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Increasing Students' Responsibility and Learning Outcomes Using Partial Flipped Classroom in a Language Processors Course

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ABSTRACT More than twenty years have passed since the term Flipped Classroom was coined. Despite of the increasing interest in this teaching methodology, fields like Computer Science still need more research in order to judge the impact of this methodology in the learning process. This work presents a comparative study between traditional lectures and a partial application of the Flipped Classroom methodology in the subject Language Processors of a Computer Science degree. The study involved 158 students during two weeks and focused on practical contents of the subject. The results show that students in the Flipped Classroom group were more responsible of their learning process, consequently they got significant better learning outcomes either during or at the end of the learning process. Students' satisfaction was highly positive as well. This work increases the amount of experiments about Flipped Classroom within the field of Computer Science. In addition, this work serves as an example of how to begin the transition from traditional lectures to the Flipped Classroom methodology.

INDEX TERMS Flipped classroom, computer science education, students' responsibility.

I. INTRODUCTION

The European Higher Education Area and the Bologna Process have triggered many changes in higher education institutions. Many of these changes could be grouped in the application of active learning methodologies [1]. One of the main aspects of active learning is the engagement of students with their own learning process, which could improve students' responsibility with it.

On the other hand, technological developments have provided new infrastructures that better support distance education and the production, and availability, of new learning materials. The existence of websites providing educational materials like the OpenCourseWare (OCW) initiative[1] or educational videos like Khan Academy[2]; or even more complete courses, e.g. Coursera,[3] edX[4] is nothing new. The use of this type of educational resources has increased due to the new context imposed by the COVID-19 pandemic. The transformation from in-person education to live online classrooms is not straightforward, mostly due to the lack of teachers' preparation and institutional resources. However, the production of online educational materials, e.g. educational videos, has increased; and many teachers are considering the use of innovative methodologies like Flipped Classroom.

Even before the COVID-19 appearance, there has been a growing interest in innovative educational methodologies. Nowadays it is easy and cheap to produce videos. In addition, internet connectivity, resources, and technology are much more accessible. These conditions have also supported the increase of interest in the Flipped Classroom methodology [2], also known as Inverted Classroom.

Students' study time could be divided in face-to-face time with the teacher (in-class time for the rest of the work) and

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[1]http://ocw.mit.edu/about/our-history/, 2020
[2]https://es.khanacademy.org/, 2020
[3]https://es.coursera.org/, 2020
[4]https://www.edx.org/, 2020

time without the teacher that could be used for self-work or group-work activities (out-class time for the rest of the work). The traditional lecturing approach dedicates in-class time to lectures given by the teacher. Depending on the contents, these lectures can be enriched with examples or even exercises. Other in-class time can be just dedicated to exercises, if they are needed, but only after having attended other in-class sessions where the underlying theory has been explained. Usually, out-class time is dedicated to solve questions and/or exercises about the concepts explained during the lectures.

The Flipped Classroom approach changes the kind of activities performed during in-class and out-class time [3]. Although a simple description could be the swap between in-class and out-class activities, this does not reflect what the Flipped Classroom approach proposes. Firstly, the order of activities is maintained, i.e. first the students receive the theoretical explanations and then some activities are performed in order to work with the concepts previously explained. Secondly, the main change is the context where those activities are performed. Thus, theoretical explanations are translated to out-class time while in-class time is dedicated to solve students' doubts and work on the theoretical concepts and their practical implications, if any. Therefore, this is not a swap of the traditional lecturing approach because neither traditional lectures could be directly translated to out-class time without an adaptation process nor typical exercises from traditional lecturing would take full advantage of the possibilities offered by the face-to-face context of in-class sessions.

Thus, theoretical contents are adapted by means of electronic documents, podcasts, or videos; so they can be delivered to students using standard courseware. Moreover, these materials could be adapted to students' particular needs or study preferences [3]. This out-class materials can be enriched with other activities like simple problem-solving or quizzes, asking students to use the explained concepts and thus increasing learning possibilities. Now that in-class time is free of theoretical explanations, more activities could be done apart from typical problem-solving ones. In fact, teachers can use well known active learning approaches, e.g. cooperative learning, collaborative learning, peer-teaching; so the learning process could be improved.

Some authors differentiate between full and partial applications of the Flipped Classroom methodology. Long *et al.* [4] consider that a full application of the methodology must cover the whole course. Therefore, applying the methodology during part of the course results in a partial Flipped Classroom approach. Prashar [5] explains that some concepts and activities need previous face-to-face explanations before beginning the flipped process. Therefore, since some of the contents that should be delivered out-class are provided within an in-class context, these kind of experiences should be considered as partial rather than full applications of the flipped approach. As it will be detailed in the following sections, the use of the Flipped Classroom approach in this experience could be classified as a partial application of this methodology. This work compares both approaches, traditional lectures and partial Flipped Classroom. The study is framed in the subject Language Processors of a Computer Science degree, focusing on practical contents and observing students' learning outcomes and students' satisfaction.

The rest of the article is structured as follows. Section II describes the literature related to this study. Next, sections III and IV detail the objectives of the study and their educational context. Section V explains the design of the study followed by its results in section VI. Finally, we discuss these results and draw our conclusions in sections VII and VIII.

II. RELATED WORKS

One of the foundations of the Flipped Classroom (hereafter "FC") methodology is the constructivist theory. It states that meaningful learning is supported by student's engagement in the learning process and active interaction with the learning materials [6]. Both aspects seem to be facilitated by the changes proposed by the FC methodology. Moreover, this methodology can be easily integrated with other active methodologies, e.g. Problem Based Learning [7], Peer Instruction [8], or Just in Time Teaching [9]. This could improve the learning experience increasing students' responsibility on their own learning process [10], e.g. some studies show how students engage in out-class activities [11] while in-class activities help them correct errors and address misunderstandings almost at the moment they are detected [12].

Another important advantage of FC is flexibility. From the students' point of view, they can choose when to work with out-class materials (taking into account the restriction of doing it before in-class sessions). Also, if these materials are videos, they can be viewed as many times as needed and only play the parts students are interested in [11], [13]. From the teachers' point of view, FC allows the use of different materials depending on students' learning styles [3].

Thus, many studies with positive results can be found in the literature. These results range from improvements in learning outcomes when FC is used [14], [15], through better motivation and attitude [13], [16] to better students' opinion about the learning experience [17], [18]. In addition, other studies show that FC classes are more enjoyable and make students more confident in their performance [3], [19], [20].

But all these advantages seem to take place when FC is utilized within an ideal context, which also does not seem to be unique. Literature shows that more work is needed in order to check which conditions support those positive results. Here below we review related works about materials and activities, problems and unclear results, and how this methodology has been used within the scope of CS education.

A. MATERIALS AND ACTIVITIES

Out-class materials provided in FC could be any kind of documentation deliverable to students, e.g. electronic documents, podcasts or videos. But the latter are the most frequently used in this methodology. Generally, students prefer educational materials in video format [13], [21], [22]. The best valued features are their review and rewind possibilities, which supports a better understanding of the explained concepts [15], [18]. In addition, videos allow to explain different kinds of concepts and from different points of view [23]. Some studies have analyzed the desired features of videos from the students' point of view. There are two important aspects about educational videos, they should be enjoyable [24] and motivating [25]. Although these are also desired characteristics in traditional lectures, they are important because in FC methodology students watch these videos as part of their out-class work. Other interesting features are: interaction possibilities [21], short duration [26] (some studies report on a limit of 20-30 minutes [22]) and to be authored by the teachers [22].

In addition to video-watching, out-class activities should be complemented with other ones like exercises, problem-solving or quizzes. The latter are one of the most used tools to complement videos, their main aim is to motivate students to work with out-class materials and other activities [13]. Galway *et al.* [27] detected that quizzes can serve as an incentive to complete the study of the concepts explained in the out-class materials. Although their use should have positive effects on the learning process, some studies show that students only answer these quizzes if they have any impact on their grades [28].

In-class sessions are another important part of the FC methodology. There is the risk of becoming traditional lectures if they are not specially designed [29]. Thus, many educational techniques could be used like problem-solving, small group activities, discussion, collaborative group work, and feedback [13].

B. PROBLEMS AND UNCLEAR RESULTS

As it has been said before, this is a promising educational methodology. But many studies have found problems, challenges and even unclear results after experimenting with FC.

One of the important problems is teachers' adoption, it is hindered by many reasons. Firstly, there is a lack of courseware specifically designed for FC [30]. Although some software is being delivered, e.g. edpuzzle,[5] its integration with standard courseware is not often supported by educational institutions, becoming this task the teachers' responsibility. Secondly, teachers have to prepare specific materials for the FC sessions [12]; at least, usable materials have to be redistributed in short videos [31]. In addition, teachers have to prepare in-class sessions with new materials and pedagogical techniques. Consequently, many studies have detected a significant increase of teachers' workload [15], [32]; Wanner and Palmer [33] quantified this workload in six times the amount of work needed to prepare a traditional lecture.

Another important problem concerns students. They have to complete many tasks during their own-study time (out-class activities) but they have a lack of experience in self-directed study contexts [34]. On the one hand they feel that new responsibilities have appeared in out-class time [15], [35]. On the other hand, some students are not familiar with the use of out-class materials and they cannot receive immediate attention when they are using them [13]. In this aspect, while some studies found evidences of an increase of students' workload [21], [32] others did not find any difference against traditional lecture environments [11]. Finally, some authors state that students from last courses of the degree have more difficulties because of their experience with traditional lectures in previous courses [12], [31].

Although successful experiences can be found in the literature, as mentioned before, there are no clear results about effectiveness of this methodology or its adoption by students. Of course, this is a field still under research and the generalization of results is difficult [13]. However, many studies provide weak results or even contradictory to other ones. For example, it has been said that students prefer videos as educational materials, but if videos are too long [19] or deal with complex concepts [36] this preference disappears. Moreover, Long *et al.* [22] detected that engineering students had no clear preference between videos and text as out-class materials, and Zhang *et al.* [37] found that the effectiveness of video lectures and traditional lectures was similar.

Regarding quizzes, even if they have an impact on students' grades, this could not ensure that students work with out-class materials. Lacher and Lewis [38] hypothesize that it could be due to the kind of questions included in the quizzes.

Finally, although we mentioned some studies showing positive results, Giannakos *et al.* [39] conclude that, on the one hand, many positive results lack of either sound demonstration or enough strength, on the other hand, there are some contradictory results that need to be clarified. For example, Baldwin [40] said that students recognized what they learnt but they were not satisfied with the learning experience. Other studies show that there is not a clear preference between FC and traditional lectures [13], especially in the last courses [31]. Finally, other works studied students' attendance rates finding no differences between FC and traditional lectures [41] or even surprisingly low ones in FC sessions [21].

C. THE USE OF FLIPPED CLASSROOM IN COMPUTER SCIENCE

It could appear that the application of FC was focused on pre-university studies, but the number of works in the university scope is increasing, although many of them do not justify why they use this methodology [32]. There are interesting reviews that have surveyed the use of FC in university grades. Thus, most of the works studied the application of FC in Chemistry, Physics, Calculus, Nursing and Statistics [2]. But there has been little work in engineering studies [32]. Moreover, Yang *et al.* [42] quantified the number of publications about Computer Science in less than 4.7% of their review.

However, there is a general increasing trend in the number of publications about FC and so within the scope of CS [13], [39]. Thus, many publications deal with Programming, since this is one of the most researched areas in CS education. We have found some examples of integrating FC with another

[5] https://edpuzzle.com/, 2020

teaching technique or methodology: Llamas-Nistal *et al.* [43] observed improvements in student retention and passing rate when mixing FC with intensive assessment in a Computer Architecture course, and Chis *et al.* [7] detected positive results in a CS1 course mixing FC with Problem Based Learning. On the contrary, Jonsson [21] measured low participation rates mixing FC and Just in Time Teaching in an Object-Oriented Programming course.

Other works just study flipped courses without any comparison, again with mixed results. Gannod *et al.* [36] flipped a Software Engineering course (focused in SOA and web services) with positive results while Herold *et al.* [44] flipped another Software Engineering course without any reported result. Finally, Baldwin [40] observed low student's engagement in a CS1 course for non-majors in CS.

There are also comparative studies between FC and traditional lectures. Thus, improvements in learning outcomes were detected in a Human-Computer Interaction course [45] and a MATLAB programming course for non-majors in CS [14]. On the contrary, other studies did not report any learning difference between both methodologies in a variety of courses: Computer Architecture [12], CS1 [41], CS1 with Scala [38] and CS1 with Python [26]. Students' satisfaction has been also studied in many publications, some studies detected improvements (in favor of FC) in different courses: Computer Programming in Meteorology [17], Computer Systems [16] and Databases [46]. In the later study, students from the FC group commented on the increase of their workload. Finally, in the previously cited work about and CS1 with Python [26], students were not satisfied with some aspects of the FC approach.

III. OBJECTIVES OF THE STUDY

Based on the previously mentioned publications, we have not found any work within the CS field dealing with Language Processors. This subject has both, theoretical and practical contents, with the same level of importance and strong links between them, as it will be seen in the following section. This makes FC suitable for this subject. The first objective of this study is to increase the body of knowledge regarding the use of FC in CS degrees.

In addition, the authors have not found any work that objectively measures the impact of the increase of students' responsibility [10] on their learning outcomes. Therefore, the second objective is to test the following hypothesis: *Flipped Classroom support students' responsibility towards their learning process, engaging with the contents taught with this methodology and achieving a more regular learning pace*.

In order to test this hypothesis, we have conducted an experiment taking into account the knowledge provided by the previously mentioned publications. Therefore, short videos with quizzes were used as out-class materials and activities and in-class activities were designed in order to avoid becoming traditional lectures. In addition, teacher's effort dedicated to produce FC materials and design activities (out-class and in-class) was minimized. Thus, this work will provide empirical evidence of the impact of those features in the learning process. Detailed information about these aspects will be provided in the section V that describes the experiment.

IV. EDUCATIONAL CONTEXT

This study has been carried out in a Language Processors (LPs) course, located at the 3rd year of a four-year Computer Science graduate program at the Universidad Rey Juan Carlos. LPs are a significant part of compilers and interpreters (hereafter compilers). A compiler processes a source code, analyzing it and translating it to binary or low-level code which is executable by a computer or a virtual machine. An LP is the part of a compiler that analyzes the source code and provides part of the theoretical foundations to make the proper translation to binary or low-level code. LPs are also highly dependent on other fields like automata and formal languages theory. All these theoretical concepts are one of the main reasons why students identify LPs as a complex subject within CS degrees [47].

The syllabus of the course consists of four topics: introduction to LP, lexicographic analysis, syntax analysis and syntax directed translation. The course lab project evolves in the same way starting from the second topic. Thus, students firstly develop the scanner (lexicographic analyzer), secondly the parser (syntax analyzer) and finally the syntax directed translator. This experiment is located in the second topic, the lexicographic analysis, focused on the development of the scanner. So students have to understand and apply theoretical concepts like finite state automata and regular expressions, which are the theoretical basis of the scanner. They also have to learn how to design and develop scanners using a scanner generator, in our case this tool is JFlex.[6] This kind of tools require from students to integrate code (Java in the case of JFlex) with regular expressions, being the scanner the resulting software.

These contents are covered during eight sessions, of two hours each. Using a traditional teaching approach, the first two sessions are devoted to the theoretical classes and the second two are laboratory sessions focused on the design and development of scanners finishing with an optional lab project. The rest of the sessions are dedicated to the work on the scanner of the course lab project. This experience will be located in the first four sessions and will investigate the educational impact of using the partial FC approach when students are learning how to design and develop scanners with the scanner generation tool JFlex.

Scanner design has a significant amount of practical work but is closely related to the theoretical concepts of regular expressions. Therefore, we think that it fits with the FC approach by providing out-class materials and activities about how to use regular expressions in JFlex together with particular features of this software, and by planning examples and

[6] https://www.jflex.de/, 2020

exercises for in-class activities where students' doubts will be addressed. A detailed description of materials and activities will be provided in the next section.

V. EXPERIMENTAL DESIGN

In order to evaluate the effect of using the partial FC approach we have conducted a comparative study against a traditional lecture-based approach within the previously described educational context. The study follows a quasi-experimental design [48] and will be detailed in this section.

A. SUBJECTS & INDEPENDENT VARIABLES

Participants were students enrolled in two LPs courses, actually they were the same course taught in two different campuses. Since both classes could not be divided, a random assignment of treatment/control conditions to groups was performed. The independent variable was the teaching approach: partial FC for the treatment group and traditional lectures for the control group.

The number of participants was 172, 109 students in the treatment group and 63 in the control group. The participation was incentive-based with a maximum increase of 1 point (out of 10) in the grade of the subject, but only after being passed the course exam. The increase will depend on the grade the students get in the optional lab project.

In order to achieve a balance between treatment group and control group, both groups were taught by the same teacher covering the same concepts and using, when possible, the same materials. Students from the treatment group had not previous experience with the FC methodology. In addition, both groups took a theoretical test regarding lexicographic analysis but without any question about scanner development with JFlex (the contents taught during the study). After analyzing students' grades in this test, no significant differences were found ($U=2633$, $p=0.587$) between treatment group ($M=0.7805$, $SD=0.2559$) and control group ($M=0.7272$, $SD=0.2765$).

B. TREATMENTS

As it was said before, the study will be focused on scanner development, the practical part of the topic. We describe below how it was taught under the control and treatment conditions.

The control condition, a traditional teaching approach, was made of lecture and lab sessions. During the lecture, students were taught with three different contents. Firstly, a lecture about the JFlex tool, secondly, they had to work solving some questions about the previous explanations and finally they had to work with some simple examples. Lab sessions were dedicated to work on solving an exercises sheet (supported by the teacher) and the optional lab project. The materials provided to students were the slides of the lecture together with the online documentation about the JFlex tool, the exercises sheet, and the optional lab project wording.

The treatment condition, the partial FC approach, was made of a FC session together with lab sessions. In order to avoid confusion among students due to the change in the teaching methodology, we followed the controlled pacing pattern [29] in our FC approach. This pattern consists in providing the students with information about the schedule of the sessions, out-class materials an activities and in-class activities. The involved students received this information before the beginning of the treatment.

Before the FC session, students were provided with out-class materials and activities. Out-class activities consisted in questions answered by students after using the materials, and integrated with them.

In our study, the out-class materials were four videos lasting an average of 7.4 minutes, being the lengthiest 13 minutes long, and the online documentation about the JFlex tool. In order to provide out-class activities, each video ended asking a question that must be answered using a Moodle Question & Answer forum. These kind of forums oblige students to send an answer before they can see others' answers and provide feedback on their answers together with discussion possibilities. There was no incentive due to video watching or question answering for treatment group.

The videos were made based on the lecture slides and the questions were the same posed to the control group during its lecture. The production process of the videos followed these steps: (1) add narratives to slides using MS Powerpoint, (2) check the correctness of the slides with the narratives, (3) save the presentation in WMV format,[7] and (4) transform the WMV file in a MPEG4 file with ffmpeg software.[8] The quality of the videos is a significant factor in the success of using FC [13]. Producing our videos from the lecture slides provides a tradeoff among video quality, control-treatment group balance and additional teacher workload.

The main objective of FC in-class activities is to avoid the traditional lecture approach. KÃČÂűppe *et al.* [29] recommend to work on contents related to students providing an added value. In our study, the FC class began answering students' doubts and questions about the out-class materials, and addressing misconceptions detected in out-class activities, followed by work with some simple examples (the same as the control group). Lab sessions were also dedicated to work on solving the exercises sheet (supported by the teacher) and the optional lab project.

It should be noted that we ensured as much as possible that differences between treatment and control conditions are only due to the independent variable: the teaching methodology. The teacher, the availability of materials, the questions posed to the students, the simple examples, the exercises sheet and the wording of the optional lab project were the same in both groups. The rest of the materials were different, but videos provided to the treatment group were based on the slides used with the control group.

[7] Windows Media format, the only option available in the version of MS Powerpoint used in the study

[8] http://ffmpeg.org, 2020

TABLE 1. Procedure of the study.

Week	Session	Treatment group	Control group
1st	1st	Lexicographic analysis	
1st	2nd	JFlex doubts + questions + simple exercises	JFlex theory session (1 hour) + questions + simple exercises (1 hour)
2nd	3rd	JFlex exercises sheet	JFlex exercises sheet
2nd	4th	JFlex optional lab project explanation & work Prelimnary submission	
2nd	Out-of -class	Self-work on optional project (4 days) Final submission	
		Student's satisfaction questionnaire	

C. PROCEDURE OF THE STUDY

The topic "Lexicographic Analysis" was taught during 4 weeks (8 sessions, 2 sessions per week). Our study was located in the first two weeks; the last two weeks were dedicated to work on the course lab project part related to the topic. Each session lasted two hours. A schema of the procedure of the study can be found in Table 1. The first session was dedicated to a theoretical lecture about the topic in both groups. The three following sessions were dedicated to scanner development with JFlex. The control and treatment conditions were applied from the second to the fourth sessions. The control group was taught with the lecture approach, together with the questions and simple examples. The treatment group was taught with the partial flipped approach, so immediately after the first session, materials related to the treatment were available for students. The second session of the both groups was conducted as described in the treatments subsection. The third session was dedicated to work on the exercises sheet and the fourth to work on the optional lab project. These two sessions were differentiated between control group and treatment group by the materials available from the second session due to the teaching methodology. At the end of the fourth session students were asked to submit the work they have done until that moment, the preliminary submission. Next, both groups had four days to work on their solution to the optional lab project. After the fourth day, students were asked to submit their solutions. In addition, students in the treatment group were asked to complete a student's satisfaction questionnaire.

D. DEPENDENT VARIABLES

The dependent variables of the study are three: student retention, learning outcomes, and student's satisfaction. The implementation of student centered environments is one of the main features of active learning methodologies. These environments engage students with their own learning process. One of the effects of this engagement is the development of student's responsibility regarding their own learning process [10]. As an active learning approach, FC should lead to lifelong learning [49] and meaningful learning [6]. On the contrary, the classical learning approach focuses student's effort around evaluation (exams and project) dates, leading to superficial learning [50].

In order to study this aspect, this study measures student retention and learning outcomes in two different moments: immediately after the 4th session (referred as preliminary submission) and at the project submission deadline (referred as final submission). On the one hand, preliminary submission measures students' results due to the learning process. A regularly paced learning process would produce better learning outcomes than an evaluation focused one. Students did not know that they had to submit their work in the preliminary submission, they were just asked to submit whatever they have done during the 4th session, they also were noticed that this submission did not have any effect on their grades. On the other hand, final submission measures students' results due to the learning process together with their own work dedicated to complete the optional lab project submission. Learning outcomes are measured evaluating students' preliminary and final submissions.

As it has been said, the optional lab projects deal with the development of a lexical analyzer with the JFlex tool. Students' main task is to specify patterns that will detect lexical structures in the input and, through semantic actions associated to the previous patterns, will produce the corresponding output. The optional lab project consists in visualizing a preview of a twitter message as an HTML document. Students were provided with fixed parts of the HTML code at the beginning and at the end of the HTML document. The input is plain text containing the name and twitter account of the author, web links, references to other twitter accounts, hashtags, and common text. Each of these elements will be visualized with different formats. In addition, if the number of characters is greater than a certain limit, the exceeding characters should be specially treated. The project is graded in a [0-10] range, being 5 the passing grade. Students were informed about the requirements needed to get 5, 8 and 10 points:

- In order to achieve 5 points, students must produce the output where the elements of the message were correctly formatted. It was not needed to give any special treatment to exceeding characters.
- In order to achieve 8 points, students must accomplish the previous requirements and ignore the exceeding characters. So, these characters must not appear in the output.
- In order to achieve 10 points, students must accomplish requirements for 5 points and produce an output where exceeding characters must be formatted in a specific way. Note that if the limit is achieved inside an element with special format, e.g. a hashtag, one part of the hashtag must be formatted as it should but the rest must be formatted as exceeding characters.

Intermediate grades in the ranges 5-8 and 8-10 are assigned depending on how students deal with the elements of the message that begin before the characters limit and end after it. Fig. 1 shows an example of an input and different outputs for each grade level.

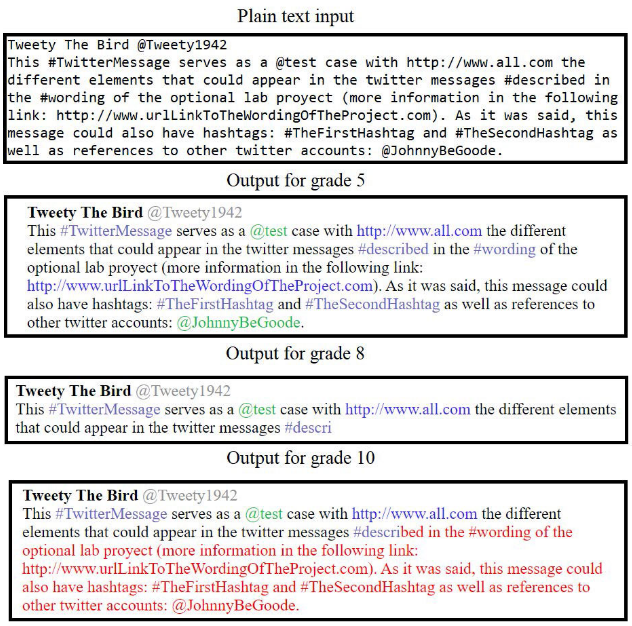

FIGURE 1. Optional lab project. Examples of plain text input and outputs for the three different grade levels: 5, 8 and 10.

The final submission will be evaluated based on these requirements, but it is quite difficult that any student achieves even 5 points in the preliminary submission. Therefore, the evaluation criteria of the preliminary submission will be based on a deeper analysis of students' progress towards the requirements, regardless of whether they are fully accomplished. Thus, the evaluation of the preliminary submission will be measured as the weighted average of the aspects designed in the lexical specification. Each aspect will be measured in a [0-1] scale being 1 the best possible value for that aspect. These aspects and their corresponding weights are:

1) Generating their own java class with `%class` option (weight=0.5).
2) Using `%line` and `%column` options together with `yylenght()` method for counting characters (weight=0.5).
3) Correct definition (weight=1) and use (weight=1) of states.
4) Correct pattern specification for detecting the different elements of the message (weight=2).
5) Use of regular definitions in the patterns mentioned before (weight=1).
6) Generation of the fixed HTML code in the header of the lexical specification (weight=0.5).
7) Generation of the fixed HTML code with the `%{ %}` or `%init{ %init}` clauses (weight=0.5).
8) Correct specification of semantic actions that generate the HMTL code of the elements of the message (weight=1).
9) Provide a valid JFlex specification (weight=1).

Student retention is measured in terms of the percentage of students that have submitted a solution with evaluable content. Empty or inconsistent files are not accounted as evaluable submissions. This measurement is the same in the preliminary and the final submission.

Student's satisfaction is measured with an anonymous opinion questionnaire analyzing three aspects: general comments about the course and, positive and negative comments about the use of the FC methodology. Since these comments are focused on this methodology, only students from the treatment group were asked to complete this questionnaire.

TABLE 2. Comparison among groups based on students' grades in the theoretical exam.

Group	Grade	Coparison vs. Traditionals	Coparison vs. Flippers
Traditionals	(M=0.7272, SD=0.2765)	N/A	(U=1951, *p=0.511*)
Flippers	(M=0.7807, SD=0.2407)	(U=1951, *p=0.511*)	N/A
Viewers	(M=0.7800, SD=0.3032)	(U=682, *p=0.954*)	(U=896, *p=0.667*)

VI. RESULTS

After analyzing the treatment group students' interactions with materials, we realized that there are two changes with respect to the initial design of the experiment. Firstly, the initial number of students was 109 but only 95 used the materials provided by the teacher. Secondly, 12 out of these 95 students were not fully involved in the FC methodology because they did not use the out-class materials before class sessions but during or after them. Therefore, the methodology they used to learn was not FC. In order to address these changes, we have classified students of the initial treatment group into two groups: Viewers, composed by students from the treatment group who did not follow FC methodology but used the materials, and Flippers, composed by students who followed the FC methodology. Therefore, our groups are actually three: control group (n=63, hereafter Traditionals), Flippers (n=83) and Viewers (n=12). In order to avoid Type I error, when the analyses compare the three groups, we will apply the Bonferroni correction, being the new p threshold *0.016* (0.05/3).

Given this new group division, we analyzed again students' grades in the theoretical test. Table 2 shows these exam grades and the comparisons. No significant differences were detected among the three groups; therefore, we could hypothesize that the groups are not skewed and comparisons in this study are valid. Here below, the results at the preliminary and final submissions are described.

A. PRELIMINARY SUBMISSION

As it was mentioned before, students were asked to submit the current version of their work on the optional lab project at the end of the 4th session. We will measure how many specifications were submitted (student retention) as well as their correctness (learning outcomes).

TABLE 3. Student retention preliminar submission.

Group		Coparison vs. Traditionals	Coparison vs. Flippers
Traditionals	65.08% (41/63)	N/A	***p=0.0061***
Flippers	77.11% (64/83)	***p=0.0061***	N/A
Viewers	75.00% (9/12)	*p=0.0753*	*p=0.2543*

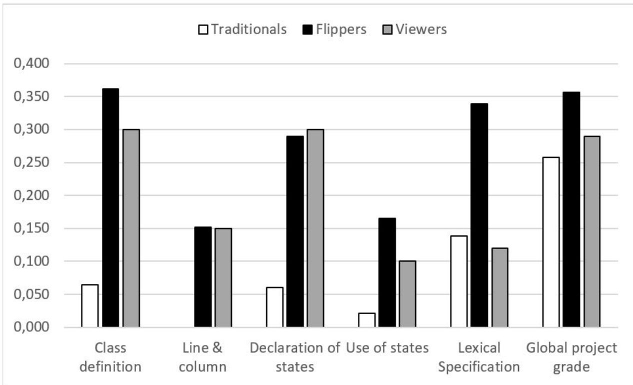

FIGURE 2. Graphical representation of the preliminary learning outcomes.

1) STUDENT RETENTION

The amount of submissions per group can be seen in Table 3. In order to detect significant differences among Traditionals, Flippers and Viewers we have used the binomial distribution test. We did not detect any significant difference between Viewers and Flippers (*p=0.2543*). But when they were compared against Traditionals, results suggest that the number of Viewers' submissions is slightly greater than Traditionals (*p=0.0753*) and the number of Flippers' submissions was a 12.03% significantly greater than Traditionals (***p=0.0061***).

2) LEARNING OUTCOMES

Regarding the preliminary learning outcomes, significant differences have been mainly detected between Traditionals and Flippers. Fig. 2 and Tables 4 and 5 show average learning outcomes and statistical analysis of the variables where significant differences have been detected. Most of these results show how Flippers outperform Traditionals in: the definition of the main class (29,8%), use of line and column count (15,2%), declaration of states (23%) and its use (14,4%), correctness of the lexical specification (20,1%) and finally the global project grade (9,8%). Viewers only outperforms Traditionals in the use of line and column count (15,0%). No significant differences have been detected in the rest of comparisons among the tree groups.

B. FINAL SUBMISSION

1) STUDENTS' RETENTION

The results regarding students' retention have changed from the preliminary to the final submission (see Table 6). The percentage of students who submitted final solution to the project in the Traditionals group is a 12.11% significantly greater (*p<0.001*) than Flippers and a 11.91% slightly greater (*p=0.092*) than Viewers.

TABLE 4. Preliminary learning outcomes per group.

	Traditionals	Flippers	Viewers
Class definition	(M=0.064, SD=0.224)	(M=0.362, SD=0.484)	(M=0.3, SD=0.483)
Line & column	(M=0.0, SD=0.0)	(M=0.152, SD=0.331)	(M=0.15, SD=0.338)
Declaration of states	(M=0.06, SD=0.247)	(M=0.29, SD=0.457)	(M=0.3, SD=0.483)
Use of states	(M=0.021, SD=0.146)	(M=0.165, SD=0.355)	(M=0.1, SD=0.316)
Lexical Specification	(M=0.138, SD=0.226)	(M=0.339, SD=0.236)	(M=0.12, SD=0.29)
Global project grade	(M=0.258, SD=0.16)	(M=0.356, SD=0.242)	(M=0.29, SD=0.457)

TABLE 5. Significant differences analysis for preliminary learning outcomes.

	Traditionals vs. Flippers	Traditionals vs. Viewers	Flippers vs. Viewers
Class definition	**(U=1147,** ***p<0.001*****)**	(U=181,5, *p=0.049*)	(U=323,5, *p=0.702*)
Line & column	**(U=1316,** ***p=0.002*****)**	**(U=188,** ***p=0.002*****)**	(U=344, *p=0.983*)
Declaration of states	**(U=1255,** ***p=0.003*****)**	(U=179.5, *p=0.029*)	(U=341.5, *p=0.948*)
Use of states	**(U=1352.5,** ***p=0.007*****)**	(U=216.5, *p=0.223*)	(U=316.5, *p=0.527*)
Lexical Specification	**(U=787,** ***p<0.001*****)**	(U=116, *p=0.121*)	(U=175, *p=0.574*)
Global project grade	**(U=906,** ***p=0.008*****)**	(U=114.5, *p=0.076*)	(U=287.5, *p=0.993*)

TABLE 6. Student retention final submission.

Group		Coparison vs. Traditionals	Coparison vs. Flippers
Traditionals	95.24% (60/63)	N/A	***p<0.001***
Flippers	83.13% (69/83)	***p<0.001***	N/A
Viewers	83.33% (10/12)	*p=0.092*	*p=0.296*

TABLE 7. Student learning outcomes in the final submission grades.

Group		Coparison vs. Traditionals	Coparison vs. Flippers
Traditionals	(M=5.324 , SD=2.533)	N/A	**(U=1374 ,** ***p<0.001*****)**
Flippers	(M=7.094 , SD=3.583)	**(U=1374 ,** ***p<0.001*****)**	N/A
Viewers	(M=5.167 , SD=3.769)	(U=363 , *p=0.828*)	(U=343 , *p=0.080*)

2) LEARNING OUTCOMES

The learning outcomes of the final submission is measured with the grades of the project. As it can be seen in Table 7, Flippers get the best results. Flippers significantly outperform (*p<0.001*) Traditionals in a 17.7% and slightly get better results (*p=0.080*) than Viewers. On the other hand, no significant differences were found between Viewers and Traditionals.

We have also studied passing rates of the project for each group analyzing the differences using the binomial test. The results are similar than grades, see Table 8. Passing rate of Flippers is significantly greater (*p<0.001*) than Traditionals in a 24.38% and slightly better than Viewers.

TABLE 8. Student learning outcomes in the final submission passing rate.

Group		Coparison vs. Traditionals	Coparison vs. Flippers
Traditionals	57.14% (36/63)	N/A	***p<0.001***
Flippers	79.52% (66/83)	***p<0.001***	N/A
Viewers	66.67% (8/12)	*p=0.1898*	*p=0.1392*

TABLE 9. Student's satisfaction: analysis of students' comments.

Category	% of all comments	% of comments related to FC
General comments	38% (30/79)	-
More traditional lectures	3.8% (3/79)	6.1% (3/49)
Good video lectures	7.6% (6/79)	12.2% (6/49)
No changes needed	50.6% (40/79)	81.7% (40/49)

3) STUDENT's SATISFACTION

The number of answers received to the questionnaire was 70. Some answers had comments regarding different aspects, therefore they were considered as different comments. Thus, 79 comments were detected and they were classified within four different categories, see Table 9 for a summary of comments and categories.

One category collected general comments regarding the course while the other three collected comments related to the use of the FC methodology. Thus, the 38% (30/79) of the comments were classified within the general comments category. Most of these comments (26 out of 30) asked for more exercises with solutions while the rest of them dealt with different questions about the JFlex tool and the optional lab project.

We will focus our analysis on the other three categories, comprising the rest of the comments (62% - 49/79). They were positive and negative opinions about the use of the FC methodology. Only the 6.1% (3/49) of these comments asked for traditional lectures during in-class sessions instead of the FC approach. The 12.3% (6/49) of the comments explicitly highlighted the advantage of having video lectures. Finally, the 81.6% (40/49) of the comments said that nothing should be changed in the experience.

VII. DISCUSSION

In this study, traditional lecturing and partial FC methodologies are compared. Three objectives guide this work: increase the amount of experiences dealing with the use of FC within CS education, test the hypothesis about the increase of students' responsibility due to the FC methodology, and provide empirical evidences about the impact of some design aspects regarding the use of the FC methodology.

A. INCREASING THE BODY OF EXPERIMENTS ABOUT THE USE OF FLIPPED CLASSROOM IN CS

Some of the last published surveys regarding the use of FC highlight that more work is needed in engineering education [32] and so, in CS education [42]. Moreover, few studies performed formal evaluations and few of them found significant results in engineering education [32]. In many studies, the lack of information about the evaluation [39] undermine the validity of results hindering their use for further research. This work reports an experience in CS with formal evaluation and significant results detected. In addition, many of the experiences have been carried out with populations less than 100 students [39] while this work effectively involved 146 students. Finally, while most of the works mentioned within the scope of CS study full applications of the FC methodology, this work considers a partial application of it.

The studies that observed positive results, either in learning outcomes [7], [14], [43], [45] or student's satisfaction [17], [46], mostly seem to deploy the FC approach on practical contents. Only Horton & Campbell's study [46] specifically focuses on an introductory topic about databases. This work is another successful experience of FC methodology applied to practical contents. Probably, labs (session about practical contents) are better adapted by teachers and better accepted by students as in-class sessions. Therefore, activities and materials could be better and students could be more engaged with the contents; consequently, better results could be observed.

As it has been said before, no experience where FC had been used in a LPs course has been found. Within the CS scope, and leaving apart that Programming and LPs are in different levels of abstraction, Programming is the closest topic to our experience. While basic programming contents deal with organizing actions (sentences) using flow control structures and data in order to achieve a result, the design of translators is based on organizing actions (semantic actions) using the flow control imposed by the parsing process as it applies grammar productions. The experiences about the use of FC methodology to teach programming have shown mixed results. Some of them detected improvements in learning outcomes [7], [14] while other did not [7], [26], [38], [41]. One experience observed satisfied students [17] while other observed unsatisfied ones [26]. Finally, two studies detected low students' engagement [40] and low participation in the in-class sessions [21]. From the point of view of the final submission, this work contributes with an experience where high retention rates and significant improvements in students' learning outcomes who were taught with the FC methodology have been observed. In addition, students from the Flippers group were highly satisfied with the learning experience.

It seems that there is a contradictory result in the observed student retention at the final submission. Although Flippers got better results than Traditionals in the preliminary submission, Traditionals' student retention was a 12.11% significantly greater than Flippers' one in the final submission. Is this a positive result from the Traditionals point of view? We have analyzed Traditionals' results without preliminary submission but with final submission. These students' average grade was 5.34 having a 37% of non-passing grades in this submission. Our impression is that, since this submission is not compulsory and just add points to the final subject grade, many of these students just submitted poor solutions, showing that they have not worked enough on the topic. In our opinion, a high student retention rate with significantly greater grades (the Flippers' results) is better than a higher student retention rate with significant lower grades (the Traditionals' results). Therefore, we think that this increase in student retention does not reflect an advantage in the Traditionals' learning process.

Finally, some of the students initially included in the treatment group did not follow the FC methodology. On the contrary, they just watched videos during sessions or after them in their self-study time. Therefore, we classified them in a new group called Viewers. They have to be taken into account in order to identify what has impacted the final submission grades, just the availability of videos (the Viewers condition) or the whole FC methodology? No significant differences ($p=0.828$) have been detected between Viewers and Traditionals but closer to significant differences ($p=0.080$) have been detected between Viewers (average grade of 5.167/10) and Flippers (average grade of 7.094/10), and significant differences ($p<0.001$) have been detected between Traditionals (average grade of 5.324/10) and Flippers. This means that the main cause of the increase in the Flippers' final submission grades is the whole FC methodology.

B. STUDENTS' RESPONSIBILITY

Felder and Brent [10] state that student centered environments, like the ones created with FC methodology, support the development of student's responsibility increasing student's engagement with the learning process. One way to measure this impact is checking whether the student's learning process is regular rather than more focused on evaluation. Since most of the evaluations carried out in experiments measure results at the end of the treatments [32] it is not possible to differentiate whether the learning is regular or focused on evaluation.

This work measures learning outcomes and students' retention in two different moments: once the FC sessions have finished -preliminary submission- and at the end of students' work -final submission. The aim of preliminary submission is to measure students' performance due to their work during in-class sessions and their corresponding out-class study time. If students' work is focused on evaluation their performance would be low, on the contrary, if students' work is regular their performance should be greater. In the observed learning outcomes at the preliminary submission, Flippers significantly outperformed Traditionals with an increase of 9.8% in the global grade. The same effect has been observed regarding student retention, being a 12.03% greater. Therefore, this work confirms Felder and Brent [10]'s claim because Flippers' performance was better than Traditionals' one in the preliminary submission. This means that Flippers have been regularly working with materials and studying because they have become more responsible of their learning process due to the FC methodology. This regular pace can also be seen in the fact that student retention at the final submission hardly increased a 6% ($p=0.047$) while Traditionals' one did more than a 30% ($p<0.001$), note that this evidences how evaluation-driven is the Traditionals' learning process.

Is the FC methodology the main cause of improvement in learning process? We still have to take into account the Viewers group, those who just viewed videos without completely engaging with the FC methodology. Thus, no differences in learning outcomes have been detected between Flippers and Viewers, neither between Viewers and Traditionals, except for a concrete aspect but not in the global preliminary submission grade. Therefore, we can affirm that Viewers got worse results than Flippers in comparison against Traditionals. This means that the main cause of improvement in the learning process was due to the FC methodology and not just the availability of videos.

C. OTHER LESSONS LEARNED FROM OUR EXPERIENCE

One of the important challenges is the adoption of FC by teachers due to the increase of teachers' workload [13], [15], [32], [33]. In order to minimize this workload increase, a reuse strategy has been followed in the design of the FC treatment in this experience. We have used exercises sheets from previous years to prepare most of the in-class activities. The workload produced by the generation of new out-class materials [12] has been diminished reusing existing slides used in traditional lecturing. The distribution of these slides in groups [31] could not be avoided since it is needed in order to make short videos. Narratives were added to these slides, then the correctness and length of the narrated slides were checked. Next, they were saved as MS Windows video format and finally transformed to MPEG4 files using ffmpeg free software.[9] Note that these two steps can be performed in batch mode minimizing workload. Finally, instead of learning how to use specific new software [30], we have used the current and official courseware at our institution, Moodle and MS Powerpoint. We only had to learn how to use ffmegp, which is also an easy step as can be seen in their website. Moreover, the last version of MS Powerpoint produces directly videos in MPEG4 format so nowadays, ffmpeg is not needed.

Students' acceptation of the FC methodology is another challenge to face. This study offers empirical evidence of a clear students' acceptation, given the high student retention rate and the student's satisfaction in the Flippers group. They had the advantage of knowing how to use out-class materials [13], since they were simple videos and the quizzes were posed through the standard courseware already used in previous years of the degree. But they also accomplished with possible negative features because this subject belongs to the second semester of the third year (out of four) of the degree [12], [15], [31], [34], [35] and none of the students had any previous experience with FC methodology. In our opinion, students' maturity and the short duration of the treatment have more impact than the difficulties of adapting to a new teaching methodology. Students understood that the classes were focused on a two weeks long project that

[9]https://ffmpeg.org/, 2020

would increase their grades and would help them to face the compulsory course project.

Regarding the out-class materials, there have been previous mixed results about videos and quizzes. From a general point of view, students prefer videos as out-class materials, except if they are too long [19] or deal with complex concepts [36]. This work provides an empirical evidence of a successful use of short videos (less than 13 minutes) focused on practical contents. Note that, although JFlex could have some complexity, is not by far the most complex concept in this subject. On the other hand, Long *et al.* [22] detected no clear preference between videos and text in engineering students while Zhang *et al.* [37] found no differences in the effectiveness of video lectures compared against traditional lectures. This work provides empirical evidence that CS students have a good opinion about videos due to the high student's satisfaction, and obtain better learning outcomes when compared against traditional lectures.

Quizzes are an important tool to involve students in a reflection process about the contents of out-class materials. Although Frydenberg [28] states that they should have an impact on students' grades as an incentive, Lacher and Lewis [38] found that even as an incentive they could fail in engaging students with out-class materials. In this study, quizzes have no impact on students' grades but we think that the whole experience does work as an incentive. Firstly, it is a short-term experience, since students had to submit their solutions two weeks after the beginning of the experience. Secondly, this submission would increase their grades. And thirdly, videos and quizzes dealt with the tools that would help students to complete the submission of the course lab project. Therefore, although there was not explicit incentive to watch videos and answer quizzes, they were the means to achieve the incentive of the optional lab project.

Literature provides examples of mixed or even negative results regarding students' attendance rates [21], [41] and students' satisfaction [13], [40]. This study provides empirical evidence of a high students' engagement and retention, and the teacher did not notice differences in attendance rates, although it has not been objectively measured. In addition, students' satisfaction with the FC methodology has been clearly high. Finally, since some studies detected an increase of students' workload [21], [32], our results seem to be in line with those from Lockwood and Esselstein's work [11] because no complains were received regarding the students' workload within the experience.

VIII. CONCLUSION AND FUTURE WORK

This work presents a comparative study between the traditional lecturing methodology and a partial application of the Flipped Classroom methodology within the scope of CS, more precisely in the subject Language Processors. No research has been found regarding the application of this promising methodology to this subject, which is also well known by its complexity [47]. There are many studies about the Flipped Classroom methodology. However, the field of CS needs more research about this teaching methodology in comparison to other academic scopes [42] but also because there are some contradictory results that need to be clarified [39].

On the one hand, this study provides empirical evidence of improvements in learning outcomes and student's satisfaction when a partial application of the Flipped Classroom methodology is used. The results show that students involved in this methodology are more responsible of their learning process [10], studying in a more regular pace and achieving significant better learning results either during the learning process (increase of 9.8%) or at the final evaluation (increase of 17.7%). In addition, it can be seen that students in the traditional lecturing approach focus their effort around the evaluation dates. Some of the students in the Flipped Classroom group did not completely get involved with the flipped methodology, they just viewed videos during or after sessions. These students' results were not as good as the students' results in the flipped group. Therefore, the whole Flipped Classroom methodology, and not just viewing the videos, was the main cause of improvements in the learning process. In addition, students were highly satisfied with the Flipped Classroom methodology.

On the other hand, this is an example of how to begin the transition from traditional lecturing to the Flipped Classroom methodology [32] using a partial application of it. First, adapt concrete parts of the course with short treatments that can be better controlled. And next, extend the application of the methodology to other parts of the subject.

The generalization of the results of this work is limited due to its design. This work studies the short-term and partial application of the Flipped Classroom methodology in a Language Processors course (within the scope of CS) and about practical contents. In fact, the results of the study leave open questions that will guide future lines of work. Would the results be the same if the use of this methodology was applied to more than one concrete part of the syllabus, e.g. the whole course? Would the results be the same if the contents were also theoretical or more complex? Within these new contexts, would the results be the same without any explicit incentive due to the use of out-class materials? Answering these questions will provide more information to clarify the impact of the Flipped Classroom methodology in the students' learning process.

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