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Design and Application of Project-Based Learning Methodologies for Small Groups Within Computer Fundamentals Subjects

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ABSTRACT In higher education, it is usual to separate the theoretical contents from the practical ones and use teacher-centered methodologies. This fact makes students lose motivation due to the lack of connection with real professional tasks. Conversely, student-centered learning methods, such as project-based learning (PBL) or flipped classroom, aim to integrate both theoretical and practical contents and to apply them on real-world problems, thus increasing the students' motivation and involvement. These methodologies are usually applied in the last years of a degree, but it is difficult to find them in basic first-year subjects. The aim of this paper consists in assessing the application of a PBL methodology in the first-year subjects of computer engineering. This methodological change aims to achieve a significant improvement in the students' learning achievement of the core subject computer fundamentals. The project involved in the PBL proposal consists of developing a portable calculator. The performance of the PBL group is compared with that of other groups with a traditional, teacher-centered learning system. The evolution of the knowledge acquisition is determined by means of an initial evaluation and a final assessment after developing the project. An exhaustive statistical analysis is performed so as to evaluate the PBL application. Quantitative results show a significant improvement in the experimental group marks, which increased by up to 20% compared to the control groups. As a conclusion, applying PBL and flipped classroom engaged students within the subject, thus achieving a deeper understanding of its theoretical concepts.

INDEX TERMS Project based learning, flipped classroom, computer engineering, high academic achievement, core subjects.

I. INTRODUCTION

The different European higher education systems began a harmonization process under the joint declaration of education ministries of France, Germany, Italy, and the United Kingdom, which was signed in La Sorbonne (Paris, France) in 1998. This declaration was lately subscribed by Spain which joined the related discussions in 1999. That year, the European Ministers of Education met in Bologna (Italy) and agreed on a new joint declaration. The Declaration of Bologna collected different approaches towards the creation of a common European Higher Education Area (EHEA), among which universities adopt a main role in the development of the European cultural dimensions.

This trend of change has conditioned the development, evolution, and even the aims of the different European universities. Regardless of the curricula before the creation of the EHEA, European universities have faced a great number of challenges which, in many cases, are currently being solved. The implementation of student-centered learning is among those challenges. In these learning methodologies, the teacher acts as a guide in the learning process. This approach must be able to adapt the learning process to the new academic and social environment in all its aspects, from the teaching methods to the evaluation of the knowledge acquired. Moreover, it must try to encourage students to have a high level of motivation, which is essential for them to face their studies successfully and to obtain the maximum performance. Another desirable feature must be the orientation towards a global learning, integrating both the theoretical and the practical concepts, and guiding the process towards the application of the acquired knowledge in real life situations, which the student is likely to face once studies have finished.

The application of such methodologies implies several difficulties, including the different features of the students who access higher education, as well as the configuration of student groups. The transition from school, -where the teacher plays a very active role- to higher education, in which the student is asked to be more autonomous, is not direct and easy for every student. Indeed, some students can be demanded more independence and self-control in their learning process and, therefore, the traditional method of a master-class and later evaluation of the acquired knowledge by means of a simple written exam, can be omitted. Moreover, in larger groups the implementation of novel learning methods can be more difficult given that communication between the students and the teacher is less fluid. On the other hand, the cost of incorporating more personalized evaluation systems can be higher.

In the academic year 2010-2011, the Education Department of the Valencian Autonomous Government started, in collaboration with the public Valencian universities, the High Academic Achievement groups (ARA, from the Spanish *Alto Rendimiento Academico*). The aim of this strategy is to strengthen the potential of the most qualified students from the beginning, offering some courses taught in the English language and incorporating other important advantages in their curricula.

According to the Education, Culture and Sports Department of the Valencian Autonomous Government [1], the ARA groups have the following features:

- Optimal number of students in the first year of the degree (small groups of 20 to 25 students).
- Basic courses taught in the English language.
- Highly qualified teaching staff, with a minimum of two completed research periods in the case of Professors, and one research period in the case of Associate Professors.

The University of Alicante and the Education, Culture and Sports Department of the Valencian Autonomous Government subscribe each year the corresponding agreement which determines the conditions, features, and funds for the correct development of the ARA groups, not only for students, but also for teachers. Students are required to have the B2 certificate in English by the end of their first year of the degree.

The advantages of belonging to an ARA group are:

- Mention of this membership in the European Diploma Supplement.
- Preferential treatment when accessing different scholarships and grants for research staff training.
- Preferential treatment when accessing Erasmus Program grants

In this paper, the design of a PBL methodology and its application on Computer Engineering degree ARA groups for teaching the Computer Fundamentals course is proposed. Despite the advantages mentioned above, the ARA groups do not perform better in this subject than the other groups.

Once the proposed methodology is implemented, the results of the students group in which it is applied are analyzed, comparing them with other ARA groups of students of the same subject.

II. AIMS

The main aim of this research on the teaching-learning process consists of implementing a methodological approach supported by PBL and complemented by the flipped classroom. The proposed methodology is applied to a small group of students with specific characteristics, which is the Computer Engineering degree ARA group. The methodology is carried out in the Computer Fundamentals (CF) subject, which is taught in the first year of the above-mentioned degree. CF is a core, compulsory course taught in the first year of the Computer Engineering degree consisting of two hours of theory and two hours of practice a week during the first four months of the academic period, that is, 15 weeks from September to December. The methodological change aims to bring about a profound evolution in the student's learning patterns. On the one hand, it aims to increase the student's motivation and their involvement in their own learning process. On the other hand, it seeks to offer a style of teaching that integrates the theoretical content with its practical application in problems close to the real world, so that the student perceives his/her learning as a fundamental basis for the professional performance that will be required after completing their higher education studies.

III. STATE OF THE ART

In the University environment, the continuous adaptation to new teaching methods is essential. The development of new teaching systems and activities must be well-thought out and employ didactic resources that promote positive attitudes in students and encourage them to be involved in the teaching-learning process [2]. Universities must play an active role, meaning that they must incorporate new educational models, which consider that learning must be student-centered instead of teacher-centered, since each individual is different and has particular needs and different learning strategies and cognitive processes [3]–[5].

The evaluation criteria must establish, on the one hand, how the results of the learning process must be evaluated and, on the other hand, the tools for evaluating that process. The objective will be to obtain evidence of the student's sufficient proficiency regarding their knowledge, skills and attitudes, by means of control mechanisms that ensure that the expected academic performance of the student is achieved correctly [6].

For the evaluation design, it is important to take real or simulated situations of professional activity as [7]. To this end, the EHEA-guided approach placed special emphasis on a curricula design based on problem solving. When students have a professional reference with a link to the resolution of real difficulties or problems, the social, affective and cognitive learning dimensions are strengthened [8]. The evaluation not only measures competencies but also promotes learning. A way of evaluating through comprehensive and holistic strategies and models must therefore be designed that determines the knowledge, skills and attitudes achieved. Strategies such as authentic evaluation, training evaluation, self-evaluation and co-evaluation should be considered [8], [9]. In [10], several evaluation methods are proposed: headings, portfolios [11], evaluation and practice reports, simulations, videos, tests or essays, case studies, research projects [12], external and internal professional practices, self-evaluation or apprenticeship dossiers, among others. Evaluation must involve different agents. It should be performed by teachers, partners, the student him/herself, or even by all of them; moreover, it must provide information about the progress in the achievement of competency and suggest some improvements [13].

Among the new teaching-learning methodologies, the Project-Based Learning (PBL) is worth mentioning. This learning method is emerging strongly within higher education, especially in technical degrees in which ''the Project'' is the main element when working in real professional situations [14]. This learning methodology can, therefore, encompass a complete degree, as in the case of the Multimedia Engineering degree at the University of Alicante, or just a set of courses or even a single one. The project focuses on the importance of using a series of practical situations rooted in real professional contexts, which involve realistic and complex tasks [15].

It is worthwhile mentioning that the application of PBL or another alternative pedagogical approach on a subject depends only on the decision of the teacher. Sometimes, the stringency of the evaluation recommendations proposed by the university itself makes this decision harder.

The didactic activities developed when PBL is applied are intended to guide the student to achieve the aims of the proposed project. To this end, the student is responsible for his or her own learning and the teacher becomes a catalyst for that learning. When this methodology is used, traditional classes become meaningless, and even textbooks may become less important [16].

One of the most used didactic activities in a PBL context is the flipped classroom or flipped learning [17], [18]. When applying this activity, learning starts at home: the student takes the audiovisual material as reference or any other documentary reference provided by the teacher. The teacher later develops appropriate activities in class to consolidate the knowledge acquired at home. This means that certain learning processes are transferred out of the classroom and class time is used, together with the experience of the teacher, to facilitate and enhance other processes of knowledge acquisition and implementation within the classroom. The flipped classroom is not limited exclusively to the PBL field but, in this context, it adapts perfectly since the students carry out the project at home, while questions about its realization are transferred to the classroom, where the teacher introduces new concepts and reinforces the students learning.

Several recent research works have proposed computer science teaching student-centered [19]–[22] and supported by the PBL methodology [23]. Most of these experiences are done in advanced course subjects, although some interesting works related to the application of PBL in the first year of Computer Science studies can also be found [24]–[26]. These subjects make it easier to find a real application on which to base the project.

One of the main obstacles when applying these methodologies is the effort that the teacher must make to adapt to them when he/she is used to traditional teaching systems.

IV. METHODOLOGY

A. COURSE DESCRIPTION AND CONTEXT

As previously mentioned, the ARA groups are small groups of students funded by the Department of Education, Culture and Sports of the Valencian Autonomous Government in order to enhance the teaching-learning process of students with higher qualifications. In the first year of the Computer Engineering degree at the University of Alicante, there are ARA groups for all subjects where the University of Alicante Polytechnic School (EPSA) facilitates the configuration of common scheduling and classrooms for theory and practice sessions. Given the small number of students, it is feasible to use EPSA laboratories to teach both theoretical and practical content.

The EPSA provides ARA groups with a continuous time range of four hours on the same day and in the same laboratory. Although for administrative reasons the hours for the CF course are considered as two hours of theory followed by two hours of practice, this organization in space and time allows the teacher flexibility, which is compatible with PBL. In this kind of teaching, the development of a project throughout the semester will be the reason to introduce and strengthen the theoretical and practical concepts of the subject. As can be expected, the competences and objectives associated with the PBL-ARA group are identical to those of the rest of the student groups.

The laboratories where practical sessions are held have 24 general-purpose workstations, as well as a projection system and a whiteboard. The open source software *Logisim* version 2.7.1 [27] is used for digital circuit simulation purposes.

The main competencies and the expected learning results of the CF subject are listed in Tables 1 and 2 respectively.

It is worthwhile mentioning that, since the course is taught in the first year of the degree, the students' background on digital design is usually very poor or even null. Therefore, the above competences and objectives seems to be at first quite ambitious, so the application of good teaching and motivation practices is strongly recommended.

The traditional methodology applied on CF consists of theory sessions where the teacher explains the main

TABLE 1. Computer fundamentals specific skills.

ID	*Skill*
S1	Ability to understand how information is represented in a computer and to be able to interpret it.
S2	Ability to design, build and analyze simple digital circuits and to use them to solve problems.
S3	Ability to know the operation of a simple computer and its structure.

TABLE 2. Expected learning results in computer fundamentals.

ID	*Result*
R1	To know the binary number representation system and its related systems (octal, hexadecimal, binary coded-decimal)
R2	To know the complement representation systems and the way to perform binary arithmetic operations in these systems.
R3	To know the floating-point representation systems.
R4	To understand the Boole's Algebra laws and the logical operators AND, OR, NOT.
R5	To be able to construct the logical functions that provide a solution to a problem statement, determining the input and output Boolean variables.
R6	To be able to combine logical gates for implementing the digital circuit that corresponds to a logical function.
R7	To know how to simplify a logical function by means of the application of Boole's Algebra laws.
R8	To know how to simplify a logical function by means of the application of Karnaugh maps.
R9	To know the basic combinational circuits: coders, decoders, multiplexers, demultiplexers, comparators.
R10	To know the digital circuits that perform binary arithmetic operations: half adder, full adder, BCD adder, complement adder/subtractor.
R11	To be able to design a combinational system that provide a solution to a problem statement, determining the input and output Boolean variables, the system response through logical functions, and its implementation.
R12	To understand the functioning of flip-flops as the basic digital components of a sequential system.
R13	To know the way to use flip-flops for implementing registers and basic binary counters.
R14	To be able to design a sequential system that provide a solution to a problem statement, determining the input and output boolean variables, the system states and the transitions from each state to the others.
R15	To be able to analyze a sequential circuit.
R16	To know the main components of a computer: arithmetic-logical unit, control unit, memory, basic input/output system, buses.

theoretical concepts and solve related exercises on the black board. Therefore, the interaction with students is quite limited. With regard to the students' practical tasks, in this conventional approach they are proposed to face some problems or questions related to the thematic unit that teacher has been explaining, which must be solved manually in some cases but, in general, with the help of general purpose software (calculator, spreadsheet, and so on) or by performing a digital design with the help of *Logisim*. It is worthwhile mentioning that there is no direct relationship between the different practical works, so they are addressed independently. The main differences between the proposed methodology and the traditional one are shown in Table 3.

TABLE 3. Differences between the proposed methodology and the traditional one.

	Project Based Learning + Flipped classroom	Traditional
Competencies Acquisition Strategy	Learning takes place from practice and theoretical concepts are introduced as needed.	Learning comes from theory and is reinforced by practice.
Session types	There is only one type of session where the project is carried out.	There are two types of sessions: the-theory sessions, where the teacher gives a master class, and the practical sessions ~~one~~ carried out in a laboratory, where the theoretical knowledge acquired previously is applied.
Homework	The basic knowledge of each unit is acquired before being taught in the classroom. This is done using the material suggested by the teacher.	The basic contents already taught by the teacher in the classroom are reinforced. This is done through the study and the realization of problems.
Relationship between the units of the subject	The project is the common core for the acquisition of skills. It serves as a link between all the units.	There is no relation other than that established by the contents. Practices can be independent one from another.

B. PROJECT DESCRIPTION

This section includes the description of the project, which is the main piece in the PBL methodology, as well as its relationship with the theoretical and practical contents of the subject. The project consists of developing a simple calculator of three decimal digits. The calculator must be able to perform the basic arithmetic operations of addition, subtraction, multiplication and division. It also must be able to store results in a cumulative, subtractive or restart manner. It must be able to show results in binary and in Binary Coded Decimal (BCD), and admit integer numeric formats and, optionally, floating point depending on the operation to be performed.

The proposed project is structured in five phases. In each of them, a result is obtained, which can be a set of specifications in the case of phase 1, or a series of digital electronic circuits in the remaining phases. A realistic implementation supported by the simulation tool used in the subject is finally provided.

The theoretical and practical contents addressed in each of the phases are content-related with the unit of the same number for the non-PBL groups (see Table 4). The PBL schedule (see Table 5) has been distributed in classroom sessions dedicated to the presentation of the aims of each phase of the project, issue solving about theoretical concepts, and the orientation towards the resolution of practical aspects of implementation and design. As mentioned before, the planning is based on 15 weeks, and each week has a four-hour session for the subject. For the case of conventional

TABLE 4. Contents for non-PBL CF groups.

Units	Time assigned (h)
Unit 1: Data representation. Numerical systems	12
Unit 2: Boole's Algebra	10
Unit 3: Combinational circuits design	16
Unit 4: Sequential circuits design	16
Unit 5: Basic computer structure	6
Total	60

TABLE 5. Project phases and schedule for PBL CF group.

Phases of the Calculator Project	Time assigned (h)
Phase 1: Choice of the data representation system	12
Phase 2: Implementation of the data display	8
Phase 3: Implementation of the arithmetic unit for addition and product	16
Phase 4: Implementation of the memory unit and control unit	16
Phase 5: Implementation of the full calculator	8
Total	60

ARA groups, that is, those which follow a traditional teaching scheme based on separated theoretical and practical contents, the 60 teaching hours are distributed according to Table 4. In the case of the PBL group, the increase of two hours in the last phase (see Table 5) was decided not to increase the content of this last unit, but to allow time for the students to complete the integration phase of the project, in which all the parts developed in previous phases are combined in a single design.

PBL students must complete the project individually. However, they may require the help of the teacher at some point. Precisely, the PBL methodology and the flipped classroom allow the teacher to guide students through those aspects which they may find more complex. Each student's doubts may be different from those of their classmates. In any case, the teacher focuses the student's orientation, reminding him/her of the principles of clarity, efficiency and cost savings in the design.

1) PHASE 1

In this phase, the Project is proposed to students, by means of an informal specification of the calculator and its different building blocks. Next, the first task consists in defining a specific way of representing the numbers using binary representations. The calculator will operate with signed numbers and hence the need to use an integer format. To conclude this phase, binary formats that are compatible with radix 10 (to be able to view the data in a format understandable to users) are taught to student, commenting on the characteristics of the BCD format.

2) PHASE 2

In this phase, Logisim is introduced and the implementation of simple circuits is proposed so that students acquire basic skills on working with this simulation tool. The transformation of the binary integer format information into a 3-decimal digit visual representation in the calculator will be required. A circuit that converts a natural 10-bit number into its 3-digit BCD representation is provided as a basis. Another circuit will be needed to transform these digits into visual information for the user, using the 7-segment display (see Figure 1). Students will use truth tables for defining the Boolean functions that turn the display on, and later they will apply simplification techniques on these functions as a way to reduce both cost and complexity and increase speed of the corresponding circuit.

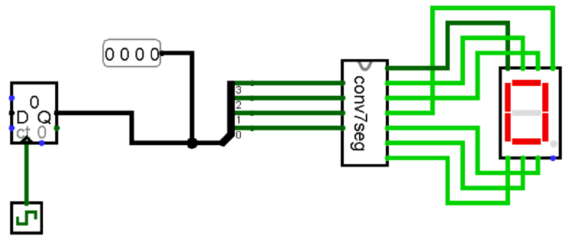

FIGURE 1. BCD converter design.

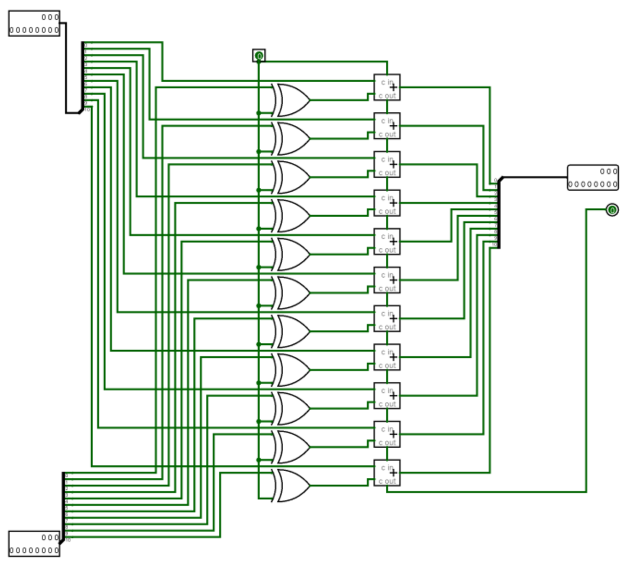

FIGURE 2. A student-like design for phase 3: adder/subtractor.

3) PHASE 3

In this phase, the binary addition algorithm is analyzed. Students are taught the concept of a full 1-bit adder with carry propagation. The concatenation of several of these adders results in the logic circuit for adding two n-bit numbers. Next, the adoption of the 2-Complement format will be proposed in order to convert subtractions into additions, so the adder circuit will be modified with the inclusion of a signal that will produce an addition or a subtraction (see Figures 2 and 3).

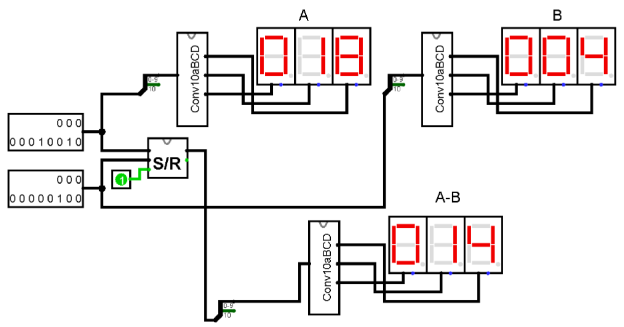

FIGURE 3. **A student-like design for phase 3: Testing the computation "18 - 4" with the 11-bit adder/subtractor.**

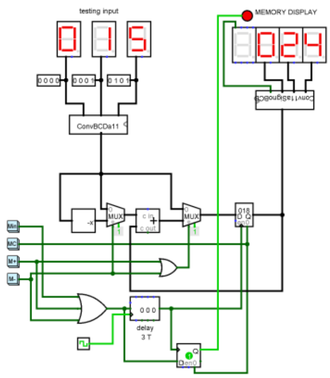

FIGURE 4. **A student-like design for the memory unit of the phase 4.**

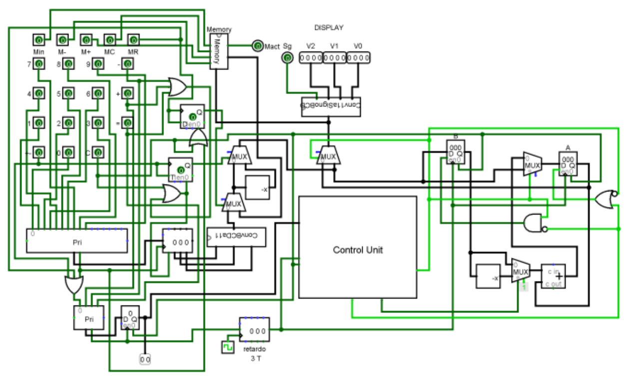

FIGURE 5. **A student-like design for phase 5.**

Finally, a simple modification of the above circuit will provide the change of sign of any number.

4) PHASE 4

In this phase, the behavior of a push-button without interlocking that switches a light on and off will be introduced, which will serve as a basis for explaining the concepts of status and memory. The concept of flip-flop is introduced by means of explaining the basic RS flip-flop implemented with NOR gates. More complex, but also more complete, flip-flops and its functionality are explained. The extension of a single flip-flop implementation to store more than one bit is proposed, arising the concept of register.

By means of D flip-flops, a storage register will be carried out. The "Min" signal will be included in the calculator which, when activated, loads a datum in the register. In the above circuit, the D flip-flops will be replaced with asynchronous inputs D flip-flops, inserting a new signal "MC" that, when activated, deletes the contents of the register.

Next, the students are required to design a sequential circuit for adding two numbers of any length. As a basis, the concept of state diagram is introduced as a way for describing the operation of a sequential system and its response to inputs. The concepts of state table and flip-flop excitation table are explained, which derive in obtaining the equation for the flip-flops inputs and for the system outputs.

Students then will develop the additive memory functionality ("M+" button). When this "M+" signal is activated, the sum of the number previously stored in the storage register plus the number present at the adder inputs will be stored. This milestone allows students designing a multiplier based on a cumulative series of sums.

Finally, student will implement the memory with Decrement ("M-") functionality. They will subsequently develop a circuit with counters for the integer division with remainder, by means of the procedure of successive subtractions (see Figure 4).

5) PHASE 5

This phase begins with the explanation of the importance of count on a computer coordinator: the control unit. Students will develop an automaton to create the control system that manages data input from the keyboard to add two numbers. These numbers are input sequentially (separated by the "+" key) and shown on the display after pressing the "=" key (see Figures 5 and 6).

C. ASSESSMENT

The acquisition of the competences related to the subject is evaluated by means of an exam at the end of the course. This examination consists of a series of questions (*problems*) corresponding to the different thematic units. The weight of each of these problems on the final grade is shown in Table 6. These weights are assigned according to the difficulty of each of them. Table 6 also shows how each exercise is related to the expected learning outcomes.

It should be noted that the final test was the same for all students, i.e. for those who followed the PBL methodology (experimental group) and for those who used a traditional method (control group). The test was held on the same day and at the same time in common classrooms where students from both groups were mixed.

The problems proposed in the exam were designed by the staff according to the learning objectives. The structure of the exam is similar to the one of previous years, but it is obvious that the questions are changed every year. In order not to benefit the experimental group, it was avoided that

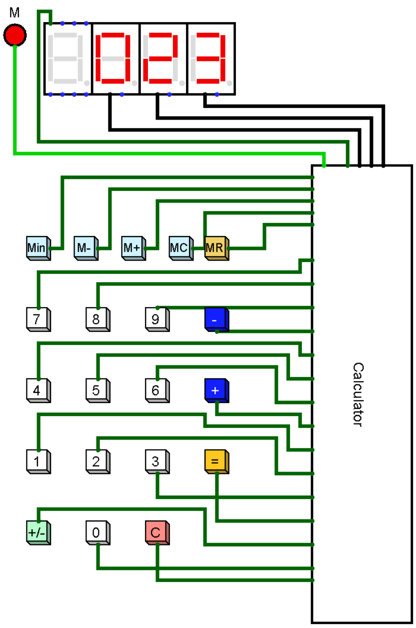

FIGURE 6. A student-like design for testing the full calculator.

TABLE 6. Items covered in the final CF assessment.

Exercise #	*Unit*	*Learning Results**	*%*
1	Data representation.	R1-3	20
2	Boole's Algebra	R4-8	10
3	Combinational circuits design	R9-11	25
4	Sequential circuits design	R12-15	35
5	Basic computer structure	R16	10

* related learning outcomes, see table II

these problems were directly related to the Calculator project. Thus, for unit 1, a question of conversion between different integer and floating representation formats was chosen, as well as addition/subtraction exercises using Complement 1 and 2 formats. With regard to unit 2, a problem involving the simplification of Boolean functions using Karnaugh maps was included. For unit 3, the design of a combinational system for a product classification system was proposed. For unit 4, the design of a sequential system for the control of the lighting of a residential area was proposed. For unit 5, short questions on general concepts of the computer structure were proposed.

Regarding the correction of the test and to avoid possible biases, a code was assigned to each student so that teachers would not know the student's group when the test was corrected.

In addition to this final evaluation (called post-test in the experimental section), an initial knowledge exam (called pre-test in the experimental section) was carried out at the beginning of the course. This initial exam consisted in a multiple-choice test that assessed the basic computer and mathematical knowledge required of students accessing the CF subject. The objective of this initial test was to know the level of knowledge of the students before applying the methodology and, therefore, be able to rule out possible initial biases in the selection of the experimental and control groups.

The scores of the initial (pre-test) and final (post-test) assessments are in the range [0-10]. Thus, a student with a grade of 0 means that he/she has not acquired any subject-related competence, and a student with a grade of 10 means that he/she has fully acquired all the competences of the subject.

D. SOME CONSIDERATIONS ABOUT THE APPLICATION OF THE METHODOLOGY

Each phase of the project is articulated according to the PBL and flipped classroom criteria. Before the start of each phase, students are provided with complete documentation on the theoretical contents so that they can review and study it before the classroom session takes place. These contents coincide fully with the documentary material provided to the other groups of the subject that follow a traditional teaching methodology. Each session is structured as follows:

i. Part of the current phase of the project is explained and a discussion about its solution is started.

ii. The theoretical concepts which are the basis of the solution are addressed.

iii. The theoretical and practical issues related to the design are solved.

iv. The student is guided in the design and implementation of the solution.

The previous steps can be repeated several times in the same session and in the same order to address different parts of each phase of the project development.

The tasks that must be addressed in the PBL working sessions must be meticulously planned before the start of each session. There are significant differences in the way in which these sessions should be taught when the student is in the first year, as in the case of CF, and when he/she is in higher grades. The difference lies in the level of autonomy that students have. In the PBL methodology, the teacher can adopt the role of guide or promoter of learning, move to the background and have a more effective guardianship. However, this type of teaching is more likely to be successful when it is applied in non-initial courses, where the student already follows a more autonomous learning system and is aware of the way of working in the university environment.

In the case of CF, the teacher usually cannot move to the background, so he/she must adopt a more active role in class. The teacher should create a time script, minute by minute if required, of the milestones that students must complete in each session. This is recommended because these types of students, newcomers to the university, often feel self-conscious and prefer not to ask when they are unsure, which can complicate the success of this method. Another difference between first-year students and other students is that the latter are more used to reviewing the materials that are proposed as a previous work. The teacher should therefore check students' level of knowledge by asking appropriate questions at the start of each new session. This means that the teacher can detect whether he/she needs to introduce new theoretical concepts to reach a practical milestone and explain the mentioned concepts with more or less detail, where necessary.

The sessions last 4 hours with a break of about 15 minutes in the middle and problems of concentration can appear. Normally, however, the students' attention can be recovered easily by changing the class rhythm: discussions, practice, exercises, consultations, explanations etc.

V. EXPERIMENTAL RESULTS

The effectiveness of the new PBL methodology was examined by comparing the academic performance of students belonging to an experimental group and a control group. This research aims to find out whether for a small group of students such as the ARA group, it is better to use a project-based and flipped classroom methodology or a traditional one. Therefore, this experiment does not involve students from large groups of the subject, but only ARA groups. The experiment was carried out on 77 students of the subject distributed between experimental (two PBL-ARA-groups of 20 students each) and control groups (two non-PBL-ARA-groups of 18 and 19 students). Student scores on academic performance was considered as the dependent variable, being the intra-subject factor at the time of assessment both before and after applying the methodology; the independent variable is the applied methodology, being the inter-subject factor belonging to the experimental group or to the control group.

TABLE 7. Descriptive statistics for the initial and final evaluations.

Group	Score Mean		Std Dev.		N	
	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
Control	5.26	5.32	2.49	2.49	37	37
Experimental	5.31	7.31	3.19	2.43	40	40

Firstly, in Table 7, we present the main descriptive statistics corresponding to the results of the initial knowledge test carried out before the experiment (pre-test) and the final subject evaluation carried out afterwards (post-test). Table 7 shows the mean of the scores obtained by the participants of each of the groups in the pre-test and the post-test.

The research was performed by means of the general linear model with repeated measures, using the Statistical Package for the Social Sciences (SPSS, version 23.0) software. The academic performance assessment time (pre- and post-test) was considered as the intra-subject factor and belonging to the experimental group or to the control group was considered as the inter-subject factor, as previously mentioned.

The sample of population participating in the research is normally distributed, since the result of the Box M-test shows homogeneity in the variance-covariance matrices (p= .125). Therefore, the dependent variables are the same in all groups.

TABLE 8. Test of inter-subjects effects.

	Intercept	GROUP	Error
Type III Sum of Squares	5174.320	39.989	780.210
df	1	1	75
Mean Square	5174.320	39.989	10.403
F	497.397	3.844	
Sig.	.000	.054	
η^2 partial	.869	.049	
Noncent. Parameter	497.397	3.844	
Observed Power[a]	1.000	.490	

[a]Computed using alpha = .05.

Once the normality of the sample was checked, the marks of both groups was compared, before (pre-test) and after (post-test) the intervention to evaluate the effect of the new methodology on students' performances. The values of the inter-subject test (Table 8) show that there are no significant initial differences between the groups of students about their group since the average of all the observations differs from zero, being the result of the significant tests ($p < .000$) for intersection, but not for group membership ($p = .054$).

TABLE 9. Test of intra-subjects effects.

	Perform.	Perform. * GROUP	Error (Perform.)
Type III Sum of Squares	40.660	36.155	297.807
df	1	1	75
Mean Square	40.660	36.155	3.971
F	10.240	9.105	
Sig.	.002	.003	
η^2 partial	.120	.108	
Noncent. Parameter	10.240	9.105	
Observed Power[a]	.885	.846	

[a]Computed using alpha = .05.

On the other hand, Table 9 shows the effectiveness of using the new PBL methodology through the intra-subjects effects test. From the results of this test, it can be observed that the effect of the interaction between the time of the assessment (pre- and post-test) and the application of the new methodological strategy is significant ($p = .003$). With regard to the observed power, the result was .846, indicating that it is correct to reject the null hypothesis of equality of means. The size of the effect (η^2) which produces the interaction between the time of assessment and the program application is .108.

A t-test was performed on the difference of means to check if there are differences between the experimental group and the control group both at the pre- and post-test moment (Table 10).

The results of this test show that there are no significant differences at the pre-test time ($p = .939$), and both groups can be considered to start from comparable situations as suggested by the inter-subject test. However, the post-test shows a significant difference between the two groups once

TABLE 10. Parameter estimation.

Dependent variable	Parameter	B	Std. err.	t	Sig.	95% confidence Interval Lower limit	Upper limit	η^2 partial	Noncent. Parameter	Observed Power[b]
PRE	Intercept	5.262	.474	11.106	.000	4.318	6.205	.622	11.106	1.000
	Experiment	.050	.657	.076	.939	-1.259	1.360	.000	.076	.051
	Control	0[a]	.	.	.	.	.[a]	.	.	.[a]
POST	Intercept	5.320	.405	13.136	.000	4.513	6.127	.697	13.136	1.000
	Experiment	1.990	.562	3.541	.001	.870	3.109	.143	3.541	.938
	Control	0[a]	.	.	.	.	.[a]	.	.	.[a]

[a]The parameter was assigned the zero value because it is redundant.
[b]Computed using alpha = .05

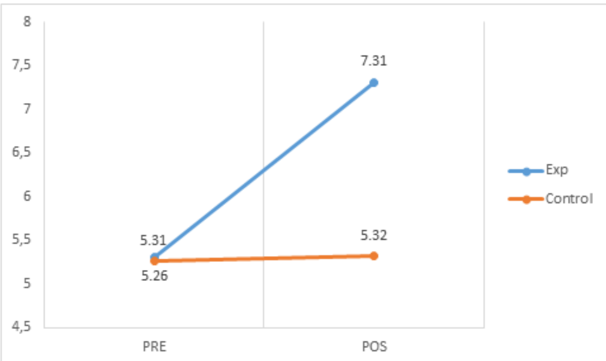

FIGURE 7. Academic performance of control and experimental groups at pre-test (PRE) and post-test (POS).

the methodology is applied (p = .001), this difference being 1.99 points higher for the experimental group.

Lastly, Figure 7 shows the marks obtained by both groups before and after the intervention. The graph clearly shows that the experimental group improved more after using the new methodology based on the Calculator Project, when compared to the control group. As previously mentioned, the initial marks (PRE) were obtained by means of a multiple choice test, and the final marks (POST) were obtained by means of an exam made up of a series of questions corresponding to the items shown in Table 5, whose contents are explained in subsection C (*Assessment*) of the Methodology Section.

VI. CONCLUSIONS

The theories of situated learning emphasize the importance of starting from practical situations - such as case studies, the development of projects or the solution of problems close to the work environment - in order to produce learning linked to real contexts, in which authentic, realistic and complex tasks are tackled [28].

These approaches should complement direct teaching and are especially effective in higher education. The authors of this research think that learning occurs in a much more natural way when it starts from a practical, close-to-reality scenario.

Based on the research undertaken, the PBL methodology and the flipped classroom were very well received by the ARA student group in the Computer Fundamentals course of the Computer Engineering degree. The work sessions proved to be very satisfactory for both the teacher and the students, although the teacher's workload is very high at the beginning, when the subject is still taught in a traditional way.

The experimental results showed an improvement of +2.0 points for the PBL group, which is significant with respect to the improvement obtained by the control group (+0.06) between pre- and post-test times. Although the experimental group had the lowest pre-test score, the study showed that it was not significant with respect to the control group. Despite starting with a very similar score (+0.05), the experimental group scored significantly better than the control group with 1.99 more points.

As a general rule, teachers observed a greater level of involvement in the experimental groups, showing a greater effort on behalf of the students while completing the project.

From the teachers' experience, some findings and good practices should be taken in the classroom to take advantage of the PBL methodology.

i. The use of such a methodological approach for numerous groups is not advisable in the context of this subject, since the teacher acquires a role as a simple counselor or catalyst for the learning of each student.

ii. The tasks to be addressed in the PBL working sessions should be carefully planned before the start of each session. In the PBL methodology, the teacher usually takes on the role of a learning promoter and takes a back seat for a more effective mentoring. However, this type of teaching has a better chance of success when it is applied in non-initial courses. Students in the first year of the degree, as in the case of CFs, have a level of autonomy different from that of students in advanced courses, who have already adopted an autonomous learning system.

iii. In the case of first year subjects, as CF, the teacher usually must play an active role. He/she must create a time script, minute by minute if necessary, of the milestones that students must complete in each session. This is recommended because newer university students often feel self-conscious and prefers not to ask when unsure, which can complicate the success of the PBL method. Another difference between freshmen and sophomores is that the latter are more used to reviewing materials as a task before the PBL work sessions. Therefore, the teacher should check the students' level of knowledge by asking the appropriate questions at the beginning of each PBL session. In this way, the teacher can detect whether it is necessary to introduce and explain new theoretical concepts so as to reach a milestone.

Regarding how to continue in the future, a systematic framework for the proposed methodology must be established, since the teacher must frequently improvise in each work session according to the circumstances that arise regarding the project that is being developed. Such a framework should include as many contingencies as possible.

On the other hand, it would be useful to carry out a student satisfaction survey on the methodology used, since the feedback that the teacher receives should be based on objective data, although the comments of the students in the work sessions could also be included in such feedback.

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