Flipped Classroom in the UCSC School of Engineering: Enhancing in-class time

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ABSTRACT

In this work we present a peer-based Flipped Classroom model used by our UCSC School of Engineering Flipped Classroom teaching community. This model considers three essential components: technological resources for outside class learning, collaborative actitivites for in-class work, and a virtual learning environment to enrich the formative actions and strengthen asynchronous communications among the educational agents. We present application of this model to the Strength of Materials course of the Civil Engineering program and to the Programming Laboratory I of the Computer Science program. Our results show improvements in student performance and in teacher performance evaluations, where the use of emerging methodologies is positively valued. These results feed a virtuous cycle, as they turn out to be a motivating force for more faculty members to improve their practices and to incorporate active learning methodologies.

KEYWORDS

Active learning, flipped classroom, pedagogical competences, Standards: 5, 6, 7, 8, 10, 11.

INTRODUCTION

From 2008 to 2010, the School of Engineering of the Universidad Católica de la Santísima Concepción (UCSC) underwent a comprehensive curricular reform of its five undergraduate engineering programs, driven by the results of diagnostic studies that showed, among other problems: inflexible curricula having too many courses emphasizing technical knowledge acquisition rather than personal and interpersonal skills development, and lack of student motivation in their field of study (Loyer et al., 2011). This curricular reform was based on the CDIO initiative, which defines a framework for engineering education that emphasizes engineering fundamentals by conceiving, designing, implementing and operating real-world products, processes and systems. Its main resources are the CDIO Syllabus and the CDIO Standards (Crawley et al., 2014). As a result of this curricular reform, all undergraduate engineering programs at UCSC incorporated a student-centered teaching and learning approach, supported by the UCSC teaching and learning centre. This centre provides faculty training to aid the development of teaching skills (CDIO standard 10) and to boost innovations in their teaching and learning processes. It offers a teaching skills program which promotes both the implementation of active learning (CDIO Standard 8) and collaboration among instructors to improve teaching competences. Participation in teaching communities has been an effective mechanism for supporting instructors while conceiving, designing, implementing and assessing pedagogical innovations. The Flipped Classroom teaching community was created in 2016 and includes members of the Computer Science and Civil Engineering departments. Its peer-based model, described in greater detail later, provides instructors with a peer framework to support the use of active learning and information technologies in the classroom focusing on problem solving and collaborative work.

In this article we describe two teaching innovations that use the flipped classroom approach, implemented in the Strength of Materials course of the Civil Engineering program and the Programming Lab I of the Computer Science program. We present results about personal and interpersonal skills and academic performance, as well as future challenges for the Flipped Classroom teaching community. This work was funded in part by UCSC institutional grants for enhancing teaching and learning processes FAD[1] 11/2016 and FAD 06/2017.

FRAMEWORK

Recent works define Flipped Classroom as a teaching and learning model which dedicates the time spent in the classroom to practical and cooperative activities that facilitate the acquisition, practice and application of the theoretical knowledge, and transfers individual study to autonomous activities outside the classroom (Karabulut-Ilgu et al. 2017; Lee, Lim & Kim, 2017; Observatorio de Innovación Educativa, 2014; Tourón & Santiago, 2015). In this model, students take active learning roles and instructors guide and facilitate the learning process. This allows students to understand, analyze and apply information, and fosters their cognitive skills development (Ávila & Torres, 2014; Kong, 2015).

From a methodology implementation perspective, Hamdan et al. (2013) have identified a continuous learning assessment process which emphasizes permanent and on-time feedback to students. This requires the creation of flexible learning environments that go beyond the traditional physical and time boundaries of a class (Burbules, 2012). To this purpose, Tucker (2012) recommends using video for student learning outside class and emphasizes the importance of integrating the contents seen in the videos with the activities to be developed in class, so that they can effectively deepen and apply those contents.

The Flipped Classroom methodology is applicable to different educational contexts, showing improvements in the classroom environment and in learning outcome achievement levels, as well as increased student motivation and involvement in their learning process. Also, both instructors and students value positively the efficient use of in-class time and the fostering of autonomous activities that leverage information and communication technologies (Ávila & Torres, 2014; Chen et al., 2014; Observatorio de Innovación Educativa, 2014; Şengel, 2016).

Flipped Classroom Model

The peer-based flipped classroom model used by our Flipped Classroom teaching community considers three essential components of the Flipped Classroom methodology: the use of technological resources such as videos for outside class learning, collaborative activities for in-class work, and a virtual learning environment to enrich the formative actions and strengthen asynchronous communications among the educational agents. Figure 1 illustrates this flipped classroom model, which is based on Basso et al. (2017). It shows the five relevant actors: the instructor, the student, the media support group in charge of class video development, the pedagogical support group, formed by members of the teaching community, and an online

[1] FAD: Fondo de apoyo a la docencia.

teaching assistant in charge of answering student questions and monitoring their outside-the-classroom activities. It should be noted that the pedagogical support group is fundamental when helping an instructor unfamiliar with the Flipped Classroom methodology, and has only a sporadic advisory role with more experienced instructors.

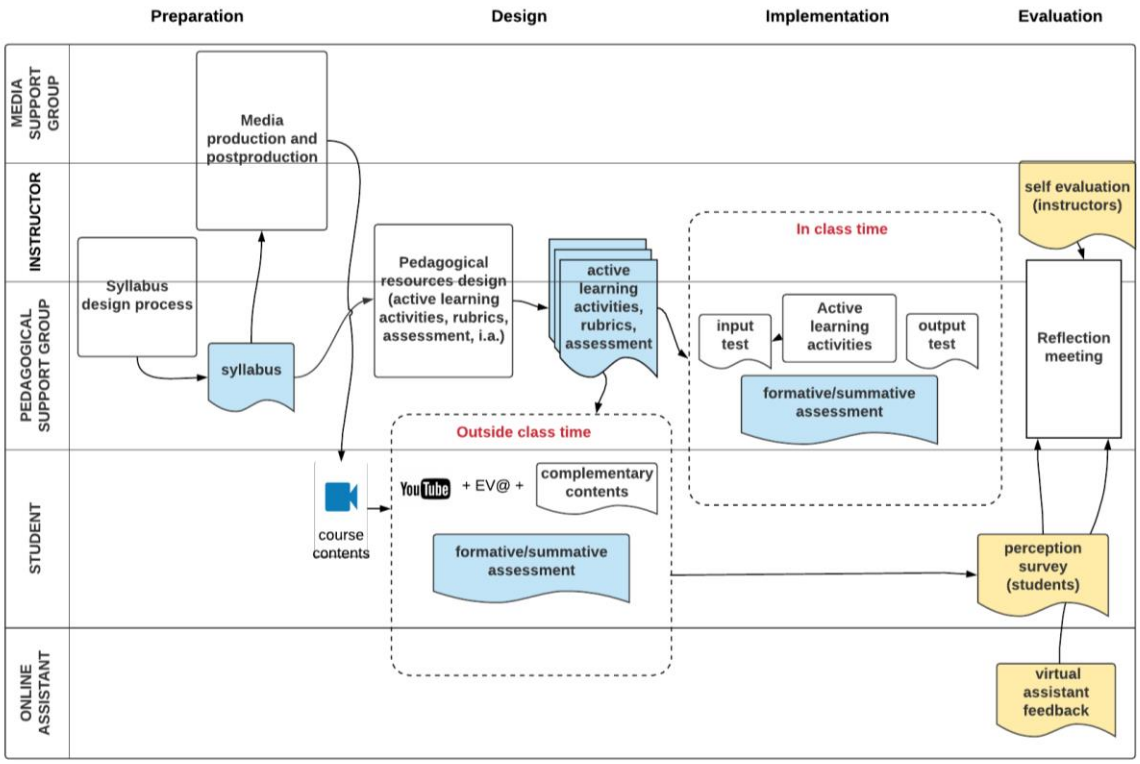

Figure 1. Flipped classroom model applied in Strength of materials course

Figure 1 shows each actor's participation in the model's four phases: preparation, design, implementation and evaluation. The square boxes indicate the model's processes, while the document icons show the artifacts associated to them. It also shows student activities outside the classroom and inside the classroom, organized in didactic sequences. Following Tobón et al. (2010), we define a didactic sequence as an articulated set of learning and assessment activities which, under instructor guidance, must be followed to achieve an educational goal.

The Preparation phase includes syllabus development and course media production and postproduction. The Design phase involves the development of the different pedagogical resources such as active learning activities and rubrics. The Implementation phase of the model is where students work in teams to solve problems during class time applying the disciplinary knowledge acquired outside the class (CDIO Standard 7). The Evaluation phase includes reflection meetings where instructors and the pedagogical support group discuss the results of student activities and the feedback gathered from all relevant actors for continuous improvement of the teaching and learning process (CDIO Standard 11). An important point is students continually receive feedback from formative and summative assessment from the instructor and the online assistant whether they are performing outside or in-class activities of the weekly didactic sequence.

In the following sections, we present the didactic sequences used in the Strength of Materials course and in Programming Lab I to promote active learning.

CASE 1. STRENGTH OF MATERIALS COURSE

In this case, we consider the Strength of Materials course taught during the 4-week summer term from December 18th, 2017 to January 12th, 2018 to 16 third-year Civil Engineering students. Two professors with experience in the field were in charge of the course, supported by three members of the Flipped Classroom teaching community with experience in active learning. The course was taught Monday through Friday in 4-hour modules, and it demanded the students' total dedication. The course syllabus describes student activities designed for individual learning outside the classroom, as well as those designed for in-class work. These activities' weekly structure is replicated week by week in order to facilitate the implementation of the didactic sequence, which is shown in Figure 2.

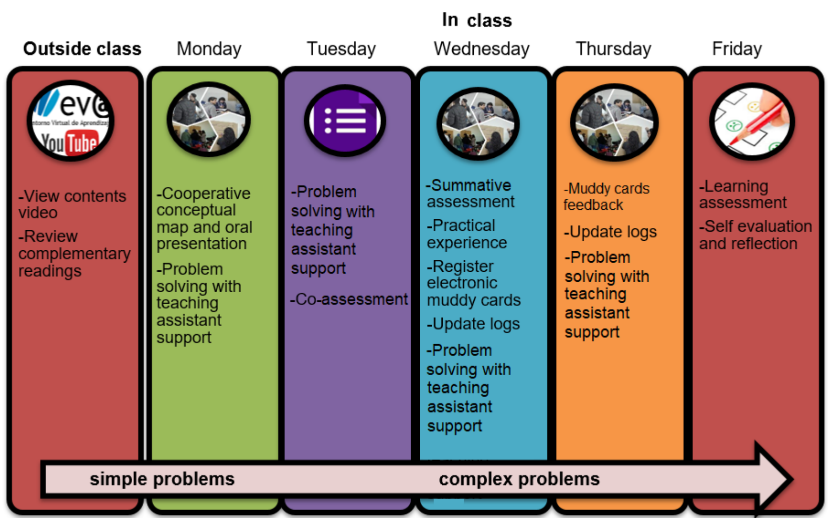

Figure 2. Didactic sequence for outside and in-class Strength of Materials course work.

This structure follows a progression in the learning activities complexity level. In other words, it starts with the use of superficial thinking skills (Bloom Taxonomy) such as the recognition and explanation of main concepts through concept maps, progressing to higher cognitive levels, by the resolution of simple and increasingly complex problems, and the analysis and application of practical experiences with concrete material. During the in-class sessions, students carry out different learning activities using active methodologies in teams mediated by the instructor (López, 2013; De Miguel, 2005). Diverse strategies such as: drawing concept maps, oral presentations, solving problems of different complexity levels, individual logs and practical experiences are applied so as to achieve meaningful learning (Osses & Jaramillo, 2008; Perdomo, 2016).

To strengthen the learning process, several pedagogical resources such as videos, readings, proposed and resolved exercise guides designed for individual outside class work are set out in an institutional moodle-based virtual learning environment. It also includes an asynchronous forum for student queries and a space for students to give evidence of the achieved learning outcomes, based on each week's practical activity with concrete material.

From an evaluation standpoint, the students' learning process is continuously monitored through quizzes, practical activitiy reports and exams. The in-class work methodology promotes immediate teacher-student and student-student feedback and continuous reflection by all actors. This reflection is carried out systematically during implementation by using various techniques, such as muddy cards, leading questions, peer feedback in problem solving, among others. A student survey is applied in the evaluation stage to collect information about their preferences and perceptions regarding the type of activities carried out outside and inside the classroom (McNally et al., 2017).

Results

Figure 3 shows the results of this student survey regarding students' preferences. Most students lean towards classes using a b-learning (blended learning) approach (56%), priviledging practical over theoretical work (62%) and in which they can actively participate and learn in collaboration with others (94%). A significant majority of students (81%) recognize the importance of having resources such as readings, videos or other complementary material in the learning process.

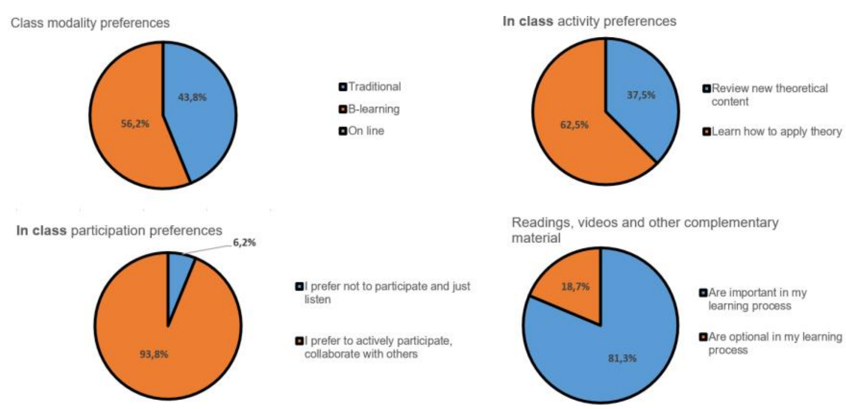

Figure 3. Students' preferences regarding the type of outside and in-class work

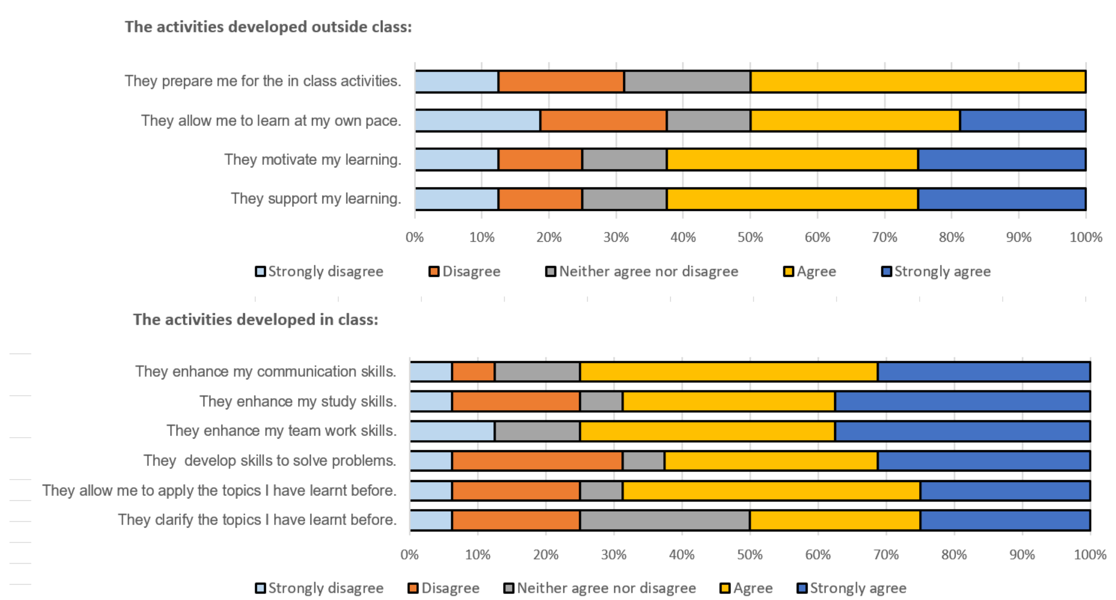

Figure 4. Students' perceptions regarding outside and in-class activities

Figure 4 shows the results of this student survey regarding students' perceptions. More than 50% of students agree that the activities developed outside class time motivate and support their learning process. Students positively recognize that the in-class activities improve their communication skills and teamwork (75%). They also recognize that this methodology allows them to put into practice what they have learned and boosts their study skills (69%).

CASE 2. PROGRAMMING LAB I

In this case, we consider the two spring term versions of the Programming Lab I course taught to first-year Computer Science students from August to December of 2016 and 2017. A professor with experience in the field and in active learning methodologies was in charge of the course. The course demanded 5 hours per week of in-class time during 16 weeks. These two versions of the Programming Lab I use ADPT++, an active learning method described by Martínez & Muñoz (2017) which adds flipped classroom strategies to the original ADPT (Analysis - Design - Programming – Testing) method described by Martínez and Muñoz (2014) (CDIO Standard 5). Figure 5 shows the didactic sequence for this lab, where stage 0 corresponds to outside class activities, where students must watch videocasts allocated in a Youtube channel covering the theoretical fundamentals to be applied in classes, as well as review complementary readings. Stages 1 to 3 are related to in-class activities. In stage 1, in-class work begins with a formative test developed by means of a Google Forms tools to detect whether students have previously seen the videos and to make sure they are ready for other in-class activities. In stage 2, students follow the ADPT sequence, which consists of solving a problem in teams and generating the deliverables for the ADPT stages. This activity is assessed using two specially designed rubrics: (i) a ADPT process-product rubric, oriented toward assessing learning outcomes associated to solving problems applying disciplinary knowledge, and (ii) a rubric designed to assess issues related to teamwork. Finally, in stage 3 the instructor gives students feedback reinforcing theoretical aspects with a close reflection activity guided by conceptual questions.

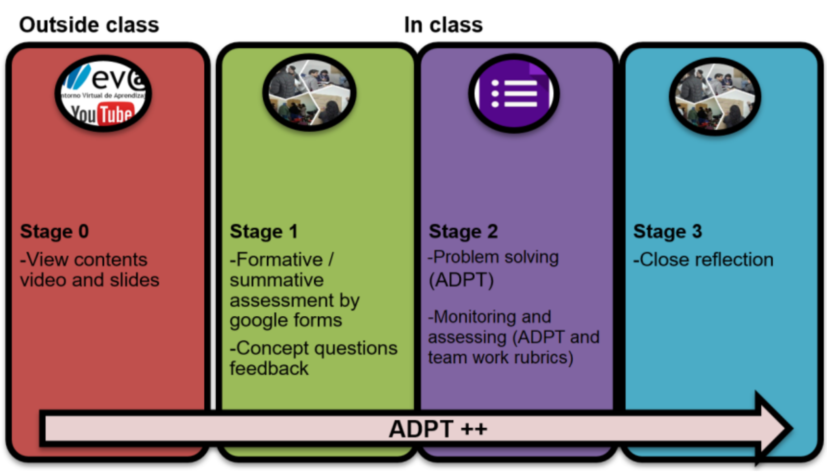

Figure 5. Didactic sequence outside and inside class Programming Lab I work

Results

In this lab, students follow 3 didactic sequences per semester and their grades are calculated assigning weights of 80% to process-product performance and of 20% to teamwork performance. Figures 6, 7, and 8 show grade results for the Programming Lab I course in terms of the student performance in Problem 1, Problem 2 and Problem 3, respectively. We must note that the ADPT active learning strategy was first applied in 2013, while the ADPT++ strategy was followed in 2016 and 2017. Results show an improvement in student performance starting in 2013, seen as a of the score boxes toward higher scores.

Figure 6 shows that grade dispersion for Problem 1 is high regardless of the methodology used. In the case of year 2017, the large grade dispersion for ADPT++ can be explained by noting that 20% of students did not watch the video before class (Source: Google Analytics). However, by the time students follow the second didactic sequence in Problem 2, grade averages are higher and grade dispersion is much lower for both the ADPT and ADPT++ active learning methods. When students follow the third didactic sequence for Problem 3, which is more challenging, our preliminary results show that the use of Flipped Classroom in ADPT++ results in much better average scores and lower grade dispersion.

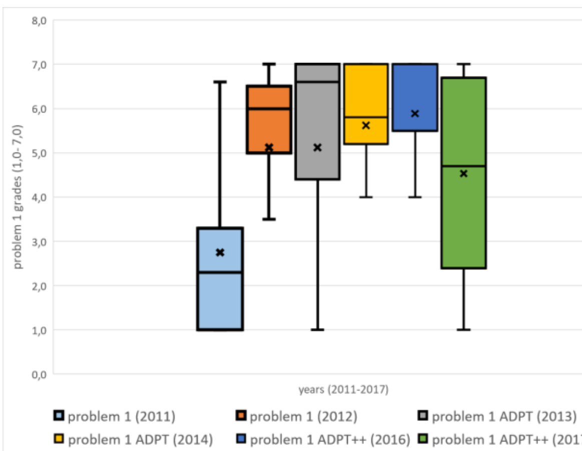

Figure 6. Problem 1 grades, 2011 to 2017

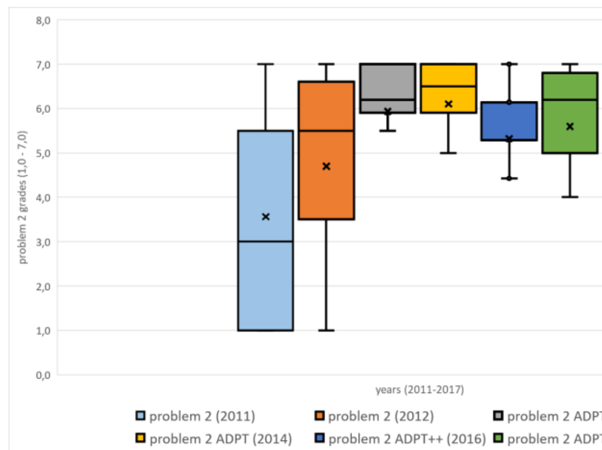

Figure 7. Problem 2 grades, 2011 to 2017

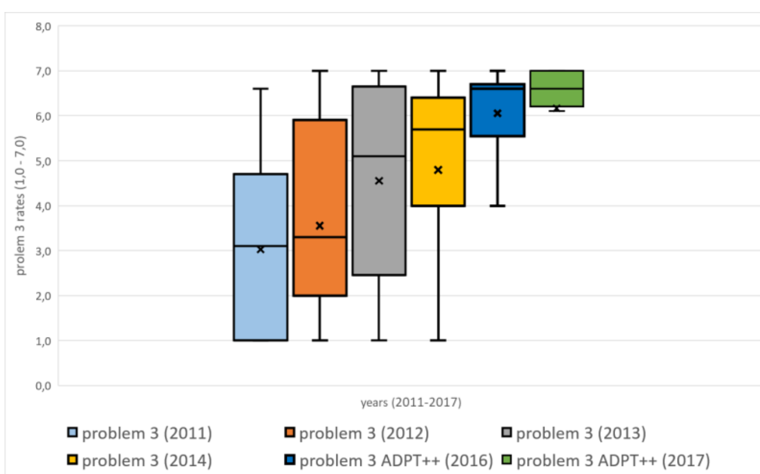

Figure 8. Problem 3 grades, years 2011 to 2017.

Figure 9 shows results from the teacher performance survey given every six months to students in all courses, which allows evaluating different aspects of teaching. In this case, only those items related to activities that facilitate self-learning, promotion of autonomous and collaborative work, and incentive to reflection on learning are shown. In all of them, positive opinions exceed 80%, reaching in some cases 100%.

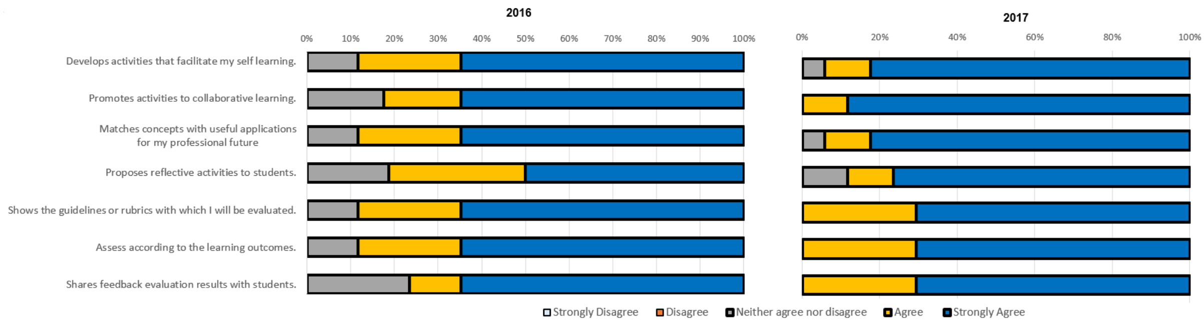

Figure 9. Teacher performance survey results (2016-2017).

DISCUSION AND CONCLUSIONS

Our preliminary results lead us to believe that the use of Flipped Classroom methods increases in-class student participation, because of their commitment to outside class work. The inclusion of practical activities also positively impact students' active participation and collaborative learning (CDIO standard 8). This leads to metacognition in students by making them aware of their learning process, and stimulates reflection in faculty about their teaching.

The Flipped Classroom model presented here is a generic and replicable proposal that can be applied to both regular and intensive courses in any disciplinary area in Higher Education. The model is a framework for promoting educational innovation and thus generating a positive impact on student learning. Even though the model relies on access to information technologies and 70% of our students belong to the first three quintiles, the educational resources are easily accessible by using low cost ubiquitous devices such as cellphones, tablets and notebooks available to most 21st century students (CDIO Standard 6).

Our results for the Strength of Materials course show that the incorporation of the Flipped Classroom methodology increases students' motivation and generates a greater student commitment to their learning process. This is consistent with Chen et al. (2014), in particular, with the positive student evaluation of the experience, in which they highlight the possibility of seeing the contents again and again through video and the development of in-class dynamic activities that allow them to clarify doubts and strengthen their learning.

Regarding the methodological innovations applied in the Programming Lab I during the last 4 years, the academic performance of the students has improved consistently. At the same time, the opinions students have of the teachers' performance have also improved. This is consistent with the teachers' self-perception about their pedagogical practices, motivating them to continue incorporating innovations that favor student learning (CDIO standard 10).

Some of the lessons learned from these implementations are:

- The pedagogical support given by the Flipped Classroom teaching community to the instructor is crucial. The pedagogical team should observe the instructor's practical in-class sessions the first time the model is implemented, in order to give him timely feedback, fostering reflection and allowing him to improve his pedagogical practice.
- It s more effective to use videos of maximum 10 minutes and to have reading materials of maximum 20 pages, which are more appropriate to the times students actually dedicate to audiovisual material review and autonomous study.

- The instances of communication between educational agents should be systematized so that they can evaluate the implementation and collect information on its advantages and difficulties. This allows adjustments and improvements to the educational processes, encouraging more reflective teaching and promoting a quality education.
- Including a media support group helps overcome the initial preparation time for creating high quality videos, which is a well known limitation of the flipped classroom method.

Our future research challenges are: designing effective mechanisms to allow transferring expertise to instructors less experienced in the implementation of b-learning methods; data gathering to determine this strategy's suitability to generate deep and durable learning; and measuring the metodology's impact on teaching competences via a phenomenological study.

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