International Journal of Engineering Education Vol. 35, No. 6(A), pp. 1–8, 2019
Printed in Great Britain

0949-149X/91 $3.00+0.00

Cooperative Learning and Embedded Active Learning Methodologies for Improving Students' Motivation and Academic Results*

ANTONI PEREZ-POCH, FERMÍN SÁNCHEZ CARACEDO, NÚRIA SALÁN and DAVID LÓPEZ
UPC—EEBE. Universitat Politècnica de Catalunya —BarcelonaTech. Campus Diagonal-Besós, c. Eduard Maristany 16, ES08019 Barcelona, Spain. E-mail: antoni.perez-poch@upc.edu

In recent years, a number of teaching strategies have been applied in higher education to improve students' academic results and motivation, with a focus on active methodologies. Embedded Methodologies, defined as a mixture of learning strategies which are combined in a single educational environment, have a potential for boosting this impact. An Embedded Methodology with Cooperative Learning, Just-In-Time Teaching and active informal methodologies is proposed herein. Both methodologies are an integral part of the course design, and students are exposed to a variety of on-line and face-to-face activities, which enhance their educational experience. The authors present a ten-year longitudinal study in which academic results and student satisfaction were reported by a standardized survey among 294 students attending a subject on "Telecommunications and Internet" at EEBE Engineering School from UPC-BarcelonaTech (Spain).The results show that these Embedded Methodologies significantly improved students' motivation and their final marks; in particular, for those students at risk of failing the subject, but not with the lowest grades. This approach was found to be the best predictor of their grades in the subject, among other factors such as their performance in the University Entrance exam. Students' perception of the quality of teaching and their academic results were significantly enhanced when compared with those students that were exposed to only one active methodology or none at all, thus suggesting that a mixture of motivational learning techniques boost their impact on the students' learning process and on their motivation.

Keywords: embedded methodologies; cooperative learning; active methodologies; just-in-time teaching; teaching quality; engineering education

1. Introduction and context

Prince and Felder [1], among other authors, have shown that methods that encourage students to participate actively in class are at least as effective as traditional methods, and also improve some aspects of student learning such as motivation. Enhanced attention and motivation induce students to become more involved in course work and to do more personal work outside class. Students are already used to connecting to the virtual campus by using smartphones, tablets or computers. Teachers should invest more forethought in the design of each class as well as a greater personal involvement, and the same commitment is demanded of the students. The hypothesis is based on the assumption that this attitude will increase student performance, and also the time that students spend working outside the class will be increased, as well as their motivation for the subject. Learning by Design has also proven to be a successful strategy in Engineering Education as shown recently, for example, by Pastor et al. [2].

Cooperative learning is a well-known technique that has proven to foster positive relationships among students and to increase student achievement [3]. Cooperation means that students work together to accomplish shared goals [4]. When cooperative situations in the classroom are established, individuals should seek outcomes that are beneficial for themselves and for all other group members at the same time. Cooperative learning is the instructional use of small groups so that the students work together to maximize their own and each other's learning capabilities.

It may be compared with competitive learning and individualistic learning, which are situations in which students work by themselves to accomplish learning goals unrelated to those of the other students. In cooperative and individualistic learning, students' efforts are evaluated on a criteria-referenced basis, whereas in competitive learning they are evaluated on a norm-referenced basis. Several methodologies implement cooperative learning, such as the Jigsaw, team learning, group-investigation, reciprocal teaching or project-based cooperative work in a formal group. Aside from a well established literature supporting this strategy, recent findings show that cooperative learning can be successfully applied in different contexts: Tran et al. [5] have successfully conducted a course in research methods in Education with cooperative methods, and have shown their positive outcomes when evaluating academic achievement and knowl-

* Accepted 24 August 2019.

edge retention [6]. Korkmaz [7] has reported that project-based cooperative studio studies are contributing more meaningfully to students' intermediate level electronics skills. Furthermore, Luo [8] has found that design fixation and cooperative learning enhance students' skills while conducting an engineering design project. In the present work, the authors present their experience when using embedded Just-in-Time Teaching.

Just-in-Time Teaching (JiTT) [9] consists in using the virtual campus to provide new exercises and educational experiences for students, and adapting the classes to this input. It is a combination of face-to-face interaction in the classroom and website-based learning support, which in fact optimizes the time and effort that students make in class. Although it employs current online technologies like virtual campus, it should not be confused with Distance Learning or Computer-Aided Instruction. Rather, it focuses on providing a good feedback loop that motivates students to engage themselves fully in their learning process. The three main objectives of this methodology are as follows:

- To optimize the efficacy of the face-to-face classroom session, where the instructor is present.
- To plan out-of-class time in order to structure the efforts made by students.
- To promote team spirit between students and instructors, while providing an individualized support for every learner.

A description of JiTT can be found on the webpage devoted to this methodology at Indiana University—Purdue University Indianapolis [10]. The application of this approach has been described in various educational settings with very promising results. Among others, Bangs [11] applied this method in a Statistics Business course and improved the motivation of the students. Chantoem and Rattanavich [12] provided both on-line and face-to-face support during an English language skills course. Paulson [13] conducted his classes with both Cooperative Learning and JiTT methodologies while lecturing on Organic Chemistry, although his analysis does not elucidate whether the two methodologies are enhanced when conducted together. Similar strategies using a Flipped classroom and online MOOCs have also been recently reported [14].

Arthur Levine [15] has recently supported the idea that the so-called "Just-In-Time" learner is actually provoking a real change in Higher Education. This assertion is backed by the fact that "millennial" students can get their information in real time from a variety of digital sources. This cascade of inputs can properly be used to enhance well-established methodologies such as cooperative learning, and therefore boost engineering students' motivation. In effect, McGee et al. [16] have reported using web-based questions in an Engineering course, while Liberatore et al. [17] have studied the effectiveness on academic achievement of JiTT in an introductory Thermodynamics course.

The authors of this paper have also used JiTT to teach computer programming in first-year courses of a Bachelor's degree in Industrial Engineering. This experience of using JiTT in another compulsory subject, but with no embedded methodologies, was conducted in the 2016–2017 academic year with remarkable success, since it showed a potential for improving academic results and motivation at the freshman level. Results are shown in [18].

By using an online campus based on Moodle, students are required to undertake gradable tasks to be resolved before the class starts. The results of such homework are used to design the "Just-in-Time" class. The tasks are graded and form part of the continuous assessment. They help to contextualize the exercises done in class, and provide teachers with information about the objective distance of the students with regard to the difficulty of the task they have to do. The tasks should also motivate the students to achieve better grades in the individual exams held during the course.

Third-year students in the Bachelor's Degree course in Industrial Engineering at the Barcelona East School of Engineering (EEBE) of the Universitat Politècnica de Catalunya (UPC-BarcelonaTech) study "Telecommunications and Internet" as an optional subject. However interesting the subject may appear to students who enrol, we believe a problem exists regarding the inconsistency of students' work habits, since they often attend a class without having read the previous lecture topic on which the work in class is about. As a consequence, students may lose interest in it after the term starts.

In order to overcome these challenges, we propose the application of an active methodology in class, combined with Just-in-Time Teaching and a final project in which Cooperative Learning is applied. This proposal is given the generic name of Embedded Methodologies by the authors. By Embedded Methodologies we define a number, two or more, of educational strategies that are not only applied in the same educational context, but are also on some occasions simultaneously applied, and form part of the development of the syllabus. The methodologies are carefully chosen to fulfil the learning objectives of the given educational situation. The consequence is that their impact on motivation and academic results are multiplied. In the academic terms from 2015 to 2017, this embedded strategy was applied in the above-mentioned subject at the EEBE Engineering School. Results from this experience suggest that this approach could further be applied to different Engineering Education scenarios in order to provide a more individualized and effective learning environment.

2. Embedded methodologies

Embedding different active learning methodologies within the objectives of a given subject in Engineering requires detailed planning. Student activities should be designed not only for adding more diversity to the activities, but also in accordance with the learning outcomes of the subject. This is an original concept that has not been developed so far including Just-In-Time teaching. Turnip et al. [19] has showed that JiTT was significantly better than cooperative learning in their study, but did not evaluate the effect of embedding both methodologies together. Darabi et al. [20] evaluated the outcomes of conducting a peer discussion in class with or without JiTT prior information. However interesting their findings, this study cannot be seen as trying to implement two methodologies together in the same context. On the other hand, Kalaian et al. [21] have conducted a metaanalysis in which different small-group learning pedagogies in Engineering and Technology education were evaluated with positive results. Moreover, Fidalgo-Blanco et al. [22] have recently studied if students who follow active methodologies have the active habit of sharing their knowledge thus enhancing their team work skills. The question of which may be the effect of joining together some of these strategies naturally arises.

The proposal set out in this paper is to deliver an engaging course for students with the aim of increasing student interest in the subject beyond the end of the course. Thus, the activities should be focused on motivating attendance at the classes and stimulating students to adopt an active role in order to grasp the contents of the syllabus. Regarding class activities, different short activities conducted in informal groups are proposed throughout the term. This involves not only an active participation, but also short breaks throughout the presentation of the core lectures. Activities should include, but are not restricted to, exchange of notes in pairs, short activities about the contents of the class, group discussion or informal groups Jigsaw, all of which is intended to reinforce the acquisition of the concepts during face-to-face classroom time.

Just-in-Time Teaching means using the virtual campus for individualized assignments. This is done in different weeks throughout the 15-week semester. Some activities are proposed on the virtual campus, where the students are required to provide answers forty-eight hours before the face-to-face class. Such activities may consist of answering questions in the forum after watching an online video, resolving exercises associated with the current chapter, or completing a brief research assignment. The exercises are then open to comment in class in an individual face-to-face dialogue. While this may be time-consuming, it provides in essence an individualized approach to teaching for all students, so that they can go on to the next class with a precise feedback on their own learning process. The course instructor usually sets students new assignments concerning the next chapter to be addressed in the following class, in accordance with a graded level of difficulty based on a prior assessment of student performance. The course was therefore designed with Embedded Methodologies that included both face-to-face and online work time, thereby providing an active experience in class that encourages the free discussion of topics.

Lastly, a final project is assigned to be undertaken over the last six weeks of the course. Students organized into groups of three are expected to work together cooperatively in order to complete a real project of designing a telecommunications network for a small company. The project requires a study of the Engineering requirements, design of the data network, analysis and teamwork. Two deliverable assignments are set during the course and are assessed by the course instructor, in order to provide students with an immediate feedback about their progress towards the final deliverable. This final assignment consists of a mandatory oral presentation in class in front of their classmates. The quality of the work is assessed on the basis of the mid-term reports, which must include details of student commitment and common objectives, and also on a final anonymous co-assessment.

All the activities are evaluated, and the final presentation carries a single mark for the members of the group as a whole. Students should submit online activities as well as participating in class, but online activities are not graded if students do not attend the face-to-face classroom sessions. Students require a minimum grade in every part of the subject in order to achieve a pass: online and face-to-face activities (35%), final project (40%) and individual exam (25%).

As it may be seen, the activities are embedded in the course, so there is no possibility of achieving a pass in the subject on the sole basis of a final exam or assignment. Results with this methodology show that absenteeism is very low, as it is the number of students who drop out before completing the course. Students are aware from the outset that they are required to attend the classes and carry out all the activities in order to participate in the learning activities, and thereby miss no opportunity to become conversant with the subject.

3. Objectives of this work

A study conducted before introducing this Embedded Methodologies strategy found that students invest on average less than one hour per day on the subject outside class, and only buckle down to work immediately before an examination or when they must meet a deadline to hand in exercises. This is a common problem in many universities and learning scenarios. By merging different kinds of activities and learning situations within the same subject and group, we aim to create a motivational environment to encourage students to participate actively in a challenging course.

In order to validate this strategy of Embedded Methodologies, it is the objective of this work to determine whether a better activities design with embedded strategies is capable of improving the students' experience or not. In particular, we wish to achieve the following goals:

1. To increase the motivation of students.
2. To improve student satisfaction with the subject.
3. To increase the academic results of the subject (final mark).

4. Methodology

During the spring semester of 2015–2017 academic years, active and cooperative learning methodologies were employed in the subject of "Telecommunications and Internet" during the 6th semester of the EEBE Industrial Engineering degree studies. This subject deals with abstract concepts, such us the OSI model of functional layers [23], which are usually difficult to understand [24]. An active learning is proposed for the students to achieve a complete understanding of the underlying concepts involved that will be assessed by two presential activities and an individual written exam during the term.

In 2009 only Cooperative Learning was applied, and in the 2010 spring term only active learning was applied. Teaching without the introduction of the described methodologies was used in the 2007 and 2008 academic fall terms and in the 2015 spring term. Quantitative and qualitative data were collected on individual grades, student satisfaction surveys and structured interviews with the students, as well as University Entrance Exam grades. Just-In-Time teaching was applied in selected weeks of the recent academic years 2015–17. Five face-to-face activities and five online activities were initially conducted in the first week of the course, up until the first stage of the course during which the fundamental concepts of the subject were addressed. Subsequently, and following a written evaluation, the Cooperative Learning project was introduced with both face-to-face and on-line activities, leading up to a final presentation of the project. Six laboratory activities, including a technical visit, were also scheduled in coordination with class assignments. Multivariate analysis was performed to see whether or not JiTT was an important factor that could be correlated with student grades. A comparison of means was performed between different groups, and also among the different topics covered in the student surveys regarding their learning experience.

Data analysis was conducted from 2007 to 2017, a period of ten academic years during which the subject was taught only once a year in the spring term, except for 2007 and 2008, when it was repeated in the fall semester. An overall number of 294 students studied the subject "Telecommunications and internet". The contents and syllabus of this subject remained unchanged throughout this period of time. The average yearly composition of the class was 25 students (24.7 +/− 3.4), with an average of 78% male and 22% female students. Students were usually in the third year of their 4-year Bachelor in different majors in Industrial Engineering. The course was imparted by the same instructor throughout the ten-year period. The average age of students was 21.3 +/− 2.5 years. Satisfaction surveys were sent to all students engaged in the subject. The Students' Evaluation of Educational Quality (SEEQ) [25] standardized satisfaction surveys were used throughout the study to provide quantitative and qualitative information on different aspects of students' perception of their learning process. Statistical evaluations were performed with the IBM SPSS package version 23 [26].

5. Results

For the sake of comparison between different learning scenarios, we divided the different classrooms groups analysed into three different groups:

- Group 1: (G1) Spring term 2015–17: Group of Embedded Methodologies: JiTT, Cooperative Learning, and active learning.
- Group 2: (G2) Spring term 2009–2014. Cooperative Learning and/or active learning, but no JiTT.
- Group 3: (G3) Fall term 2007, 2008 and Spring terms 2015. Teaching without these methodologies.

5.1 Academic performance

The hypothesis that the average final mark would

Table 1. Academic performance: final mark differences between groups

	G1	G2	G3
Average Final Mark	7.8	6.5	5.3

improve with the application of the Embedded Strategy is tested herein. The average final grade for students was significantly higher when more active learning activities were conducted.

Results are shown in Table 1. The mean final grade was significantly higher among students in Group 1 when compared to those in Group 2, while those in Group 2 scored better than those in Group 3.

To test the hypothesis, an ANOVA multivariate comparison of the average final marks in the three groups mentioned above was performed with the Bonferroni correction. Normal distributions, homogeneity of variances and independence between groups were assumed. Differences between groups were all significant at significance level $p < 0.01$.

5.2 Students' satisfaction surveys

A multivariate ANOVA was performed to check whether the means of student satisfaction were homogeneous between groups from different years. Again, normal distribution, homogeneity of variances and independence between groups was assumed. The test was carried out for both the mean overall satisfaction given by the SEEQ survey and for each section of the survey, which provides an indicator of every aspect of the learning process, as listed below. Students were questioned about the following eight indicators: Student motivation; teacher enthusiasm; teacher organization; interaction with the group; personal attitude of the teacher; subject content and suitability of exams. We asked our students to evaluate the level of satisfaction of these indicators by using a Likert-type scale rated from 1 (poor satisfaction) to 5 (very high satisfaction).

The hypothesis in this case was that the impact of applying Embedded Strategies would enhance student satisfaction and motivation. Significance was set to $p = 0.01$. We tested the homogeneity of the average students' reports from the three different groups for every indicator with the Bonferroni correction. Significant improvements ($p < 0.01$) were obtained in the overall mean and in the category "Student motivation", whereas no significant differences were found in regard to the other indicators. The results are shown in Table 2. Therefore, in G1, in which JiTT was applied, the overall motivation was significantly higher than in the other two groups. In regard to the initial hypothesis, significant differences in the overall mean satisfaction were found ($p < 0.01$) when comparing groups G1, G2 and G3, and also in the "Motivation" indicator, where the indicator for G1 obtained a higher rate than the indicator for G2 and G3.

Table 2. Mean overall satisfaction and Motivation show differences between classroom groups

Indicator	G1	G2	G3
Overall mean	4.1	3.8*	2.7*
Motivation	4.3	3.5*	2.9*
Enthusiasm	3.5	3.4	3.1
Organization	3.0	3.2	2.5
Interaction	3.4	2.8	3.2
Attitude	2.9	2.8	3.1
Content	4.1	4.2	4.3
Exams	3.1	3.0	2.6

When the students were asked how many hours a week they spent on average on the subject during the semester, a majority of students belonging to all three groups answered between 0 and 4 hours, and only a small number answered more than 4 hours. However, in the structured interviews mentioned later in this section, students reported that most of those belonging to the group G1 devoted more hours to the subject (between 2 and 3 hours a week on average), while students belonging to groups G2 and G3 stated that they spent fewer than 2 hours. In accordance with the syllabus set out for the subject, they should have devoted a minimum of four hours to the subject outside of class time.

5.3 Multivariate analysis of academic performance

After obtaining the students' final marks, we performed a multivariate analysis in which the independent variable was the final mark for the subject, while the dependent variables were as follows: University Entrance Exam grade, age, origin (categories: from access-to-university exams; from other degrees they had failed to complete, and exchange students), and the Embedded Strategy, which is a categorical variable indicating whether or not the student belonged to the group in which it was applied (G1). We assumed normal distribution, homogeneity of variances and independence among different factors. Multivariate regression assumes that a linear dependency exists between the independent factors and the dependent variable. For each factor ($1-\beta_i$), we obtained the percentage of the value of the dependent variable it explains and the statistical significance. In comparison with the other factors, high values of ($1-\beta_i$) indicate a preponderance of this factor over the rest. Statistical significance was set at $p < 0.01$. For a detailed description of the model on which this analysis is

Table 3. Multivariate regression analysis model for the "Telecommunications and Internet" subject

Independent variable	**1- β_i**	***p***
Embedded Strategy	0.083	0.002**
University entrance grade	0.132	0.065
Age	0.224	0.124
Origin	0.256	0.133

based, see the description from Wayne [27]. For exchange students, whose University Entrance Exam grade was unknown, we assumed the group average. The results obtained are shown in Table 3.

Only one of the factors in the model was statistically significant: whether the Embedded Methodologies strategy was applied or not. The grade for the University Entrance Exam grade was the second factor explaining performance, but with no significance.

5.4 Structured interviews

Interviews with students were randomly conducted at the end of the term (5 students per group) to discover how they perceived the learning process. From these structured interviews, most students stated that they had benefitted from real-time, individualized correction of exercises, similar to those proposed in the exams. In comparison with the responses by students belonging to the groups of traditional teaching, however, they also complained that more work was required of them. Despite these complaints, it is also worthwhile noting that they dedicated more time to the subject, coming close to the expected amount of time as set out in the teaching guide.

5.5 Analysis of students with different academic performance

A comparison between the final marks for the subject was made by dividing the students into three groups or tiers, depending on this final mark. The hypothesis was that students with medium or lower grades would benefit more from this Embedded Strategy than students with higher marks. Significance was set to p = 0.01. As mentioned above, we also conducted an ANOVA multivariable test with the Bonferroni correction.

In order to compare the impact of Embedded Strategies on students with different performances, we divided the sample into three parts for each group: T1 was the third of students with highest grades, T2 the third with intermediate grades and T3 the third with the lowest grades. We then repeated the comparison test for the mean final grades between groups for each of the thirds. For example, we compared the mean final grade of T1 for group G1 with that of T1 for G2 and G3. We also conducted the same homogeneity test of mean final grades for T2 and T3. A significant difference between the means was obtained only for T2. The mean final grade for T2 (6.3 out of 10, where 5 is the pass mark) was significantly higher in G1 (6.8) than in G2 (5.3) and G3 (4.7). These results suggest that, in terms of their final performance, greater differences exist between students who were not the best and those with lower marks when exposed to different learning strategies during the term. The initial hypothesis has therefore proven to be correct solely for students with medium grades, but no for those with lower grades.

6. Discussion

In this study, an improvement in academic results and also in motivation was found in the students attending the course in which the Embedded Methodologies strategy was introduced. No significant differences between the average University Entrance Exam grades of students belonging to a particular group were found across the courses in different years. Thus, the differences found in academic performance (final marks) and motivation are unlikely to be due to individual differences among students.

Regarding the three objectives stated in Section 1, it is clear that, on comparison of the final results for the subject with those in the groups that were not exposed to Embedded Methodologies, the third objective (improve academic results) was achieved,. For the second objective (improve student satisfaction), the overall results were not conclusive; however, in terms of motivation, which was our first and foremost objective, a clear improvement is observed. Furthermore, when different activities were embedded (G1), attendance at the face-to-face classes reached nearly 90%. The fact that all these activities contributed independently to the final mark was clearly an important factor.

The students' perception and their motivation showed an overall improvement when these learning strategies were applied as Embedded Methodologies. The remaining aspects observable from the SEEQ survey were reasonably high, but no significant differences were found when evaluating different groups with different learning strategies. The results suggest that students acquire a greater motivation for the subject when provided with different and diverse learning activities in class. The course imparted is the result of the extensive experience gained by the course instructor while teaching this subject at an undergraduate level. More studies are needed to determine whether these results would be sustained with other teaching staff and in other educational contexts. Among many factors, the teaching strategy was found to be the most relevant for a better prediction of the final marks of students. This is a significant finding, since it validates the hypothesis that teaching strategies do have an impact on the overall performance of the students attending a course such as the one reported in this work.

The results obtained after the post-study dividing of the groups into three parts (those with better grades, those with lower grades, and those in the middle) are of particular interest. When comparing academic results and motivation between students in groups exposed to different learning activities, a higher significant difference was found on average between those students that are not classified either into the upper tier or the lower tier of academic performance. Students in the middle tier are more likely to benefit from an embedded and individualized teaching experience, which suggests that those students who, despite an acceptable performance, are still at risk of failure, can profit from the dedicated efforts of course instructors to help them. On the other hand, those students who in fact have the lower grades and are therefore also at risk of failure do not appear to benefit from such experiences. These findings are in accordance with other studies [18] in which we observed that students with lower grades may be beset with other difficulties that are not addressed by the learning environment proposed herein.

This study has some limitations. The sample was restricted to a particular subject imparted in a school of Engineering at the UPC BarcelonaTech. The course was given by the same teacher throughout the time period covered by this study. However, given the attendance figures and the results of the survey on student satisfaction from other subjects taught by the same teacher, and from colleagues at the EEBE Department of Computer Science, it would be appropriate in the future to repeat the study with other subjects and teaching staff as well as in different universities. The subject is taught in English in a non-English speaking country such as Spain. The fact that many students (between 15% and 33%) are exchange students may lend diversity to the course, which is specific to this particular learning environment. Students were not selected randomly to attend the course or to form part of different groups with different teaching strategies.

7. Conclusions

A ten-year longitudinal study of the application of Embedded Methodologies is presented in this work, together with project-based Cooperative Learning, Just-in-Time Teaching and active methods. The experience was carried out during the course of a Bachelor's Degree in Industrial Engineering. The results show that Embedded Methodologies significantly improved academic performance and student satisfaction, and notably student motivation was also improved.

The motivational effect of the methodology was significant for all the students enrolled in the subject, but was less effective for students with the highest or the lowest final marks. Results of the quantitative and qualitative analyses suggest that, in comparison with the case where only one of these techniques is applied, Embedded Methodologies are considerably more effective, which implies that a combination of two or more methodologies (Cooperative Learning, Just-in-Time Teaching, active methodologies in informal groups) included in a well-designed syllabus design, boosts the effects of such techniques. Efforts to provide a more individualized learning active experience, both online and face-to-face, constitute a current trend in Engineering Education, and given their promising outcomes, they are likely to be more widely employed in our universities in the years to come.

Acknowledgements—We wish to thank the students who voluntarily participated in the study, the assistant director of studies and the academic management staff of the EEBE for kindly providing us with the necessary information for the present work. The Institut de Ciències de l'Educació—UPC made this study possible.

References

1. M. Prince and R. Felder, Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases, *Journal of Engineering Education*, **95**(2), pp. 123–138, 2006.
2. M. M. Pastor, F. Roure, M. Ferrer, X. Ayneto, M. Casafont, J. M. Pons and J. Bonada, Learning in Engineering through Design, Construction, Analysis and Experimentation, *International Journal of Engineering Education*, **35**(1B), pp. 372–384, 2019.
3. D. W. Johnson and R. T. Johnson, Making cooperative learning work, *Theory into Practice*, **38**, pp. 67–73, 1999.
4. D. W. Johnson, R. Johnson and K. Smith, *Active learning: Cooperation in the university classroom* (3rd ed.), Edina, Ed.Interaction, 2006.
5. V. D. Tran, T. M. L. Nguyen, N. V. De, C. Soryaly and M. N. Doan, Does Cooperative Learning may Enhance the Use of Students' Learning Strategies?, *International Journal of Higher Education*, **4**(8), 2019.
6. V. D. Tran, The Effects of Cooperative Learning on the Academic Achievement and Knowledge Retention, *International Journal of Higher Education*, **2**(3), 2014.
7. O. Korkmaz, The Effect of Project-Based Cooperative Studio Studies on the Basic Electronics Skills of Students' Cooperative Learning and Their Attitudes, *International Journal of Modern Education and Computer Science*, **5**(10), pp. 1–8, 2018.
8. Y. Luo, Design Fixation and Cooperative Learning in Elementary Engineering Design Project: A Case Study, *International Electronic Journal of Elementary Education*, **1**(8), pp. 133–146, 2015.
9. G. Novak, Just-in-Time Teaching, *New Directions for Teaching and Learning*, **128**, pp. 66–73, 2011.
10. Purdue University, *Just-in-Time Teaching*, http://jittdl.physics.iupui.edu/jitt/what.html Accessed 1 April 2018.
11. J. Bangs, Transforming a Business Statistics Course with

Just-in-Time Teaching, *American Journal of Business Education*, **5**(1), pp. 87–94, 2012.
12. R. Chantoem and S. Rattanavich, Just-in-Time Teaching Techniques through Web Technologies for Vocational Students' Reading and Writing Abilities, *English Language Teaching*, **9**(1), pp. 65–76, 2016.
13. D. Paulson, Active learning and cooperative learning in the organic chemistry lecture class, *Journal of Chemistry Education*, **76**, pp. 1136–1140, 1999.
14. C. Alario-Hoyos, I. Estévez-Ayres, C. Delgado, P.J. Muñoz-Merino, E. Llorente-Pérez and J. Vilena-Román, Redesigning a Freshman Engineering course to promote Active Learning by Flipping the Classroom through the Reuse of MOOCs, *International Journal of Engineering Education*, **35**(1B), pp. 385–396, 2019.
15. A. Levin The ''Just in Time'' Learner and the Coming Revolution in Higher Education, *Change: The Magazine of Higher Learning*, **50**(3–4), pp. 27–29, 2018.
16. M. McGee, L. Stokes and P. Nadolsky, Just-in-Time Teaching in Statistics Classrooms, *Journal of Statistics Education*, **24**(1), pp. 16–26, 2016.
17. M. W. Liberatore, R. M. Morish and C. R. Vestal, Effectiveness of Just In Time Teaching on Student Achievement in an Introductory Thermodynamics Course, *Advances in Engineering Education*, **6**(1), 2017.
18. A. Perez-Poch and D. López, Just-in-Time Teaching improves engagement and academic results among students at risk of failure in computer science fundamentals, *Proceedings of the ASEE-IEEE 47th Frontiers in Education Conference*, Indianapolis, USA, pp. 1–7, 2017
19. B. Turnip, I. Wahyuni and Yul I. Tanyung, The Effect of Inquiry Training Learning Model Based on Just in Time Teaching for Problem Solving Skill, *Journal of Education and Practice*, **7**(15), 2016.
20. A. Darabi, S. Pourafshar, R. Suryavanshi and T. Arrington, Comparison of Three Instructional Strategies in Food and Nutrition Education: Developing a Diet Plan for a Diabetic Case, *International Journal of Science Education*, **38**(7), pp. 1197–1211, 2016.
21. S. A. Kalaian, R. M. Kasim and J. K. Nims, Effectiveness of Small-Group Learning Pedagogies in Engineering and Technology Education: A Meta-Analysis, *Journal of Technology Education*, **29**(1), 2018.
22. A. Fidalgo-Blanco, M. L. Sein-Echaluce and F. J. García-Peñalvo, Enhancing the Main Characteristics of Active Methodologies: A Case with Micro Flip Teaching and Teamwork, *International Journal of Engineering Education*, **35**(1B), pp. 397–408, 2019.
23. W. Stallings, *Data and Computer Communications*, 10th Edition, Pearson Ed. 2015.
24. K. E. DiCerbo, Knowledge Structures of Entering Computer Networking Students and Their Instructors, *Journal of Information Technology Education*, **6**, pp. 263–277, 2007.
25. SEEQ students satisfaction survey, https://www.smu.ca/webfiles/ICEInstructorSelfRatingForm.doc Accessed 1 September 2018.
26. IBM SPSS Solutions for Education, https://www-1.ibm.com/software/analytics/spss/academic/ Accessed 1 April 2018.
27. K. Wayne, *Quantitative Research in Education: a primer*, Ed. SAGE, London (2009).

Antoni Perez-Poch is Deputy Director at the Education Sciences Institute (ICE—UPC, Universitat Politècnica de Catalunya—UPC-BarcelonaTech). Lecturer of Computer Science and Telecommunications at EEBE (School of Engineering Barcelona East). He is Director of the STEM Training Master program, a postgraduate degree from FPC (Fundació Politècnica de Catalunya) that provides competence-based teaching training to lecturers at UPC. His research interests focus on higher education training and quality, microgravity and medical image processing. He has a wide experience in industrial design and advanced electronics projects.

Fermín Sánchez Carracedo received a Master's degree in industrial electronics for the E.A. SEAT in 1981, the BS in computer science in 1987 and the PhD in computer science in 1996. The last two degrees were obtained at Universitat Politècnica de Catalunya (UPC-BarcelonaTech). His fields of study include computer architecture, innovation in education and education for sustainability. Since 1987 he has been lecturing in the Department of Computer Architecture from UPC-BarcelonaTech, where he has been an Associate Professor since 1997. He was a course instructor at the Universitat Oberta de Catalunya (UOC) from 1997 to 2010 and Vice-Dean for Innovation at the Barcelona School of Informatics (FIB) from May 2007 to June 2013. Since July 2013 he has held the position of Deputy Dean for Innovation at FIB.

M. Nuria Salán Ballesteros has a PhD in materials science and metallurgical engineering from UPC-BarcelonaTech, and a metallurgical (chemistry) degree. As professor in the Department of Materials Science and Metallurgical Engineering, since 1992, she teaches several Degree and Master subjects in School of Industrial and Aeronautic Engineering of Terrassa. She is the Academic Coordinator of RIMA Project (Research and Innovation in Learning Methodologies), in which 18 Communities of Practice related to Skills and Learning Methodologies in TECH environments are involved. She is also leading a girls' mentoring program (M2m) as a pioneer experience in TECH universities, and she has produced an international traveling exhibition about the invisibility of women's tech (''(In)Visible ingenuity'').

David López Álvarez received the MSc and PhD degrees in computer sciences from Universitat Politècnica de Catalunya—BarcelonaTech (UPC), Spain, in 1991 and 1998, respectively. He also received the M.A. in Asian studies with a major in East Asia Arts and Societies (Universitat Oberta de Catalunya—UOC, 2008). His technical skills included computer organization and architecture; input/output and storage devices; data centre organization; and the relationship between sustainability, education and ethics with computing and services. He has been lecturing at the Computer Architecture Department at UPC since 1991.