Flipped classroom in a CS1 course

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Abstract—**In 2019 in Universidad ORT Uruguay a new curriculum for the Computer Science 1 (CS1) course was developed. We decided to create a more engaging course and to continue to improve student's learning experience. We concentrated on a multi-paradigm approach and we switched from Java to JavaScript as the main language. The course included not only changes in the curriculum, but also in the pedagogy: we used blended and active learning, with focus on flipped classroom. Those strategies combine face-to-face instances with a strong content of online activities. In this paper, we describe our experience and initial results.**

Keywords—Computer Science 1, Active Learning, Blended Learning, Flipped classroom

I. INTRODUCTION

Teaching introductory computer science courses is not an easy task [1]. Dropout and failure rates are high in CS1 [2]. Watson and Li [3] refer a pass rate of 67.7%. Also, the need for appropriate methods and tools for teaching programming is a frequent issue [2]. With the fundamental goal of achieving greater student engagement with the course, and also to collaborate in promoting skills to become self-directed learners, we decided to use the "blended learning" (BL) or hybrid approach (a combination of asynchronous and synchronous learning activities) in the CS1 course.

E-learning, especially BL, is gaining "more and more impact" [4]. The concept behind a flipped class is "that which is traditionally done in class is now done at home, and that which is traditionally done as homework is now completed in class" [5].

As Alammary [1] refers, "the current state of knowledge and practice in applying BL to introductory courses is limited". In this work, the focus is to contribute to the discussion and to present our experience and results related to using BL and JavaScript in CS1.

The organization of this paper is: in the subsequent sections, we describe blended learning and CS1, and our new CS1 course: the redesign, how we prepared for the BL approach (materials and teachers preparation), and details of the first edition in 2019. After that, we present results and we offer some conclusions and guides to future work.

II. BLENDED LEARNING AND COMPUTER SCIENCE 1

The courses to be converted to BL mode need a complete review and both the support of the authorities as well as that of experts in instructional design [6] [7]. Teaching in BL environments requires different approaches than face-to-face teaching and how educators are prepared impacts in the quality of the instruction [8].

Bishop and Verleger [9] define a flipped classroom as a pedagogical method with two parts: a) interactive, group-based problem solving activities inside the classroom and, b) computer-based individual instruction outside the classroom.

Alammary [1] classifies different models of BL in introductory programming courses: "flipped" (learning programming concepts outside the class through online resources, class-time to active learning with focus on coding and problem solving), "mixed" (content delivery and practical coding activities are done both face-to-face and online), "Flex" (content delivery and practical coding activities are online but there are compulsory face-to-face sessions to check the progress), "supplemental" (content delivery and coding activities are face-to-face and online supplemental activities are added to the course), and online-practicing model (an online programming environment is used as a backbone).

The use of flipped classes in CS1 may impact in the performance of the students. The reported results are varied: increased pass rates and competency acquisition [10], scores of problem-solving using programming skills and program analytical skills are better but no difference in programming conceptual understanding between flipped and traditional model [11], and no evidence that flipped helps beginners [12].

III. OUR COMPUTER SCIENCE 1 COURSE

In this section we describe the redesign of the CS1 course, how we prepared the teachers and materials for the new course, and the implementation of the first course.

A. Redesign of CS1

The CS1 course was redesigned, not only the syllabus but also in methodology. In previous years the focus of our CS1 was object-oriented programming with Java. The classes were mainly lectures. Now, the main goals of the reviewed CS1 course are to provide an introduction to programming, to develop problem solving and basic programming skills that enable the students to design and develop non-trivial problems using a programming language (JavaScript). The course structure is the same as the previous course: it lasts 15 weeks, with 6 hours each week: 4 hours with one teacher in a class and 2 hours in a lab with another teacher.

In the new course different programming paradigms are presented: imperative (includes procedural, and object oriented programming), declarative (for example, some notions of functional programming are presented), and event-driven. The CS1 topics are: pseudo code, variables, expressions and control structures, functions, arrays, notions of Web programming (with HTML: hyper text markup language and CSS: cascade style sheets) and introduction to objects and classes (see Table 1 for details by week).

TABLE I. COURSE DETAIL

Week	Main Topic
1	Notions of Computational Thinking Pseudo code

27–30 April, 2020, Porto, Portugal

Week	Main Topic
2	Variables Expressions Control Structures
3	Booleans Codification in JavaScript
4	Strings
5	Functions
6	Functions
7	Arrays
8	Sorting and Searching
9	HTML and JavaScript
10	HTML and CSS
11	Classes and Objects
12	Association
13	References. JSON
14	Integrative examples
15	Practice/Final test

The tools for the course were Notepad ++ [13] and Chrome [14]. They were selected for their simplicity of use and availability. The idea that all the code must be explicitly written by the student (without using, for example, automatic generators that would hide part of that code) is a strategy that was required and evaluated positively by teachers.

The course evaluation was also redesigned. It includes one large programming task with two parts (four weeks each, total: 35 points), two individual tests done in class (total: 50 points) and activities (total: 15 points). The activities were for preparation at home for the following class (quizzes, small programming challenges) and others to be done in class. We used a common rubric to evaluate each piece of student's work. To pass the course it is required at least 70 points out of 100.

The methodology to be used in the course changed to blended. The model is "Flipped Model" in the classification of Alammary [1]. Each class, the teacher refers the topics of the next class, including which video, and, or, activity should be done to be prepared for the next class.

B. Preparation of the course

Traditionally, we have about 300 students in the first semester in groups of 25-30, so the organization and coordination is very relevant. During 2018 the course was prepared. The Dean of the School of Engineering and all related departments fully supported the process. As referred in [15], roles of "leading professors" are incorporated, who plan and direct a team of professors, train them and analyze data, "collaborating professors" who work as a team, "support teachers" to tutor students and "teachers in training", who collaborate while they learn their work. In our case, the main preparation was done by a team formed by a Full Professor and two Associate Professors. Other two teachers collaborated with the videos and materials.

For the new course two electronic and interactive books (theory and practice with 98 exercises, more than 150 pages

each book) (Fig. 1) and 23 videos (3-9 minutes each) were developed collaboratively. We took into account the recommendations of Hibbert [16]: strategizing videos to tie directly to course assignments, adding audio/visual elements to the video to supplement the content, producing high-quality videos and keeping the four-minute view average time as a design consideration. In our case, each video included sample code and/or animations and also a related quiz (Fig. 2, video available in [17]).

All the material was available in a new website. The site was designed taking into account a simple, attractive, and easy to use interface. It is on a Moodle [18] platform. In the site, there is a specific area for teachers, with the new instructional design: a detailed class-to-class plan and multiple resources and activities.

In the instructional design, we included, for each class, the topics, the materials, examples and a guide on how to use each one. Some of those examples were based in others of previous courses, in order to facilitate the preparation for the teachers.
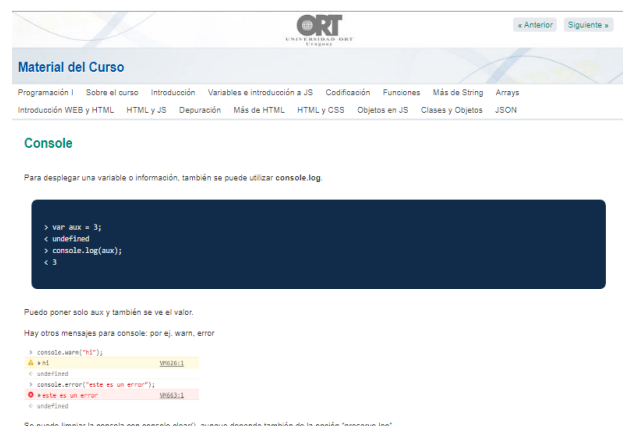

Fig. 1. Electronic Book

Fig. 2. Example of Video with animation

The preparation also included a training workshop (4 sessions of 2 hours each) for the teachers (two editions: October 2018 and February 2019). The main objectives were not only to train in the specific topics (JavaScript) and to validate the materials, but also to know and practice the teaching approach (BL). In the workshops, the methodology used was also BL, so participants could experience for themselves the materials and process, as suggested Gurley [8].

The first session dealt with the objectives of the new course, detailed syllabus, class dynamics, blended learning, evaluation and aspects of JavaScript (use of console, snippets

and coding of basic exercises). Also, technical aspects as the use of "let" and "var" were discussed. As homework, some specific materials should be checked.

In the second session those aspects of the online course were discussed and, computational thinking exercises were done emphasizing how to use them in class. Quizzes developed with Quizizz [19], Kahoot [20] and other activities were also used to experience the students' own challenges.

In the third session, we focused on the electronic books and evaluation. Also, examples of JavaScript with HTML and CSS were analyzed.

In the last session, the focus was to go deeper in JavaScript. After those workshops, some minor improvements were done to the materials.

After the workshops, we conducted interviews to 12 teachers out of 20. We asked their opinion of the preparation and all the answers were positive. Some examples were: "Very complete", "The workshop was a huge checkpoint for the materials", and "An ideal environment to discuss ideas".

Regarding to the change of approach to BL, the comments were also positive. Some opinions were: "It is good to improve learning and create a culture of self-sufficiency" (Teacher 1), "It is important because it makes students keep up with the course (Teacher 3), "Addresses the way in which current generations of students learn" (Teacher 6), and "It makes students feel more owners of the course and that progress is their own merit " (Teacher 8).

Related to the change in technology (Java to JavaScript), it was also mostly positive: "JavaScript is one of the most used languages in the world, it is a good option both to learn and to develop as a professional" (Teacher 9). "The paradigm shift is necessary to keep the profile we want to give students updated" (Teacher 3). Another teacher said that it generates "mixed feelings": "I understand the change, I realize the positives that JavaScript has, like flexibility in coding, but I also have mixed feelings because I see that JavaScript has some things to be careful of, such as null values or undefined. However, I think the change is very positive and students will be interested in a language with which they interact since it is widely used on the Internet" (Teacher 8).

The preparation was also perceived as effective. "I think the preparation and the workshop were clear and consistent, leaving no doubt about the issues or how to develop the course. The discussions that arose were great. I felt that I was heard in the opinions I expressed and that the teachers were open to everyone's suggestions" pointed Teacher 7. "Very complete" referred Teacher 2. "The workshop was a great control point for the material" (Teacher 4). "An ideal environment was generated for discussions of very good technical richness, with contributions from colleagues who work daily with these tools, both for the course agenda and the way to give it" (Teacher 3). "It was spectacular to adapt examples of the previous course and take them to JavaScript, the learning curve is much simpler from the teaching point of view" (Teacher 12).

Materials were valued positively. Some comments are: "The material is very complete and very well prepared, the exercises increase the level gradually" pointed Teacher 5, "I consider the materials to be of very good quality, positioning myself as a student"(Teacher 10), and: "They are adequate in terms of content, quality of explanation and organization, without neglecting continuous improvement and review" (Teacher 11).

Both the preparation and the materials were rated as "5-excellent" or "4-very good" of a five point scale by all who were interviewed.

C. First Edition

The first edition of the course started in March 2019. At the beginning of the course, it was explained the BL methodology to the students. Each week, it was informed the main topic for the following class: one or two short videos should be seen at home and multiple choice tests or activities, related to the videos, were available for students.

In each class, the corresponding topics were summarized, new examples or applications were discussed and a new set of activities were developed. Activities used in the course included: crosswords (Fig. 3), Jeopardy game [21], a game similar to "Pass the word" created using [22], multiple choice questions [20] [21], and infographics. Almost all of them used students' mobile phones.
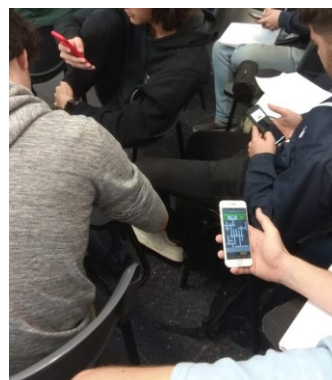

Fig. 3. Use of Crosswords in class

For example, for the first two hours of class of "Functions", students at home saw the specific video and answered a multiple choice test. In class, adapting ideas from [23], the video of the song: "A balancing elephant" [24] is viewed. This children's song contains repetitions that could help to understand the concept of function and also parameters in another context. After that, a pseudo code version of the song is written. Then, some basic examples of functions are coded in JavaScript. To go deeper with function concepts, based on the image of [25], an association game is done [26], and all the terms are analyzed (Fig. 4). In this game, each student should associate a concept (for instance: "formal parameter") with the concrete element in the code using their mobile phone. To finish the class, the fundamentals of functions are summarized and the preparation for the next class is presented.

Clearly, the role of the teacher changed: from giving lectures to conducting activities dynamically. The students actively participate in class and it is remarkable that almost all of them viewed the videos before the class. It is worthy to point out that, based on the experiences of previous years and to motivate students, each activity outside class sum points for the course (for instance, each correctly completed quiz adds 0.5 points). We also took into account not to overload the course with activities and tasks, as Alammary [1] points.
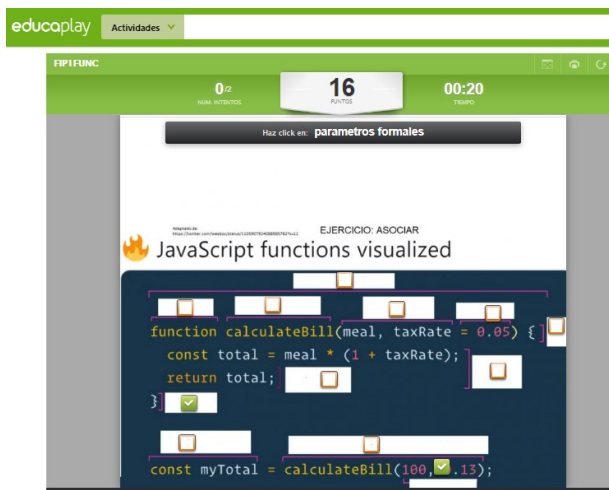
Fig. 4. An activity based on JavaScript functions

Weekly, during the semester, the most experienced teachers met with the new ones, to share ideas, guidance and to detect any difficulty as soon as possible. Also, in order to coordinate the groups, we shared a common sheet where each teacher wrote down the topics of the class and notes of any problem or lesson learned. Each week, during 9 hours out of class, three advanced Engineering students took the role of "teachers in training" and mentored the students, supporting them with coding problems.

IV. RESULTS

At the present moment, we completed the first edition with 299 students distributed in 12 groups. During the course, we conducted two anonymous surveys to the students (one in week 4 to detect early opportunities for improvements, and the other at the end) and interviews with the teachers.

The first survey was answered by 166 students (55.5%). The course was evaluated as excellent/very good/good (E/V/G) by 96.4%. The materials, videos and methodology of BL were also well evaluated (98.1%, 92.8% and 94.1% referred E/V/G). The use of JavaScript and the self learning was evaluated by 86.7% and 91.6% as E/V/G. (Table II: Results of Survey 1).

A total of 116 students answered the final survey, 96.5% of them referred that the course was excellent/very good/good. At the end of the course, the methodology was also well evaluated (95.7%: E/V/G). Also, 92.2% of those students refer that their own learning of programming is excellent/very good/good (Table III: Main results of Survey 2). The results were similar to the first survey.

Also, in the final survey, some students included suggestions: "we want more Kahoots" (5 students), "more exercises", "more class hours" (2 students), "I liked the dynamics", "Present first HTML and after JS", "The course is very complete", and "More examples of classes and objects".

TABLE II.   RESULTS OF SURVEY 1 (WEEK 4)

First Survey (166 answers)				
	Excellent	*Very good*	*Good*	*Regular/ Bad*
Opinion of the course	25.3% 42 students	46.4% 77 students	24.7% 41 students	3.6% 6 students
Material	31.3% 52 students	56.6% 94 students	10.2% 17 students	1.9% 3 students
Videos	33.1% 55 students	41.6% 69 students	18.1% 30 students	7.2% 12 students
Blended Learning	39.2% 65 students	39.8% 66 students	15.1% 25 students	5.9% 10 students
Use of JavaScript	33.1% 55 students	34.3% 57 students	19.3% 32 students	13.3% 22 students
Learning perception	15.1% 25 students	43.4% 72 students	33.1% 55 students	8.4% 14 students

TABLE III.   MAIN RESULTS OF SURVEY 2 (WEEK 15)

First Survey (116 answers)				
	Excellent	*Very good*	*Good*	*Regular/ Bad*
Opinion of the course	22.4% 26 students	49.1% 57 students	25.0% 29 students	3.5% 4 students
Blended Learning	37.1% 43 students	33.6% 39 students	25.0% 29 students	4.3% 5 students
Learning perception	10.3% 12 students	55.2% 64 students	26.7% 31 students	7.8% 9 students

The total number of visualizations of the 23 videos was 9343, which gives an average of approximately 1.36 visualization per video per student. In general terms, the students engaged with the proposal: they prepared for the classes and participated. In the final survey, we also asked the students how they used the videos to learn. The most common answer was "I take notes". Also, some students mentioned that they tried the code presented in the video at the same moment.

The pass rate of the course (67%) is similar to our previous years and also to the referred values [3]. Considering that this is the first complete experience with the new syllabus and methodology, we could infer that is a good result.

At the end of the course, we asked the teachers about their main reflections. In general, they referred that the main difference with the previous courses was higher student engagement. Also, they pointed out that the students had a more active role and the classes were more dynamic. The availability of the instructional design was also well considered.

From the teachers notes, we detected opportunities to improve some technical topics. For instance, two examples of lessons learned related to details of functions in JavaScript were:

- it is necessary to remark that to invoke a function is required to include "( )". We observed a common mistake when they used "alert". Some students coded: *alert="this is the result";* instead of:

alert("this is the result");. After that, if they try to use alert correctly, appears an error "alert is not a function". A similar situation occurs in this case: *var t = "hi".toUpperCase;* and: *var s = t.charAt(1);.*

- Another common error is a misunderstanding of "let" and "var". In some cases, they redefine the same variable many times in the same block or function.

V. CONCLUSIONS AND FUTURE WORK

In this paper we described a new version of the CS1 course, which included new contents and the use of a blended learning approach with flipped classes. For the new course, we developed materials to be used online at home and also materials for the teachers to be used in class.

Previous to the first edition of the course, a workshop was offered to the teachers. There the syllabus and teaching strategies were discussed in detail, allowing adjustments to be made. The survey of teachers reflected a high degree of conformity with the entire proposal of the change. All teachers who taught the new course attended the workshop. Also, the institutional support during all the process was remarkable.

The first edition of the CS1 course was in the first semester of 2019. We had 299 students in 12 groups, with a total of 20 teachers.

Based on the two anonymous surveys to the students (week 4 and week 15), the interviews to the teachers at the end and the results, we could infer that the course has a positive perception and achieved the objectives. From the teachers point of view, the shared instructional design is very useful and appreciated and the course was enjoyable and highly motivating.

Although the pass rate was similar to previous CS1 courses and considering that this is the first application of the new course, we could perceive that the BL approach and the new curriculum promoted more dynamic and intensive classes, with high engagement.

As future work, we will analyze the performance of students in the following courses as well as enhancements to the course.

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