IMPROVING THE IMPLEMENTATION OF A FIRST-SEMESTER PROGRAMMING COURSE

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ABSTRACT

The flipped classroom (FC) is a form of active learning in which in-class and out-of-class activities are flipped: students are expected to study a specific material outside the class and then be able to apply the knowledge to complete various activities related to the material during class under the guidance of an instructor. FC is often used together with team-based learning (TBL), where students work in teams to apply their knowledge as opposed to working individually on activities. During that last two years (2018 and 2019), the Department of Computer Science at Reykjavik University has experimented with applying FC and TBL in the first-semester programming course. In previous publications, we have described our experience using FC and TBL during the first experimental year (2018), i.e., the motivation for restructuring the course, the implementation, the results of two student surveys, and the outcome of several exams. In this paper, we describe the improvements made during the second experimental year (2019), both with regards to the online learning material and the course assessment. Furthermore, we compare the outcome of student surveys between the two years as well as students' performance on various exams. The results of a student survey given in the second year show that students' attitudes towards the FC approach were much more positive compared to the previous year. We argue that this is due to the specific changes made to the online material and the assessment of programming projects in class. Finally, it is interesting that the failure rates in the course in 2019 are much lower than the failure rates in 2018.

KEYWORDS

Flipped classroom, team-based learning, first programming course, Standards 7, 8

INTRODUCTION

When teachers move from traditional lecturing to a more active learning environment, they have many different pedagogic options to study, customize, and implement. The aim of redesigning a course, maybe to increase students' interest in their study, their engagement, activity, knowledge, and skills needed for them to be successful in their search for further educational development. Flipped classroom (FC) is one way of activating students in the learning process with its learner-centered focus, where direct instruction is replaced with effective out-of-class work and different learning activities in the classroom with the teacher as the facilitator. The learning activities that used to happen outside the classroom are now inside the classroom and vice versa.

Mclaughlin, Roth, Glatt, Gharkholonarehe, et al. (2014) recommend FC as an achievable and essential educational model when educating a large group of students. There seems to be no single model for the FC, but we can identify three main parts in the model: the out-of-class/before class activity, usually supporting individual learning, the learner-centered classroom activity often with group work, and the assessment and evaluation of the learning.

A thoughtful design of pre-class learning activities is needed for FC, where students have an opportunity to gain information and knowledge before the class activity. Today, the course material can be in a diverse format, e.g., traditional textbooks/papers or more modern e-textbooks/papers and videos for the students to explore and develop new skills and ideas from, on their own or with peers. Research has shown that students claim they do not use the textbook as expected to prepare for class, but videos are highly regarded and considered useful to prepare for class and gain an understanding of the subject (Matthíasdóttir and Loftsson, 2019). Nevertheless, a study by Cheah, Sale, and Lees (2017) revealed that watching videos before class can be boring. Research has also shown that "it's not the instructional videos on their own, but how they are integrated into an overall approach, that makes the difference" (Tucker, 2012, p. 82). Watching educational videos corresponds to Bloom's taxonomy lowest levels of remembering and understanding (Slavensky, 2019), but can be at higher levels if followed by complementary activities.

It is important to connect out-of-class activities to in-class activities and organize the students' work well. In the classroom, use of team-based learning (TBL) is a known way to organise a FC, in which students work in groups on projects and other applied activities. Number of interactive activities can be used with both individual and collaborative actions, e.g. project work, case studies, active discussions, presentations and quizzes. Group work can support cooperation and build a learning community where students can learn from each other. All this is to support active learning and knowledge application (O'Flaherty and Phillips, 2015) and reach higher levels of Bloom's taxonomy.

Evaluating student-learning outcomes is important, and the assessment methods have to be consistent with the teaching and learning methods. Some studies of FC have revealed that the pass rates have not improved at first when using FC (Gommer, Hermsen & Zwier, 2016; Loftsson and Matthíasdóttir, 2019), but others have shown higher course grades (Wilson, 2013; Mason, Shuman, and Cook, 2013).

Finelli et al. (2018) point out that concerns about students' resistance, defined as "negative behavioral responses to active learning," is one of the barriers faced by teachers when adopting active learning methods. Other barriers mentioned are, for example, the efficacy of the methods, teacher preparation time, and the ability of the teacher to cover the course syllabus. Deslauries et al. (2019) identify an inherent student bias against active learning that can limit its effectiveness and may hinder the wide adoption of these methods. They show that students in active classes perceived that they learned less, compared with students in traditional lectures, while in reality, they learned more.

During that last two years, the Department of Computer Science (DCS) at Reykjavik University (RU) has experimented with applying FC and TBL in the first-semester programming course. In previous publications (Matthíasdóttir and Loftsson, 2019; Loftsson and Matthíasdóttir, 2019), we have described our experience using FC and TBL during the first year (fall 2018), i.e., the motivation for restructuring the course, the implementation, the results of two student surveys, and the outcome of several exams. In this paper, we describe the improvements made during the second year (fall 2019), both with regards to the online learning material and the course assessment. Moreover, we compare the outcome of student surveys between the two years as well as students' performance on various exams. The improvements made to the course during the second year were influenced by the experience of the students and the teachers during the first year, and the authors' research (Matthíasdóttir and Loftsson, 2019; Loftsson and Matthíasdóttir, 2019).

COURSE IMPLEMENTATION

In this section, we describe the implementation and the assessment in the 12-week first-semester programming course in the DCS at RU in the fall semester 2019. In the last two years, Python has been used, whereas previously, C++ had been used for many years. At the start of the course in the second experimental year (fall 2019), 390 students were registered. The students were divided into seven sections and then into groups of 5-6 students within each section, which met in class twice a week for 4*45 minutes. Each class had one teacher and one teaching assistant as facilitators and tutors.

The course implementation in the first experimental year (fall 2018) has been previously described in Loftsson and Matthíasdóttir (2019), on which the implementation in fall 2019 is based. In what follows, we repeat some of the individual items from that paper, but we specifically note the changes made during this second experimental year:

- In advance of most of the classes, students were expected to read a given chapter of the textbook (Punch and Enbody, 2017). Results from surveys in 2018 had shown that a large proportion (45%) of the students never or seldom read the textbook (see section RESULTS). This result was consistent with the fact that the teachers felt that many of the students did not come sufficiently prepared for classes. Therefore, this year the teachers specifically emphasized the importance of reading the textbook before coming to class.

- At the beginning of each class, a video (15-25 minutes) was shown in each of the sections. The purpose of the videos, made by the main instructor, was to be supplementary material for the given textbook chapters. In the previous experimental year, the students were expected to watch short videos (5-10 minutes each) before coming to class. These videos were a selection from YouTube made by various people (but not the main instructor). The reason for this change in 2019, i.e., showing a video made by the instructor at the beginning of each class, as opposed to expecting students to watch a short video before coming to class, was that our surveys in 2018 (see section RESULTS) showed that many students wanted some traditional lecturing in the course, specifically from the main instructor.

- After the video had been played, students were given a short quiz (in most of the classes), containing ten multiple-choice questions, which were directly linked to the given textbook material and the video. After this individual quiz, students discussed the same quiz in groups and handed in the groups' answers.

- For the remainder of the class, students were given several short programming assignments for practicing the specific concepts. Students worked on these assignments in groups, but each student needed to submit his/her solution at the end of class. These programming assignments were automatically graded using test cases. In fall 2018, each student received a programming grade at the end of each class, which was then accumulated over the whole semester as the overall class programming grade for the student. In contrast, in fall 2019, students only needed to obtain 50% "green tests" over the whole semester to receive full marks for the programming part of the class. The reason for making this change is that in 2018 many students felt that there was too much pressure on submitting the solutions to the programming assignments in class and that they were always competing against the clock in order to submit before the class finished. By only demanding that students fulfilled 50% of test cases over the whole semester, this pressure disappeared, and students were able to concentrate better on the assignments without having to worry about the time running out.

- In addition to the short programming assignments given in class, students were given larger programming projects each week to work on at home, optionally in a group of two students.

- In addition to the video shown at the beginning of each class, in fall 2019 (but not in 2018), the main instructor made several videos, for the student to watch at home, that demonstrated how to break a problem description into individual tasks and implement functions for those tasks (i.e., apply functional decomposition).

- In the first experimental year (2018), two midterm exams, a final exam, and a retake exam were given in the course. In the second year (2019), the third midterm exam was added. All the exams were "open book," i.e., students were allowed to use the textbook, slides, notes, and solutions to assignments in the exam. Grades are given on a 0–10 scale, and a grade below 5 is a fail. In 2019, two best out of three midterm exams counted towards the final grade, compared to the better ones out of two in 2018. The learning material (see Loftsson and Matthíasdótttir, 2019) for the first two midterm exams, as well as the final exam, was similar between years.

The course assessment in 2019 was the following: 1) Quizzes (individual and group) in class: 10%; 2) short programming assignments in class: 10%; 3) homework programming projects: 20%; 4) three midterm exams (two best counted): 20%; and 5) final exam: 40%.

Canvas (www.canvalms.com) is RU's learning management system (LMS), Piazza (www.piazza.com) was used for questions and answers in the course, and Mimir Classroom (www.mimirht.com) for administrating quizzes, assignments, projects, and exams.

METHOD

A survey was conducted in fall 2019, based on a survey from the previous year (Matthíasdóttir and Loftsson, 2019; Loftsson, Matthíasdóttir, 2019) with some minor changes of wording.

Participants

The participants were the 390 registered students, out of which 251 (64.4%) answered, 159 (63.3%) males and 92 (36.7%) females. The average age was 23.7 years, ranging between 18 and 47 years. Most students, or 185 (73.7%), were first-semester students, 103 (41.0%)

students rated their programming skills prior to the course very little or little, and 45 (17.9%) students rated it as great or very great.

Measures

The online survey consisted of 26 questions, out of which 22 were from the previous year's survey (described in Matthíasdóttir and Loftsson, 2019). The background questions were the same; about gender, age and semester, and one about computer skills. Four new questions were added to obtain better information and understanding of the students' attitudes: "*I like FC in this course," "I like the organization of the programming assignments in class (50% submission)", Programming assignments in class are consistent with the class material",* and "*Weekly homework programming projects are consistent with the class material".* All the questions were rated on a five-point Likert scale, ranging between "Totally disagree" and" Totally agree."

Procedure

The system Free Online Surveys (https://freeonlinesurveys.com) was used to put the survey online and a link sent to the students by e-mail in the 10th week of the course. Excel and the Statistical Package for the Social Sciences (SPSS) were used for data analysis.

RESULTS

In this section, we present the results of the individual questions from the two surveys conducted in the first (2018) and the second (2019) experimental year. Furthermore, we present students' performance on various exams for two years.

Surveys 2018 and 2019

Table 1 shows the results of the questions administered in both 2018 and 2019. The first column lists the individual questions, and the second and third columns show statistics for 2018 and 2019, respectively. To see the development in the participants' answers, an independent t-test was used to compare the means from the two surveys. Table 1 shows that the difference was significant for ten questions.

As Table 1 shows, the main difference between the two years seems to be regarding the use of the textbook (see questions no. 3 and 4). Both questions indicate more use of the textbook in the second year.

Table 2 shows the participants' answers to the four new questions. For all the questions, the majority of the students agreed with the corresponding statement.

Exams

The results of all the exams conducted in both years are shown in Table 3. The "Students" column shows the number and the ratio of students (the number of students that showed up divided by the number of registered students) that showed up for the given exam.

Table 8: Results of survey questions presented in both experimental years, 2018 and 2019.

	2018	2019	
Questions	**Mean (SD) (N)**	**Mean (SD) (N)**	**t-value**
The organization of the course is good	3.2 (1.2) (179)	3.6 (1.0) (244)	-3.94***
The class hours each week are useful to me	3.3 (1.3) (178)	3.6 (1.2) (248)	-2.08*
The book of the course helped me in my study	2.6 (1.3) (179)	3.4 (1.2) (245)	-5.97***
I usually read the book before class	2.8 (1.4) (179)	3.4 (1.5) (247)	-4.23***
The videos in the course helped me in my study	3.6 (1.2) (178)	3.5 (1.2) (248)	0.59
I watch the video that I should watch before or after the class	4.1 (1.2) (179)	3.9 (1.2) (251)	1.51
I miss traditional lecturing in the course (minor changes)	3.4 (1.5) (179)	3.1 (1.5) (248)	2.32*
I like the organization of the short exams at the beginning of class (take the exam alone and then with others)	3.2 (1.3) (179)	3.3 (1.3) (259)	0.70
I like the arrangements of the midterm exams (two out of three are graded)	4.4 (0.9) (179)	4.4 (0.9) (249)	-0.14
To discuss with fellow students in class helped me to study	3.6 (1.3) (179)	4.0 (1.1) (249)	-3.58***
To discuss with fellow students outside the class hours helped me study	3.7 (1.3) (179)	3.9 (1.1) (249)	-1.64
I like to work in a group with fellow students	3.6 (1.3) (178)	3.9 (1.2) (252)	-2.14*
Communications with teachers in class help me to study	3.7 (1.2) (179)	3.6 (1.3) (252)	1.26
I liked to use Canvas in my study	4.0 (1.0) (179)	4.0 (1.0) (249)	-0.32
I liked to use Piazza in my study	3.6 (1.2) (179)	3.8 (1.2) (252)	-1.45
I like to use Mimir in my study	3.9 (1.1) (179)	4.3 (1.0) (252)	-3.69***
This course is overall a good learning experience	3.5 (1.3) (179)	3.8 (1.2) (250)	-2.43*
I have done well in this course	3.3 (1.3) (179)	3.7 (1.2) (251)	-2.89**

$^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$

Table 9 Answers to the four new questions

	Totally disagree and disagree N (%)	**Neutral N (%)**	**Totally agree and agree N (%)**
I like FC in this course	55 (22)	61 (24)	134 (53)
I like the organisation of the programming assignments in class (50% submission)	31 (12)	39 (16)	180 (72)
Programming assignments in class are consistent with the learning material	43 (17)	35 (14)	174 (69)
Weekly return assignments are consistent with the class material	70 (28)	50 (20)	130 (52)

Table 10: Results from all exams in 2018 and 2019

Exam	Students	Average grade	Failure rate
Midterm 1			
2018	281 (86.5%)	7.1	19.9%
2019	346 (88.7%)	8.5	8.1%
Midterm 2			
2018	227 (69.8%)	6.3	36.1%
2019	323 (82.8%)	6.0	39.6%
Midterm 3			
2019	263 (67.4%)	5.6	41.8%
Final			
2018	279 (85.8%)	4.4	55.6%
2019	304 (77.9%)	5.9	33.9%
Retake			
2018	133 (40.9%)	5.4	41.3%
2019	91 (23.3%)	4.0	51.6%

DISCUSSION

Surveys

In what follows, we discuss the ten questions from Table 1, for which the difference in means was statistically significant.

- *"The organization of the course is good" and "This course is overall a good learning experience":* The results of these two questions show that students were more positive towards the organization and the teaching methods of the course in 2019, in comparison with 2018. We believe that this is due to the main changes made to the course in 2019:

    1. The videos made by the main instructor, both the ones that were shown at the beginning of each class, and the ones about functional decomposition to be watched at home.
    2. The change in submissions of class programming assignments (50% green tests).
    3. Making two best midterms out of three counts towards the final grade, as opposed to the better one out of two.

- *"The class hours each week are useful to me:"* The students in 2019 felt that the class hours were more useful to them compared to the students in 2018. This may be explained by the videos shown at the start of each class in 2019, and a possible reduced submission pressure of class programming assignments.

- *"The book of the course helped me in my study "and "I usually read the book before class":* It is evident from the answers to these two questions (and the t-values) that the students responded well to the emphasis that the teachers made in 2019, regarding the importance of reading given chapters of the textbook before coming to class.

- *"I miss traditional lecturing in the course":* Almost half of the students agreed on this question in 2018 (Matthíasdóttir and Loftsson, 2019). Consequently, we decided to introduce videos, made by the main instructor, at the beginning of each class in 2019. In the strict sense, these videos do not constitute traditional lecturing (because the videos were recorded in a studio, but not in a lecture hall with students present). Nevertheless, by making the videos the students were at least able to see how the main instructor presented the learning material. The mean of students' answers to this question is significantly lower in 2019 compared to 2018, which indicates that these recorded videos can, at least partly, replace traditional lecturing

- *"To discuss with fellow students in class helped me to study" and "I like to work in a group with fellow students":* Evidently, the students in 2019 agreed to a larger extent to these questions than the students in 2018. It is difficult to explain the reason for this change, but it is possible that the students in 2019 felt more at ease in class because of the change in the submission of the class programming assignments.

- *"I like to use Mimir in my study":* Mimir is the web-based solution that we use for administrating and grading quizzes, assignments, projects, and exams. There is a very significant change in the positive attitudes of the students between the two years in using Mimir. We do not have a specific explanation for this.

- *"I have done well in this course":* On average, the students in 2019 felt that they had done better in the course compared to the students in 2018. It thus seems that there is a correlation between the increased positive attitudes in the course and how well the students feel that they are performing. In the section on Exams below, we also see that the failure rate decreased significantly between the two years.

The results from the four new questions (presented in Table 2) show that the majority of the students (53%) liked the FC in the course. A large majority of the students (72%) liked the organization of the programming assignments in class and felt that the assignments/projects were consistent with the learning material (69%). Although 52% of the students felt that the weekly homework assignments were consistent with the learning material, still 28% of the students disagreed. FC is a new method for most if not all students in this course, and our experience, surveys, and exam results indicate that we are on the right track with FC.

Exams

A discussion about the exam results in 2018 has been presented in Loftsson and Matthíasdóttir, (2019). Here, we discuss the main differences in the results between the two years.

- First, the average grade in the first midterm in 2019 (8.5) is significantly higher than in the previous year (7.1), and the failure rate in 2019 significantly lower than in 2018. We believe that this is due to the fact that one of the assignments on the first midterm in 2019 was mistakenly made too easy, compared to a corresponding assignment on the same midterm in 2018.

- Second, the ratio of students showing up for the second midterm in 2018 (69.8%) is much lower than the corresponding rate in 2019 (82.8%). This can be explained by the fact that in 2018, two midterms were given and the higher one counted towards the overall midterm grade. Thus, many students that scored high on the first midterm exam decided not to show up on the second exam. In contrast, in 2019, three midterm exams were given, of which the two highest counted. This also explains why the ratio of students showing up in the third midterm exam in 2019 (67.4%) is low compared to the corresponding ratios in the first and second midterm exams in 2019 (88.7% and 82.8%, respectively).

- Third, the most striking difference is in failure rates on the final exam between the two years. In 2019, the failure rate was 33.9%, whereas in 2018, it was 55.6%. In Loftsson and Matthíasdóttir (2019), the authors argued that the main reason for the exceptionally high failure rate in 2018 was the inability of many students to apply functional decomposition, i.e. break a problem description into individual tasks and implement functions for those tasks. Therefore, during the running of the course in 2019, a larger emphasis (compared to the previous year) was made on practicing this skill. In particular, the main instructor made several demonstrative videos in 2019 that showed how to apply functional decomposition. Another important factor, which explains much lower failure rates on the final exam in 2019, is that in 2018 the students were not given any practice exams. In 2018, the Python programming language was used for the first time in the first-semester programming course in the DCS at RU. Therefore, no previous Python programming exams at RU were available for the students to use as preparation material. On the other hand, in 2019, students were able to use both the final exam and the retake exams from 2018 in their preparation for the final. Additionally, two other practice exams, which were made for the students that needed to take the retake exam in 2018, were available for the students that took the final exam in 2019. Thus, four exams in total were available for the students before the final in 2019 compared to none for the students in 2018. Finally, much lower ratio of students needed to take the retake exam in 2019 (23.3%) compared to the ratio in 2018 (40.9). This is due to the fact that the failure rate on the final exam in 2018 was much higher than in 2019.

CONCLUSION

Engineering and computer science education is shifting away from traditional teacher-based format to a more learner-based format using different pedagogical approaches (Mason, Shuman, and Cook, 2013) that we could even call a more modern method. FC is one of the options because it offers the opportunity to emphasize an integrated learning experience and active, experiential learning methods in line with CDIO standards 7 and 8. The question educators are asking is how to organize FC in our environment? In this paper, we have discussed an experiment over two years in applying FC in a first-semester programming course where the development of the organization of the teaching and learning has taken in account the students' views and attitudes. The survey conducted in the second year the FC was used, after the improvements of the implementation of the course, does support the work that has been carried out and encourages the faculty to continue with developing the FC further.

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BIOGRAPHICAL INFORMATION

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