# Application of a Teaching Plan for Algorithm Subjects with Active Methodologies: a Pilot Case Study Report

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***Abstract*—This Research to Practice Full Paper presents that teaching of algorithms or an equivalent subject is quite challenging in higher education courses in computing. The algorithms subject, in Computing courses, represents the basis for the formation of skills related to computer programming, where it is through these introductory courses that most students will have their first contact with computer programming The learning of teaching units in the subject of algorithms is considered complex, requiring a greater effort to acquire knowledge. Difficulties in completing the course satisfactorily can be one of the reflections of the high failure rates in the course, which can vary between 40% and 50%. In this sense, several intervention proposals have been explored in the literature with the aim of promoting improvements in the teaching and learning of algorithms, with emphasis on the use of active methodologies, which allow students to be engaged and become protagonists in their learning, making them take the lead in their learning and, consequently, increasing their engagement and interest in the contents covered in the subject of algorithms. Therefore, the purpose of this work is to present a pilot study that consisted in the application of a teaching plan for the algorithms subject that uses the active approaches: Virtual Learning Environments, Coding Dojo, Gamification, Problem Based Learning, Flipped Classroom and Serious Games. The objective of the pilot study was to evaluate, based on the students' perception, the applicability of the intervention proposal presented in this work. The results were considered promising and may contribute to future research by providing a support instrument for the algorithms subject, as well as its good usage practices. So, this paper this paper presents: (i) the research methodology, detailing its main steps, (ii) a pilot case study, which allowed the application of the proposal presented in this work, (iii) the results of the evaluation and the discussions related to the study**.

***Keywords—active methodologies, algorithms, teaching plan, case study, evaluation.***

## I INTRODUCTION

The algorithms subject, in Computing courses, represents the basis for the formation of skills related to computer programming, where it is through these introductory courses that most students will have their first contact with computer programming [1]. As it is a basic subject, it requires the development of algorithmic skills, such as logical reasoning, abstraction and interpretation of problems to solve them through a sequence of steps, that is, algorithmically [2].

For [3], the subject of algorithms or equivalent seeks the development of skills and competences that significantly contribute to the development of programming skills, such as programming logic and the abstraction needed to solve problems in an algorithmic way.

Despite the importance of the subject of algorithms in the development of programming skills and in the training of students in computing, failure rates in algorithms are high, and failure rates can be reached that vary between 40% and 50% [4], [5].

For [4], in teaching the subject of algorithms, the traditional methodology is commonly used, through lectures where the teacher is the central character of the teaching and learning process, acting as holder of knowledge. Students act as spectators, whose learning is mainly focused on memorization, fixation and reproduction of concepts and contents [3].

For [6], there is a set of difficulties that are faced by students and that need to be minimized, such as interpretation of computational problems and how to solve them properly, discouraging attitudes in the face of difficult problems in which students have difficulties of solving, not understanding key concepts, little math skills and lack of motivation.

One of the ways to minimize such problems is to use forms of intervention that allow the development of active work by the students, making them take the

lead in their learning and, consequently, increasing their engagement and interest in the contents covered in the subject of algorithms [7], [8] and [9].

Therefore, this work seeks to present the results of the application of a study of a teaching plan for the subject of algorithms that makes use of multiple active approaches such as Virtual Learning Environments - VLE, Coding Dojo, Gamification, Problem-Based Learning (Problem Based Learning - PBL), Flippes Classroom and Serious. In addition, we sought to evaluate the students' perception of the application of this proposal in learning algorithms.

In addition to this introductory section, this paper is structured as follows: Section II presents the research methodology, detailing its main steps, Section III presents the related works, Section IV presents a case study, which allowed the application of the proposal presented in this work, Section V presentes the results of the evaluation, Section VI presents the discussions related to the study, and, finally, Section VII presents the conclusions, limitations of this study and future work.

## II RESEARCH METHODOLOGY

This research is the result of carrying out a sequence of steps that were defined in order to achieve, in a coordinated manner, the objectives related to the evaluation of the use of a teaching plan for the subject of algorithms based on the students' perception. The steps adopted that enabled the application of the aforementioned material will be presented in the next subsections.

### *A. Review of Specialized Literature*

The choice of approaches was based on a previous work [10], which consisted of conducting a quasi-Systematic Literature Review (RqSL), allowing to identify the main active methodologies that are being used in teaching algorithms. A total of 1014 studies were analyzed, where the summarization of the data allowed to identify the positive and negative aspects of each methodology found, as well as its way of application in the courses.

From the analysis of active methodologies, it was possible to establish a strategy for the joint use of some methodologies within a teaching plan for the subject of algorithms, so that each methodology can be correlated with a set of teaching units in the subject.

### *B. Analysis of Active Methodologies for Use in the Subject of Algorithms*

A strategy for the joint use of active methodologies that were selected from the results generated by [10] was defined. Each methodology was analyzed and had an identified purpose for its use, as shown in Table I.

TABLE I. ACTIVE APPROACHES IDENTIFIED.

| Approach | Purpose |
|---|---|
| **Virtual Learning Environment – VLE** | Provision of Materials, Communication, Data Sharing, Socialization of knowledge. |
| **Coding Dojo** | Active practice of active activities focused on the community to solve problems and share ideas. |
| **Gamification** | Insertion of game elements to guide the evaluation of the subject of algorithms in an active way. |
| **Problem Based Learning - PBL** | Active practice of activities focused on student engagement and proactivity through activities focused on solving problems in an active way. |
| **Flipped Classroom** | Active practice of seeking and acquiring extra-class knowledge autonomously. |
| **Serious Games** | Insertion of game logic to engage students in knowledge acquisition. |

In this sense, the authors of [11] present a strategy for the application of active teaching methodologies for the subject of algorithms from an exploratory study on how to use them. The details presented in that work were planned based on good practices identified in the specialized literature and the proposed use was evaluated using a peer review technique that included the participation of experts in the use of active methodologies, as well as in the teaching of algorithms.

The evaluation made it possible to carry out a technical analysis of the correct applicability of active methodologies in the teaching units of the subject of algorithms, and its results allowed the identification of points of improvement, as well as elements that could compromise the applicability of the proposal.

### *C. Definition of the Teaching Plan*

Furthermore, the work [12] presents the teaching plan for the subject of algorithms, which makes use of multiple active approaches. The aforementioned teaching plan was divided into modules, which allow students to actively work on the contents of the subject, in addition to enabling the professor to monitor the evolution of the class in each class through a ranking that uses gamification criteria to record the performance of each student [12].

The model proposed by authors of [12] has a duration of 68 class hours and has the following modules:

- Initial Evaluation Module (2 class hours): it happens on the first day of the course and makes it possible to identify prior knowledge that the student has and that can be used during the course,
- Teaching Modules I, II and III (18, 24 and 22 class hours, respectively): these are modules intended for teaching and learning the subject. In these modules, classes and evaluation activities take place, which will be guided by active methodologies applied to the content of each teaching module,
- Final Evaluation Module (2 class hours): it happens at the end of the course and makes it possible to identify the positive and negative aspects of the course, as well as the benefits and difficulties found in the use of each methodology, thus enabling a continuous improvement of the proposal.

### *D. Evaluation of the Teaching Plan through Peer Review*

The teaching plan was evaluated using the peer review technique, which made it possible to identify some items that could be improved to provide greater accuracy of the proposed material. The evaluation results are presented in [12], which carry out a more in-depth discussion on the improvement items that were identified and which corrective actions were taken based on the adjustments to the plan suggested by the reviewers.

## III RELATED WORKS

In [13] the results of a study that used the gamification methodology in algorithms subjects are presented. The authors realized that the use of game elements with homogeneous data structure contents allowed increasing student engagement, making them start to dedicate themselves more to the studies of the components taught in the classroom, causing there to be a increase in the final grades of the students who participated in the study.

The work of [14] carries out a study focused on the use of the active methodology of tutoring applied in the subject of algorithms. The study was applied through 16 tutoring meetings with individual follow-up of students. The study also evaluated the relevance of the follow-up carried out in the proposed approach and obtained positive feedback, showing that the approach was well accepted by the participants.

In [15] the joint application of the active methodologies Flipped Classroom, Collaborative Learning and Gamification was carried out. The joint use allowed the creation of a prototype that consisted of a collaborative environment for teaching/learning programming. The study involved the participation of two groups of students, the first being composed of students who studied through the proposed approach and the second having traditional classes. The results showed that the first group obtained higher scores than the group that used the traditional approach.

In [16] the reports obtained through a study carried out in the subject of algorithms that consisted of the use of active methodologies through a set of actions are presented. The results of the study indicated that there was an increase in the approval rates in the classes that participated in the experiment.

The work of [17] made a study based on the joint use of active methodologies Problem Based Learning - PBL and Flipped Classroom, in order to increase student engagement and autonomy. The authors made a comparison between the proposed approach versus the traditional teaching method, the results obtained showed that the joint use of active methodologies generates positive effects on learning and that it can stimulate students as well as develop their logical reasoning.

Given the above, it is possible to observe that the results found in the specialized literature, despite showing promising results, are still focused, mainly, on the use of one or two specific approaches, not presenting many details about the implementation strategy of these approaches or about the elaboration of a teaching plan that details the implementation of these approaches or their relationship with the algorithm teaching units. This research presents a different aspect from the others because in addition to using multiple forms of intervention, it seeks to evaluate from the point of view of students of higher education courses in the area of computing the effects of using a teaching plan based on active methodologies Virtual Learning Environments, Coding Dojo, Gamification, Problem Based Learning, Flipped Classroom and Serious Games.

## IV CASE STUDY

The case study was carried out in 2021, in July and August, in the format of an algorithms extension course with a workload of 68 class hours and had the participation of undergraduate students of courses in computing and who had not yet attended the subject of algorithms in their regular course.

As the teaching plan had already been evaluated by experts through peer review, the case study sought to evaluate the effects of using the teaching plan in an algorithms subject from the students' point of view, so that, in this way, make it possible to obtain feedback from both sides of the teaching and learning

process, through professors and students, respectively.

All participants in the case study were volunteers and the case study was carried out with 10 participants. In addition, the course had a teacher with more than 5 years of experience in teaching algorithms and had the support of an assistant tutor, who was responsible for conducting the course through the application of the teaching plan.

On average, 3 weekly virtual meetings were held, lasting approximately 4 class hours per meeting and the case study lasted 6 weeks, totaling 17 virtual meetings. These classes took place remotely due to the COVID-19 pandemic.

The case study was guided by the teaching plan, which guides how to conduct each teaching unit and which active methodology can be used in each class day [12]. Based on the guidelines of the teaching plan, in the first contact with the students (Day 1), a survey of information from the students was carried out, seeking to know a little about their socioeconomic profile, as well as their prior knowledge that could be applied in the subject. For this, an evaluative questionnaire was applied, which has multiple choice questions. The questionnaire also contained a challenge that presents a problem that can be solved using logic, whose purpose was to identify whether the steps used in the resolution have a logical sequencing of ideas, the questionnaire can be consulted at *https://zenodo.org/record/6380849*.

After collecting information, the teaching plan was presented emphasizing its approaches and forms of evaluation. With the completion of this step, the theoretical and practical classes began with their respective approaches and forms of evaluation, as directed by the teaching plan for the subject of algorithms.

At the end of the course content, a final evaluation of the teaching plan was carried out based on feedback from students, aiming to identify, in general, the positive and negative aspects of the approaches used in the course. For this step, an electronic spreadsheet based on the best practices of SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) was used. SWOT analysis was chosen due to the possibility of identifying vulnerabilities and points of adjustment in the teaching plan based on student feedback.

We chose to use this approach, because at the end of the course, students can have a macro view of the course and, with the SWOT analysis, it was possible to identify factors that contributed to the improvement of learning, as well as points that could be improved and adjusted for future applications of the teaching plan. In addition, a challenge was also applied that presented a problem that could be solved with the use of logic and programming knowledge, whose purpose was to identify whether the steps used in the resolution had a logical sequencing of ideas and whether the knowledge of languages programming were applied correctly. With this final test, it was possible to compare it with the initial test that was carried out on the first day and verify the evolution of the students' knowledge through the application of the contents learned in the course in their final answers.

## V EVALUATION

As a way to quantitatively measure the effectiveness of the PBL, Flipped Classroom, Coding Dojo, Gamification and Serious Games methodologies, an analysis of the activities that were guided by such approaches was carried out. In this sense, the maximum score that the student could achieve in the task that used the methodologies was compared against the score achieved. The calculation of effectiveness was based on Equation I.

$$Effectiveness = \frac{\left(\frac{A1 * 100}{Max}\right) + \left(\frac{A2 * 100}{Max}\right) + \left(\frac{An * 100}{Max}\right)}{N}$$

EQUATION I. EFFECTIVENESS CALCULATION.

Where:

- **A1**, **A2**, ..., **An**, represent the scores obtained by the students,
- **100**, represents the multiplication factor used to obtain the total percentage value,
- **Max**, represents the maximum score that can be obtained in the activities,
- **N**, represents the total number of students who participated in the case study.

In addition, as a way of classifying the percentages of effectiveness of the methodologies, the following indicators were defined (Critical, Alert and Satisfactory), it is important to highlight that a scale of 3 indicators was used due to the low number of participants in the study, therefore not there was a need to add more precision indicators:

- **0 - 50% effectiveness – Critical**: this indicator represents Inefficiency and Ineffectiveness in Teaching and Learning using the Active Methodology,
- **51% - 70% effectiveness – Alert**: this indicator represents a possible Efficiency and Effectiveness in Teaching and Learning using the Active Methodology, but with still doubtful gains,

- **71% - 100% Effectiveness – Satisfactory**: this indicator represents Efficiency and Effectiveness in Teaching and Learning using the Active Methodology.

### *A. Quantitative Analysis of the PBL Methodology*

The quantitative analysis of the PBL methodology took into account all activities that were influenced by the use of this methodology. In this sense, the following activities were listed: Challenges (DES), Extra-Class Challenges (DEC) and Mission (M). The maximum score that could be obtained with the sum of all Challenges is 11 points, in the same way the Extra-Class Challenges are equivalent to 4 points and the Mission 10 points. Thus, the Maximum score (Max) of these activities is equivalent to 25 points.

The score obtained by the students was extracted from the activities they performed and was included in Table II, which allowed for the identification of the effectiveness of the PBL methodology.

TABLE II. EFFECTIVENESS OF THE PBL METHODOLOGY.

| PBL | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Activities** | **A1** | **A2** | **A3** | **A4** | **A5** | **A6** | **A7** | **A8** | **A9** | **A10** | **Max** |
| DES 1 | 1 | 0,75 | 1 | 0,75 | 1 | 0,75 | 1 | 0,75 | 1 | 0,75 | 1 |
| DES 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| DES 3 | 0,75 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0,75 | 1 | 1 |
| DES 6 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| DES 7 | 1 | 1 | 0,75 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| DES 8 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| DES 9 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0,75 | 1 | 1 | 1 |
| DES 12 | 0,75 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| DES 13 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| DES 14 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| DES 15 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| DEC 1 | 1,8 | 1,6 | 1,5 | 1,6 | 1,9 | 1,6 | 1,9 | 1,6 | 1,9 | 1,6 | 2 |
| DEC 2 | 1,2 | 0,9 | 1,1 | 0,8 | 1,3 | 0,9 | 1,3 | 0,9 | 1,3 | 1,3 | 2 |
| M1 | 7,5 | 8,5 | 7 | 8 | 7,5 | 7 | 7,5 | 8 | 7,5 | 8,5 | 10 |
| **Total** | **21** | **21,75** | **20,35** | **21,15** | **21,7** | **20,25** | **21,7** | **21** | **21,45** | **22,15** | **25** |
| **Effectiveness** | **85,0%** | | | | | | | | | | |

The tabulation of the data allowed to calculate the effectiveness of the PBL methodology, indicating that it reached an index of 85.00%, this indicator being classified as satisfactory.

### *B. Quantitative Analysis of the Flipped Classroom Methodology*

The quantitative analysis of the Flipped Classroom methodology contemplated all activities that were impacted by the use of this methodology, namely: DES, DEC and M. The maximum score that could be obtained with the sum of DES is 4 points, similarly DEC equivalent to 2 points and the Mission (M3) 10 points. Thus, the Maximum Score (Max) of these activities is equivalent to 16 points. In this sense, the score achieved by the students was extracted from the activities carried out and was included in Table III, which allowed for the identification of the effectiveness of the Flipped Classroom methodology.

TABLE III. EFFECTIVENESS OF THE FLIPPED CLASSROOM METHODOLOGY.

| Flipped Classroom | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Activities** | **A1** | **A2** | **A3** | **A4** | **A5** | **A6** | **A7** | **A8** | **A9** | **A10** | **Max** |
| DES 12 | 0,75 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| DES 13 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| DES 14 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| DES 15 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| DEC3 | 2 | 1,9 | 1,7 | 1,9 | 2 | 1,5 | 2 | 2 | 2 | 1,7 | 2 |
| M3 | 7,5 | 8 | 7,5 | 7 | 8 | 6,5 | 9 | 9,5 | 7,5 | 7 | 10 |
| **Total** | **13,25** | **13,9** | **13,2** | **12,9** | **14** | **12** | **15** | **15,5** | **13,5** | **12,7** | **16** |
| **Effectiveness** | **84,97%** | | | | | | | | | | |

The maximum score that could be achieved is 16 points. In this sense, the calculation of the effectiveness of the Flipped Classroom methodology showed that its percentage of use was 84.97%, this indicator being classified as satisfactory.

### *C. Quantitative Analysis of the Serious Games Methodology*

The quantitative analysis of the Serious Games methodology covered the activities that were influenced by this form of intervention, therefore the activities DES (6, 7, 8 and 9), DEC (2) and M (3) were analyzed. The maximum score that could be obtained with the sum of all Challenges is 4 points, in the same way Extraclass Challenges equal 2 points and Mission 10 points. Thus, the Maximum Score (Max) of these activities is equivalent to 16 points. The scores obtained by the students in these activities were extracted, as shown in Table IV, which contains data that allowed for the identification of the effectiveness of the Serious Games methodology.

TABLE IV. EFFECTIVENESS OF THE SERIOUS GAMES METHODOLOGY.

| Serious Games | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Activities** | **A1** | **A2** | **A3** | **A4** | **A5** | **A6** | **A7** | **A8** | **A9** | **A10** | **Max** |
| DES 6 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| DES 7 | 1 | 1 | 0,75 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| DES 8 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| DES 9 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0,75 | 1 | 1 | 1 |
| DEC 2 | 1,2 | 0,9 | 1,1 | 0,8 | 1,3 | 0,9 | 1,3 | 0,9 | 1,3 | 1,3 | 2 |
| M2 | 9 | 7 | 7 | 8,5 | 7,5 | 8 | 7,5 | 8 | 9 | 7,5 | 10 |
| **Total** | **14,2** | **11,9** | **11,85** | **13,3** | **12,8** | **12,9** | **12,8** | **12,65** | **14,3** | **12,8** | **16** |
| **Effectiveness** | **80,94%** | | | | | | | | | | |

The maximum score that could be achieved is 16 points. In this sense, the calculation of the effectiveness of the SAI methodology showed that its percentage of use was 80.94%, this indicator being classified as satisfactory.

### *D. Quantitative Analysis of the Coding Dojo Methodology*

The quantitative analysis of the Coding Dojo methodology sought to identify the activities that were influenced by its use. In this sense, the activities COD - Coding Dojo (1, 2 and 3), M (1, 2, 3) were analyzed. The maximum score that could be obtained with the sum of all COD is 3 points, in the same way Missions (M) total 30 points. Thus, the Maximum Score (Max) of these activities is equivalent to 33 points. The scores obtained by the students in these activities were extracted, as shown in Table 5, which contains data that allowed us to identify the effectiveness of the Coding Dojo methodology.

Given the results in Table V, the data tabulation allowed calculating the effectiveness of the Coding Dojo methodology, indicating that it reached an index of 78.33%, this indicator being classified as satisfactory.

### *E. Quantitative Analysis of the Gamification Methodology*

By analyzing the effectiveness of the Gamification methodology, we sought to identify the game elements that were used as evaluation criteria. In this sense, the following criteria were listed: Bonus, Penalties and Score acquired for carrying out activities, as shown in Table VI.

It can be observed that the maximum score that could be obtained through activities involving gamification reached an index of 72.92%, this indicator being classified as satisfactory.

TABLE V. EFFECTIVENESS OF THE CODING DOJO METHODOLOGY.

| Coding Dojo | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Activities** | **A1** | **A2** | **A3** | **A4** | **A5** | **A6** | **A7** | **A8** | **A9** | **A10** | **Max** |
| COD 1 | 0,5 | 1 | 0,7 | 0 | 0,9 | 1 | 0,8 | 1 | 0,9 | 0 | 1 |
| COD 2 | 0,8 | 1 | 1 | 0,8 | 1 | 1 | 1 | 0,7 | 0,9 | 1 | 1 |
| COD 3 | 0,8 | 0,9 | 0,9 | 0,7 | 1 | 1 | 1 | 0,7 | 1 | 1 | 1 |
| M1 | 7,5 | 8,5 | 7 | 8 | 7,5 | 7 | 7,5 | 8 | 7,5 | 8,5 | 10 |
| M2 | 9 | 7 | 7 | 8,5 | 7,5 | 8 | 7,5 | 8 | 9 | 7,5 | 10 |
| M3 | 7,5 | 8 | 7,5 | 7 | 8 | 6,5 | 9 | 9,5 | 7,5 | 7 | 10 |
| **Total** | **26,1** | **26,4** | **24,1** | **25** | **25,9** | **24,5** | **26,8** | **27,9** | **26,8** | **25** | **33** |
| **Effectiveness** | **78,33%** | | | | | | | | | | |

TABLE VI. EFFECTIVENESS OF THE GAMIFICATION METHODOLOGY.

| Gamification | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Activities** | **A1** | **A2** | **A3** | **A4** | **A5** | **A6** | **A7** | **A8** | **A9** | **A10** | **Max** |
| Bonus | 414 | 470 | 395 | 518 | 587 | 450 | 603 | 501 | 520 | 437 | 720 |
| Penalties | -20 | -30 | -25 | -65 | -28 | -50 | -10 | -33 | -25 | -40 | -277 |
| Score | 1048,8 | 915,6 | 800,5 | 900 | 1100 | 930,4 | 973 | 915,6 | 932 | 915,6 | 1200 |
| **Total (Ranking)** | 1442,8 | 1355,6 | 1170,5 | 1353 | 1659 | 1330,4 | 1566 | 1383,6 | 1427 | 1312,6 | 1920 |
| **Effectiveness** | **72,92%** | | | | | | | | | | |

### *F. Quantitative Analysis of the Virtual Learning Environments Methodology*

The evaluation of the effectiveness of the Virtual Learning Environment was based on the analysis of the use of the tool by downloading materials from the course of the classes, as well as uploading the tasks performed by the students within the stipulated deadlines, so that the non-compliance with any of these tasks would imply a proportional reduction in the percentage of student access, as shown in Table VII.

The results of the analysis of the Virtual Learning Environment used (Google Classroom) showed that the effectiveness index of the virtual environment showed a result of 97.00%, this indicator being classified as satisfactory.

Based on the results, it could be observed that all active methodologies used had an effectiveness rate

higher than 70%, with the Virtual Leanring Environment methodology showing the highest result (97.00%), while Gamification had the lowest result (72, 92%).

TABLE VII. EFFECTIVENESS OF THE VIRTUAL LEARNING ENVIRONMENT.

| Virtual Learning Environment (Google Classroom) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Activities** | **A1** | **A2** | **A3** | **A4** | **A5** | **A6** | **A7** | **A8** | **A9** | **A10** | **Max** |
| Delivered Activities | 17 | 17 | 17 | 16 | 17 | 17 | 17 | 17 | 17 | 16 | 17 |
| Download Materials | 100 % | 100 % | 100 % | 100 % | 100 % | 100 % | 100 % | 100 % | 100 % | 100 % | 100 % |
| Access percentage | 100 % | 100 % | 100 % | 85,00% | 100 % | 100 % | 95 % | 97 % | 100 % | 94,11% | 100 % |
| **Effectiveness** | **97,00%** | | | | | | | | | | |

## VI EVALUATIVE DISCUSSION

The data obtained allowed to identify the perception of students from the use of the teaching plan. It is important to highlight that, due to the low number of participants, the results cannot be generalized, but allow for an insight into the possible effects of applying the proposed teaching plan and its multiple active approaches in a real scenario, highlighting the point of view of student from the use of teaching strategies.

It can be noted that the active methodologies used in the study: Virtual Learning Environment (97.00%), Problem-Based Learning (85.00%), Flipped Classroom (84.00%), Serious Games (80.94%), Coding Dojo (78.33%) and Gamification (72.92%) were classified as satisfactory, as they all reached an effectiveness rate higher than 70%.

The Virtual Learning Environment (VLE) methodology was the only one that the participants reported having familiarity with, as they already used it in their undergraduate courses. The VLE had the highest score (97.00%), this may be a reflection of the prior knowledge that the participants already had with the VLE tools, so there was no rejection or great difficulties in handling them.

Feedback from participants for the use of VLE positively highlighted points such as (i) “Good organization of the tool, simple and easy to use”, and (ii) “It enhances communication between class members, as well as making content accessible in an accessible way”.

With regard to the Problem-Based Learning, Flipped Classroom and Serious Games methodologies, they presented effectiveness scores with a very similar percentage, where the participants, despite never having participated in interventions that made use of these methodologies, reported that they contributed significantly to the increased engagement and autonomy in the learning process, so that they would always want to learn more, more independently, making them more participative and proactive.

Coding Dojo was the methodology that had the smallest participation within the teaching plan, being applied in key moments of the study as a way to engage and prepare students for the evaluation activities that were carried out at the end of each teaching module. This may have reflected in their effectiveness rates, making them above only the gamification methodology. Feedback from participants on the use of Coding Dojo positively highlighted points such as the possibility of group work, cooperativeness and active practices that encourage content fixation.

Gamification was the one with the lowest percentage of effectiveness among the methodologies used, this may be a reflection of the way the methodology was used in the study, in order to act on the inclusion of game elements that guided the rules for scoring and penalties of the study, so that the higher the scores obtained by the participants through the delivery of tasks and other bonuses or penalties, the values would be directly reflected in the effectiveness score of the proposed methodology.

It is noteworthy that, despite the gamification effectiveness rates being the lowest among the other methodologies used, the participants highlighted that its use was extremely important, as it made it possible to use elements that promote a healthy dispute for knowledge and this was directly reflected in the quality of their work and in their grades. Feedback from participants on the use of Gamification positively highlighted points such as the search for knowledge through healthy competitiveness, autonomous learning and playful dynamics through game elements.

## VII CONCLUSION

The results of the implementation of this study provided preliminary evidence that the approach to teaching algorithms based on multiple active methodologies reported in this research was well accepted by students and enabled the achievement of good performance results, which were reflected in the final grades. obtained by the participants of the study.

As contributions to this work, it was found that the teaching plan elaborated and evaluated through the peer review technique in [12] has feasibility of application within a subject of algorithms and that the way with that active methodologies were correlated with teaching units can enable professors and students to have new positive experiences in the process of teaching and learning algorithms.

This work can be considered as an exploratory study that aims to obtain a view from the perspective of the student with regard to the experience and learning effectiveness provided by the teaching proposal explored in this work, allowing to identify its advantages, disadvantages and, in this way, to know what can be improved in the teaching plan based on feedback from participants.

The form of use of each active methodology was applied and evaluated through this study. The evaluation included the participation of students from higher education courses in computing, who had not yet taken the course of algorithms. The evaluation results made it possible to identify points of improvement, which will be adjusted so that the technical quality of the use of each active methodology is enhanced.

The results were of great importance, considering that the participants showed during the course that the teaching and learning process of algorithms was achieving positive results, so that the participants reported that the active methodologies motivated them to seek and learn the contents of course. In this sense, the results obtained in this study are significant and consistent, but it is important to emphasize that the results cannot be generalized to other application contexts yet, making it necessary to carry out new applications with a larger target audience.

It is expected that this work can contribute to future research that seek the joint use of active methodologies in subjects of algorithms or equivalent. It is intended to continue evolving this research, so the next steps are to adjust the teaching plan and carry out a new case study in algorithmic classes, where it is intended to use a larger number of participants as a way to validate the teaching plan, evaluating the performance of students, as well as the strengths and weaknesses of the use of each methodology used.

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