Learning Supported by Peer Production and Digital Ink

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***Abstract*— This paper describes experiences that combine digital peer production with digital ink affordances. Rather than preparing papers to obtain a summative final mark, students work over the course of the term producing different small learning resources such as short engineering problems, reasoning or synthesis where the lecturer acts as manager and supervisor. Teacher intervention is carried out using digital ink over each individual student production being possible to share the results throughout a public or group repository and in class offering a pro-active argument about preventing common mistakes. In order to enhance students' programming skills important efforts are oriented to produce learning objects in the form of Java applets. It has the additional advantage of fostering collaborative knowledge construction because any object serves to the whole group as learning material as soon as it is already produced and validated. Qualitative and quantitative results show both an overall satisfaction from students participating in the experiences, and better results in the common written exams, when compared to the other groups following the traditional method.**

Keywords—digital ink; student-centered techniques; learning objects;

I. Introduction

Student-centered techniques to promote both effective classroom interaction and self-organization learning are fundamentals to engage students in a continuous learning effort throughout the academic term. However, an actual challenge for instructors is to use the more appropriate pedagogical techniques according to the number of students in charge. In many cases, the number of students enrolled in an undergraduate course ranges from small groups of less than ten students to large groups, having more than sixty students per group inside classroom boundaries.

A common feature in computer engineering courses is that students are given frequent opportunities to solve exercises and problems, or tackling short projects over the term to demonstrate that they have achieved the expected learning outcomes. The feedback gained by the corresponding assessment is essential to detect mistakes or misunderstandings on the subject. Moreover, experience show that lecturers frequently find reiterations over these deficiencies that with a prompt detection could be pro-actively used rather than reactively. Digital ink has showed its potential to improve this process.

This paper describes experiences that combine digital peer production with digital ink affordances. Rather than preparing papers to obtain a summative final mark, students work over the course of the term producing different small learning resources such as short engineering problems, reasoning or synthesis where the lecturer acts as manager and supervisor. On the one hand, teacher intervention is carried out using digital ink over each individual student production being possible to share the results throughout a public or group repository. Some classroom activities are focused on these productions offering a pro-active argument about preventing common mistakes or highlighting brilliant contributions in a public presentation, what it is usually well received by students.

On the other hand, important efforts are oriented to the production of learning objects in the form of Java applets that are shared through a public digital learning platform, increasing students' motivation and, at the sime time, enhancing programming skills.

The rest of this paper is organized as follows. Section II describes the context where this approach was implemented. Section III presents the key aspects about the proposed teaching approach. Section IV gives details about the digital repository and introduces some examples. Section V summarizes the results and finally, section VI draws some conclusions and outlines further work.

II. Context

Computer technology (11544) is a first-year core subject taught during the spring term (second semester) in the computer engineering degree program at the *Universitat Politècnica de València* (UPV). 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 [1]. 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.

Computer technology skills and objectives suppose an important challenge for first-year (freshmen) students in our computer engineering program. Research carried out in recent years suggests that students need to make a sustained effort during the whole term to pass the course. The lack of maturity in freshmen students, the poor habits for effective self-study, or the overloaded course programs, makes things harder. As a consequence, the approach to teaching the subject was to blame for allowing a significant number of dropouts and underachievement.

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 rather passive and often concentrate their efforts at the end of the term. This fact makes difficult to provide formative feedback (essential to deep learning).

The introduction of student-centered operative models of activities supported by digital resources has produced successful results since European universities moved towards convergence reforms within the framework of the Bologna Declaration [2] to establish the European Higher Education Area (EHEA) [3] and promote a European quality system for higher education worldwide. The key teaching issue was to engage students in a student-centered learning process [4] [5] with actions that encourage an active and continuous participation in order to guarantee an effective formative feedback.

However, among the challenges that computer technology course faces every year is the lack of motivation of our students in the subject. Computer technology course 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.

III. TEACHING APPROACH

Provided that the computer technology course has often more than 50 students per group, and in order to foster student participation in classroom sessions, Tablet PCs and digital ink have been introduced. Tools such as Classroom Presenter [6] that support sharing digital ink on slides between teachers and students, contribute to make classes more interactive and better adapted to the students. Lecturers raise the exercises and 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 on the classroom screen for public review.

However, digital ink boundaries are not limited to classroom activities. Out-of-classroom, self-study is essential for deep learning. In a digital dimension, lecturers can also be present during this time guiding students by means of suitable activities and providing them with prompt feedback.

Moreover, face-to-face classroom activities consume too much time when feedback is given orally and in-situ. Individual self-study tasks complemented by written feedback will guide students in their work planning very effectively [7] and [8]. Besides, according to the current European ECTS system, university courses recognize credits of self-study activities, around 15 hours per credit.

Like many other universities, UPV offers a learning management system, based on the Sakai Project [9], that includes many of the features common to these systems, such as resource repositories, gradebook, forums, chat room, assignment uploads, and tests and quizzes (SAMigo [10]), among others. In spite of the enormous potential of this system, other ICT tools will be considered to support our approach.

In addition to in-class activities, tests, and quizzes, homework tasks also form part of student activity. Sakai project offers an environment useful to tasks uploading, feedback and assessment. Task complexity depends on the expected worked competences. Computer technology works with two different types of tasks: weekly exercises and learning object production.

Weekly exercises are an extension of networked classes as they serve to reinforce some concepts already presented there, as well as to practice some procedures and skills. Before next lecture, the instructor reviews the student submissions by using digital ink, and assigns a score into the system (gradebook). The process is quite straightforward, although the required time obviously increases with the number of students. This score will form part of the student activity mark, as it will be explained in the result section. In this case, students are not allowed to resubmit any exercise after it has been graded. Besides, these student submissions are also extended in the next classroom session, since the instructor points out common mistakes or misunderstandings.

Fig. 1 and Fig. 2 show an example of exercise reviewed by digital ink. In this case, there were no mistakes in the student answer, but the solution was incomplete. Thus, the instructor has added the missing information and then, it is ready to be posted and used as reference material. In many occasions, the own material prepared by students is perfect and can be posted as delivered. This approach tends to motivate students more than when is the teacher who publish the results of the proposed activities.

At the beginning of the semester, students' activity is focused on these weekly tasks. However, tasks are not necessarily disconnected. On the contrary, at the end of each unit, students have worked enough to produce a learning object.

This is a scaffolding process, from small and uncomplicated circuits, to build the virtual lab that comprises the fundamentals of circuitry.

Learning objects are small pieces of knowledge that might, for example, display knowledge comprehension & practical application. The production of digital objects 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.

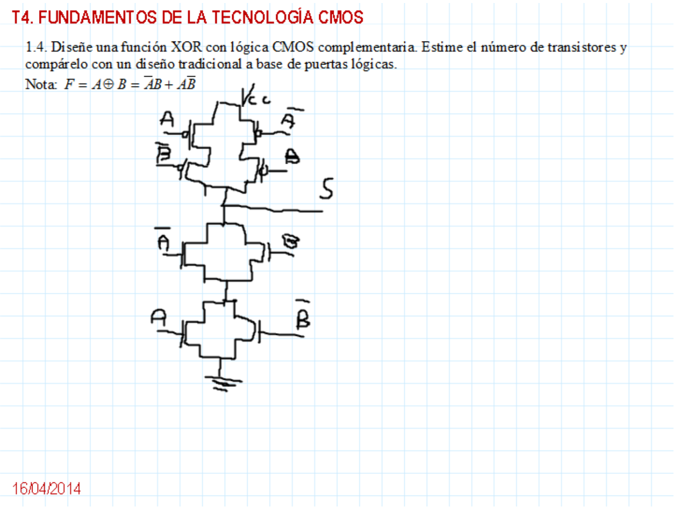

Fig. 1. XOR exercise submitted by a student

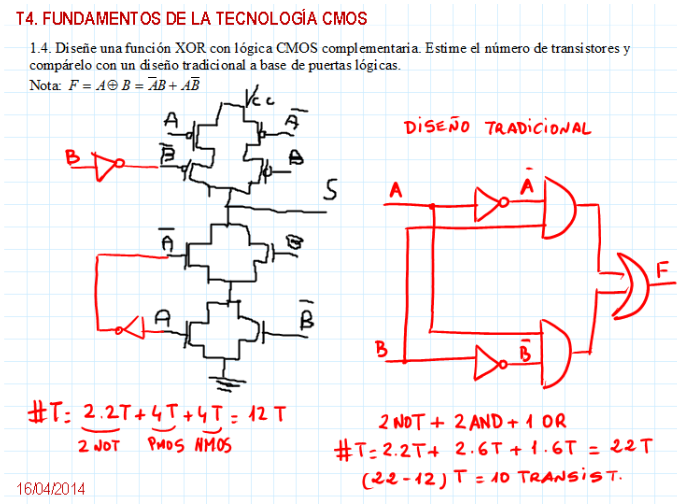

Fig. 2. XOR exercise enhanced using digital ink

Examples of knowledge applications for engineering are model-based activities such as Java applets [11]. However, any piece of information produced by students within the course context is useful to gain feedback by reviewing bugs or misconceptions, as well as developing responsibility and a sense of commitment.

Java applet production has other positive effects on our students. Programming is part of the professional profile as future computer engineers as well as transversal competence. Thus, this activity helps students to link the subject with programming skills by producing virtual labs in Java.

Moreover, peer production is shared within the group, forming digital collections that are made available through both the course intranet and public repositories. Some examples are shown in Fig. 3 and Fig. 4. Best productions may be saved on *Riunet* [14], the institutional repository of the UPV that collects the University community's production, catalogued by metadata such as:

- Data
- Type, context and area
- Keywords
- Copyright
- Summary
- Difficulty level
- Expected average time
- User profile
- Interactivity level
- Language
- Bibliography cite

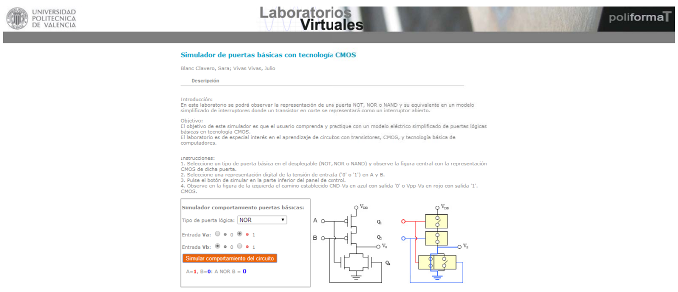

Fig. 3. CMOS example of Java applet done by a student [12]

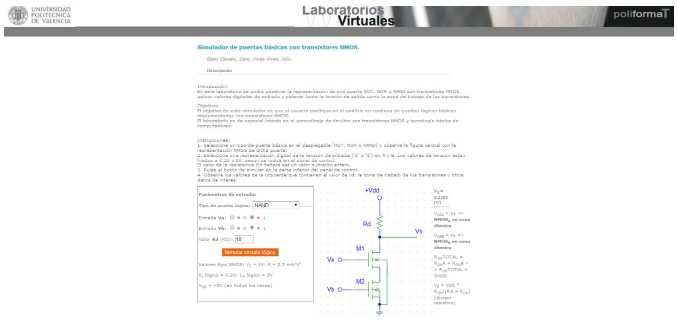

Fig. 4. NMOS example of Java applet done by a student [13]

IV. DIGITAL REPOSITORIES

A digital repository, accessible by every student enrolled into the course, to share their works and to promote positive criteria and enhancement is inherently effective.

However, the effectiveness strongly depends on the teacher management. The cooperative creation of learning material by students needs flexible tools to support both students and lecturers usability.

Many universities offer digital repositories designed to support digital communication between teacher and student. However, the cooperative creation of learning material by students needs flexible tools to support student uploading, teacher review, re-submission and sharing.

Necessary actions available to teachers are:

- Creation of conceptual units

- Students grouping and membership
- Validation of uploaded objects; validated objects should be promptly visible to the group
- Management of uploaded and non-validated objects
- Allow resubmission

Necessary actions available to the student are:

- Visualize and download validated object
- Upload new objects linked with a conceptual unit
- Resubmission
- Management of proprietary non-validated objects (only visible by the owner)

V. RESULTS

To assess the experiences presented so far, both quantitative and qualitative data have been collected.

Concerning quantitative information three main indicators have been introduced: a) *Student activity* mark (*Stud_Act*), refers to the continuous assessment made over the course of the term. This mark is introduced to take into account student efforts both inside and outside the classroom. Thus, it considers aspects such as assignments delivered during the term, short quizzes, student attitudes, fulfillment of deadlines, engagement, and observation in the classroom. Instructors in charge of the different groups, have the freedom to define this mark slightly differently, but always fulfilling the general criteria agreed by the course faculty; b) *Written exam* mark, represents the average score in tests that are common to all the course groups, and are carried out at key points in the term, as scheduled well in advance. It can be therefore considered the most objective indicator of students' performance; c) *Final* mark, includes all the dimensions assessed during the course, with their corresponding weights, thus representing the overall student achievement in the subject.

In the 2012-13 academic year, 511 students enrolled in the Computer Technology course. These students were distributed into 11 groups and each group was assigned a different lecturer. The approach described in this paper was implemented in two out of 11 groups, which we call *Experimental* groups.

Given the high variability among groups and teachers, and taken into account that is a first-year course, we decided to use the admission mark to identify similar or *Control* groups, since many studies show the relevance of this indicator in the student performance [15]. Therefore, three groups of students have been distinguished in the dataset: the *Experimental* group, the C*ontrol* group, and what we have called the *All groups*, which includes all the students except those belonging to the experimental ones.

In order to get a visual idea of the student performance in the 2012-13 academic year, the corresponding box and whisker plots (Fig. 5) for the three indicators described above (*Stud_Act*, *Written exams, Final mark*), and for the same three groups, have been generated.

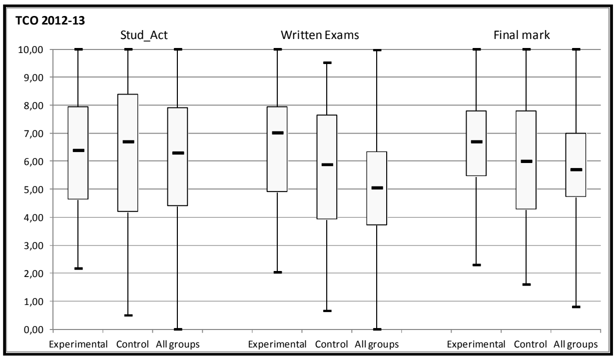

Fig. 5. Boxplot for the academic indicators

The median values for the indicator *Stud_Act* are quite similar, although somewhat better in the *Control* group than in the *Experimental* group. We should remember here that instructors in each group have some freedom to compute this indicator, as stated before. However, in the case of the *Written exams* and *Final mark* indicators, both the lower quartile (Q1) and the median for the *Experimental* group are clearly better than the corresponding values in the other two groups (*Control* and *All*). The same is true for the upper quartile (Q3), but in the case of the *Final mark*, there is a little difference when Experimental and Control groups are considered. Taken into account this exception, and for the same indicators (*Written exams* and *Final mark*), a certain upward shift can be observed into the "boxes" of the *Experimental* group against the other two, indicating better results in half the population, which corresponds with the central area of the distribution (from Q1 to Q3).

Concerning qualitative information, students participating in the experiences were asked to answer a survey. In addition to generic personal information, it includes 10 questions covering two main categories, the first one focused on teaching methods and student learning, and the second one related to expectations and overall student satisfaction. In order to obtain participant's degree of agreement with the different statements, we used a 5 point Likert scale ranging from "Strongly Disagree (SD)" on one end to "Strongly Agree (SA)" on the other with "Neither Agree nor Disagree (N)" in the middle.

With regard to methodological approach and its impact on learning, five questions covering aspects such as motivation, commitment, interaction and learning, have been introduced. The corresponding results are represented in Fig. 6, among which we can highlight the following: 73% stated that the instructional approach increased their motivation for the subject; 68% responded that the approach helped them to be more engaged in the classroom; 60% considered the approach contributed to increase interaction with the teacher or to facilitate collaborative work; finally, 82% declared that their learning experience improved.

Finally, it is important to note that 87% had very high expectations at the beginning of the term, but only 40% felt that their initial expectations were met. However, these views contrast with questions about overall satisfaction, where 80% said they were satisfied with the approach of the course and up to 87% would recommend the approach to their colleagues, as shown in Fig 7.

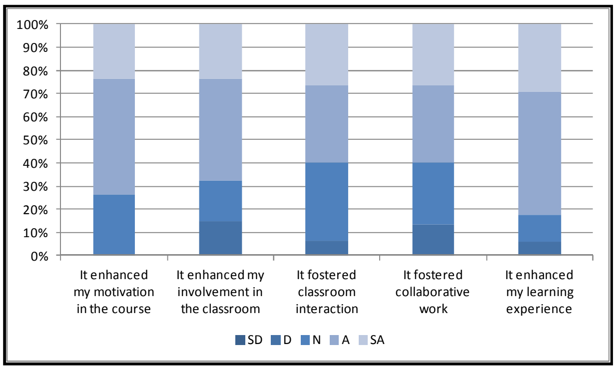

Fig. 6. Questions focused on teaching methods and student learning.

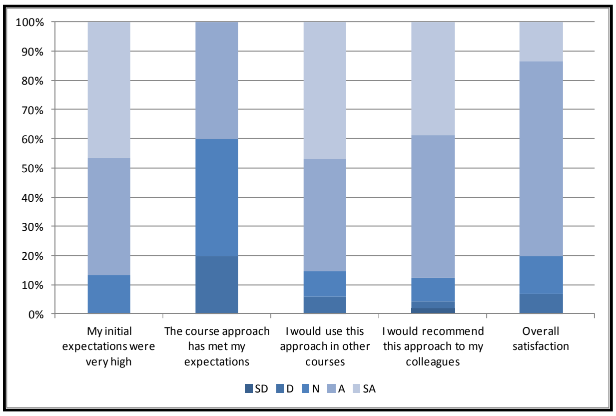

Fig. 7. Questions focused on expectations and overall student satisfaction.

VI. CONCLUSIONS

In the 2012-13 academic year some experiences that combine digital peer production with digital ink affordances have been carried out in computer technology, a first-year course in the computer engineering degree program at the Universitat Politècnica de València.

The approach has proved successful to face the initial lack of motivation of our students in the subject, as the production activity has increased their engagement into the course and, at the same time, it has enhanced their programming skills.

Qualitative and quantitative results show both an overall satisfaction from students participating in the experiences, and better results in the common written exams, when compared to the other groups following the traditional method.

Further works will be devoted to implement this approach in similar courses and, additionally to involve programming colleagues in order to tackle more complex learning objects.

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