N.K. (2008). Perceptions of mathematics and gender. School Science and Mathematics, 108, 149–162. doi:10.1111/j.1949-8594.2008.tb17821.x
Köge, D., Yildiz, C., Aydin, M., & Altundağ, R. (2009). Examining elementary school students’ attitudes towards mathematics in terms of some variables. *Procedia-Social and Behavioral Sciences*, 1(1), 291–295. doi:10.1016/j.sbspro.2009.01.053

Lee, K., & Anderson, J. (2015). Gender differences in mathematics attitudes en coeducational and single sex secondary education. *En mathematics education in the margins* (38th ed., pp. 357–364). Sunshine Coast: MERGA.

Lopes, A.P., & Soares, F. (2018). Perception and performance in a flipped Financial Mathematics classroom. *International Journal of Management Education*. doi:10.1016/j.ijme.2018.01.001

Love, B., Hodge, A., Grandgenett, N., & Swift, A.W. (2014). Student learning and perceptions in a flipped linear algebra course. *International Journal of Mathematical Education in Science and Technology*, 45, 317–324. doi:10.1080/0020739X.2013.822582

McGivney-Burelle, J., & Xue, F. (2013). Flipping Calculus. *Primus*, 23(5), 477–486. doi:10.1080/10511970.2012.757571

MINEDUC. (2014, August 25). Resolución exenta Nº 5518. Retrieved from http://dfi.mineduc.cl/usuarios/MECESUP/File/2014/InES/2014_pre/REX_5518_BasesFDI-PM2014.pdf

Mohamed, L., & Waheed, H. (2011). Secondary students’ attitude towards mathematics in a selected school of maldives. *International Journal of Humanities and Social Science*, 1(15), 277–281.

Mohd, N., Mahmood, T., & Ismail, M.N. (2011). Factors that influence students in mathematics achievement. *International Journal of Academic Research*, 3(3), 49–54.

Morrison, G.R., Ross, S.M., & Kemp, J.E. (2007). Designing effective instruction. New Jersey: Wiley.

Moya, B., Turra, H., & Chalmers, D. (2018). Developing and implementing a robust and flexible framework for the evaluation and impact of educational development in higher education in Chile. *International Journal for Academic Development*, 1–15. doi:10.1080/1360144x.2018.1555757

The National Center for Academic Transformation. (2014). The CAT viewpoint. Retrieved from http://www.thencat.org/Newsletters/Apr14.html.

Nicolaïdou, M., & Philippou, G. (2003). Attitudes towards mathematics, self-efficacy and achievement in problem solving. European Research in Mathematics III. Bellaria, Italy: University of Pisa.

OCDE. (2016). *Resultados Clave Pisa 2015* (pp. 1–15. 6). Organización Para La Cooperación Y El Desarrollo Económico. Paris, France. doi:10.1787/9789264266490-en

OECD. (2017). *Education at a Glance 2017: OECD Indicators*. Paris: Author.

Peña-Ayala, A. (2018). *Learning analytics: Fundaments, applications, and trends a view of the current state of the art to enhance e-learning* (Vol. 1, 1st ed.). Cham: Springer International Publishing.

Piaget, J. (1926). The language and thought of the child. *Psychological Bulletin*, 24. doi:10.1037/h0067537

Pollock, S., & Finkelstein, N. (2008). Sustaining educational reforms in introductory physics. *Physical Review Special Topics, Physics Education Research*, 4. doi:10.1103/PhysRevSTPER.4.010110

Reid, S.A. (2016). A flipped classroom redesign in general chemistry. *Chemical Education Research and Practice*, 17(4), 914–922. doi:10.1039/c6rp00129g

Rein, K.S., & Brookes, D.T. (2015). Student response to a partial inversion of an organic chemistry course for non-chemistry majors. *Journal of Chemical Education*, 92(5), 797–802. doi:10.1021/ed500537b

Ryan, M., & Reid, S. (2016). Impact of the flipped classroom on students performance and retention: a parallel controlled study in general chemistry. *Journal of Chemical Education*, 93 (1), 13–23. doi:10.1021/acsjchemed.5b00717

Sarouphim, K., & Chartouny, M. (2017). Mathematics education in Lebanon: Gender differences in attitudes and achievement. *Educational Studies in Mathematics*, 94(1), 55–68. doi:10.1007/s10649-016-9712-9
Strayer, J.F. (2012). How learning in an inverted classroom influences cooperation, innovation and task orientation. *Learning Environments Research, 15*(2), 171–193. doi:10.1007/s10984-012-9108-4

Tapia, M., & Marsh, G. (2004). An instrument to measure mathematics attitudes. *Academic Exchange Quarterly, 8*, 16–21.

Trigwell, K., & Prosser, M. (2004). Development and use of the approaches to teaching inventory. *Educational Psychology Review, 16*(4), 409–424. doi:10.1007/s10648-004-0007-9

Trogden, B. (2015). The view from a Flipped Classroom: Improved student success and subject mastery in Organic Chemistry. In A. Scheg (Ed.), *Implementation and critical assessment of the flipped classroom experience*. Hershey, PA: Information Science Reference. 119-138.

Vygotsky, L.S. (1978). *Mind in society*. Cambridge, Massachusetts: Harvard University Press. (Original manuscripts [ca. 1930-1934]).

Wieman, C., & Perkins, K. (2005). Transforming physics education. *Physics Today, 58*, 36–41. doi:10.1063/1.2155756