Just-in-Time Teaching improves engagement and academic results among students at risk of failure in Computer Science Fundamentals

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***Abstract*— One of the desirable features of quality teaching is individualized attention to students. In this work we present a teaching innovation of individualized support called Just-in-Time-Teaching (JiTT). We describe a pilot experience conducted in a laboratory group and two control groups of the Computer Science Fundamentals subject of bachelor's degrees in industrial engineering at the Barcelona East School of Engineering [EEBE] of the Universitat Politècnica de Catalunya in the first semester of 2016-2017 academic year. In this subject it has been observed that students tend to do fewer exercises than are required. They usually do them in the vicinity of the exams rather than throughout the course, and this has an impact on their learning and their academic performance. The aim of the experience was therefore to improve academic performance and student satisfaction, and to reduce absenteeism. In the JiTT group, exercises were collected via a virtual campus and assessed before the next laboratory class. Data of the university entrance grade, age and origin of the students were collected. The results are presented and compared with the those obtained in the control groups. Significant improvements were found in the final grades and in student satisfaction with the teaching, and absenteeism was reduced. In conclusion, this is a promising method that promotes individualized teaching at a reasonable cost for the teaching staff.**

Keywords—* *Just-in-Time Teaching; computer science, individualized attention, teaching quality, active methodologies.

I. Motivation

Students in the first year of bachelor's degrees in industrial engineering at our school, the Barcelona East School of Engineering (EEBE) of the Universitat Politècnica de Catalunya, spend too little time on the Computer Science Fundamentals subject each week according to the course design and the ECTS credits assigned. We previously [1] improved the academic results in our subject and partly improved student satisfaction by using student portfolios and introducing active learning in lectures. However, this did not lead to an increase in the time students dedicated to the subject. In addition, the students spend time on the portfolio irregularly, copying is detected intermittently, and the students fail to show a comprehensive and continuing involvement in the course.

During the past year there have been major changes in the organization of the course: part of the syllabus and the assessment tests have been changed, and the final examination has been replaced with a continuous assessment model with five gradable assignments. There are three objective laboratory tests and one practical test to be done in groups, each of which counts for 17.5% of the final grade. The remaining 30% of the grade comes from a written final control that is performed during the final examination period. This model does not allow for the portfolio grading that we performed previously, so we decided to replace this teaching tool with individual monitoring of the learning. In addition, in the new model, attending the laboratory classes is no longer compulsory except on days when there is a control. This has forced us to replace the weekly monitoring of laboratory work with voluntary, individual tutoring. Students are told that their participation in class will be taken into account in cases of doubt in setting the final grade, as the current rules do not allow daily assessment notes to be added.

Finally, the subject is now coordinated very strictly, and the exercises and topics of the lectures and laboratory classes are set for each week. The subject is now common on our virtual campus (based on Moodle), i.e. all groups of professors of the subject share the same virtual space, although it can be customized with materials or activities that are only visible to the students of each group.

We believe it is still a problem that students do not work regularly, often coming to class without having read the previous lecture topic on which work will be done. They therefore make poor use of class time by studying things they should already know. In addition, the gradable work has to be reinforced just before and during the class to increase motivation. Copying is difficult to eradicate unless daily grades are set during class time, which no longer makes sense. We want students who come to the laboratory to find meaning in

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their learning and for it to be useful for their summative assessment.

The number of hours worked by students, as measured by the SEEQ [2] questionnaire on dedication to the subject, is clearly low both with and without the use of teaching portfolios.

II. JUST-IN-TIME TEACHING

Prince and Felder [3], among other authors, have shown that methods that encourage active participation in class are at least as effective as traditional ones, and generally also improve some aspects of student learning, such as motivation. On the assumption that the exercises proposed here are motivating (they do not merely repeat the class exercises), student attention and motivation should improve, and students will be obliged to do more work outside class. Students are used to connecting to the virtual campus by phone, tablet or computer, and this can be taken advantage of.

The professor must show greater anticipation in the design of each class and greater involvement, and the same is demanded of the students. However, the hypothesis is that this will increase performance, the time students work outside class, and their motivation with regard to the subject. Moore et al. [4] showed that introducing active methods causes changes in us (professors) regarding our beliefs and ways of thinking about our teaching.

One of these methodologies that procures active participation both in class and out of class is Just-In-Time teaching (JiTT) [5], which appeared in our universities with the on-line campus and educational websites. JiTT consists in using the virtual campus to collect exercises of students and adapting the classes to this input. It is a mixture of face-to-face interaction in the classroom and website-based learning support that optimizes the time and effort that the student will undertake at class. Whereas it benefits from the internet era technologies, it should not be confused with Distance Learning (DL) or Computer-Aided Instruction (CAI). Rather, it focuses on providing a good feedback loop that motivates the student to be engaged in her or his learning process. The three main objectives of this methodology are:

- Optimize the efficacy of the face-to-face classroom session, where the instructor is present.
- Plan the off-class time in order to structure the effort of the student.
- Sustain a team spirit between students and instructors, while providing an individualized support for every learner.

More information about JiTT can be found on the page dedicated to it at Indiana University–Purdue University Indianapolis [6]. The application of this method has been described in various educational settings, with very promising results. Among others, we can cite how Bangs [7] applied this method in a Statistics Business course, improving the motivation of the students. Furthermore, Chantoem and Rattanavich [8] provided both on-line and face-to-face support during an English language skills course. Kathleen, Mars and Novak [9] reported an improvement of the quality of the course with a more active methodology in a Cell Biology course. Paulson [10] conducted both his classes with both Cooperative Learning (CL) and JiTT methodologies while lecturing Organic Chemistry; and Udovic et al. [11] ran a Workshop in class as an introductory Biology course with this JiTT methodology.

We now propose to use JiTT to teach computer programming in a first-year courses of Bachelor's degrees in Industrial Engineering. Herein we present our experience in the 2016-2017 academic year, and in the next chapters we explain the objectives of our empirical study based on this JiTT implementation, the analysis methodologies we applied, and then we present the results and conclusions obtained with this pilot experience.

By using the virtual campus, students can be asked to do a gradable task to be resolved before class. The results of the exercises are used to design the class "Just-in-Time". These exercises do not form part of the continuous assessment grade, but help situate the exercises done in class and give the professor information about the objective distance of the students with regard to the task they have to do. The tasks should also motivate the students to get better grades in the partial controls.

We will focus on this problem because the most difficult goal is getting students to do the exercises at home. Several strategies are described in the literature (see the compilation of Del Canto et al. [12]), but some of them did not work for us. A new problem that we have detected now is that absenteeism has increased, whereas we wished to reduce it with this technique.

We now describe our educational context and our particular implementation of JiTT. During the first term of a degree in Industrial Engineering in our College EEBE, students must pass an introductory subject on Computer Science Fundamentals (6 European Credits equivalent to 150 hours of student time). During a 15-week semester the student has two face-to-face hours of theory and problems and two hours of laboratory every week. During these laboratory sessions the student is faced with basic programming tasks by using a modern programming language (in our case, Python). Students must complete on-line an assignment every week and submit it via the Moodle virtual campus of our university two days before the laboratory session. This task is related with the topic of the upcoming face-to-face laboratory session. Then the instructor corrects the submitted work during the face-to-face class, and provides her or him with new assignments, which are graded in difficulty, according to the previous performance of the student. The on-line tasks are not mandatory, but the learners are encouraged to submit them, and those who regularly complete them have the possibility to earn extra points on the final assessment. The marking structure of the subject consists of three laboratory objective controls, a practical work using Python libraries and a final control which accounts for only 30% of the final mark. Therefore, continuous work during the term is encouraged.

III. Objectives

We have a long series of results from the SEEQ [2] surveys and academics results [1], correlated with the university entrance grade and other factors. We have observed that students spend on average less than one hour on the subject per day outside class, only working on it when they have an examination or have to hand in exercises. The academic results are fairly good but could be better (about 70% passed). The SEEQ surveys show room for improvement in several areas.

We wish to achieve the following goals:

1. To increase the time students devote to exercises before each laboratory session and improve their use of class time.

Indicators: number of students who do the exercises before each session in each group; academic performance in the subject; students' university entrance grades and origins.

2. To improve student satisfaction with the subject.

Indicators: SEEQ surveys of the subject; questionnaire on student satisfaction; specific comments by students.

3. To reduce absenteeism in laboratory classes when there is no gradable control.

Indicators: percentage of class attendance in each group; student performance compared with attendance.

IV. Methodology

A. Sample and Procedure

During the fall semester of the 2016-2017 academic year, as a pilot experience we followed the JiTT method in a subgroup of the Computer Science Fundamentals subject in the first semester at the EEBE. In this subject students enroll for lecture groups of about 60 students, which are divided into three groups of 20 students for the laboratory classes. The JiTT method was applied in one of the laboratory groups (G1) but not in another (G3) with the same professor, the author of the present work. The method was not followed in Group G2, with a different professor, but the learning objectives and level of requirement are equivalent and are coordinated with the other groups of the subject. The three laboratory groups had the same professor for the lectures. Students signed up for this teaching group by order of enrollment, which depends on their university entrance grade and their origin.

The sample was composed of 59 students (15 women [25.9%] and 44 men [74.1%]) taking the Computer Science Fundamentals subject of bachelor's degrees in industrial engineering in the first semester at the EEBE. The age of the students ranged from 18 to 25 years (mean 18.98±1.69). As for the origin (previous studies), 8 students (13.6%) were participating in mobility programs, 9 (15.2%) came from other degrees that they had not finished, and the rest (71.2%) came from the Spanish university entrance examinations (PAU). With the exception of exchange students (N′=51), the university entrance grade was between 5.63 and 12.58 (maximum 14; mean 9.91±1.58).

The following data were collected during the semester in which this subject was taught:

- Individual grades of each of the first four assessment tests.
- SEEQ surveys for each group.
- The UPC student satisfaction surveys (not yet available).
- Interviews with five students from the teaching group chosen randomly.
- The percentage of attendance at each laboratory group (not individual attendance, as there is no roll call).
- The percentage of completion of individualized exercises in group G1. The full name of each student who does the exercises, and their attendance at class on the next day, to study the correlation.
- Data on the students obtained from the school's academic management service (cut-off mark, age, origin, and group in which they were enrolled).

For the statistical processing, we used IBM SPSS Statistics version 23 [13].

B. Data analysis methodology

To meet the research objectives, we performed the following studies:

- Multivariate analysis (ANOVA) to see whether the introduction of JiTT is an important factor in performance, compared with the university entrance grade, a change of teacher or the students' age. Since the percentage of exchange students was high (8 students, 13.56%) this factor was also included as an origin.
- A comparison of means of each section of the SEEQ survey among the groups. A statistical test comparing means and distribution of grades by groups.
- Qualitative analysis and assessment of the interviews and comments received in open questions and questionnaires.
- Comparison of performance and satisfaction with previous values for the subject. The drawback here was the difference in professors, in organization of the subject and in content.

V. Results

A. Academic Performance

We compared the average grades of the three controls of laboratory programming for each group (52.5% of the final grade). For group G1, using the JiTT methodology, we obtained 5.3; for the control group G2, with another professor, we obtained 4.9; and for the control group G3, with the same professor as G1, we obtained 4.6. The one-factor ANOVA of homogeneity of means showed the results to be significant ($p<0.01$), so the mean of G1 was significantly higher than that of the other two groups.

We performed a chi-square goodness-of-fit test to check whether the distribution of grades was homogeneous in the three groups, but the results were not statistically significant. The distribution of the grades within each group was not significantly different from that in the others.

In the comparison of the mean final grade for the subject, which also includes a final practice and a written final control, the results were significant. For group G1 the mean final grade was 6.8, which is significantly better than that of G2 (5.7) and G3 (6.1).

To compare the impact of this method between different student profiles, 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. Then we repeated the comparison test of the mean final grades between groups for each of the thirds. For example, we compared the mean final grade of T1 of group G1 with that of T1 of G2 and G3. We also performed the same test of homogeneity 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 (7.5) was significantly higher in G1 ($p<0.05$) than in G2 (5.8) and G3 (6.0). A one-factor ANOVA of homogeneity of means between the university entrance grades of each group for students for whom these grades were known (N'=51) showed no significant differences. The hypothesis that the groups would have students with significantly different university entrance grades cannot therefore be sustained.

B. Student Satisfaction Surveys

A multivariate ANOVA was performed to check whether the means of student satisfaction were homogeneous between groups. The test was carried out for both mean overall satisfaction given by the SEEQ survey and for each section of the survey. The results are shown in Figure 1.

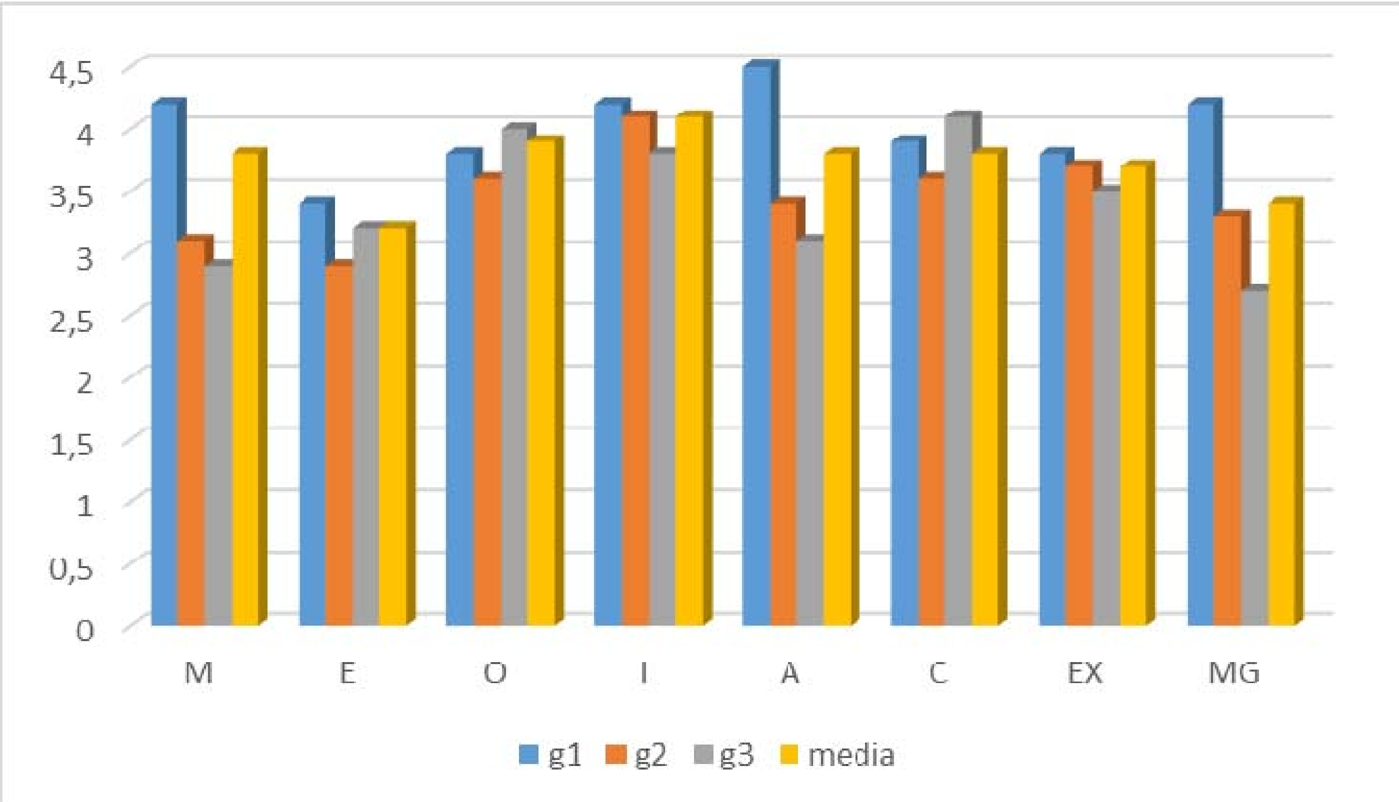

Fig. 1. Means of the sections of the SEEQ surveys for the three groups.

TABLE I.

	Group 1	Group 2	Group 3
Overall mean	4.2	3.3	2.7
Motivation	4.2	3.1	2.9
Attitude	4.5	3.4	3.1

a. Mean of different sections in the SEEQ survey with significant results ($p<0.05$).

Significant improvements ($p <0.05$) were obtained in the overall mean and in the sections "Student motivation" and "Personal attitude of the professor", as shown in Table 1. Therefore, in G1, in which JiTT was applied, the overall student satisfaction was significantly higher, especially in two sections of the survey. The results are shown in Figure 1 according to the following legend:

M: Student motivation
E: Enthusiasm of the professor
O: Organization of the professor
I: Interaction with the group
A: Personal attitude of the professor
C: Subject content
EX: Suitability of exams
MG: Overall mean

Table I shows the results of the survey for the sections in which significant differences were obtained.

When asked how many hours a week they spent on average on the Computer Science Fundamentals subject during the semester, most students in the three groups answered 0 to 4 hours, and only a small number of them answered more than 4 hour.

C. Multivariate Analysis of Academic Performance

When we had obtained the final grades, we performed a multivariate analysis in which the independent variable was the final grade for the subject and the dependent variables were university entrance grade, age, origin (categories: from access to university exams; from other degrees that they had not finished; and exchange students) and JiTT, a categorical variable indicating whether the student was in the group in which it was applied. Multivariate regression assumes that there is a linear dependency between the independent factors and the dependent variable. For each factor ($1- \beta_i$), we obtain the percentage of the value of the dependent variable that it explains and the statistical significance. High values of ($1- \beta_i$) in comparison with the other factors indicate a preponderance of this factor over the rest. Statistical significance was set at $p<0.05$. For a detailed description of the model on which this analysis is based, see [1, 14]. For exchange students whose university entrance grade was unknown, we assumed the group average. The results obtained are shown in Table 2.

TABLE II.

Independent variable	$1- \beta_i$	*p*
University entrance grade	0.083	0.021
JiTT	0.132	0.043
Age	0.178	0.124
Origin	0.231	0.133

b. Table 2. Multivariate regression model for the Computer Science Fundamentals subject.

Only two factors of the model were statistically significant: university entrance grade and whether or not JiTT was applied. University entrance grade predominated as the main factor explaining performance, followed by the application of JiTT.

Finally, we repeated this analysis dividing the sample into three thirds by academic performance, as described in the previous section. However, in this case, no significant factors explaining the students' final grade were observed. It should be noted that the number of students in the sample for each third was less than 20, making it difficult to obtain relevant statistical significances.

D. Qualitative Analysis. Structured interviews of some students

Interviews were conducted with three students of group G1, in which JiTT was applied, and two students of the control group G3.

Among the students of G1, the most relevant comments were:

<u>Strengths</u>:

- The exercises were corrected every week.
- The problems were similar to those of the controls and helped to prepare them.

<u>Points for improvement</u>:

- The problems done at home and in class did not count toward the final grade, except to adjust it at the end of the course in cases of doubt.
- More solved exercises should be given.
- Controls 2 and 3 were far more difficult than control 1.
- Hardware problems in the classroom-laboratory.

The students of G3 made the following comments:

<u>Strengths</u>:

- Exercises were published in the virtual classroom to prepare the controls.

<u>Points for improvement</u>:

- Hardware malfunctions in the classroom.
- More exercises should be corrected in the virtual classroom.
- Laboratory control on the last day of class (December 23).

The interesting aspect for our study is that most of the interviewees of group G1 stated that the exercises they did at home helped them study for the controls, so they found them useful, while the students of group G3 stated that they did not do the exercises outside of class because they do not count for the grade and they have a lot of work that does count for other subjects. No exercises for doing outside of class were proposed to group G2, although they had practical exercises to do in the virtual campus.

E. Other Relevant Results. Comparison with Previous Years, Preparation Time, Absenteeism in the Classroom

The academic results were similar to those obtained for the subject in previous academic years. The pass rate was still 70%-80%, which is very satisfactory considering that this is a core subject of the first year. The assessment system has changed in the current academic year, and although the general objectives of the subject (teaching the fundamentals of computer programming) have not changed, there have been many changes in the teaching staff. For this reason, it is difficult to accurately compare current performance with that of previous years. Nevertheless, no major qualitative change was observed in the number of passes or in the overall student satisfaction with the teaching.

To assess the cost of applying JiTT for each professor, we asked the two professors of this pilot experience how long they spent on preparing this laboratory group each week, including preparing the problems, correcting the exercises, studying the topic, etc.

The professor of group G2 said he spent on average one hour a week preparing the laboratory class and the professor of groups G1 and G3 said he spent 3.5 hours for G1 and 2 hours for G3.

The mean attendance of the laboratory classes (which was not compulsory except on days when there was a control) was 77% for G1, 64% for G2 and 56% for G3. In G1, 57% (8 of 14 students) delivered the exercises regularly every week before the laboratory session.

VI. Discussion

In this pilot study we obtained better academic results and better student satisfaction in the JiTT group, despite the small sample of students. It does not appear that the inclusion of a different professor significantly changes the results between groups G2 and G3, although it remains to be seen whether the less popular class time of G3 influenced the results. The results also indicate that the groups were homogeneous in terms of university entrance grade. This has been reported to be a major factor explaining academic performance in some studies at Spanish universities [15, 16, 17].

It is notable that when the mean final grades were analyzed by performance thirds (T1, highest grades; T2, intermediate grades; T3, lowest grades) a statistically significant difference was only observed in T2, and with a small sample of students. It seems that the motivating effect of JiTT is highest for the group of students who are at risk of failing. For students with high or low performance, JiTT is less effective at improving their final grades.

Dedication of students may increase with JiTT, because they have to perform exercises and hand them in between classes. However, the results obtained are disappointing, because despite the improvement, the time the students spend is far lower than the time expected according to the course design and the number of ECTS credits.

Compared with previous years, and specifically with the same professors teaching this morning group, no significant changes were observed. Absenteeism of the students in non-compulsory laboratory classes was significantly lower in the JiTT group than in the other groups. In groups G1 and G3, the unfavorable class time, 8 a.m., could be a deterrent. However, in group G2, which had class from 12 p.m. to 2 p.m., after the lectures, no increased attendance was observed.

The professor who applied JiTT required on average 1.5 hours a week more than the one who did not. If the professor has many laboratory groups, this additional effort may not be sustainable. However, the pilot experience was the first time that this teacher had used JiTT, so preparing graduated exercises for each topic was an additional task. From the second application of JiTT, this difference in effort should drop to a reasonable level.

Multivariate analysis revealed that, as is usual in first-year engineering subjects, the university entrance grade was the main factor explaining student performance. However, exposure to JiTT was the second factor that was statistically significant. Further studies with a larger sample are needed to confirm these results and to determine whether the teaching method is more important than the university entrance grade for students at risk of failing the subject (students with the middle third of final grades).

VII. Conclusions

We have presented a pilot experience of application of JiTT in the first semester of the 2016-2017 academic year in the Computer Science Fundamentals subject of bachelor's degrees in industrial engineering. The results show that JiTT significantly improved academic performance and student satisfaction, and reduced absenteeism in laboratory sessions. The motivating effect of the method was significant only for the students with intermediate notes who were at risk of failing, but was less effective for students with high or low performance. Further studies with a larger sample of students in various schools are needed to obtain conclusive results about the influence of JiTT on academic results.

However, the results of the quantitative and qualitative analyses show JiTT to be a promising method at a reasonable cost of additional dedication by professors. The results encourage us to continue the study and we are open to collaboration to investigate the application of JiTT in other educational contexts.

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