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IMPLEMENTING THE FLIPPED CLASSROOM METHODOLOGY TO THE SUBJECT "APPLIED COMPUTING" OF TWO ENGINEERING DEGREES AT THE UNIVERSITY OF BARCELONA

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Abstract

This work is focused on the implementation, development, documentation, analysis, and assessment of the flipped classroom methodology, by means of the just-in-time teaching strategy, for a pilot group (1 out of 6) in the subject "Applied Computing" of both the Chemical and Materials Engineering Undergraduate Degrees of the University of Barcelona. Results show that this technique promotes self-learning, autonomy, time management as well as an increase in the effectiveness of classroom hours.

Keywords – Flipped class, Active learning, Learning sequence, Innovation.

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1. Introduction

The Chemical and the Materials Engineering Undergraduate Degrees offered by the University of Barcelona (Spain) have been undergoing a process of change to fit with the European Higher Education Area requirements. The most widespread change has been focused on assessment. After lecturing, teachers give some individual/group home assignments as part of evaluation evidences. In this way, the summative assessment is not only determined by the final exam. The use of continuous formative assessment methodologies has been also introduced to increase feedback, to promote acquisition/development of transferrable competences, such as teamwork, professional ethics, written and oral communication, personal autonomy and self-regulation (Iborra, Ramírez, Tejero, Bringué, Fité & Cunill, 2014; 2015; 2016). However, these classroom methodological changes have not been uniform, and the revamping of the teaching/learning methodology has been mostly applied to the last academic terms. Hence, it is time to proceed with methodological changes in earlier academic semesters to put students at the center of the teaching-learning process from the beginning.

A typical teaching problem is the utilization of the classroom time in constructing knowledge instead of transmitting it. This implies a change in the role of students in the teaching-learning process. This fact originated the flipped class methodology, constructed by many contributions beginning by that made by King (1993), Mazur and Somers (1999), Lage, Glenn and Treglia (2000) and Khan (2014) among others, until Bergmann and Sams, who launched the Flipped Learning Global Initiative (2016).

Within the available methodologies based on the student-centered teaching (Bowden & Marton, 2011), the purpose of the flipped-classroom methodology is that pupils become actually involved in the teaching-study-assessment sequence and to reverse it into a study-assessment-(auto, peer, hetero)-teaching sequence (Sams & Bergmann, 2013). Main strategies to address such methodology are just-in-time teaching (JiTT) (Prieto, 2011), peer instruction (Mazur & Somers, 1999; Crouch & Mazur, 2001) and team-based learning (Michaelsen, Knight & Fink, 2002).

Flipped classroom approaches remove the traditional transmissive lecture and replace it with active in-class tasks and pre-/post-class work, integrating peer instruction and different strategies. As Abeysekera and Dawson (2015) point, "The flipping of the traditional lecture can take many forms" but all approaches are characterized by:

- A change in the use of classroom time,

- A change in the use of out-of-class time,
- Doing activities traditionally considered 'homework' in class,
- Doing activities traditionally considered as in-class work out of class,
- In-class activities that emphasize active learning, peer learning, and/or problem-solving,
- Pre-class activities,
- Post-class activities, and
- Use of technology.

With regards to the adopted JiTT strategy, its main feature is that preparatory assignments are provided to students so that they can prepare each unit's content beforehand. Their results will be processed by teachers to provide immediate feedback, and to base the contents delivered in the classroom on the students' performance in the activities (Cashman & Eschenbach, 2003; Chen Lin, Chang, Liu & Chan, 2005). Consequently, teachers can invest face-to-face sessions on clarifying common mistakes and do not need to spend time on aspects that students have already shown not to have problems with. Therefore, two convenient effects are combined: classroom sessions' time is more efficiently used and students' motivation can be increased, given that their own comments and questions to the preparatory assignments are incorporated to the sessions contents.

Main goals of the present work include the implementation, development, documentation, analysis, and assessment of the flipped classroom methodology, by means of a JiTT strategy, that has been adopted for a pilot group (1 out of 6) in a theoretical-practical subject, scheduled for the first curricular semester. The aim is to adopt a student-centered approach, to maximize the use of face-to-face classes, and to assess the implemented technique by means of comparing the pilot group performance to those of traditionally handled groups where teacher is the center of the process and performs the typical lecture supplemented with materials and homework.

2. Design/methodology/approach

The flipped-classroom technique was applied to the subject "Applied Computing", which is taught in the first curricular semester of the Chemical Engineering and the Materials Engineering Undergraduate Degrees of the University of Barcelona. It must be pointed out that both Undergraduate Degrees are taught in the same Faculty of Chemistry and that they have eight fundamental subjects in common, consequently, they share teachers and classroom time. "Applied Computing" is a required course that includes both theoretical and practical contents (6 ECTS). Learning outcomes are related to knowing and understanding the use of different useful tools for mathematical calculus and graphical representation. Thus, the specific learning outcomes are to provide basic knowledge of computer tools and numerical methods needed to solve engineering problems and to develop the necessary skills. The list of topics included in the course is divided into two main areas, which are, firstly, Introduction and Programming Languages, and, secondly, Spreadsheets, which so far have been taught trough traditional lectures. There were 123 pupils, distributed into six groups, each one tutored by 1 senior teacher and 1 teaching assistant. The flipped classroom methodology was implemented into a pilot group with 22 pupils and, specifically, on the Spreadsheets subject. The focus for that subject is that students become familiar with the used software (i.e., Microsoft Excel) and able to apply the included theoretical contents (mainly, numerical methods) on engineering-related practical computer exercises.

Traditionally, pupils have access to the subject documentation (lecture notes) through the Moodle platform (Virtual Campus). In order to take advantage of this available material, the strategy adopted was the Just in Time Teaching. Nevertheless, it was also necessary to develop the following additional materials:

- A diagnostic survey (Figure 1) to determine the group characteristics, to know the students' previous background and to identify their needs and expectations;
- Reading guides and instructions, which include a brief description of the contents to revise (with both theory and guided examples) for each block, and a self-learning activity (Figure 2);
- Online questionnaires (generated through Google Forms) to assess the acquisition of the academic contents by the students and to generate a flipped-classroom dynamic. Questions included in the questionnaires were formulated to obtain different types of answers (i.e., right or wrong, multiple choice and open answers) (Figure 3);

- Satisfaction survey to allow students to assess the flipped-classroom methodology (Figure 4).

Face-to-face sessions for the subject are scheduled twice a week, on Tuesday and on Thursday, and they last two hours each (Figure 5). To allow students to tackle each self-learning activity (this includes the reading guide and instructions documents, as well as the online questionnaires) on time, those were delivered, preferentially, after the Thursday sessions.

The planned methodology (Figure 6) establishes that before each session, results from each students' self-learning activity had to be assessed. This allow the teaching staff to plan the classroom working sequence accordingly with the aspects that need further explanation. In order to increase the students' participation and to favor their habit to the flipped-classroom technique, these activities count for 10 percent of the final summative assessment.

Both the exercises and the questionnaires were individually assessed before each session to know the degree of understanding of the unit's content. With that information, teachers could adapt the face-to-face sequence, focusing on the aspects that needed more attention and feedback could be provided for each student. Once in the classroom, the most relevant particularities of each activity were highlighted, focusing on the major detected problems, the questionnaires' answers were commented, and every concept was put into context, as required. In addition, pupils' participation during the sessions was fomented by giving them voice to raise particular doubts. Next, further contents were introduced alternating them with computer exercises to be solved during the session (either individually or guided by the teachers) to achieve the lesson's learning objectives. To close the face-to-face session, a comprehensive task was posed to establish the degree of integration of the acquired contents. After the classroom session, tasks were assessed and individual feedback was provided through the Moodle platform.

It should be noted that the teachers' time investment to adopt a such methodology clearly contrasts with that of the traditional lecture, in which, since both temporal planning and contents are already pre-established, teachers only need to assess the students' performance in three evaluative exercises as well as in the final exam. For the proposed methodology, not only new materials needed to be developed and/or adapted but also a considerable more demanding effort had to be faced, because on-time feedback and flexibility to adapt each session's contents to the students' outcome in the corresponding self-learning exercise are the cornerstone of the present methodology. However, once materials were developed and the working structure was defined, the team of teachers found it easier to handle the, at first, overwhelming load work. Therefore, it is the authors' belief that the initial time investment is worth it, provided that some stability is granted to teachers and all new materials could be used, and improved, in the following years.

1) Mark which of the following options did you follow to access to the degree: a. Access test PAU. b. Access test for people older than 25 years old. c. Access for students from professional training. d. Other. If you choose this option, please explain how did you access to the degree.				
2) Mark which of the following options describes best the academic curriculum you followed during high school: a. Scientific: more emphasis in subjects such as Biology and Earth and Environment Sciences. b. Technological: more emphasis in subjects such as Technical Drawing, Electrical Engineering and Industrial Technology. c. Scientific and Technical: any combination of the above. d. Other. If you choose this option, please explain the most relevant aspects of the academic curriculum you followed.				
3) Did you choose the University of Barcelona as your first choice? a. Yes. b. No. If you choose this option, please indicate which university was your first option.				
4) Did you choose this Degree (either Materials Engineering or Chemical Engineering) as your first choice? a. Yes. b. No. If you choose this option, please indicate which degree was your first option.				
5) From 1 to 4 (1 meaning you totally disagree, and 4 meaning that you absolutely agree with the sentence), please answer the following:				
	1	2	3	4
My knowledge in Mathematics is high				
My knowledge in Chemistry is high				
I use the calculator regularly for solving problems				
I use the computer regularly for solving problems				
I usually prepare class contents in advance				
6) In your opinion, how is this subject going to be useful to you? (Please, describe briefly what do you think this subject is going to contribute with in relation to both your degree and the development of a career.)				

Figure 1. Diagnostic survey

INSTRUCTIONS AND READING GUIDE "NUMERICAL INTEGRATION"

The present flipped-classroom activity document introduces the basic notions to perform numerical integration calculations by means of the polynomial approach known as **Newton-Cotes numerical method**.

The present task pursues multiple goals. On one hand, the ability to apply the principles and basic knowledge related to Chemistry/Mathematics/Computing is going to be developed so that numerical methods can be properly used and, using a spreadsheet, the numerical value of an integral defined between two values of a known function or a series of values can be achieved. At the same time, the student's autonomy is fomented as well as their active learning by granting them an active role within their own learning process through previous construction of knowledge.

At the end of the classroom session, the students should be able to answer to the following questions:

ü When should numerical integration be used?

ü Is it possible that the value obtained through numerical integration is almost identical to the one obtained through solving the analytical integration?

ü Which are the criteria to select the most appropriate integration method?

ü How are used the computing resources (i.e., Excel, spreadsheet)?

To prepare the classroom session, the following text needs to be read and the proposed self-learning activity must be done (JiTT: questions + problem).

TOPIC 4.4 Numerical Integration

Please consider a series of pairs of values (x, y) determined by an independent variable, x, and a dependent variable, $y = f(x)$, which is a function of the former. The determination of the area is named as *integration* and it can be achieved through analytical methods, if the function $f(x)$ is available and it can be integrated, or through numerical methods…

By using the previously presented information, solve the following problem: from the values listed in the table for a function $f(x)$, determine the value of the integral through the trapezoids method (with one single trapezoid and with multiple trapezoids), Simpson 1/3 method and Simpson 3/8 method (to carry out the integral calculation within the whole rangeof values a combination of the Simpson 3/8 methods with another method is recommended).

x	$y = f(x)$
1	1550
2	4780
3	5470
4	4290
5	660

The exact value of the analytical integration of the function $f(x)$, in the given range of x, is 16507. For each of the estimated values of the integral, calculate the relative error. With the retrieved information, describe, briefly, which is the obtained precision as a function of the used method(s). Do not forget to hand in your file through the Moodle platform before **23 November**.

Figure 2. Excerpt from instructions and reading guide for the numerical integration unit

JITT NUMERICAL INTEGRATION
Write down your name and surname
Why do we use an integration for? (No more than 6 lines.)
When do we use numerical integration methods? (No more than 6 lines.)
The value obtained through numerical integration methods can be as exact as the one obtained through the analytical integration method (Right/False). Why?
Which are the criteria to select the integration methods polynomial order? (No more than 10 lines.)
Which is the indispensable condition to apply either Simpson 1/3 or Simpson 3/8 methods?
☐Values of y must present an exponential-like trend with the x axis. ☐Values must be equispaced. ☐Function y=f(x) must be known. ☐Other reasons.
To apply these numerical integration methods to Excel, the following is needed: (No more than 6 lines.)
In your opinion, which aspects of the present text need to be further explained in class? Why? (No more than 6 lines.)
Which parts of the present text were you NOT able to understand? (No more than 2 lines.)
Which parts of the present text SHOULD NOT be explained in class? (No more than 2 lines.)
How long did it take you to prepare the present activity (including the reading, answering the questionnaire, and solving the problem)?

Figure 3. Questionnaire for the numerical integration unit

1. Please, from 0 to 10, assess the flipped-classroom strategy. Justify the assigned value.
2. Which are, in your opinion, the differences between the flipped-classroom strategy and the master-class strategy?
3. Can you indicate positive and negative aspects for both strategies? (At least, two each.)
4. In your opinion, how was your learning process? Was it any deeper?
5. Do you consider that the classroom sessions' efficiency was higher/lower/the same than for master classes?
6. Itemize the observed changes in your personal learning process.
7. Do you think that the temporal planning for the present subject/degree is adequate for implementing this technique? Please, indicate your needs.

Figure 4. Satisfaction survey

APPLIED COMPUTING TEMPORAL PLANNING FOR THE COURSE 2015/2016	
UNIT	NUMBER OF SESSIONS (DATES)
BASIC COMMANDS – FIGURES	1 (5 November)
INTERPOLATION	2 (10 and 12 November)
ITERATION: FIXED-POINT, GRAPHIC AND NEWTON-RAPHSON	2 (17 and 19 November)
INTEGRATION	2 (24 and 26 November)
STATISTICS AND REGRESSION	2 (1 and 3 December)

Figure 5. Temporal planning

STUDENT	TEACHER
OUTSIDE THE CLASSROOM (before the face-to-face session)	
	Preparation of the reading guide and instructions and the questionnaire.
Reading and solving the proposed activities.	
	Correction of the self-learning activity, feedback preparation and classroom session planning.
INSIDE THE CLASSROOM	
	Comment on the results. Deepening and further explanation of the topics in the unit. Proposal of problems-examples to solve.
Questions and comments	
	Summary. Consolidation and expansion of content. Approach and problem resolution.
Solving of problems-examples (either autonomously or guided by the teachers).	
	Comments and concepts clarifying. Proposal of an activity to solve in the classroom.
Solving of the activity	
OUTSIDE THE CLASSROOM (after the face-to-face session)	
	Correction of the activity and feedback preparation.

Figure 6. Methodological sequence

3. Results and analysis

The diagnostic survey shows that:

- Most of the participants in the pilot group had accessed the degree trough ordinary access tests (PAU).
- 56% of pupils declare that the high school academic program they followed was focused on a combination of scientific and technical aspects.
- The first choice for the vast majority of the students had been both the University of Barcelona and their degree (either Chemical Engineering or Materials Engineering).
- With regards to their background, the greater part of the students considers that their knowledge in Mathematics and Chemistry is rather high.
- Pupils use the calculator regularly but, on the other hand, they are not used to solve exercises with the computer.
- In relation to the question raised concerning whether they were used to prepare classes in advance, results are inconclusive.
- Finally, from the expectations-related open question, it can be inferred that students had not read the syllabus of the subject.

Out of the 22 students registered in the pilot group, 9 belonged to the degree in Materials Engineering and 13 to the degree in Chemical Engineering. However, there were 6 students that did not attend to any classroom session nor participated in any activity. Among them, 4 were from Materials Engineering and 2 from Chemical Engineering. Therefore, the actual number of participants in the proposed activities was 16.

As seen in Figure 7b, the students' participation in the proposed tasks throughout the course changed trough time. Poor engagement in the first task (clearly the lowest) should be highlighted: only 8 out of the 16 registered pupils delivered it, and 2 of them did so out of time. On the other hand, though, the performance of the engaged pupils was globally remarkable (7a).

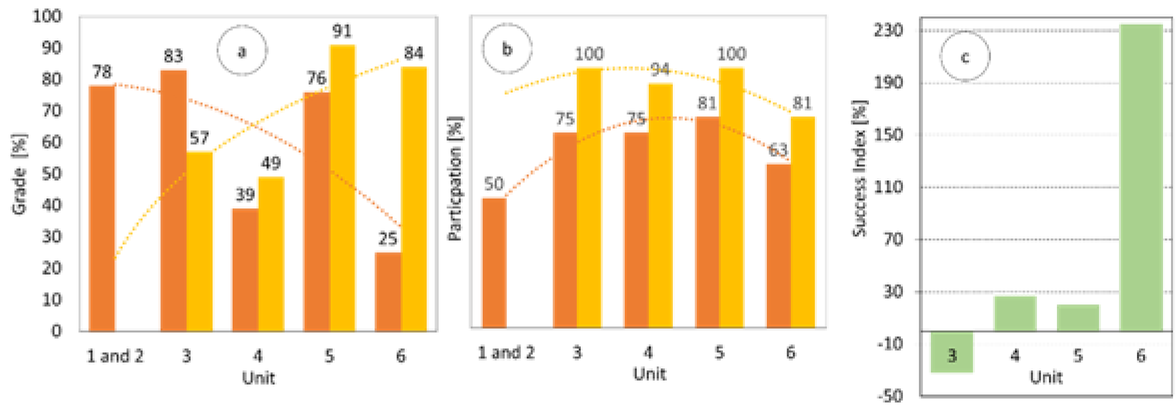

Figure 7. a) Percentage of student participation in the tasks throughout the course; b) Obtained grades for each unit; c) Obtained Success Index (I) for each unit.

(■ PRE: self-learning activity before the classroom session; ■ POST: activity carried out at the end of the classroom session)

The low degree of participation in the first task can be explained by considering multiple factors, the most important one being the lack of habit of the students to the proposed type of methodology. On the other hand, once students were briefed on the procedure that was going to be adopted from that moment onwards in the first classroom session, the proposed learning strategy was widely accepted and, consequently, their engagement in the following three units was significantly higher than in the first one. However, participation decreased again in the last activity (unit 6), which is in part attributed to fatigue, but also to the higher complexity of that unit contents. In general, students' engagement reached average values of 73% and 94% participants in the proposed self-learning and in-classroom activities, respectively.

From the average students' grades for each activity (Figure 7a), it can be inferred that, globally, students achieve better learning results after the classroom session (the sole exception being the unit 3 activity). This fact indicates that the concepts clarification in the classroom, based on the pupils' performance in the self-learning activities, improves the degree of understanding of the taught contents. The methodology Success Index (I) for each unit has been defined as follows: I=((POST-PRE)/PRE)x100, where POST is the average obtained grade in the activity carried out at the end of the classroom session and PRE is the average obtained grade in the self-learning activity before the classroom session. As seen in Figure 7c, as a general trend, Success Index (I) increases as the course progresses, which indicates that the methodology success increases as well.

On the other hand, the students that actively engaged in all the proposed activities (both self-learning and in-classroom tasks) achieved, globally, better learning results than those who only engaged in the in-classroom activities (Figure 8a). Concerning those students who only took part in some of the proposed activities, their grades clearly increased throughout the course. In contrast, grades trend of the students who engage in both self-learning and in-classroom tasks show a more constant evolution (since their grades were higher since the beginning of the course, the increase was less sharp). This fact leads us to infer that the proposed methodology is more successful when students follow it scrupulously.

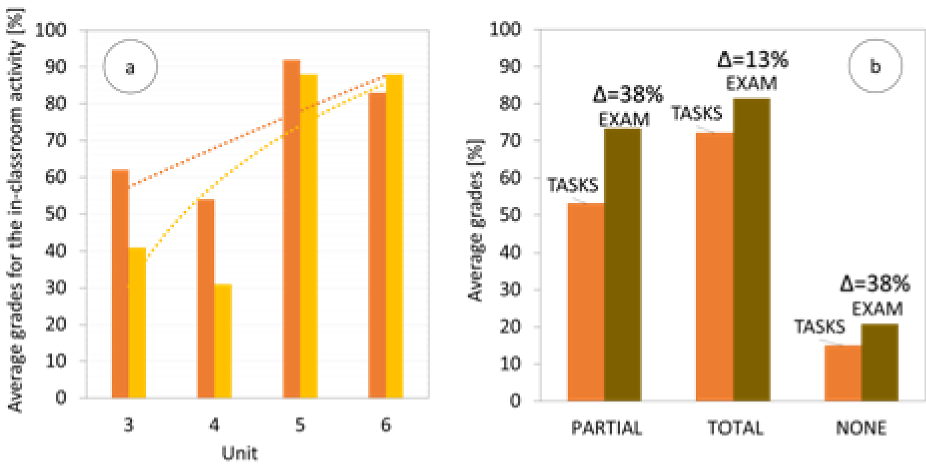

Figure 8. Analysis of the results in the pilot group: a) Average achieved grades for every unit, as a function of the students' degree of involvement in the learning strategy:

■ Students that participated in both activities and ■ those that participated only in the in-classroom activity; b) Effect of the involvement degree on the final examination grade.

In addition, an important aspect to analyze is how the flipped-classroom strategy redounds in the final examination grade of the subject, depending on the students' degree of involvement. Figure 8b shows that the grades growth between tasks and final exam was less pronounced (13%) for students who were fully involved with the flipped-classroom strategy than for those who engage partially or those who did not participate in the proposed tasks. On the other hand, though, it is clear that fully involved pupils (about 53% of participants) always obtained higher grades than the others did.

At this point, the academic results of the students in the pilot group are compared to those from the other groups of the subject (Figure 9). In those groups, the teaching-learning strategy is a combination of classic lecture with guided tasks and homework. Within the pilot group, two types of average grades have been considered: on one hand, the mean grades achieved by the fully involved pupils (tagged as TOTAL in Figure 9) and, on the other hand, grades of the whole group (tagged as PILOT in Figure 9). As it can be clearly appreciated in the figure, fully involved pupils obtained better results than the whole pilot group and, in general terms, their results were also better than for any other group.

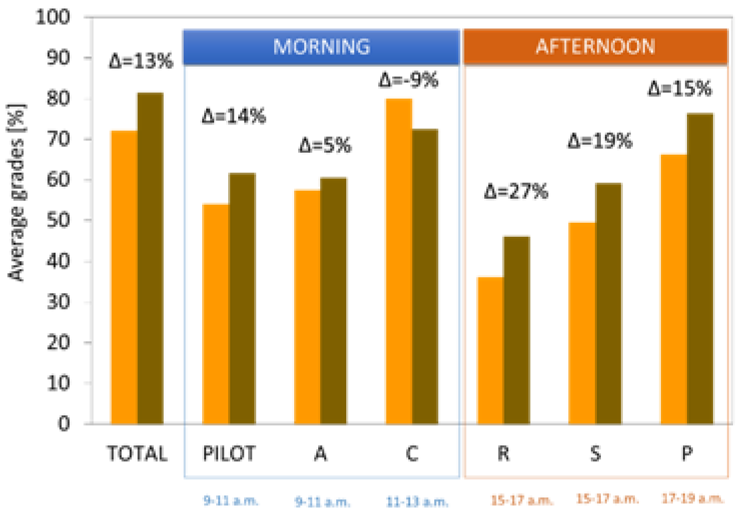

Figure 9. Average grades for tasks and final examination for every group as a function of the class schedule.

On the other hand, the observed differences between tasks and final examination average grades (Δ) is less pronounced in the groups scheduled during the morning than it is for the afternoon groups. Group C showed an abnormal negative value of Δ. When comparing the average grades of the final exam, all morning groups presented similar results, whereas for the afternoon groups, grades increased as the class schedule advances. Morning groups, though, obtained higher average grades than afternoon groups (Figure 10a). These results are consistent with the fact that the students' allocation system helps distributing higher-profile students mainly into morning groups (see Figure 10b).

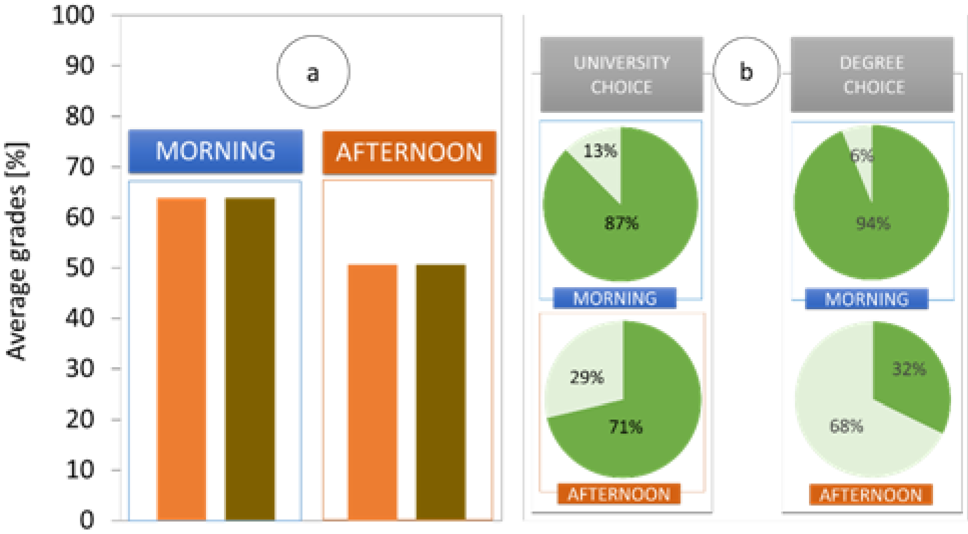

Figure 10. a) Average grades as a function of the time slot: Tasks and Exam; b) Overview of the diagnostic survey results: UB and Degree as the first choice and UB and Degree not the first choice.

Multiple factors in the teaching-learning process could explain the anomalous behavior of group C and the observed trend for the afternoon groups. For instance, the particularities of each teacher and the quality of the provided feedback, which are difficult to assess with the available information, could have played a determinant role.

Finally, students assessed the proposed flipped-classroom methodology by means of a satisfaction survey. The rate was 76/100, but the participation was rather poor (about 44%). As positive aspects, students highlighted self-learning, time management, classroom sessions effectiveness, and received feedback. As negative aspects, students mentioned highly-demanding effort to keep up-to-date, and significant level of stress generated by the evaluations in the classroom. They perceived the schedule as adequate but putting forward the need to relax the amount of daily work. Some students of this group remark, as a positive aspect of the traditional lecture methodology, not having to work autonomously or in advance. Despite that, the generalized opinion is ambivalent. In general terms, then, the students' answers clearly reflect their lack of habit in autonomous study and a high concern for the evaluation.

4. Conclusions

The experience has proven that adopting a flipped-classroom strategy is satisfactory because it promotes self-learning, autonomous working, and time management concern in students, and because it helps increasing the classroom session effectiveness. By this, students achieved a deeper understanding of the taught contents. However, students presented a dichotomy when weighting the profits and the required effort investment. Therefore, attention should be paid not to overload students and teachers with too much work, since they have more subjects to work in the same semester. Burnout is always a negative effect.

With regards to the possibility of applying a similar methodology to larger groups, several modifications should be done first because providing individual feedback for each activity (that includes both activities performed before and during the classroom sessions) is highly demanding. In line with this, some automatizations could be applied (for instance, solutions to every problem/questionnaire could be recorded as a video file and uploaded in a shared virtual site with an associated discussion forum). Particularly, similar approaches can be found related to engineering degrees involving groups between 18 and 43 pupils (Yeverino, Morales & Rivera, 2016; Wagner, Laforge & Cripps, 2013).

From the observed results, the team of teachers concludes that this methodology fomented student proactivity and extended the habit of autonomous working. However, it will be necessary to consider a proper restructuration of the classroom sessions throughout the academic program of the entire degree. It is of dire importance to provide enough time and space to the students, so that they can work autonomously without interfering with their performance in other subjects. Once academic planning is no longer an issue, perspectives of the present methodology will be positive for the student-centered learning process.

References

Abeysekera, L., & Dawson, P. (2015). Motivation and cognitive load in the flipped classroom: definition, rationale and a call for research. *Higher Education Research & Development*, 34(1), 1-14. https://doi.org/10.1080/07294360.2014.934336

Bowden, J., & Marton, F. (2011). *La Universidad, un espacio para el aprendizaje: Más allá de la Calidad y la Competencia* (Vol. 30). Narcea Ediciones.

Cashman, E.M., & Eschenbach, E.A. (2003). Active learning with Web technology-Just in time. In: *Frontiers in Education. FIE 2003 33rd Annual* (Vol. 1, pp. T3F-9). IEEE. https://doi.org/10.1109/fie.2003.1263352

Chen, Y.F., Lin, W.H., Chang, S.B., Liu, C.C., & Chan, T.W. (2005). TIPS: a JiTT& PI pedagogical method with handheld computer as mediating tools. In: *Fifth IEEE International Conference on Advanced Learning Technologies (ICALT'05)* (pp. 844-845). IEEE. https://doi.org/10.1109/ICALT.2005.284

Crouch, C.H., & Mazur, E. (2001). Peer instruction: Ten years of experience and results. *American journal of physics*, 69(9), 970-977. https://doi.org/10.1119/1.1374249

Iborra, M., Ramírez, E., Tejero, J., Bringué, R., Fité, C., & Cunill, F. (2014). Revamping of teaching–learning methodologies in laboratory subjects of the Chemical Engineering undergraduate degree of the University of Barcelona for their adjustment to the Bologna process. *Education for Chemical Engineers*, 9(3), e43-e49. https://doi.org/10.1016/j.ece.2014.04.002

Iborra, M., Ramírez, E., Bringué, R., Tejero, J., Cunill, F., & Fité, C. (2015). Generic skills development and learning/assessment process: Use of rubrics and students validation. *Journal of Technology and Science Education*, 5(2), 107-121.

Iborra, M., Ramírez, E., Tejero, J., Bringué, R., Fité, C., & Cunill F. (2016). Aula virtual de la asignatura Reactores químicos. Puesta en marcha de estrategias y prácticas de evaluación formativa. In T. Pagès Costas & J. Calvo Lajusticia (Comps.), *El aula Moodle. Aprender y enseñar en la UB* (pp.63-87). Barcelona: Octaedro -ICE-UB.

Khan, S. "Khan academy" (2014). Available online at: https://www.khanacademy.org/

King, A. (1993). From sage on the stage to guide on the side. *College teaching*, 41(1), 30-35. https://doi.org/10.1080/87567555.1993.9926781

Lage, M.J., Glenn, J.P., & Treglia, M. (2000). Inverting the classroom: A gateway to creating an inclusive learning environment. *The Journal of Economic Education*, 31(1), 30-43. https://doi.org/10.1080/00220480009596759

Mazur, E., & Somers, M.D. (1999). Peer instruction: A user's manual. *American Journal of Physics*, 67(4), 359-400. https://doi.org/10.1119/1.19265

Michaelsen, L.K., Knight, A.B., & Fink, L.D. (2002). *Team-based learning: A transformative use of small groups*. Westport: Praeger Publishers.

Prieto, A. (2011). El proceso de Just in Time Teaching. Disponible online en: http://profesor3punto0.blogspot.com.es/2013/09/como-lograr-que-los-alumnos-adopten-un.html. (Last access date: February 28th, 2014).

Sams, A., & Bergmann, J. (2013). Flip Your Students' Learning. *Educational leadership*, 70(6), 16-20.

The Flipped Learning Global Initiative (2016). Available online at: http://flglobal.org/about/. (Last access date: August 2nd, 2016).

Yeverino, J.C., Morales, G.R., & Rivera, M.H. (2016). Efectividad de la metodología de aula invertida en un curso de álgebra para ingenieros. *XLIII Conferencia Nacional de Ingeniera*, Monterrey, México.

Wagner, D., Laforge, P., & Cripps, D. (2013). Lecture material retention: A first trial report on flipped classroom strategies in electronic systems engineering at the University of Regina. *Proceedings of the Canadian Engineering Education Association*. https://doi.org/10.24908/pceea.v0i0.4804

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