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Engaging Students in an Undergraduate Computer Technology Course: An Active-Learning Approach*

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Research carried out in recent years suggests that students in Higher Education are not always motivated and lack the learning skills and work habits to overcome first-year difficulties at the university. As a consequence, the approach to teaching the subject was to blame for allowing a significant number of dropouts and underachievement. Starting from several educational experiences carried out since 2005, this paper presents an overall model with the emphasis on student-centered learning and formative feedback. The teaching approach is based on good practices that are supported by commonly available technology resources so as to maintain a manageable faculty workload. Technical resources are a very helpful resource to face large groups of students without losing learning feedback quality, but it is not a solution per se. Thus, on-line activities have been designed to support individual formative feedback with asynchronous teacher interaction, while face-to-face learning is still very important and oriented to promote peer interaction and collaboration. The presented model has produced successful results during several consecutive academic years with samples of more than 500 students per year and the participation of 11 lecturers. This work analyses quantitative indicators to demonstrate that teachers are able to carry out a reliable representation of their student progress, despite the use of different student-centered activities. Generally speaking, student active participation has grown significantly, achieving 65% success. The model and its starting conclusions can be extrapolated to many high education courses.

Keywords: higher education and computer engineering; educational technology; first-year (freshmen) engineering success; student engagement; tactile displays; technology assessment

1. Introduction

European universities moved towards convergence reforms within the framework of the Bologna Declaration [1] to establish the European Higher Education Area (EHEA) and promote a European quality system for higher education worldwide. Numerous engineering courses have made significant changes since 2010 in their methodology, in accordance with the EHEA priorities [2].

These changes suppose a major challenge in the case of courses with a significant number of dropouts and important levels of underachievement, such as the computer technology course at the School of Computer Science in the Universitat Politècnica de Valencia (UPV—Valencia, Spain).

Computer technology is a first-year core subject taught during the spring term (second semester) in the computer engineering degree program. The syllabus was compiled according to national and international recommendations, the main sources being the ACM/IEEE curricula recommendations, as well as the Computer Engineering Degree Program White Paper of the National Agency for Quality Assessment and Accreditation [3]. The course is included in the field of computer engineering and complements the non-computing topic of electronics, as it is focused on semiconductor devices and logic families.

Student dropouts in engineering courses have been addressed in many general studies [4] and [5], as well as in papers focused on similar Spanish engineering courses [6, 7, 8]. However, the problem is generalized. A study published by the OECD in 2010 [9] states: "on average among the 23 OECD countries for which data are available, some 30% of students in university-level education do not graduate from the program that they enter. However rates differ widely—in Japan the completion rate is 93% while in Mexico, New Zealand, Sweden and the United States it is below 60%". Barefoot [10] affirms that student drop out has become an overriding obsession for many US campuses, and that it is at its highest between the first and second year. The author also points out that an area to be explored in retention research is the way instruction is designed and delivered.

According to Feldman and Zimbler [11], "all beginning college students face enormous challenges, ranging from the academic to the social, and the first year of college marks the period of greatest vulnerability for student attrition". Therefore, care must be taken in designing a learning environment that motivates by reducing student anxiety and minimizing dropouts. Vermetten et al. [12] showed that students adapt their learning strategies, to a certain degree, to the characteristics of the learning environment. Therefore, instructors

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should arrange conditions such that they encourage the use of a deep learning approach among students [13]. These conditions are set mainly by the teaching methods, content and assessment methods in a course. Trigwell et al. [14] noted that in classes where students report adopting significantly deeper approaches to learning, teaching staff describe their own approach to teaching as more oriented towards students and to changing students' conceptions.

Student-centered learning could improve course quality and support learning achievements [15, 16]. However, the main difficulty in establishing a student-centered learning model in computer technology is the large number of students enrolled annually on the course. Computer technology has registered more than 500 students annually since 2010, when the school carried out the Bologna grade extension. In fact, a course challenge is precisely the distribution of enrolled students, being necessary divided into 11 groups with 11 lectures, one per group. It means an additional level of cooperation.

In computer technology, the introduction of a student-centered operative model should be oriented to engage students in their learning process with actions that encourage an active and continuous participation in order to guarantee an effective formative feedback but without overloading the lecturers. Thus, the model incorporates synchronous activities (face-to-face) and asynchronous (web-based) learning activities as a way of helping students out-of-class. The course totals six ECTS (European credit transfer and accumulation system) [17], or 150–180 hours. Sixty hours are dedicated to face-to-face classroom work and at least 90 hours of out-of-class self-study are expected. Studies about student perceptions and preferences (comparing face-to-face and on-line learning) report that both interaction with the teacher and an individual learning process that enables the student to control her/his study pace are important [18], [19]. Face-to-face activities are designed to promote interaction with the teacher and classmates, and information technology supports the lecturer in covering out-of-class hours with assignments, tests, and quizzes that enable students to pace their self-study. On the one hand, asynchronous activities require a great lectures' effort in preparing substantial web-based material of different kinds. However, this effort has been distributed among lecturers who work cooperatively and who,each year, enhance these activities with new material and proposals. On the other hand, the use of web-based activities to support individual formative feedback helps freshmen students' self-study by conducting it in a scaffolding way.

The paper describes the model of activities and the experience of four consecutive years. Section 2 analyses important course challenges. Section 3 describes the course design, and Section 4 evaluates the results. Section 5 concludes the paper.

2. Challenges

Computer technology is not generally addressed in high school programs, so the semiconductor technology background of our students is virtually nonexistent. Thus, the university admission mark can be considered as indicative of a student's learning potential, rather than a measurement of knowledge about a subject [20, 21]. For example, in 2010–2011, the university admission exam marks was compared with the corresponding first-year student average final marks in a sample of 540 students, equivalent to the usual number of students in computer technology courses. The final first-year average mark was computed from the final mark of ten course marks taught during the first university year. The results show some degree of correlation between the initial admission mark and the final average mark reached. Thus, as expected, students with higher university admission marks end their first year with higher than average marks, and vice-versa.

However, this apparent connection between marks does not hold for our computer technology course. In Fig. 1, the final course marks (on a 10-point grading scale) are plotted against the corresponding university admission marks (on a 14-point grading scale) for the same students of the general above-mentioned comparison. As this plot shows, there is no correlation between computer technology course mark and admission mark. This phenomenon can be explained because computer technology includes contents that were not studied at high school.

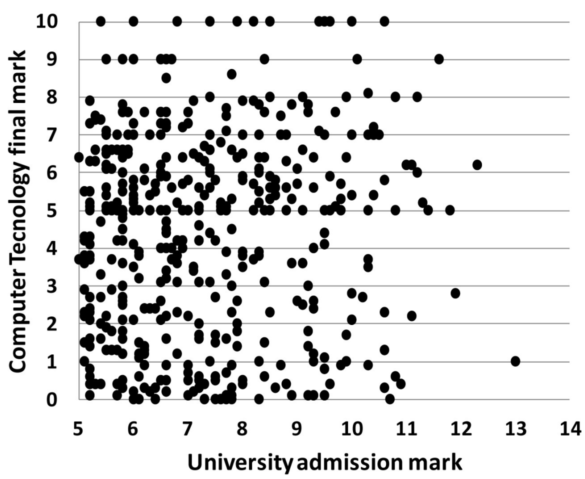

Fig. 1. Final course mark in computer technology vs. university admission mark (2010–2011 example).

The course is scheduled during the second term of the year, whereas subjects such as Foundations of Physics for Computer Science are included in the first term of the year. In this way, syllabuses are designed to overlap any student's conceptual or practical gaps. However, many students enrolled in the course take it independently of their results in the previous winter term and this affects the initial weeks of the course where the pace is slower than expected.

Moreover, the lack of maturity in freshmen students as learners and their poor habits for effective self-study makes solving the problem more difficult. The traditional instructional approach does not increase student motivation, especially at the beginning of the course when extra effort is needed to overcome unachieved skills. On the contrary, students are passive and often leave study until the end of the term. This makes formative feedback (essential to deep learning) difficult to offer.

In addition, computer technology is focused on electronics, a non-computing subject that, generally speaking, is not closely linked to the main topics of interest to computer engineers, such as information systems management, programming, or computer networks. Thus, many students perceive the course as a threat rather than an opportunity to enhance knowledge. This calls for the need to re-orient the course by using attractive real examples. However, even the simplest of real circuits is too complicated for a newcomer, and so a delicate scaffolding process is necessary.

Active-learning methods can help otherwise passive students acquire a learning-centered approach [13], [22]. However, large groups can burden lecturers with an excessive amount of work. Classroom activities are intended to give prompt formative feedback *in situ*. However, large groups will discourage any lecturer from assisting students individually during classroom hours. Available technical resources can relieve *in situ* feedback, but it is not a solution *per se*.

Finally, as indicated, the course must coordinate 11 lecturers in offering the same quality principles to all groups, despite the non-homogeneous nature of the groups and lecturers. This constitutes an additional challenge.

3. Course overview

The Universitat Politècnica de València (UPV) launched an action plan for European convergence in 2005 to support initiatives leading to an improvement in educational quality. In the same year, the computer technology course initiated an educational upgrade. Bologna convergence proposals were due in 2010, so that the course had five years to define the final curriculum. Course changes have been mainly focused on teaching methods and the student workload distribution during the term, while syllabus and expected learning outcomes have been largely maintained but updated for technological advances.

To increase student–teacher interactions, the course defined a problem-based learning methodology that was suitable for the course subject. Students work on practical activities with real circuits in a scaffolding approach. However, between 2005 and 2010 it became clear that individual formative feedback in face-to-face classroom time is difficult to manage in large groups. Freshmen students need a confidence-building learning model that, in addition to interaction, provides individual opportunities to manage their work.

Studies on blended learning emphasize that students can confront learning in more objective and reflective ways than might be possible in face-to-face contexts [23]. In a computer technology course, on-line learning activities are designed neither for collaborative learning nor as a way of 'delivering old content in a new medium' (Marshall McLuhan, cited in [23]). Face-to-face learning is designed to promote peer interaction and collaboration, while on-line activities support individual formative feedback with asynchronous teacher interaction.

3.1 Course design

Figure 2 shows course length and assessment percentages. At the beginning of the course a seminar is held on the fundamentals of electrical circuit theory. Students are asked to solve circuits of varying complexity and, if necessary, some reinforcement activities are distributed.

First, problem-solving sessions are dedicated to learning-by-doing [24–26]. The introduction of real circuit examples aims to help students achieve a better conceptual understanding for deeper learning [27, 28]. Deductive reasoning is worked in small teams—discussing and sharing work favors peer interaction and this process is aided by prompt feedback from the teacher with hints and verification. These sessions help students discover and apply new concepts. Students receive both quality written material and guidance. Material hand-outs in problem-solving sessions are reusable and composed of slides about basic concepts and exercises—some of which are solved examples. Feedback is given *in situ* but there is not enough time to go deeply into individual difficulties. However, general misconceptions that are repeated on every team can be displayed to the whole class and discussed openly. Tools such as the Classroom Presenter [29] support sharing digital ink on slides between teachers and students and are used in the course to make classes more interactive and better adapted to the students. Lecturers raise the problems to be solved using this tool and students answer directly on their tablet PC using digital ink. Once they have finished, they send their solutions back to the instructor who projects them onto the classroom screen for review.

Students are used to dealing with information and communication technologies. Some researchers have tackled the subject of young people and new technologies, calling them Homo Zappiens, Digital Natives, or the Net Generation [30–32]. Thus, digital applications are not a handicap and can make the course more attractive.

Given the potential of tablet PCs to encourage dynamic classroom environments [33–35], between 2008 and 2010 the computer technology faculty developed a proposal entitled 'Improving Effective Learning in a First-year Computer Engineering Course by using Mobile Tablet PC Technology' [36]. The project was funded by an HP Technology for Teaching Grant Initiative entitled Transforming Teaching and Learning through Technology [37]. The central idea was to take advantage of digital ink and the networked classroom to enhance both student-to-student and student-to-lecturer in-class collaboration. The course received 21 tablet PCs exclusively for classroom use.

This approach deals with student classroom shyness regarding face-to-face questions. Although many students seem shy, this is less true when the instructor moves around the classroom or uses digital communication. Students feel comfortable with technology and are thus more likely to participate. Moreover, the networked classroom concept can be combined with techniques such as the minute-paper or the muddiest point [38] and by asking students which were the most important (or the least understood) points in each class session. Student answers are uploaded directly into a Sakai-based learning management system [39] and nothing is written on paper.

Secondly, laboratory sessions are planned for students to work alone or in pairs with digital tools on conventional PCs with electronic instrumentation and circuit simulation software. Graduate students must have a practical knowledge that goes beyond mere theory [40]. Laboratory work includes guides, Java applets on circuit analysis, videos, and self-evaluation questions. These sessions are intended to reinforce comprehension and each student can set their own pace. Topic-contingent feedback is given in lab sessions because students gain confidence when reinforcing their learning. However, feedback is still given orally, which is sometimes considered a negative point by poorly skilled learners [41].

Finally, tutorial sessions are voluntary and are never imposed on students. However, students demand flexible ways of keeping in touch with their lecturers—and so E-mail and web-based virtual spaces such as Adobe Connect based applications are used to encourage on-line virtual individual or group sessions.

3.2 Course methodology

On-line activities are used to complement face-to-face sessions. Like many other universities, the UPV offers a digital platform that supports several types of learning tools—such as web-based assignments, tests, and quizzes (Sakai project and SAMigo platform). Students gain feedback with open-ended questions (OEQs) by verification and hints. Multiple choice tests (MCTs) are supported by most digital multi-user platforms and are included among the course on-line activities. Tests can be restricted to specific time windows and provide students with immediate feedback since tests include correction descriptors for self-evaluation. Automatic grading is supported and this enables correct-response or response-contingent feedback.

Looking at Fig. 2, the number of hours of self-study that a student needs to pass the course has been estimated to be 6 hours per week. However, freshmen used to have real difficulties in knowing what to do at home to prepare the subject. They can review texts or work on short problems, but they need useful material that contains theoretical concepts, problems and solutions. On-line activities have demonstrated advantages over plain-text material. On the one hand, variety, dynamism, auto-controlled progression and digital access are motivation factors to our students. On the other hand, the number of students who need face interaction with the teacher has gone down significantly. Taking into account the high number of students per teacher, the decrement is a relief. Moreover, enquiries by E-mail have increased moderately and are focused on specific questions related to the on-line tests. Thus, teachers can also use office hours to correct OEQs , assignments or tasks with a maximum of 6 hours per week.

In addition to assignments, tests, and quizzes, tasks also form part of student activities. Tasks are oriented to the production of learning objects by the students. Learning objects are small pieces of knowledge that might, for example, display knowledge comprehension and practical application. The production of new digital objects by students is a complex cognitive task that facilitates critical thinking and an emphasis on written communication that is a highly effective form of encouraging reflection and precision of expression.

Examples of knowledge applications for engi-

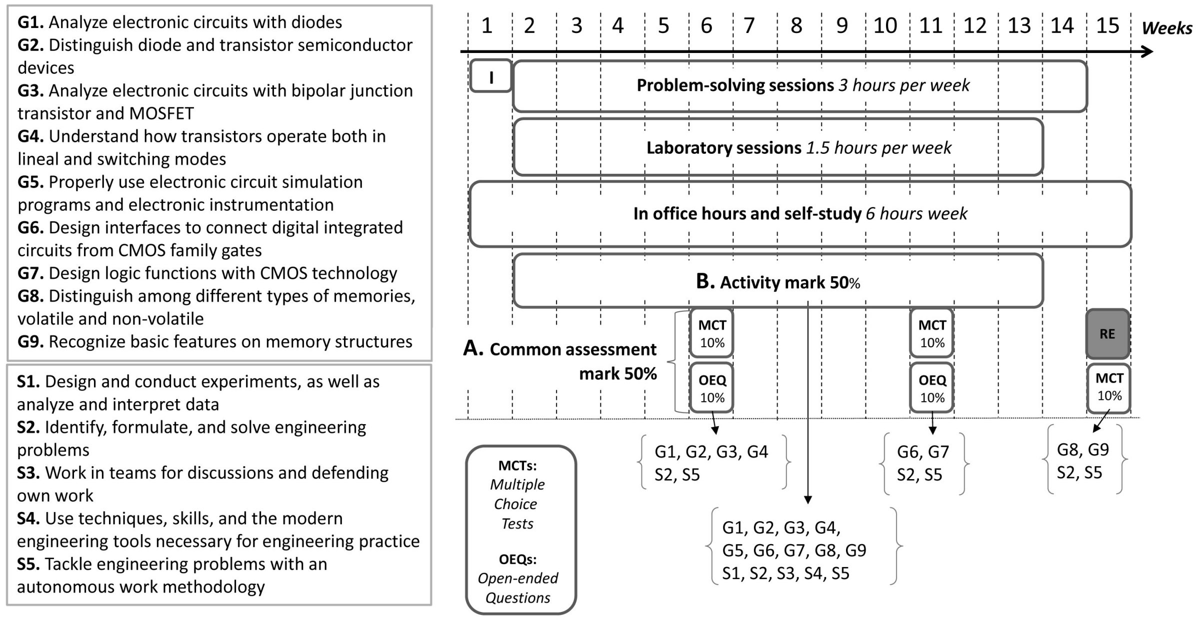

Fig. 2. Course design: goals, outcome skills and weekly schedule.

neering are model-based activities such as videos or Java applets. Students gain feedback by reviewing bugs or misconceptions, as well as developing responsibility and a sense of commitment. Moreover, learning objects are shared within the group, forming digital collections that are shown in class or made available through the course intranet.

On-line learning is planned by each teacher inside each group—and is focused on overcoming difficulties observed in face-to-face sessions and, at the same time, responding to the needs of each student. Therefore, differences appear among groups or even inside a group, and this produces different weekly schedules of activities. However, instructors have to balance this flexibility in managing each group against the important premise of maintaining both coordination and cooperation. In this way, digital material is designed collaboratively and made available to all teachers.

3.3 Course assessment

This model provides teachers with a degree of freedom not only to choose the activities to be carried out in a particular group, but also regarding the corresponding assessment. Teachers adapt student activities during the year as a function of the observed deficiencies and idiosyncrasies of a particular group. Thus, the purpose of these activities is to facilitate learning goal achievement by emphasizing skills. However, the course needs a common assertion on learning goals that must be evaluated in the same way for every student, regardless of the group.

Figure 2 introduces two assessment scores. First, Fig. 2(A) shows the count given to common assessment. Common learning goals are ensured by common written exams that count 50% towards the final mark and require the collaboration of the entire course faculty to confer impartiality on the evaluation. This type of evaluation enables faculty to address many learning goals (see Fig. 2). This evaluation includes retakes at the end of the term (RE).

Secondly, the activity mark in Fig. 2(B) represents 50% of the final mark and takes into consideration student effort inside and outside the classroom (25%), as well as laboratory achievements (25%). Equation 1 represents one example of how student efforts inside and outside the classroom (activ_mark) are computed in one group. In this case, three dimensions with different weights were considered:

1. all assignments delivered during the term (assign_mark);
2. quizzes that may include MCTs and OEQs (quizz_mark); and
3. student participation in course activities (particip_mark), including aspects such as student attitudes, fulfillment of deadlines, engagement, and observation in the classroom.

$$activ\_mark = \left(\sum_{i=1}^{n} \frac{assign\_mark_i}{i}\right) \times 0.3 + \left(\sum_{j=1}^{n} \frac{quizz\_mark_j}{j}\right) \times 0.6 + particip\_mark \times 0.1 \quad (1)$$

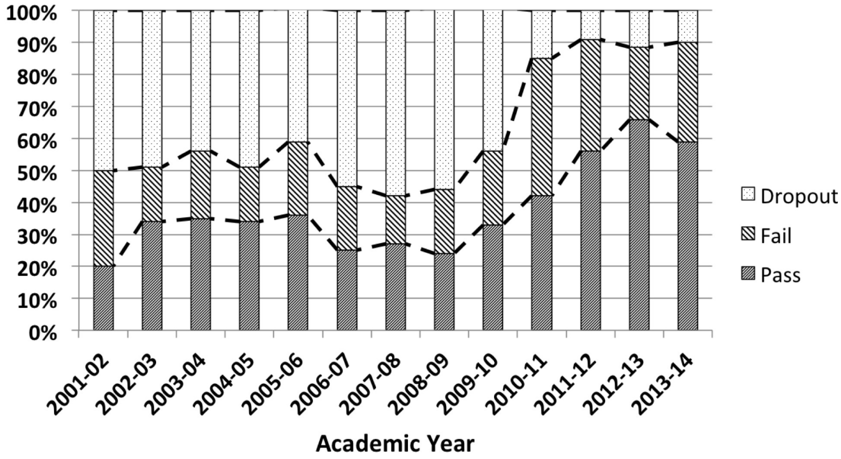

Fig. 3. Historical evolution of academic results in computer technology.

Dimensions and weights change between groups, although assignments and quizzes are usually considered, while student participation is only taken into consideration in six out of the eleven groups.

Assessment of student laboratory achievements is also evaluated by the teacher. However, in this case, lab assessment is fairly uniform as it always includes a hands-on exam, in which students have to demonstrate their practical skills, and an on-line test to measure their achievements using circuit simulation software.

4. Results

With regard to overall indicators, the most successful aspect of the proposal is the considerable decrease in dropouts experienced over the last four years, which correspond to the proposed course model (Fig. 3). The number of students who participated in the computer technology course was: 516 in 2010–11, 544 in 2011–12, and 490 in 2012–13. Increased student participation has contributed to raising student achievements (Fig. 2: pass rate).

Student activity marks refer to the continuous evaluation made during the course. The assessment, as commented on in Section 3.3, differs for each teacher and it is conditioned by the group necessities.

Figure 4 plots a dispersion graph including the data from four academic years. The graph relates student activity marks (axis B) and written exam marks (axis A). Figure 4, center, is pointed at 5 in both axes in a 10-points scale. Thus, the figure is divided into quartiles: Q1 represents students with a low activity mark and a high written exam mark. Q2 and Q3 quartiles contain the unbiased sample (high marks in both A and B or low marks in both A and B respectively), while Q4 is the percentage of students

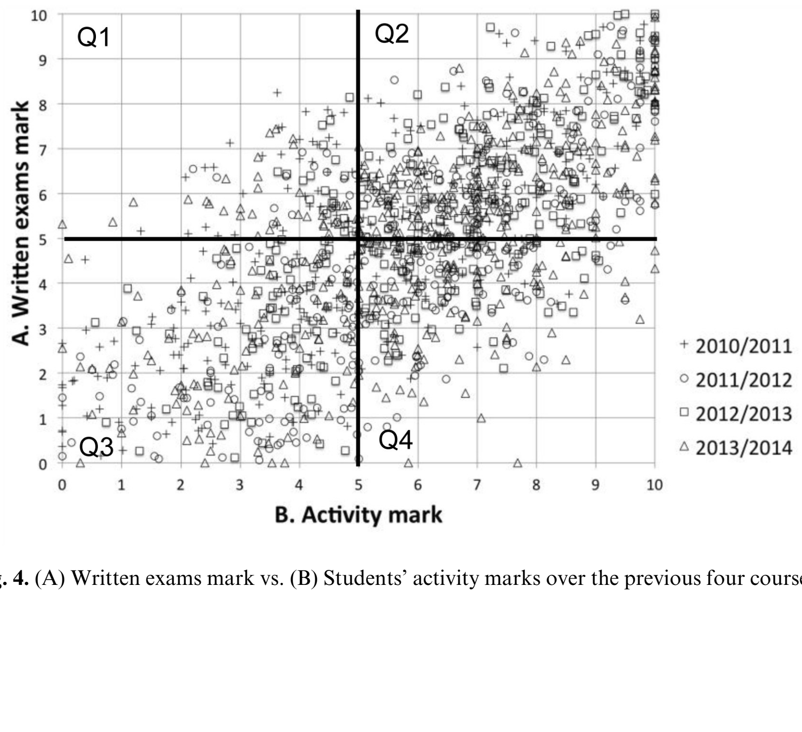

Fig. 4. (A) Written exams mark vs. (B) Students' activity marks over the previous four courses.

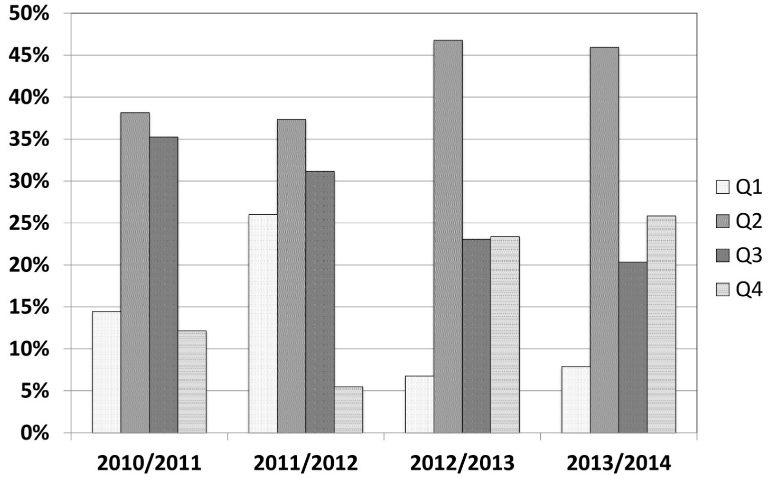

Fig. 5. Quartile distribution of Fig. 4: Q1: A ≥ 5 and B < 5; Q2: A ≥ 5 and B ≥ 5; Q3: A < 5 and B < 5; Q4: A < 5 and B ≥ 5.

with a high activity mark and a low written exam mark. Q1 and Q4 contain the biased sample.

Figure 4 shows that, generally speaking, teachers have been able to make a reliable representation of student progression over the four years. The particular teacher assessment strategies are not as important as ensuring that students work continuously during the course—from beginning to end.

Figure 5 shows that Q1 and Q3 percentages have decreased, and this is positive because both quartiles represent unsuccessful students' results. On the other hand, the number of students in Q2 has increased over the last two years, and it is positive too. Thus, student participation in Equation 1 is a reward and a motivation factor too. Activities are implemented with the goal of increasing the number of students in the Q2 quartile, while Q3 decreases close to disappearing.

However, the graph dispersion shows that a good mark in B is not always a guarantee of success. Common assessment is still worthwhile because there is a slight bias towards incrementing B marks. Comparing 2010–12 with 2012–14, Q4 has increased up to 20%. That means the model needs to be reviewed constantly. At the end of each academic year, a detailed statistical analysis of academic results per group enables faculty to identify which approaches produce the best results and also to detect possible divergences from the expected results—thereby enabling teachers to adjust the equations described previously or to re-orient activity closer to the achievement of course goals.

5. Discussion

The computer technology course presents a high number of enrolled students every academic year. Students are typically divided into 11 groups (all of them working during the same term), which means around 11 teachers involved in their learning. Moreover, the course model includes both face-to-face activities and web-based activities, which could be a handicap for lectures in terms of workload and coordination. Thus, the course needs flexibility, allowing teachers free selection of weekly activities while maintaining a coordinated work plan.

Quantitative indicators show that during the last four years and despite differences in the selection of weekly activities, and the individual assessment done by each teacher, student progression is reliable according to an established common assessment.

However, common assessment is still worthwhile because there is a slight bias towards incrementing students' individual activity marks.

Coordination is done by both discussion and the continued incorporation of new materials and new activities in the course digital learning platform. Materials and activities are immediately shared and made available to all the teachers. This type of cooperation reduces the teachers' workload. Additionally, at the end of each academic year, a detailed statistical analysis of academic results per group enables faculty to identify which approaches produce the best results and also to detect possible divergences from the expected results—thereby enabling teachers to adjust the equations described previously or to reorientate activity towards the achievement of course goals.

Student participation has grown significantly in the computer technology course with a decreasing number of dropouts. The overall success rate in 2013–14 was around 60% of the enrolled students, similar than in 2012–13, which was around 65%—the best ever academic performance achieved in the computer technology course. The key to teaching has been to motivate students to maintain effort from the beginning to the end of the course, dealing in this way with challenges that could not be solved using traditional instruction methodologies.

6. Conclusions

This paper has analyzed the educational model used since 2010 in the computer technology course at the UPV, Spain, in a first-year core course for a computer engineering degree. Although heavy time and syllabus demands have not changed since 2005, several experiences between 2005 and 2009 led the course faculty to develop a model to offer effective formative feedback to the students through face-to-face activities supported by web-based technologies.

Essentially, coordination has been fundamental to creating a common and alive digital space with materials and activities available to all the teachers that each one uses according to his/her group needs.

The model has produced successful results during the last four academic years with samples of more than 500 students per year and the participation of more than 11 lecturers. The paper has presented quantitative indicators to demonstrate that teachers are able to carry out a reliable representation of their student progression with a common work plan despite the use of different student-centered activities.

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