ADPT++
Technology-Based Combined Strategy for Problem Solving

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***Abstract* — The growth in student enrollment in the engineering programs, low student motivation and poor passing rates in first years' students in a Computer Science undergraduate program have demanded the incorporation of active learning strategies into the classroom in order to improve problem solving skills. This article describes a proposal and preliminary results of incorporating technology-based teaching strategies. The Analysis-Design-Programming-Testing (ADPT) teaching strategy was applied in the classroom, combined with a Flipped Classroom (FC) methodology. Preliminary results show clear benefits related to the availability of support media resources, increased time dedicated to solving problems in the classroom, and the creation of a collaborative and challenging classroom environment.**

Keywords-flipped classroom; ADPT, engineering education.

I. INTRODUCTION

In the last 10 years, Chile's social and educational context has generated an explosive growth in student enrollment in the engineering programs of the Universidad Católica de la Santísima Concepción (UCSC). This increase in the number of students has required optimizing the use of time in the classroom, and dedicating more time to student-centered activities supervised by an instructor.

This article presents a learning strategy that combines reverse teaching, also known as Flipped Classroom [1], and the Analysis-Design-Programming-Testing technique (ADPT) [2]. This teaching approach enables transferring part of the learning process to out-of-the-classroom activities by the use of videocasts (short videos allocated in a web-based platform), which introduce the theory and cognitive knowledge associated with the topic under study. In general terms, an instructor leads the in-classroom activities focusing on practical tasks designed to reinforce the theory and generate active and deeper learning in students.

Besides freeing in-classroom time by transferring the theoretical aspects of the course to out-of-classroom autonomous work, the use of videocasts allow students to recall those theoretical contents whenever and wherever they are.

The use of Information and Communications Technologies (ICTs) and the implementation of practical activities increased students' motivation and commitment to the assigned tasks. This new student disposition toward learning resulted in improved academic performance.

The remainder of the article is organized as follows: the next section presents the academic context where the proposed strategy for problem solving was applied. Section 3 describes the teaching and learning strategies supporting this work, which include Problem Based Learning (PBL), FC and ADPT. Section 4 shows a hybrid proposal that combines these technologies and the ADPT strategy which we have called ADPT++ (the name was chosen as a programming joke). Preliminary results are shown in Section 5. Finally, Section 6 presents our conclusions and outlines future work.

II. ACADEMIC CONTEXT

In 2011, the UCSC School of Engineering implemented a comprehensive curricular renovation of its five engineering programs based on the "Conceive, Design, Implement and Operate" (CDIO) initiative [3], which defines an educational framework for engineering programs helping identify program goals and associated learning outcomes, and promotes integrated curriculum design. Its main resources are the CDIO Syllabus and the CDIO Standards [4]. The CDIO Syllabus summarizes and organizes a set of engineering knowledge, personal and professional skills and attributes, and interpersonal skills. The 12 CDIO Standards serve as guidelines for educational program reform and evaluation, and provide a framework for continuous improvement. They address program philosophy (Standard 1), curriculum development (Standards 2, 3 and 4), design-build experiences and workspaces (Standards 5 and 6), new methods of teaching and learning (Standards 7 and 8), faculty development (Standards 9 and 10), and assessment and evaluation (Standards 11 and 12).

Among other issues, the curricular renovation addressed the problem of low motivation in first years' students by incorporating activities aimed at familiarizing students with their future professional role. Also, the new curricula incorporated the implementation of a student-centered teaching and learning approach, which was strongly supported through active learning methodologies (CDIO Standard 8), such as the strategies described in this work.

As a result of the curricular renovation, all engineering programs at UCSC were modified to include teaching methodologies based on problem solving and collaborative work. In these activities, students analyze different kind of engineering problems and design solutions following a structured approach according to their level of knowledge and training. and

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III. Teaching and Learning Strategies

This section describes methodologies and strategies on which the proposal of this paper is based.

A. *Problem-Based Learning*

Problem-Based Learning (PBL) is defined as an active learning method in which teams of students learn by solving relevant problems and reflecting on their experiences [5]. Problems must involve a cognitive conflict, and must be challenging enough to motivate students to find a solution and, at the same time, must be complex enough so that their solution requires cooperation among all team members. The instructor must act as a facilitator, making the problem a real team challenge to be solved and thus preventing students from just dividing up the work. In this way, PBL not only helps students learn the specific subject of the course, but it also helps develop teamwork, autonomous learning, information searching from diverse sources, problem solving, decision making, oral and written communications, among others.

B. *Flipped Classroom*

At the beginning of the 21st century, methodological innovations known as "reverse classes" have been documented in the educational field in which what was taught in the classroom was now learnt outside of it, thus implying only a modification of the place where the activities were carried out [6][7]. Recent works define the Flipped Classroom (FC) [1][8][9] as a teaching/learning model that transfers the individual learning work to autonomous out-of-class activities and dedicates the in-class time to practical and cooperative activities that facilitate the acquisition, practice and application of the theoretical knowledge. This teaching model makes it possible for students to understand, analyze and apply information, enhancing the development of their cognitive skills [10][11][12]. From this perspective, this model considers learning at the center of the training process, with students taking an active and leading role and where instructors mainly guide and facilitate learning.

From a methodology implementation standpoint, Hamdan et al. [13] has identified a continuous process of learning assessment with an emphasis on permanent and on-time feedback to students as a key aspect to consider. Hence, flexible learning environments must be created that go beyond the traditional physical and time boundaries of a class [14]. On the other hand, Tucker [15] suggests the use of video for student learning outside the classroom and emphasizes the importance of integrating the contents seen in the videos with the activities to be developed in the classroom, so that they can effectively deepen and apply those contents.

As for the positive effect of the use of FC in the teaching and learning process, Brame [16] indicates that this strategy allows the student to have the educational material prior to the class and its revision at any time and place. In addition, the development of student-centered activities in the classroom encourages collaborative work, peer learning and greater student engagement in learning. Finally, it enables instructors to give feedback in real time, allowing them to recognize achievement, evaluate progress and thus take improvement actions. Although this methodological strategy has large benefits in the educational process, it is necessary to consider its limitations such as the low quality of videos, differences in students' autonomous work capacity, problems in the design of activities for classroom work and difficulties in synchronous and asynchronous communications between instructor and students, e. g., when fielding questions [17].

The Flipped Classroom methodology is applicable to different educational contexts, with evidence showing improvements in the classroom work environment and increased student motivation and involvement in their learning process [18]. Additionally, improvements in the learning outcomes achieved by the students have been documented [19][20]. At the same time, instructors and students both value positively the maximization of in-the-classroom time and the fostering of autonomous activities that leverage information and communication technologies [19][21].

C. *Analysis-Design-Programming-Testing strategy*

Analysis-Design-Programming-Testing (ADPT) is an active learning strategy based on a PBL approach. It is composed of the four stages of the classical software development method, also called the waterfall model [2].

Even though the ADPT method was proposed to support teaching computer programming, it includes generic elements of both PBL and collaborative learning methods. ADPT also encourages collaboration with other teams, can be applied to solving different kinds of problems, from well-structured simple problems to ill-structured relevant problems.

As shown in Figure 1, each team of students is assigned a problem to be solved using ADPT, and has to generate deliverable documentation for each stage. This process is guided and supervised by an instructor and teaching assistants. In this case, the learning outcomes are assessed through the results generated by the team for each of the stages. The analysis stage outcome is an analysis document including a description of inputs, processes, outputs, and constraints. The design stage has as output a flow diagram or pseudocode that represents the algorithm to solve problem. Next, the programming stage has as its deliverable the source code and finally, the test stage outcomes are a test plan and the results obtained of its application. Figure 1 shows the four ADPT stages and deliverables for each one.

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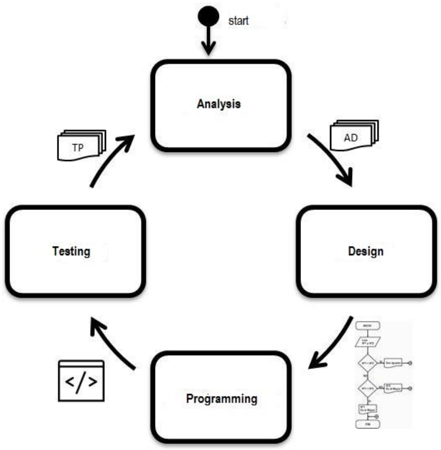

Figure 1. ADPT traditional sequence.

IV. ENHANCED ADPT STRATEGY: ADPT++

Even though other experiences that describe the implementation of Flipped Classroom strategies also encourage in-class active work [1][16], our proposal is of interest because we use this strategy to comply with the CDIO active learning standard and because there are few documents describing the implementation of flipped classroom strategies in the engineering domain, particularly in computer science, in Chile. This article presents an improved teaching and learning strategy that combines ADPT with the Flipped Classroom methodology, including elements of both PBL and collaborative learning methods. This strategy, called Enhanced ADPT or ADPT++, is described graphically in Figure 2.

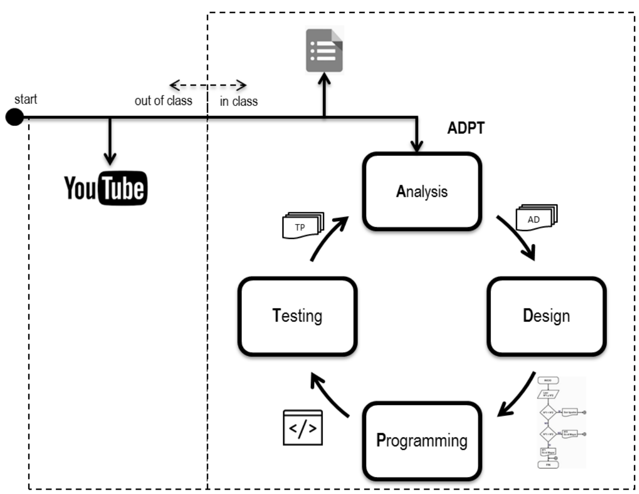

Figure 2. ADPT++ sequence.

The basic structure of this strategy involves the use of videocasts allocated in a Youtube channel which cover the theoretical fundamentals to be applied in classes. The cognitive learning outcomes associated to the contents of the videos are assessed by a formative test developed by means of a Google Forms tools at the beginning of each class. The purpose of this test is to detect whether students have previously viewed the videos and whether they were able to retain the minimum concepts needed to address the problem proposed in class. Then, the class focuses only on performing practical work based on the theoretical concepts presented in the video. Finally, the expected learning outcomes are assessed through the deliverables generated by the team for each of the stages of the ADPT method and through a perception survey.

Figure 3 details the four-step method used to guide the work involved in producing the videos and in designing the corresponding in-class didactic sequences.

Step 1 is performed by the lecturer responsible for the course with support from the program committee. Step 2 is supported by a technical crew which edits and customizes the video. Steps 3 and 4 correspond to the implementation and evaluation of the strategy. Steps 1 and 2 were performed one semester before the intervention with the students actually took place (Steps 3 and 4).

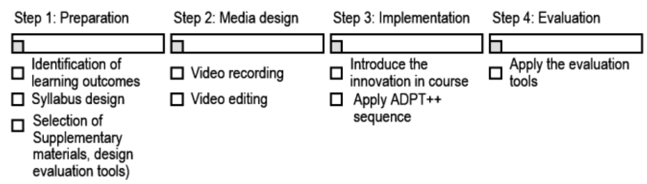

Figure 3. Workflow method.

This classroom strategy was applied to the Programming Lab I course during the Spring term of 2016 (from August to December). This course meets for 5 hours a week and corresponds to a second semester course in the Computer Science undergraduate program. The course was taught in two parallel groups of 24 and 29 students each.

In this course, students learn computer programming using basic tools and simple structured problems, and also develop teamwork skills. Table I presents the course's learning outcomes, associated to: (i) disciplinary knowledge and reasoning, (ii) personal and professional skills and attributes, and (iii) interpersonal skills.

TABLE I. CDIO SYLLABUS GOALS OF PROGRAMMING LABORATORY I

Disciplinary knowledge and reasoning	1 Fundamentals of algorithms, data structures and programming languages	
	1.1	Explains the different software development stages.
	1.2	Identifies inputs, outputs and constraints for a given problem.
	1.3	Designs a structured solution using an algorithmic representation technique.
	1.4	Builds an algorithmic solution using a structured programming language.
Personal and professional skills and attributes	2 Analyzes a problem by dividing it into identifiable parts, and propose solutions.	
Interpersonal skills	3 Can work in interdisciplinary teams.	

V. PRELIMINARY RESULTS

Student work was evaluated in two instances, first with a theoretical formative test and second with an active learning activity. The theoretical test results show if the students saw and understood the videocast before the class. The active learning activity in-class time, as in the ADPT strategy, consists of solving a problem in teams and generating the deliverables for the ADPT stages described in Section 3. This activity is assessed using two specially designed rubrics: (i) a ADPT process-product rubric, oriented toward assessing issues related to disciplinary knowledge (Table II), and (ii) a rubric designed to assess issues related to teamwork (Table III). Students grades were calculated assigning a weight of 80% to process-product performance and of 20% to teamwork performance, both evaluated using the rubrics shown in Table II and Table III, respectively.

TABLE II. ADPT++ PROCESS – PRODUCT RUBRIC

	Excellent (5 pts.)	**Good (4 pts.)**	**Satisfactory (3 pts.)**	**Poor (2 pts.)**	**Unacceptable (1 pts.)**
A	Identifies 100% of the inputs, outputs and contraints of the problem.	Identifies most of the inputs, outputs and contraints of the problem .	Identifies some inputs, outputs and contraints of the problem.	Identifies few inputs, outputs and contraints of the problem.	Fails to identify inputs, outputs and contraints of the problem.
D	Designs the algorithms and test cases correctly 100% of the time.	Designs the algorithm and test cases correctly most of the time.	Partially designs the algorithm and test cases.	Designs the algorithm and test cases poorly.	Fails to design the algorithm and test cases.
P	Source code compiles 100% and documentation is complete.	Source code compiles 100%, but style and documentation must be improved.	Complete source code is observed but compilation fails.	Incomplete source code is observed.	No source code is observed.
T	Code passes 100% of test cases.	Code passes most (≥ 80%) of test cases.	Code passes ≥ 50% and < 80% test cases.	Code passes less than 50% test cases.	Code fails for all test cases.

Figures 4 and 5 show the preliminary results of the Programming Lab I course in terms of the student performance in Test 1 and Test 2, respectively. It is important to note that the ADTP strategy was first applied in 2013, while the ADTP++ strategy was only applied in 2016.

Results show an improvement in student performance starting in 2013, which can be seen in the shift of the score boxes toward higher scores. In 2011 and 2012, students failed to achieve the highest grades, unlike later years when the ADPT and ADPT++ strategies were applied. Low score outliers were found mainly when using ADPT++. This can be explained by noting that 20% of the students did not watch the video before class (Source: Google Analytics).

As shown in Figure 5, the score for Test 2 for 2016 (with ADPT++ strategy) was lower than the score for the 2013 to 2015 course versions (which applied the ADPT strategy). This may be due to the immaturity of our implementation, which still needs some work.

Both instructor perception and student feedback show an increase in student participation and motivation, which is consistent with the student reflective memos shown in [2].

TABLE III. ADPT++ TEAM WORK RUBRIC

	Excellent (5pts.)	**Good (4pts.)**	**Satisfactory (3pts.)**	**Poor (2 pts.)**	**Unacceptable (1 pts.)**
Attitude (10%)	Positive attitude towards work.	Often has a positive attitude towards work.	Ocassionaly has a positive attitude towards work.	Often demonstrates negative attitude towards work.	Always demostrates negative attitude towards work.
Development (10%)	Prepares and plans the work. Always supports the work of the team	Supports the work of the team.	Sometimes supports the work of the team.	Rarely supports the work of the team.	Never supports the work of the team.
Work quality (20%)	Always generates high quality work.	Almost always generates high quality work.	Generates work that ocassionaly requires reviews.	Generates work that often requires reviews.	Generates low quality work.
Problem solving (40%)	Proposes solutions to the problems.	Refines solutions proposed by others.	Occasionally suggests or refines solutions to problems.	Rarely contributes to solving problems.	Never contributes to solving problems.
Work with others (20%)	Always listens and keeps a good work environment.	Almost always listens and keeps a good work environment.	Occasionally listens and keeps a good work environment.	Rarely listens and keeps a good work environment.	Never keeps a good work environment.

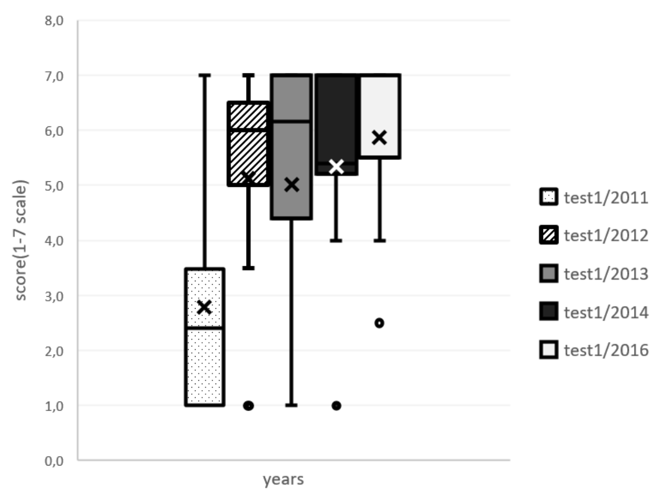

Figure 4. Scores for test 1 between years 2011 and 2016.

Figure 5. Scores for test 2 between years 2011 and 2016.

VI. CONCLUSIONS AND FUTURE WORK

This article presents a learning strategy that combines Flipped Classroom [1], and the Analysis-Design-Programming-Testing technique [2] called ADPT++. Our preliminary results lead us to believe that these methodologies help improve the students' learning of computer programming, in ways that go beyond just making better use of in-class time.

From the point of view of the students' commitment to their learning process, student participation in class increased. The inclusion of practical activities in class motivated their active participation and promoted collaborative learning. This strategy generated metacognition in students, making them aware of their learning process, and stimulated reflective work in the faculty regarding their teaching.

Aspects to be improved regarding the experience reported here are related to extending the use of this strategy to other courses. This will require specific training for faculty not familiar with this strategy. The implementation of appropriate spaces, equipment and a technical crew in charge of the production of videos are critical for the continuity and replicability of this experience. In addition, teaching assistants are needed to manage the videocast site, monitor the videos' rate of use, send out reminders and answer questions from users.

Our future challenges for this project are:

- To increase the number of courses and engineering programs applying this technology.
- To improve the quality of the videos, for example by incorporating checkpoints with short questions within videos to measure student comprehension of viewed contents.
- To create a training plan (workshop) to transfer our experience to other lecturers.
- To collect data to measure the impact of this strategy in students' performance and motivation.

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