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Combining Flipped Classroom, Project-Based Learning, and Formative Assessment Strategies in Engineering Studies*

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This paper presents a methodology that encourages and fosters proactive student participation in individual and collaborative learning. The methodology combines Flipped Classroom, Formative Assessment and Continuous Assessment, Project-Based Learning, and Problem Solving using Simulators strategies, with an integrated teaching and learning system (ITLS), called SIENA. The tool serves to automate some of the processes inherent in the methodology and serves as a bridge across all of the educational process involved. The methodology has been tested in both undergraduate and postgraduate degrees in Computer Engineering studies, the former in a blended learning subject and the last in an on-line subject findings to date have proven positive. In addition, we have applied a unified theory of acceptance and use of technology model to ITLS and it has proven to be a useful tool in the learning process.

Keywords: flipped classroom; project-based learning; continuous assessment; collaborative learning; active participation; motivation; learning performance

1. Introduction

One of the direct consequences of joining the European Higher Education Area (EHEA) is that greater emphasis is now being placed on student participation in the teaching-learning process. In 2009, student-centred learning (SCL) came to the forefront of our attention when it was listed as one of the key commitments set forth in the Bologna Process, and since then student-centred learning has become closely entwined with the concept of 'learning how to learn'. Significant progress has been made when it comes to implementing student-centred learning, but still more efforts are needed. If we are to put students at the centre of the learning process we must be ready and capable of providing them with choices in terms of curricula, assessment methods and study paths. It also entails viewing students as equal partners and co-producers of knowledge [1, 2]. It is within this setting that the authors of this paper have proposed an integral methodological approach for Computer Engineering that is designed to foster and strengthen the active participation and collaborative work of students [3].

It is well known that the flipped classroom fosters the active participation of students [4, 5], as such our methodology includes this learning strategy. To further strengthen the active participation of students, and also collaborative work, this methodology includes a final project at the end of the subject [6]. We view the evaluation process that is involved in a subject not only as a process that checks students' knowledge acquisition, but also as an additional element in the learning process involving feedback that reinforces learning [7]. If there are not a lot of students in a class, as in the case of this study, feedback is best obtained using continuous evaluation [8], small groups of no more than 5 students, and the exchange of ideas between both students and teachers.

As such, the approach detailed in this paper combines elements from the following educational strategies: Inverted Classroom (or Flipped Classroom); Formative Assessment and Continuous Assessment; and Project-Based Learning (PBL)/ Problem Solving using Simulators. A bespoke online tool, called SIENA, has been designed and built to automate many of the processes that form part of this approach. This tool [9] permits computerised adaptive testing that can tailor tests for individual or collaborative test-takers. It includes a chat function so students can exchange messages, and it is able to evaluate any such messages semi-automatically using the rubrics that are defined in the initial stage of this methodology. Given that fact that SIENA is a constituent element of this methodology, it has also been evaluated using an unified

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theory of acceptance and use of technology (UTAUT).

The proposed methodology has been validated in both undergraduate and postgraduate level studies in two subjects: *Computer Architecture*, a subject that is taught as part of an undergraduate degree in Computer Engineering; and *Advancements in Digital Technologies for Teaching & Learning*, a subject taught as part of a master's level postgraduate degree in Information and Communication Technologies.

The contents of this paper are structured as follows: Section 2 covers the theoretical foundations of this work; Section 3 presents the proposed methodology and the SIENA tool; Section 4 details the experiments and the results; Section 5 presents a discussion of the results of the experiment and, finally, in Section 6 we present our conclusions.

2. Theoretical foundations

In this section, the instructional strategies used in the methodology are specified in order to help the reader better grasp of the theoretical foundations of this work and understand the authors' approach.

In the Inverted Classroom (IC), the traditional educational model in which the focus is on the teacher is substituted for one in which the focus is on the student [4, 10]. Digital content is used to allow students to study theoretical content and materials from the comfort of their own homes, whilst time spent in the classroom is dedicated to resolving their doubts and answering questions [11, 12]. Class time is also spent pursuing activities and exercises that are deigned to make the most of face-to-face communication opportunities in the classroom [13]. The Inverted Classroom strategy fosters active learning and collaborative work [4, 5, 14, 15]. It is also argued [16] that the teacher can cover more content in inverted classrooms than in a traditional classroom, thus improving learning outcomes. In [17] it is stated that the educational value of IC lies in the fact that it allows students to apply the knowledge they have learnt within the classroom setting and take on a more proactive role in the learning process, thus making classes more dynamic.

In [8] it is argued that continuous assessment is one of the founding pillars of the EHEA, making it a mandatory element of new universities degrees. They conclude that continuous evaluation and intensive continuous evaluation improve student performance significantly. In [18] the author indicates that formative assessment (FA) relates to two objectives: *Assessment for Learning* (**Af**L) and *Assessment as Learning* (A**a**L). The objective of **Af**L is to monitor student progress as they work towards the set goals, which can be achieved by using questioning and peer feedback, for example. The goal of A**a**L, however, is collaborative reflection and individual reflection during which both teachers and students set learning objectives and assess where students are in terms of their learning curve and knowledge acquisition; this is achieved primarily through dialogue. The provision of effective feedback has been highlighted as one of the main features of a learning-focused approach to assessment [7].

The stance of the authors in [19] is that active learning is a widely used form of learning that is increasingly being used in engineering courses. Collaborative Learning and Project-based Learning are two teaching methodologies capable of demonstrating significant improvements in learning outcomes when compared against traditional teaching practices that are based on lectures and practical exercises, and in which students are merely the passive receptors of information [20]. Project-Based Learning (PBL) is a suitable complement for the Inverted Classroom, group work, continuous assessment based on active learning, and collaborative learning amongst students. PBL is particularly useful in smaller groups, although its effectiveness depends on the amount of effort that each student is willing to dedicate to resolving problems or analysing and interpreting data whilst studying [21]. In [6] it is stated that PBL not only places students at the core of teaching and learning activities, but that it also enables them to put the theoretical scientific knowledge they have acquired into practice once in out in the workforce. Project presentations serve to develop transversal competencies, such as public speaking skills, understanding how to develop a topic, etc.

Simulators, on the other hand, contribute to learning by simplifying the real world, reducing complexity, and presenting only the content that one wants to focus on. It is also possible to choose more generic vs. more specific simulators depending on the topic in question: more generic simulators such as Matlab, Octave, Calerga Sysquake [22–24] may be more suitable in subjects like Process Control or Signal Processing, etc., whereas more specific simulators, such as SIMDE [25], are more suitable in subjects such as Computer Architecture, Operating Systems, etc.

3. Description of the methodology and SIENA

This section provides a brief overview of the proposed methodology and the supporting tool, SIENA, and covers the main stages of the methodology and the instructional strategies used. Regarding the SIENA tool, we provide details of

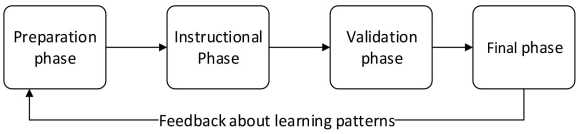

Fig. 1. The fundamental steps taken in the methodology.

its main characteristics, explain how it works with students when they work individually versus in collaboration with other students, and comment on some aspects involved in its implementation.

3.1 Proposed methodology

The proposed methodology falls under what is currently referred to as the Active Learning Methodology (ALM) [26], however it also includes evaluation as part of the learning process and feedback. The evaluation is performed via continuous assessment, the analysis of messages exchanged in an online forum and the assessment of a final project. The teaching-learning process in the methodology, which combines both teaching-learning and evaluation, is divided into the following phases and activities [27] (see Fig. 1).

1. Preparation phase. Students are divided into workgroups for the purpose of educational activities. Activities are broken down into concepts and learning objectives, for example using a conceptual map. Students' prior knowledge is identified by having them attempt intermediate level activities. The rubrics that will be used in the validation phase are also defined here in the preparation phase.
2. Instructional Phase. The instructional strategy is based on Flipped Classrooms, Project-Based Learning and/or problem solving by using simulators (in Engineering subjects). Individual and collaborative adaptive tests are performed and the rubrics are adapted in accordance with the active learning process. Students must present their projects orally to the entire class in person or via videoconference and submit them as a document for later assessment.
3. The validation phase is performed in three steps: evaluation of messages containing arguments, continuous evaluation of concepts (nodes on the conceptual map), and evaluation of the final project/s.

   The rubrics for the continuous evaluations performed during the course are compiled along with the results from collaborative online tests. One important aspect of this phase is that it offers additional learning opportunities thanks to the feedback students receive in each and every one of the tests being delivered to assess them. In presential or semi-presential courses, continuous assessment is more relevant when performed orally in person, whereas in distance learning courses assessment is performed on-line. These continuous assessments serve as an additional element in the learning process given that they allow the teacher to establish a dialogue with a small group of students (2–3 being the ideal group size), and with it identify how well each subsection (node on the conceptual map) has been understood. At the same time, the teacher can clarify any doubts (feedback) or resolve any misunderstanding that has been detected.
4. Final phase. The results of the current course—all documents generated and presentations—are compared against previous courses and significant differences are analysed. The results obtained can be used to provide feedback that will serve to fine tune the design of the 'Preparation Phase' in future editions of courses with compatible learning patterns.

3.2 SIENA

SIENA stands for *Sistema Integrado de Enseñanza-Aprendizaje* in Spanish, which translates to Integrated System of Teaching and Learning (TLIS) in English [28]. SIENA has been designed to allow self-directed learning and self-assessment. It includes conceptual maps and adaptive testing using Bayesian inference for multiple-choice questions [29, 30].

Students must engage with individual learning activities, collaborative learning activities, and assessment activities in the form of adaptive tests. These adaptive tests may need to be completed by individual students on their own (self- directed learning), or online together with other students (collaborative learning). Also, the tool contains an additional social networking feature so that students are able to engage with each other whilst completing online collaborative learning tasks. This social networking feature allows students in the same workgroup to communicate amongst each other and exchange messages in order to decide how to best answer the questions set by the adaptive test. These messages are recorded by the system so that they can be reviewed later and used for feedback & grading purposes.

Tutors are able to evaluate the messages sent by each individual in a group and provide students with personalized feedback during collaborative work. To make this individual feedback & grading possible, fuzzy logic has been incorporated into the rubric scoring for different elements within the tool, i.e. student roles in groups, tests results, and the quality of messages. The latter relies on natural language processing that is based on semantic queries in DBpedia ("a crowd-sourced community

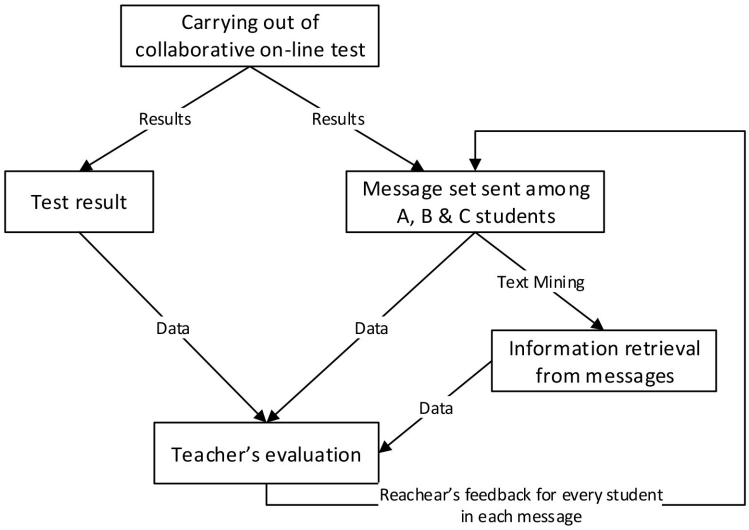

Fig. 2. Diagram showing the workings of SIENA and how it helps the tutor.

effort to extract structured information from Wikipedia and make this information available on the Web'') [27, 31].

Fig. 2 outlines the process carried out by the teacher. He or she collects information on how a new collaborative computerized adaptive tests is performed, and, using the (semi) automated features, assesses each student's contributions in the collaborative tests based on the rubric indicators.

SIENA has been tested and refined through use in different university subjects. It has also been applied to different subjects in primary and secondary education in Spain and Brazil. Furthermore, it has been used in research projects at both Masters and Doctorate levels.

Table 1 details the main educational centres in which this tool has been adopted and tested over the last ten years. As is clear from the table, it has been used across a wide variety of subjects, topics and courses at different levels in the educational system.

Table 1. Educational institutions and the subjects in which the methodology was applied for at least 10 years

Educational Institution	Projects/Subjects	Students
Escola Municipal de Ensino Fundamental Irmão Pedro no município de Canoas do estado do Rio Grande do Sul. (Brazil)	Fractions and Equations Project - Year 1, Decimal Numbers and transversal topic Work and Consumption	30
Escola Estadual de Ensino Fundamental Evaristo Flores no município de Porto alegre do estado do Rio Grande do Sul. (Brazil)	Statistics Project	30
Escola Municipal de Ensino Fundamental Franz Louis Weinmann no município de são Leopoldo do estado do Rio Grande do Sul. (Brazil)	Multiplication and Division of Natural Numbers	20
Colegio Público Andalucía. La Línea de la Concepción. Cádiz. (Spain)	Solving Arithmetic Problems in Primary Education. Year 6 of Primary School	14
Colegio Cervantes. Santa Cruz de Tenerife. (Spain)	Assisting Self-Assessment. Environmental Studies; subject: The Human Body. Year 6 of Primary School	23
Colegio Chamberí. Santa Cruz de Tenerife. (Spain)	Detecting English Grammar Level. 2nd and 4th year of compulsory secondary education (E.S.O).	49
Universidade Luterana do Brasil (Brazil)	The records of Semiotic Representation of the Line with focus on Analytical Geometry. Ph.D.	50
Universidad de la Laguna (Spain)	Computer Architecture. 3rd year Degree in Computer Engineering. Advanced Architectures and Specific Architectures. 4th year in Computer Engineering. Industrial Automation. Degree in Industrial Engineering. Advances in Digital Technology for Teaching and Learning. Master in Education and ITC.	422

4. Experiments and results

Herein we present the experimentation of the Instructional Phase of the methodology. The Instructional Phase includes flipped classroom activities, project-based learning and formative assessment strategies. Furthermore, experimentation is performed using the UTAUT model to evaluate the SIENA tool. The main results of both experiments are presented in this section.

4.1 Experiment SIENA and results

This subsection discusses user acceptance of information technology and provides details of results gathered from an evaluation of the SIENA tool. The tool was assessed based on the UTAUT acceptance model [32, 33]. The goal of the survey, based on a simplified model of UTAUT, is to identify those aspects that affect acceptance of this tool. Thirty-two questions are asked [32], covering all the model's determinants, even those that the UTAUT considers to be of little significance; the motivation behind including these is to obtain more information on student feedback (Table 2).

It is important to underline that the objective of this study is to identify major trends relating to the intended use of SIENA, and not exact values of adjustment parameters to complement the other results provided by the tool. A total of 72 students from the Universidad de La Laguna (Spain) and the Universidade Luterana do Brasil (Brazil) responded to the questionnaire (Table 3).

This UTAUT model integrates important elements from previous models and formulates a unique measurement using core determinants of user behavioural intention and usage, as detailed. (1) *Performance expectancy* (PE)—"the degree to which an individual believes that using the system will help him or her to make gains in job performance"; (2) *Effort expectancy* (EE)—"the degree of ease associated with the use of the system"; (3) *Social influence* (SI)—"the degree to which an individual perceives that it is important others believe that he or she should use the new system"; (4) *Facilitating conditions* (FC)—"the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system". These four factors are complemented by three additional factors, the effects of which are considered minor within the model itself: *attitude toward using technology* (AT), *self-efficacy* (SE), and *anxiety* (AX).

4.2 Experiment with the methodology

The experimentation is focused primarily on the Instructional Phase of the proposed methodology, which is where the main objective of our proposal resides: to foster and strengthen the active participation and collaborative work of students. As such, this phase includes the main activities found in the inverted classroom (flipped classroom), project-based learning and formative assessment. When it comes to the experiment, our goal is to observe the effects of the independent variables Inverted Classroom (IC), Project-Based Learning (PBL) and Formative Assessment (FA) on the latent variables Active Learning (AL), Engagement (ENG) and Learning Performance (LP). Thus, we have proposed and sought to verify the following hypothesis:

H1: A significant relationship exists between the independent variables of IC, PBL and FA and the latent variables of AL, ENG and LP.

The experimentation was based on a survey and was applied to two subjects: *Computer Architecture*, a subject that is taught as part of an undergraduate degree in Computer Engineering; and *Advancements in Digital Technologies for Teaching & Learning*, a subject taught as part of a master's in Information and Communication Technologies. The motivation behind selecting the aforementioned undergraduate and postgraduate degrees for the purposes of this study lies in the fact that the former, although it applies blended learning, is taught in the classroom setting, whilst the latter is taught exclusively on-line [34]. Furthermore, undergraduate students generally tend to be less mature and have less experience than postgraduate students.

The subject Computer Architecture is taught over the course of a semester. The main topics covered include: Fundamental design, Memory hierarchy, Instruction level parallelism (ILP) with dynamic and static planning, Superscalar processors and Very Long Instruction Word. These topics are taught in accordance with their difficulty over the course of 15 weeks. In Memory hierarchy (lasting 4 weeks) the Flipped Classroom learning strategy is used whilst in ILP Processors (lasting 6 weeks) the Project-Based Learning strategy is used. For the PBL strategy, students are initially made to work on a less complex project individually and later to work on a more complex problem or integrated project in groups consisting of two or three members (matrix multiplication or sorting tables). The SIMDE simulator [25] is used for both individual and group activities. The results obtained are documented and publicly disclosed. During the academic course each group of two or three students receives a total of three formative assessments that last one hour each. The learning tool SIENA is used in each topic of the subject to perform individual and collaborative adaptive testing. Messages that are

Table 2. Survey results using a seven-point Likert scale (*indicates items with an inverted scale)

Question	Mean	SD
Performance expectancy (PE)		
Cronbach's alpha: 0.92		
PE1. SIENA is useful when I study	5.30	1.30
PE2. SIENA improves student performance	5.53	1.21
PE3. SIENA helps me improve subject related competencies	5.55	1.12
PE4. SIENA is a tool that helps self-study in collaborative tasks and individual exercises	5.69	1.37
Effort expectancy (EE)		
Cronbach's alpha: 0.84		
EE1. SIENA is easy to use	5.47	1.18
EE2. Using SIENA does not require a lot of effort on my part	5.18	1.30
EE3. SIENA let's me easy do the tasks I want to perform within the tool	5.24	1.26
EE4. Using SIENA involves spending a lot of time performing mechanical operations (*)	2.05	0.59
Attitude toward using technology (AT)		
Cronbach's alpha: 0.88		
AT1. SIENA makes studying more interesting	5.04	1.48
AT2. I like using SIENA to study	4.87	1.26
AT3. I would like to use SIENA in other subjects	4.95	1.31
AT4. SIENA let's me check how well I understand a topic	5.78	1.15
Social influence (SI)		
Cronbach's alpha: 0.91		
SI1. My classmate/s help me when I use SIENA	5.33	1.60
SI2. I find being able to share the work done in one workgroup with other workgroups very useful	5.67	1.35
SI3. I find being able to chat with my workgroup partners when answering the test motivational and it encourages me to continue working	5.73	1.37
SI4. I find being able to review the answers exchanges with the rest of the group helps me to revise for exams	5.84	1.17
Facilitating conditions (FC)		
Cronbach's alpha: 0.86		
FC1. SIENA activities are temporarily coordinated with theoretical teaching	5.47	1.15
FC2. I have the technical knowledge and resources needed to use SIENA	5.58	1.16
FC3. The teaching staff has designed interesting questions and activities for SIENA	5.64	1.35
FC4. SIENA adjusts to my learning style	5.36	1.32
Self-efficacy (SE)		
Cronbach's alpha: 0.79		
SE1. I can finish the tasks set in SIENA on my own without asking anyone else for help	5.74	1.42
SE2. I can finish the tasks set in SIENA in a reasonable about of time without asking anyone else for help	5.56	1.19
SE3. I can finish the tasks set in SIENA if I can ask someone else for help when I get stuck	5.29	1.08
SE4. I can finish tasks set in SIENA if I can consult the User Guidebook	5.33	1.49
Anxiety (AX)		
Cronbach's alpha: 0.90		
AX1. I do not feel confident when starting to use SIENA (*)	2.76	1.73
AX2. I am worried about making mistakes that I cannot fix when I use SIENA (*)	3.02	1.71
AX3. I am worried about losing a lot of work if SIENA crashes or if I do something wrong (*)	3.25	1.95
AX4. I feel somewhat unsure when I use SIENA (*)	2.85	1.89
Behavioural Intention (BI)		
Cronbach's alpha: 0.93		
BI1. I intend to use SIENA to study for my final exams	4.91	1.70
BI2. I intend to use SIENA to test my understanding	5.25	1.53
BI3. I will definitely use SIENA to prepare for my final exams	4.73	1.80
BI4. SIENA helps me manage my time better and improves my self discipline	5.20	1.61

Table 3. Distribution of students surveyed by age and gender

Course	Males	Females	Age 15–20	Age 20–25	Age 25–30	Age 30–35	Age > 35	Total
Undergraduate, Postgraduate	38	34	0	32	16	12	12	72

sent by students when working collaboratively are analysed and count towards their final grade.

In *Advancements in Digital Technologies for Teaching & Learning*, Inverted Classroom strategies are specifically used with course content covering Reasoning under Uncertainty: Bayesian networks and fuzzy logic. Students are challenged with the task of designing activities that they may choose to resolve either by using Bayesian networks or fuzzy logic.

The questionnaire contained 37 questions (undergraduate, blended learning) and 24 questions (post-

Table 4. Distribution of surveyed students by qualification, age and gender

Course	Males	Females	Age 15–20	Age 20–25	Age 25–30	Age 30–35	Age > 35	Total
Postgraduate	9	12	0	4	10	5	2	21
Undergraduate	15	3	2	11	2	1	2	18

Table 5. Undergraduate Degree Survey Questions

Questions
1. Course in which methodology has been used
2. Audiovisual materials provided: videos, PDFs, explanatory notes, solved problems, etc. Those considered sufficient for the flipped classroom.
3. I study content by myself using the materials provided.
4. In classes we analyse and ask questions about concepts that appear in the audiovisual materials submitted and on any questions that are not clear.
5. I endeavor to study the audiovisual material provided before coming to class.
6. I have the opportunity to work collaboratively on content viewed in multimedia videos using the adaptive tests in SIENA.
7. The flipped classroom has allowed me to learn with the help of technology.
8. In the flipped classroom doubts are resolved stimulating debate.
9. The flipped classroom has improved your learning performance.
10. The individual adaptive tests in the SIENA tool have allowed me to improve my self-directed learning.
11. The adaptive tests in SIENA improve collaborative learning.
12. In my opinion, assessing the discussions between group members in SIENA is a good idea, as is including the assessment mark in a student's final grades.
13. I think the following rubric used to evaluate the tests are correct: Did the student start the messages in the test questions?; Did the student participate and send messages in each of the questions?; The number of false answers in the test; and the quality of the messages submitted by each student.
14. In the academic tutorials for groups the teacher evaluates students understanding of subject content and corrects any concepts that have been confused.
15. The academic tutorials, in which individual and collaborative assessments may be performed, permit feedback and this helps a student advance their learning.
16. I feel better assessed because of the academic tutorials.
17. I think it is a good idea to do a final project at the end of the subject as it permits active learning.
18. The public presentation of the project and the creation of a written report on the work performed in the final project contribute towards improving transversal skills.
19. Executing projects improves learning performance.
20. The flipped classroom permits active learning.
21. Project-based learning permits active learning.
22. Evaluation using academic tutorials and the collaborative tests in SIENA have improved your learning performance
23. Collaborative work has enabled you to improve your learning.
24. You believe that greater motivation when pursuing a subject will lead to greater performance when learning.
25. The activities that you and your classmates actively participate in during class foster learning.
26. The collaborative work undertaken has fostered motivation during the course.
27. You feel motivated when doing a project in the subject.
28. The activities that you and your classmates actively participate in foster greater motivation.
29. The academic tutorials positively promote collaborative work.
30. You feel that the academic tutorials foster active learning.
31. You feel that the SIENA tool facilitates active learning.
32. The activities you carried out with teachers and classmates motivated you.
33. Projects foster interactions between teachers and students.
34. The teacher-student interaction fosters active learning.
35. You believe that teamwork improves projects.
36. Interacting with classmates increases your motivation.
37. You believe that interacting with your classmates fosters active learning.

graduate, online), to which a total of 39 students responded from both degrees: 18 undergraduate students and 21 postgraduate students (Table 4). The items were measures using the following 7 values on a Likert-type scale.

Table 5 presents the survey questions applied to the undergraduate degree using Blended-Learning. The questions for the postgraduate degree were taken from the aforementioned survey and adapted for online teaching.

The results for the undergraduate degree are initially separated from those gathered for the postgraduate degree. Subsequently, questionnaire results for both the undergraduate degree and the postgraduate degree are combined. The results have been displayed in graphs to facilitate their analysis.

Figs. 3 and 4 show the relative frequencies and cumulative frequencies of undergraduate student answers based on the 7 Likert-type items for all variables, both independent and latent.

Figs. 5 and 6 display the relative frequencies and cumulative frequencies of postgraduate student answers based on the 7 Likert-type items for all variables, both independent and latent.

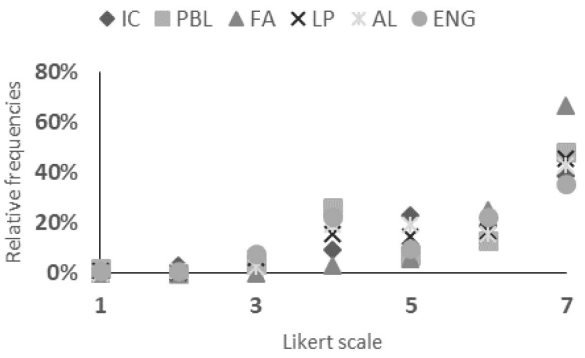

Fig. 3. Relative frequencies of undergraduate student answers on the Likert-type scale.

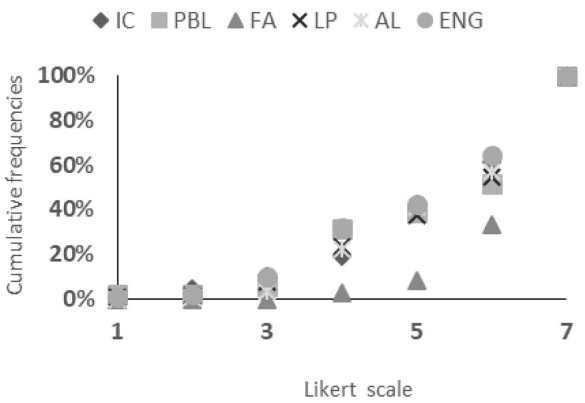

Fig. 4. Cumulative relative frequencies of undergraduate student answers on the Likert-type scale.

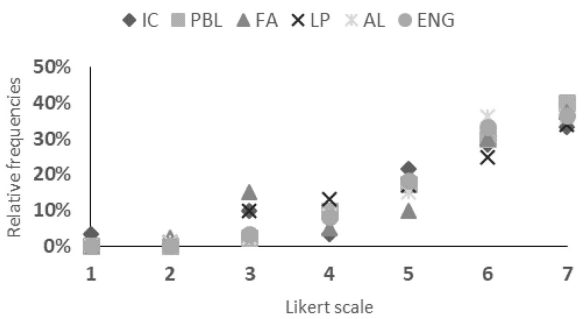

Fig. 5. Relative frequencies of postgraduate student answers on the Likert-type scale.

Figs. 7 and 8 show the relative frequencies and cumulative frequencies of both undergraduate and postgraduate student answers based on the 7 Likert-type items for all variables, both independent and latent.

5. Discussion

Having presented the experiments and their results, we shall proceed with the analysis of the results obtained from both experiments. First, we shall discuss the results obtained for SIENA using the UTAUT acceptance model, after which we shall analyse the results of the proposed methodology.

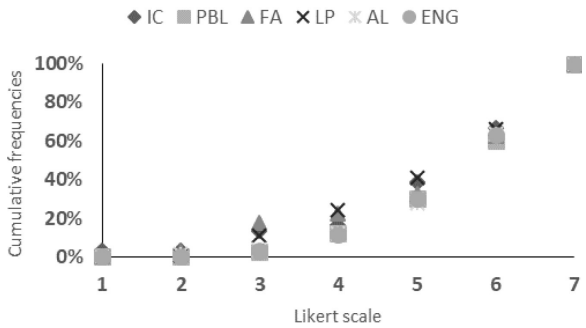

Fig. 6. Cumulative relative frequencies of postgraduate students answers on the Likert-type scale.

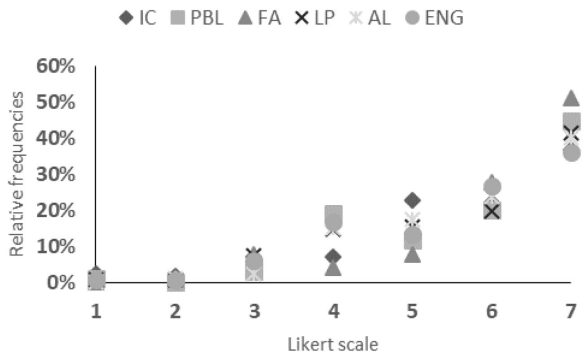

Fig. 7. Relative frequencies of undergraduate & postgraduate students answers on the Likert-type scale.

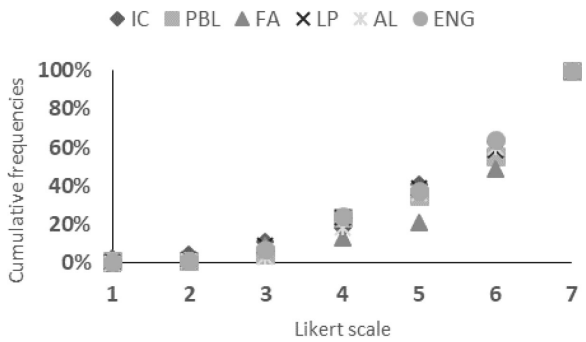

Fig. 8. Cumulative relative frequencies of undergraduate & postgraduate students answers on the Likert-type scale.

5.1 Discussion of SIENA

Respondents recognise that the tool has proven to be a useful tool in the learning process, and that it has facilitated both individual and collaborative learning (5.69) and allowed them to establish their prior knowledge on a given subject (5.78). Feedback also shows that they find reviewing questions and exchanging messages with their classmates useful when it comes to preparing for exams (5.84) (Fig. 9, Table 2). However, low values are registered for questions asking whether they like the tool. It

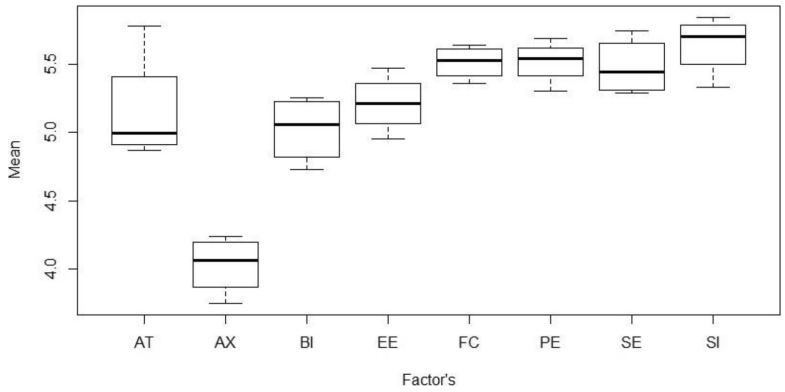

Fig. 9. Box plot of data from Unified Theory of Acceptance and Use of Technology (UTAUT).

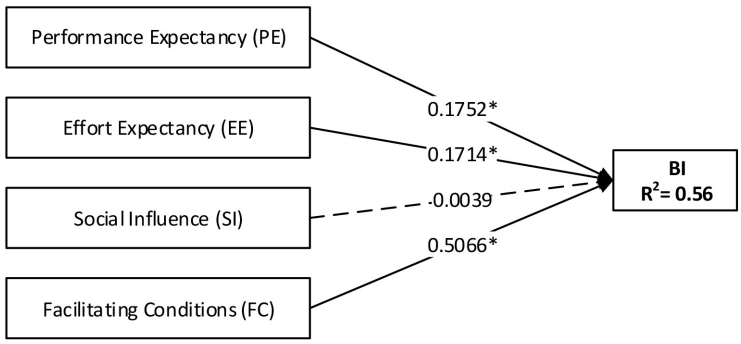

Fig. 10. UTAUT model for SIENA (n = 72), * $p < 0.05$

response to this, it should be noted that the tool is flexible, dynamic, capable of incorporating new initiatives and adapting to emerging educational trends, and it is designed to be used for different educational levels and for different branches of knowledge, e.g., science, engineering, humanities, etc. With regards to AX, it is surprising that despite the perception that SIENA is easy to use, respondents reveal feeling insecure about making a mistake when using the tool. The authors believe that these answers correspond to students in levels of education in which, on the whole, they are less familiar with technology.

After performing a statistical analysis, the following model values were obtained: GOF = 0.64. From this model (Fig. 10) it appears that the influence of SI is insignificant when compared to PE, EE (very similar) and FC (which displays a greater weight in the model).

5.2 Discussion of the proposed methodology

The results presented graphically in the previous section shall be analysed separately to begin with, both for the undergraduate degree and postgraduate degree, after which the aggregate data will be analysed.

For the undergraduate degree, in Fig. 3 it is possible to observe that the relative frequencies pertaining to Formative Assessment (FA) fall at the highest level of the Likert-type scale, at L7 (close to 70%), whilst the rest of the variables fall at L7 at close to 35% (in the case of Engagement (ENG)) and almost 50% (in the case of Project-based Learning (PBL)). In adding the relative frequencies of L6 and L7, the variable FA falls at 90% of students, whilst Inverted Classroom (IC), Learning Performance (LP), Active Learning (AL), PBL and ENG require L5, L6 and L7 to be added together in order to obtain 82%, 60%, 80%, 72% and 67%, respectively. In Fig. 4, the sum of L1, L2 and L3 only equates to 10% of students.

For the postgraduate degree, it is possible to observe that the variable FA is not as concentrated as in the case of the undergraduate degree. Instead, it is spread across several values on the Likert-type scale. However, that being said, 70% of student responses are concentrated at L6 and L7. By observing Fig. 6 for the postgraduate degree, it is possible to see that approximately 17% of responses are concentrated at L1, L2 and L3, whereas in the case of the undergraduate degree they stood at less than 10%. We can see that PBL reaches a percentage of approx. 87% when adding L5, L6 and L7 (in the undergraduate degree this figure stood at 72%). IC has approximately the same percentages as in the undergraduate degree. AL is also higher than in the

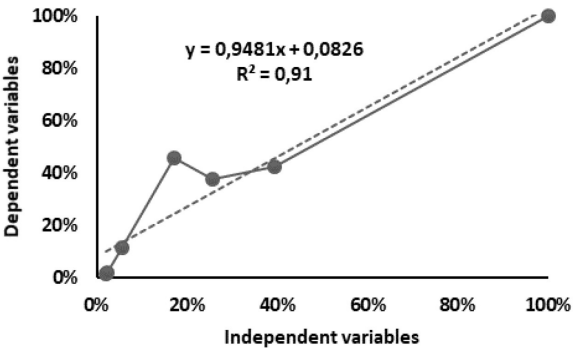

Fig. 11. Correlation between independent and dependant variables.

undergraduate degree, standing at around 89%, as does ENG, which stands at 89% versus 67%.

Following the analysis of the aggregate results for the undergraduate and postgraduate degrees (Fig.7 and Fig. 8) it was observed that both graphs display good results for FA in the undergraduate degree, and good results for PBL in the postgraduate degree.

In order to be able to verify hypothesis H1, we must first perceive of the methodology as if it were a system. In said system the inputs are the independent variables: IC, PBL and FA, and the outputs are the latent variables: ENG, AL and LP. We must then study the linear combination of the input variables and also the output variables.

In Fig. 11, it is possible to contrast both of the aforementioned linear combinations. Finally, measurements are taken to obtain the Pearson correlation coefficient. In this study a result of 0.954 was obtained, thus proving hypothesis H1.

6. Conclusions

In this work we have presented a methodology that integrates several learning strategies. The results have show that inverted classroom and project-based learning strategies fosters the active participation and improves collaboration in both undergraduate and postgraduate students, although the results have revealed that some differences exist the two degrees. The learning strategy and continuous assessment (formative assessment) were rated positively in both degrees, but significantly more so in the undergraduate degree. The author of this paper believe that the difference may possibly be due to the type of learning (blended-learning or online), ages or educational level. The results do allow us to recommend the methodology presented for use in other subjects that fall within Engineering qualifications. The results obtained in the experimentation with SIENA indicate that the tool is accepted by all students, although another teaching-learning tool could equally be integrated into the proposed methodology. The experimentation focused on the Instructional Phase of the methodology; however it would be pertinent to evaluate it at all stages of different academic courses, especially in the Final Phase because of the feedback offered.

References

1. B. Communiqué, Making the most of our potential: Consolidating the European Higher Education Area, in *Conference of Ministers responsible for higher education, Bucharest*, 2012.
2. D. Crosier and T. Parveva, *The Bologna process: Its impact in Europe and beyond*, UNESCO, 2013.
3. L. A. Van Dijk and W. M. G. Jochems, Changing a traditional lecturing approach into an interactive approach: Effects of interrupting the monologue in lectures, *International Journal of Engineering Education*, **18**, pp. 275–284, 2002.
4. M. K. Kim, S. M. Kim, O. Khera and J. Getman, The experience of three flipped classrooms in an urban university: an exploration of design principles, *The Internet and Higher Education*, **22**, pp. 37–50, 2014.
5. J. O'Flaherty and C. Phillips, The use of flipped classrooms in higher education: A scoping review, *The Internet and Higher Education*, **25**, pp. 85–95, 2015.
6. Z. Zhang, C. T. Hansen and M. A. E. Andersen, Teaching Power Electronics With a Design-Oriented, Project-Based Learning Method at the Technical University of Denmark, *IEEE Trans. Education,* **59**, pp. 32–38, 2016.
7. R. Hernández, Does continuous assessment in higher education support student learning?, *Higher Education,* **64**, pp. 489–502, 2012.
8. J.-L. Poza-Lujan, C. T. Calafate, J.-L. Posadas-Yagüe and J.-C. Cano, Assessing the Impact of Continuous Evaluation Strategies: Tradeoff Between Student Performance and Instructor Effort, *IEEE Trans. Education,* **59**, pp. 17–23, 2016.
9. L. Moreno, B. Popescu and C. Groenwald, Teaching Computer Architecture using a collaborative approach: the SIENA tool, tutorial sessions and problem solving, *International Journal of Engineering Education,* **29**, pp. 510–519, 2013.
10. J. L. Bishop and M. A. Verleger, The flipped classroom: A survey of the research, in *ASEE National Conference Proceedings, Atlanta, GA*, 2013.
11. J. Yan, L. Li, J. Yin and Y. Nie, A Comparison of Flipped and Traditional Classroom Learning: A Case Study in Mechanical Engineering, *International Journal of Engineering Education*, **34**, pp. 1876–1887, 2018.
12. I. M. Estévez-Ayres, J. Arias-Fisteus, L. Uguina, C. Alario-Hoyos and C. Delgado Kloos, Uncovering Flipped-classroom Problems at an Engineering Course on Systems Architecture through Data-driven Learning Design, *International Journal of Engineering Education*, 2017.
13. Y. Kim and C. Ahn, Effect of Combined Use of Flipped Learning and Inquiry-Based Learning on a System Modeling and Control Course, *IEEE Transactions on Education*, **61**, pp. 136–142, 2018.
14. F. Kong and H. Liu, Applying fuzzy analytic hierarchy process to evaluate success factors of e-commerce, *International Journal of Information and Systems Sciences*, **1**, pp. 406–412, 2005.
15. T. N. T. Thai, B. De Wever and M. Valcke, The impact of a flipped classroom design on learning performance in higher education: Looking for the best "blend" of lectures and guiding questions with feedback, *Computers & Education*, **107**, pp. 113–126, 2017.
16. G. S. Mason, T. R. Shuman and K. E. Cook, Comparing the effectiveness of an inverted classroom to a traditional classroom in an upper-division engineering course, *IEEE Transactions on Education*, **56**, pp. 430–435, 2013.

17. N. Warter-Perez and J. Dong, Flipping the classroom: How to embed inquiry and design projects into a digital engineering lecture, in *Proceedings of the 2012 ASEE PSW Section Conference*, 2012.
18. I. Clark, Formative assessment: Assessment is for self-regulated learning, *Educational Psychology Review*, **24**, pp. 205–249, 2012.
19. O. Arbelaitz, J. I. Martí, J. Muguerza and others, Analysis of introducing active learning methodologies in a basic computer architecture course, *IEEE Transactions on Education*, **58**, pp. 110–116, 2015.
20. J. Stolk and R. O. B. E. R. T. Martello, Pedagogical Fusion: Integration, Student Direction, and Project-Based Learning in a Materials Science-History of Technology Course Block, *International Journal of Engineering Education*, **22**, p. 937, 2006.
21. C. English and A. Kitsantas, Supporting student self-regulated learning in problem-and project-based learning, *Interdisciplinary Journal of Problem-Based Learning*, **7**, p. 6, 2013.
22. C. Moler and others, *MATLAB users' guide*, University of New Mexico, 1982.
23. J. W. Eaton and G. N. U. Octave, *A high-level interactive language for numerical computations* (Edition 3 for version 2.0. 13, 1997).
24. Y. Piguet, *SysQuake: User's manual. Calerga. Lausanne Federal Polytechnic School Automatics Institute, 1999*, 2014.
25. L. Moreno, C. Gonzalez, I. Castilla, E. J. Gonzalez and J. Sigut, Use of constructivism and collaborative teaching in an ILP processors course, *IEEE Transactions on Education*, **50**, pp. 101–111, 2007.
26. V. V. Lima, Constructivist spiral: An active learning methodology [Espiral construtivista: Uma metodologia ativa de ensino-aprendizagem] [Espiral constructivista: Una metodología activa de enseñanza y aprendizaje], *Interface: Communication, Health, Education*, **21**, pp. 421–437, 2017.
27. L. M. Ruiz, D. C. Nieves, B. Popescu-Braileanu and C. S. G. González, Methodological proposal for automatic evaluation in collaborative learning, in *Global Engineering Education Conference (EDUCON), 2018 IEEE*, 2018.
28. B. P. *Integrated Teaching and Learning System*, University of La Laguna, 2009. [Online]. Available: http://proysiena.ull.es/. [Accessed 10 June 2019].
29. C.-H. Lee, G.-G. Lee and Y. Leu, Application of automatically constructed concept map of learning to conceptual diagnosis of e-learning, *Expert Systems with Applications,* **36**, pp. 1675–1684, 2009.
30. S. Kardan and A. Kardan, Towards a more accurate knowledge level estimation, in *Information Technology: New Generations, 2009, ITNG'09. Sixth International Conference on*, 2009.
31. S. Auer, C. Bizer, G. Kobilarov, J. Lehmann, R. Cyganiak and Z. Ives, Dbpedia: A nucleus for a web of open data, *The Semantic Web*, pp. 722–735, 2007.
32. V. Venkatesh, M. G. Morris, G. B. Davis and F. D. Davis, User acceptance of information technology: Toward a unified view, *MIS Quarterly*, pp. 425–478, 2003.
33. M. Lescevica, E. Ginters and R. Mazza, Unified theory of acceptance and use of technology (UTAUT) for market analysis of FP7 CHOReOS products, *Procedia Computer Science*, **26**, pp. 51–68, 2013.
34. F. Glazer, *Blended learning: Across the disciplines, across the academy*, Stylus Publishing, LLC., 2012.

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