Computer-assisted method based on continuous feedback to improve the academic achievements of first-year students on Computer Engineering

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Abstract

The student-centered learning is being promoted worldwide in higher education, from 2005, in North-American universities [1], in 2010 in the European Union, but also in Asian countries like Japan [2]. This paradigm is characterized by applying innovative methods of teaching that involve students as active participants in their own learning.

In this paper, it is proposed a method based on detecting the students' learning gains by using low time consuming "Pretests" and "Posttests", on a selection of learning activities. The overload of using the "Pretest-Posttest" is minimized by the use of information and communication technologies.

The results of the "Pretests" and "Posttests" allows the students to be aware of their learning progress. The analysis of the results of the "Pretests" and "Posttests" helps teachers adapt their strategies when presenting the learning activities.

The method has been applied on a first course on Computer Engineering, during the

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2010-2011, 2011-2012 and 2012-2013 academic years.

To verify that the method works, two student groups, one control and one experimental, were created. The method was applied in the experimental group.

The statistical analysis of the obtained results by the experimental and control groups, shows that the method enhances the grades of the experimental group. Additionally, the support of digital system minimizes the work for using this method.

1 Introduction

From 2005, the Carnegie Mellon University offers the "Principles for effective teaching" on its webpage [1], which exposes that teaching results are enhanced when there is a feedback from students to the teachers. Later on 2009, the Texas University defines the term student-centered learning [3], and proposes how to move to that paradigm.

Since 2010, the member countries of the European Union have introduced deep changes in their curricula to normalize studies and promote student-centered learning.

This change on higher education is being considered worldwide not only in western countries. For instance, it can be found on page 51 of the book [2] that defines Keio University's Shonan Fujisawa Campus as the outstanding example in Japan, which faces the challenge to change from teacher-centered approach to the student-centered learning model. It can also find this on the online document [4] from the Ministry of Higher Education in Sri-Lanka titled "Student/Learner Centered Teaching & Learning" explaining this change of teaching paradigm.

The student-centered learning is characterized by innovative methods of teaching that involve students as active participants in their own learning. Such educational paradigm

generates new challenges:

1st challenge: How to improve the knowledge and skills degree acquired by them?

2nd challenge: How to apply the method without overburdening the teacher?

A statistical analysis is needed to evaluate whether these challenges, which are the objectives of the work in this document, are solved. To make the analysis of the knowledge[2] and skills[3] acquired by the students, it is appropriate to use learning activities (LAs) when designing courses. According to UNESCO [5] the learning activities (LAs) are defined as "any activity of an individual organized with the intention to improve his/her knowledge, skills and competence."[4]

In this article, it is proposed that the first objective (to solve the first challenge) can be achieved by adapting the teacher strategies on those LAs where students get low marks[5]. The method to detect them is to use the "Pretest-Posttest" on a control group, which is one of the proposed ways on "True Experimental Designs" [7]. The second objective (to solve the second challenge) can be achieved by using Information and Communication Technologies (ICTs).

This article is organized as follows: previous related works are summarized in Section 2. The motivation is presented in Section 3. The proposed method in this paper is described in Section 4. A case study and analysis of results are presented on section 5 and 6, respectively. The conclusions and discussion on future work appear on section 7.

2 Related work

In the teaching and learning processes, different aspects can be considered. Among them,

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[2] Knowledge can be considered as a set of facts and information that student should know through study.

[3] A skill can be defined as a practical competence acquired through practical experience.

[4] The term Learning Activity can be also considered that it was defined by Confucius, (450BC) when he wrote "*I hear and I forget, I see and I remember, I do and I understand.*", or more recently by the psychologist David Kolb when he said on his book [6] that "a person would learn through discovery and experience."

[5] Term grade stands for the final evaluation of a course, which is determined by a weighted average of the marks on all of student's course assignments and exams.

we focus on the evaluation processes and formative feedback. Authors [12, 13, 14 and 15] identify "assessment" as a core element for effective learning, because it allows us to confirm the acquisition of skills or knowledge. Recent research in education [16], has focused on three orientations of assessment:

- "Assessment for learning: It is designed to give teachers information to modify and differentiate teaching and learning activities."

- "Assessment as learning: It is a process of developing and supporting the meta-cognition among students. Assessment as learning focuses on the role of the student as the critical connector between assessment and learning."

- "Assessment of learning: It is summative in nature and used to confirm what students know and can do, to demonstrate whether they have achieved the curriculum outcomes, and, occasionally, to show how they are placed in relation to others."

Our method focuses on assessment for learning and assessment of learning. In addition, the design of the method has considered characteristics regarding the best use of formative feedback described on the following previous works:

WHY: Studies published in educational journals [17,18] indicate that formative feed-back is most effective when based not only on progress, but also on promoting students to develop learning strategies.

WHO: S. Ludwig- Hardman and J.C. Dunclap [19] stated that learning can be facilitated by sustained interactive collaboration among the teacher and learners. And this collaboration can support students to develop self-regulated learning dispositions.

WHEN: Reviews of the research on education talk about the importance of the immediate feedback. For instance [20, 21], they say that "immediacy and clarity of feedback are important in promoting satisfaction and active participation" and [22] say that "the most effective feedback is that which is given at the time the learning is constructed."

However, next characteristics need to be considered to define a method:

WHAT: Improving the feedback from students can allow teachers to modify their teaching planning and strategies, and adapt them to their students' status.

Previous works on improving feedback are based on computer applications. Among them, we can refer the proposal of learning sequenced by an application which bounds advance to new lessons until achieve some minimum marks in previous lessons [003]. Other works published on learning guided by computer application, are a system that generates messages to the students that not show progress on their work [002], and a system that helps to find the solution of guided exercises [007]. Other work related to feedback [008] proposes that modeling the three aspects of student knowledge, instructional process, and the evaluation of student's tasks, to provide feedback to the student and teachers of the results from an automatic assessment tool.

WHERE: Recover feedback in the same classroom. Then, it can be obtained feedback strongly related to the achievements done in class, and also provide the immediate feedback to students.

HOW to do it: A computer based method focused on improving student's performance is presented, taking into account ways to ease the teacher's tasks related to assessment. We also develop an evaluation tool referred as EvalTICs.

Authors on [004], propose general elements to design a distance learning application, such as the support to students to detect weak knowledge areas, improve misunderstanding and assessment on individual subjects. And help teachers to reduce the tutorial and advice times by supporting distribution and consolidation of course materials.

Other authors propose a tool to reduce teachers' tasks which consists on a general application to generate exams from existing questions [006].

3 Motivation and aim

The new paradigm in higher education is to promote student-centered learning. It implies the challenges on how to evaluate the competence degree acquired by the students and on how to improve its acquisition.

An objective way is needed to evaluate if a specific LA really helps a student to acquire the learning objectives for which the activity was designed.

Figure 1: Method applied on a LA.

In particular, we consider that continuous assessment is a good way to detect if the students achieve the objectives of the LAs. The method focuses on deploying additional strategies for such LAs where students obtain low performance (LAwPLow.)

ICT allow instructors to apply such evaluations in proper conditions, and facilitates the feedback among teachers and students.

Thus, our aim is to develop a computer-based method to do the following:

- Determine if a specific LA really helps student acquire the learning objectives for which the activity was designed.

- Avoid overloading teachers with assessment tasks using ICTs.

- Provide students with information related to their learning outcomes.

4 Method

In this section, the method proposed in this paper is described in detail. Also, the developed tool is briefly described.

4.1 Learning Activities

The concept of learning activities as learning through discovery and practical experience [6] were introduced in section 2. In this section we focus on how classify them.

4.1.1 Classification of the LAs

Some previous steps are necessary in order to adapt the teaching strategies, based on the following aspects:

- To classify each LA depending on if they teach New Knowledge (LANK) or Reinforces it (LARK).

- To determine those LAs where the student's grades are considered low (LAwPLow). It depends completely on the teacher's criteria.

4.1.2 Selection of Learning Activities

Our recommendation is to select such LAs where the teacher considers that the performance of students is low, apply the method (Pretest and Posttest), and then, study different ways to improve how the LA is presented in order to achieve the expected student performance.

4.1.3 Strategies to Analyze the Learning Activities

When designing any LA, it should be considered the learning outcomes (knowledge, skills and competences) that students have to acquire. Concerning assessment, the teacher must consider the next two questions:

Q1: Does the teacher have to evaluate all the LAs?

R1: Yes, definitely. However, there are two kinds of LAs: summative and formative. The only difference is that the evaluation of summative activities have impact on the student grades. Whereas the results of the evaluation of formative activities are not taken into account in the student grades.

Q2: How should teacher reward students for the effort made to carry out the LAs?

R2: Not all activities should be rewarded. It is the teacher who decides which of them are considered to be formative and which ones summative.

4.2 Method description

The method requires the following teacher's effort:

- He/she has to identify those LAs where the students face more difficulties. The teacher's experience and history from previous courses can provide valuable information to identify such LAs.

- When the teacher presents a LA where students face difficulties, he/she has to interact with the students to detect where they have troubles, and help students to understand how the problem can be solved.

- The teacher has to prepare 2 tests. The first one, named as 'TheoryTest', is used to evaluate the student's knowledge and skills gained with the LA. The second one, 'LabTest', evaluates the student's gains related with the laboratory session.

Remarks of the proposed method are shown in Figure 1:

1. During the lecture related to the LA, the TheoryTest is applied on a first time, at the beginning if the LA reinforces knowledge (LARK), or at the end if the LA presents new knowledge (LANK).

2. Once the corresponding LA is finished, the same TheoryTest is applied again.

3. The average mark obtained in the TheoryTest help teachers to define their strategies.

4. At the beginning of the laboratory session the LabTest is applied.

5. Before finishing the laboratory session the LabTest is applied again. The students know their gains looking at their marks in the LabTest.

6. The average mark obtained in the LabTest permits to determine if the laboratory activities are useful for enhancing student performance.

7. The TheoryTest, LabTest, the exercises and marks are available at the Web Portal

for each student and the teacher.

4.3 ICTs to minimize the teacher's workload

We propose using collaborative environment software for creating item pools, tests, statistics and grade management. Some examples are SAKAI, Moodle, WebCT, and Blackboard.

In the particular case of the institutional Learning Management System of our university, referred to as PoliformaT, offers the typical capabilities of these systems, such as the capacity to manage the course material, grade management, creation of item pools, test preparation and test application. But, it has limitations because it relies on a centralized system in the university.

The method needs to create subgroups of students, distribute differentiated tasks and exams among these groups, and statistical analyses of the results achieved. However, the institutional tool does not allow any of these features.

Therefore, it was needed to use an independent platform that allow such functionalities. So, we decided to implement our own Web application, referred to as "EvalTICs Web Portal" [25], though other collaborative environments can be used.

5 Case Study

In this section, different versions of the method applied during the last years are described. Next, a description of the courses on the computer engineering degree, and which had been selected for the experimental and control groups in each of these years. And finally, the learning activities and assessment method for skill or knowledge.

5.1 Evolution of the method

The method has evolved since the 2010-11 academic year when the Universitat Politècnica de València launched the new Bachelor's Degree on Computer Engineering (*Grado en*

Ingeniería Informática: GII). The strategy during this academic year consisted in using TEL to enhance the student's performance. One year later (2011-2012) the teaching methods were adapted to take into consideration the results of the LAs where the student's performance was low (LAwPLow) on the previous academic year. The method used on the third academic year (2012-2013) corresponds to the complete version as described in this article, including interaction and feedback on the laboratory sessions and not only on the lectures. The complete description of the actuation during that last three years is shown in Table 1.

Table 1: Actuation during the 2010-2011, 2011-2012, and 2012-2013 academic years.

5.2 Description of the courses of the Bachelor's Degree on Computer Engineering

All the students that participated in the case study were enrolled in the first year of the Bachelor's Degree on Computer Engineering. All of them have to follow the next five subjects in the first semester:

- Computer fundamentals (FCO)
- Mathematical analysis (AMA)
- Physics fundamentals (FFI)
- Introduction to computer science and programming (IIP)
- Discrete mathematics (MAD)

Among the first semester subjects, FCO was chosen to test the method, because most of the authors were teaching the subject.

After completing the FCO course students will be able to understand how a computer works. For that purpose we start from designing the main components (functional units) of a computer and then we proceed to learn how to program in assembler language. Besides students will learn how data is represented inside a computer and the fundamentals of sequential digital systems design.

In order to achieve FCO goals, the course is organized in lectures and laboratory sessions. The lecture contents are structured in the following four blocks:

- Introduction to computers

- Combinatorial and sequential digital system design

- Data Representation

- Introduction to assembly language

On the other hand the laboratory sessions are organized as follows:

- Handling of the logic trainer

- Combinatorial circuits

- Latches, Flip-Flops and sequential digital circuit design

- Data representation

- Assembler language

The general skills or competences are:

- Analytical and critical thinking, teamwork, technical competence, critical analysis and synthesis, applying knowledge in practice, decision making.

Besides general competencies, and knowledge described as contents of the course, the goal of this course focuses on improving the next skills:

- Ability to be able to design and debug combinational and sequential digital circuits

- Ability to apply verify simple algorithms in assembler language.

5.3 Assessing the method

This work has been evaluated using classroom research, because it investigates the teaching and learning processes as they occur in the classrooms [8].

Lo Castro [9] states: "Action research is one form of Classroom Centered Research which is seen as being small scale and situational, that is, focused on a particular problem, to try to understand and perhaps solve some concrete problem in an individual teacher's classroom." Paul Hachshaw states [10]: "Teachers need to be able to explain what things happen and why, and seek knowledge of the learning processes as a means to increase and maximize student knowledge." Our method is based on such ideas.

In order to assess the proposed method, students are firstly divided into an experimental group and a control one. Then, the method is applied (based on adapting the teaching strategies on LAs with low performance) on the experimental group, and the results are statistically analyzed by comparing the mean grades obtained by these student groups.

FCO instructors are in charge of preparing the curriculum and learning activities. Table 2 shows the material developed for each LA.

Table 2: Material developed for each LA

The students in FCO are split every academic year during the enrollment process into eleven theory groups (groups A to K).

Group E was considered as the experimental group, whereas the 10 remaining groups

were the control ones. Group E was selected because one of the authors has been responsible for the group since the 2010-2011 academic year.

6 Results and Analysis

In this section, in the first place it is verified that there is not a statistical difference between the experimental and control groups, and its distribution not affects the results obtained. In the second place, if the proposed method improves the success of the students in acquiring the expected knowledge and skills. Comparing the results obtained by a set of students using the method referred to as the experimental group, and a set of students not using it, referred to as control group.

The assessment method for both experimental and control groups, is based on the marks obtained in the same theoretical and practical exams, as well as in the same homework tasks. The distribution of grade points is as follows: 60% for theory exam were students are asked about their knowledge of the 4 blocks, 15% for the final practical exercise where students prove their skills (for instance, programming in assembler), and 25% from the delivered homework.

The results shown in Table 3 corresponds to the final grades of the first course students of the computer engineering degree at the UPV. These results include all the final grades since the first academic year of the *Grado* was launched (at the 2010-2011 academic year.) In particular, the results also show the final grades of the experimental and the control groups on the "computer fundamentals" subject (FCO).

In this paper, to analyze the results a significance test (F-test) is conducted , which is part of the one-way analysis of variance (abbreviated one-way ANOVA). The ANOVA analysis, that can be found in well known statistical programs such R, and SPSS, is used to compare the differences between means of two or more samples of groups (using the F distribution).The name analysis of variance comes from the way the procedure uses variances to decide whether the means are different. ANOVA looks to see what the variation (variance) is within the groups, then works out how that variation would translate into variation (i.e. differences)

between the groups, taking into account how many subjects there are in each group. If the observed differences are a lot bigger than what you would expect by chance, you have statistical significance.

Table 3: Average final grades obtained by the students of the *Grado* on Computer Engineering during the (a) 2010-2011,(b) 2011-2012, and (c) 2012-2013 academic years.

Table 4: 2010-11, 2011-12, and 2012-13 academic year results.

The analysis of the performed method is based on postulating a null hypothesis [11]. By convention, it is accepted that the null hypothesis is not true and the result is statistically significant, when the probability p (calculated using a significance test) is equal or lesser than 0.05. The significance of F-tests (ANOVA) calculated from the final grades of the students on the control and the experimental groups are shown in Table 4.

6.1 Is there any statistical difference between the experimental and control groups?

It can be confirmed that there is not statistical difference between the experimental and control groups, if the next hypothesis is verified:

Hypothesis 1:

The enrollment grouping process is fair. Thus, the students of the experimental group are as well prepared as the students of the control group.

A formal way to verify this hypothesis consists on confirming that the opposite hypothesis is not true, which is known as rejection of the following null hypothesis:

Null hypothesis 1:

The enrollment grouping process is not fair. Thus, the students of the experimental

group are the best prepared.

Table 3, shows the grades obtained on all the 11 groups during the 2010-2011, 2011-2012 and 2012-2013 academic years. It can be seen that the average grades of all the 11 groups are very similar in the following subjects: AMA, MAD, IIP, and FFI. The significance[6], in Table 4, confirms that statement.

It is confirmed that the students of group E are not better than others, because their average grades are similar to the ones obtained by the control group during the last academic years.

6.2 Does the method improve the student success?

It can be concluded that the proposed method in this paper improves the students learning if the next hypothesis is verified:

Hypothesis 2:

In the case of the FCO subject, the final average grades of the experimental group improve the control group's ones.

Similarly to the previous hypothesis, it can be confirmed if the next null hypothesis is rejected:

Null hypothesis 2:

In the case of the FCO subject, the final average grades of the experimental group are similar to the control group's ones.

Table 4 compares the average grades obtained by the experimental group against the control group. In such table, it can be seen that for the academic years 2010-2011 and 2011-2012, the average grades of the *experimental group* are not better than the grades of the *control group.*

However, in the academic year 2012-2013, the average grades of the students of the experimental group are the best in the FCO subject, and "significantly" better than the grades

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[6] The significance is calculated using the F-test.

from the students of the A, B, F, G, H, I, and K groups. Notice that ANOVA results show that the E group on the last year obtain "significantly" better average marks on FCO subject, although not better or clearly better when comparing with C and J groups. FCO is the only subject where the proposed method was applied. This answers our second hypothesis.

To sum up, although the method was applied as early as 2010-2011 it was not until 2012-2013 that significant improvements were obtained, when making full use of the feedback which is briefly resumed in Table 1.

7 Conclusions

In this article is proposed a method to improve the acquisition of knowledge and skills by students. The method key element is the use of learning feedback among teacher and students. The computer assistance allows the feedback be interactive and immediate, but also it be automatized releasing teachers from additional tasks to apply this method.

Results in this paper show that monitoring the student's learning progress can provide a valuable feedback for teachers and students. It allows students to identify and confirm their new knowledge and skills. The teacher can decide the level of interaction to be performed depending on the results of the LA. Notice that this method evaluates positively an LA only if students improved their knowledge and skills after the LA was presented.

To verify the method effectiveness, it has been applied for three consecutive years in low-performance LAs of an experimental group on the first year of the Bachelor's Degree on Computer Engineering. It has been done by a statistical analysis based on ANOVA, which is commonly used for such kind of analysis. This analysis was done using the results of the students in the experimental group and the ones from the control groups.

The results of the last three years show that the method provides the best improvement for the students when they make full use of the feedback with the teacher. This complete feedback is described in this article as the teaching strategies adopted in the 2012-2013 academic year, which is also briefly summarized in Table 1.

The objective of the work in this document is to provide a method that solves the

challenges of use the educational paradigm of Student-Centered Learning, which are:

1st challenge: How to improve the knowledge and skills degree acquired by them.

2nd challenge: How to apply the method without overburdening the teacher.

The first challenge is solved only with the last version of the method, which makes full use of the feedback. Additionally, the second challenge is solved by the use of ICTs, which minimizes the teacher's work for the creation and reuse of tests for the present and next courses. The use of technologies allows increasing interaction, and students know their improvement through the test results. This interaction becomes also a strategy to motivate students in their learning activities and to encourage autonomous learning.

The Evaltics tool is easy to use and automatically detects learning activities where the students get lower performance, regardless of the number of students. It provides a valuable feedback to teachers and students, helping the former to help and guide to the latter ones.

Further work

We are currently working for a ubiquitous version of the method to be used on tablets and smartphones, being, as in our previous works, easy to use and immediate on providing feedback. We will analyze if this new version may improve the feedback and allow students follow the course. It may help on increasing the rate of students that get successful results in the course.

Additionally, we are considering two additional improvements. First, and suggested from teachers, the idea is to provide students with a direct access to the material that can be helpful to get the missing knowledge or skill, within the feedback results. The second consideration, coming from our students, is to develop interactive graphic activities for some evaluations. Such activities will look like serious games that keep the student interest to solve challenges.

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