Validation of a gamified framework for teaching and learning for algorithms subject from a control group

José Augusto de Sena Quaresma
Graduate Program in Creativity and Innovation in Higher Education Methodologies (PPGCIMES)
Federal University of Pará (UFPA)
Belém – PA, Brazil
jq.quaresma12@gmail.com

Sandro Ronaldo Bezerra Oliveira
Graduate Program in Computer Sciense (PPGCC), Institute of Exact and Natural Sciences (ICEN)
Federal University of Pará (UFPA)
Belém – PA, Brazil
srbo@ufpa.br

Marianne Kogut Eliasquevici
Graduate Program in Creativity and Innovation in Higher Education Methodologies (PPGCIMES)
Federal University of Pará (UFPA)
Belém – PA, Brazil
mariane@ufpa.br

***Abstract*— This Research to Practice Full Paper presents the gamification as a teaching and learning practice that can be applied as a positive result allowing students to develop the necessary skills for the content of the Algorithms subject. In this context, we have as a guiding question for this work: How to validate a gamified framework for the Algorithms subject or equivalent for undergraduate courses in Information Technology? Thus, the main goal of this work is to validate the gamified approach proposed for the Algorithms subject in undergraduate courses in Information Technology. The gamified framework for the Algorithms subject or equivalent is an alternative to the teaching and learning process, which provides greater performance, as well as a motivation for students to be interacting in their learning process. Through the validation process, we can see that compared to the previously acquired grades, students achieved a higher performance. In addition, through the analysis within the same class between forms in the professor's practice, that is, the comparison of how the subject is taught with the gamified approach, we perceive a greater engagement of the students for the delivery of activities and participation in the class.**

Keywords—framework, gamification, algorithms

I. INTRODUCTION

The Algorithms subject is a fundamental curricular component belonging to the Computer Fundamentals core for undergraduate courses in Information Technology (IT) [1]. There are many names attributed to this subject, such as Introduction to Programming, Introduction to Computer Science, Introduction to Computer Programming, Programming Logic, among others. In this paper, the name Algorithms or equivalent will be used. Its goal is to develop in the student the ability to develop logical solutions by means of generic problems in a sequence of steps [2]. According to [3], their competencies and skills are the basis for the training of future professionals in the Information Technology areas, especially in the software development.

It is known that developing skills in building algorithms is important for the training of new professionals, as it acts as a subsidy in the continuity of the course. However, there is a high rate of failure and dropout in the subject. This situation is observed in [4][5]. In [6], some points of difficulty in the student's vision for learning the subject are listed, such as: previous knowledge of logic, difficulty in understanding and interpreting the problem. The authors of [4][5] present an overview of problems that occur in the Algorithms subject, such as dropouts and failure. However, it is possible to identify a reduction in failures and dropouts, based on the systematic review of the literature carried out in [6] on papers that propose teaching interventions in the subject. One of the interventions reported by the authors as a case of success in the literature is gamification.

Gamification is conceptualized as the use of games design, elements and characteristics in different game contexts [7]. With regard to teaching and learning practices, in [8] gamification has a positive result in many application, such as it allows students to develop the skills required for the content of subject, in addition to generates a stimulus for the development of the proposed activities.

In this context, we have as a guiding question for this work: How to validate a gamified framework for the subject Algorithms or equivalent for undergraduate courses in Information Technology? Thus, the main goal of this work is to validate the gamified approach proposed for the Algorithms subject in undergraduate courses in Information Technology.

In addition to this introductory section, this paper is structured as follows: Section 2 presents the theoretical foundation, Section 3 presents some related works, Section 4 provides the context in which the research was conducted, Section 5 briefly presents the research methodology, Section 6 presents the gamification design adopted, Section 7 presents the developed experiment in general, Section 8 presents the validation of the framework, and, finally, the conclusion and future work are portrayed in Section 9.

II. BACKGROUND

This section presents the fundamental concepts for a good understanding of the research described in this paper, contextualizing the presented work.

A. Teaching Algorithms

The teaching of Algorithms, according to [9], must be able to allow the student to develop strategies as solutions to problems, which are written in algorithmic language. During the teaching and learning process of algorithms, the professor aims to teach techniques, strategies and meta-knowledge in the most productive way possible to achieve meaningful learning by students in this field [9].

The authors in [4] report that the subject addresses the principles of programming logic, with the aim of developing students' ability to analyze and solve problems by means of their description in the form of computational algorithms.

There is no single way in which the subject can be approached. Among the most common approaches to teaching are: (i) the use of problems with textual statements, which the professor seeks to work on the student's dexterity in understanding the announced and after devising an algorithmic solution in pseudocode or in flowcharts, (ii) the student performs a "table test" to simulate step by step what the algorithm should do to verify that it is achieving the proposed objective, (iii) the professor accompanies the

students when they develop their exercises individually, (iv) students use a programming language, already on the computer, to visualize their progress, and (v) gamification, among several others. Some may be more interesting than others, but what is observed is that students still have learning difficulties [5].

In addition to our perceptions about how the process of teaching and learning algorithms can be worked on, the literature review proposed in [2] also points out some possibilities: (i) classroom teaching mediated by technologies, (ii) electronic learning, (iii) gamification, (iv) classroom teaching mediated by robots / photosnap board, (v) blended learning, and (v) mobile learning.

B. Gamification

Within the educational area, the study [8] conceptualizes gamification as the use of games elements, such as mechanics, strategies and thoughts, with the purpose of motivating individuals to action, helping to solve problems and promoting learning.

In [10], the gamified approach provides a system in which students are able to visualize the effect of their actions and learning, as they understand the relationship of the parts to the whole, as in games. Therefore, one of the main objectives of the approach is to develop in individuals the feeling of contribution to something bigger and more important, through their actions.

In [11], the researchers defend the use of game elements, through the gamified approach in education, as an alternative to traditional approaches in order to familiarize people with new technologies, streamline learning or training processes to make the most enjoyable tasks considered tedious or repetitive. The study [12] observed that the use of gamification through the material made available for teaching increases engagement, as it provides levels of pleasure to the user and contributes to the process of knowledge creation, which improves student learning.

In order to encourage the participant to develop certain activities, in particular by generating in the participant the feeling of contributing to something greater, such as changing a reality, within the context of gamification, we can identify in the approaches described in the literature different frameworks, which define the way in which gamification will be developed.

Werbach and Hunter's book [16] proposes the DMC Pyramid framework (Dynamics, Mechanics and Component), which is built around three categories of game elements, identified in the proposal's name. The key to the development of a gamified experience using this framework is the understanding of the three types of game elements, so that they can be used in the best possible way. At the top of the pyramid is the dynamic that describes game elements that cause the player to immerse themselves in the gamified experience. In the second layer of the DMC pyramid, there is the mechanics of the game, which has the function of stimulating and involving a player to perform an action in order to achieve a dynamic. In the third layer of the pyramid are the components, which have the function of making dynamics or mechanics clearer for the player, so it is registered as the lowest level of abstraction.

Chou's book [13] presents a gamified framework with several cores, which are adopted to support the use of gamification in several areas, including experimental software engineering, namely [14][15]. Some of the proposed cores are: Epic and Called Meaning that is the core responsible for making participants believe they are doing something superior or that they were chosen to perform that action, Development and Achievement that is a characteristic responsible for driving progress and developing skills, Empowerment of Creativity and Feedback that is expressed through a creative process where he repeatedly discovers new elements and possibilities of combination, Ownership and Possession that allows the user to be motivated to control a certain element of the game, Social Influence and Belonging that are motivating elements to the participants, and can be expressed by the ranking, bonuses, achievements, among others.

The gamification adopted in the work adopts the structure proposed by [13] as the basic principle, where it is possible to visualize the gamification core as groups, and in them the elements of games are composed and described.

III. RELATED WORKS

In relation to the use of gamification in learning, in [17] there is the application of the approach in a more specific context, in which it is carried out in a subject called Fundamentals of Computer Architecture, which used the classroom, a virtual space and the game developed. The application had as main objective to carry out knowledge duels among students, in which a set of duels constituted a battle, always related to one or more topics of the subject. As a result, there was greater interest and motivation of those involved in the game, in addition to an improvement in relation to the learning and absorption of knowledge by the students.

The paper [18] studied the possibility of teaching programming through the use of gamification elements, associating the approach to distance learning. The tasks that were performed in the course were divided into four phases, in which the initial concepts about the construction of algorithms were presented, and after each phase, as well as in a game, the student would advance in level until reaching the final mission, in which all the knowledge acquired would be used to solve the challenge. With that, it was noted that the approach used in fact contributed and favored engagement, in addition to improving the students' level of learning.

The work [19] aimed to develop a tool to support classroom teaching, using gamification and game design. The study proposed an environment that would stimulate the student's interest and attention outside the classroom, through the approximation of the contents worked with the digital medium. In addition, the research took into account the high demand for the Algorithms or equivalent subject in educational institutions, as a justification for the development of the tool.

The study [20] presents a conceptual model to support gamification planning, in which the context in which the approach is to be implemented, the educational objectives, the skills that will be required, the behaviors and interactions that are required are taken into account. In addition, a description of the process is carried out in the context of education, so that gamification is carried out in the correct way.

In some of the approaches mentioned in this paper, the authors opted for the development of tools or prototypes for the application of the gamification elements, while in others, only the concepts referring to the games dynamics and mechanics are used. However, the validation for the proposals was not portrayed in any of the studies.

IV. Research Methodology

This research started with an exploratory research related to the theoretical foundation both on gamification and on the teaching and learning process of algorithms. Soon after, we carried out a bibliographical and documentary research to deepen the theoretical basis and identify the related works.

The next step was the collection of requirements for product design, which was carried out through the following methodological procedures: survey, participant observation, experiment and systematic literature review (SRL). In addition, we have adopted as a base structure for the product the framework for gamifying classrooms in the field of Software Engineering [14].

Therefore, we can classify the research as applied, since it has as one of the objectives to generate knowledge and improve understanding from the gamification focused on the teaching and learning process of Algorithms. As for the approaches adopted for product analysis, we employ a combination of quantitative and qualitative. The quantitative approach can be expressed in the data and information that were stored and handled with the support of an electronic spreadsheet, in which all the scores and bonuses of each student during the gamified classes were contained. The qualitative approach was necessary to understand, first, how the interaction between professor and student in the subject Algorithms occurs, and also to assist in the systematization of data from: (i) students' opinions, criticisms and suggestions regarding the gamified approach, as well as (ii) notes made by the responsible researcher regarding the practice adopted in the classroom.

In addition, an experiment was developed with the aim of teaching the content of Homogeneous Data Structures in a gamified classroom, in which, at the end, the results were analyzed and discussed. After that moment, the results achieved were compared to those acquired by the Systematic Literature Review and the proposition of implementations for the development of the second version of the research product was carried out.

To evaluate the students' knowledge after the gamification execution, the traditional test of the subject was adopted as a basis, in this context a list of questions with algorithmic solutions. We adopted this proposal to follow what the literature adopts, which was verified by SRL in paper [24], in which it was verified that the use of theoretical test (traditional test) to evaluate knowledge after gamification, as well as experiment and group of control and without control, are adopted as a validation way. In addition, it is worth remembering that despite being different classes, the professor who conducted the subject was the same, as well as the methodology, content, instruments used, technologies, programming languages, evaluation tools (traditional test or theoretical test) and others assets defined in the education plan. It is worth remembering that the focus of this research is to evaluate the effects that the use of gamification can bring to students' learning and not to compare students or classes. To show this effect, the results obtained in a class in which the traditional pedagogical approach was used and in a class in which gamification was used as a support tool for teaching-learning will be discussed in this paper.

V. The Context: The Algorithms Subject

The Algorithms subject is one of the fundamental curricular components of Information Technology courses [1]. At the Federal University in Brazil where the grades were collected and the experiment was carried out, this subject has a workload of 68 hours, 4 hours per week, and has a regular offer in the first semester of the Bachelor's courses in Information Systems and Computer Science. The syllabus is present in the Political Pedagogical Plan of Courses, which follows the Reference Curriculum for Information Technology courses of SBC (Brazilian Computer Society) [3] and has equivalence with the Introduction to Programming subject of the IEEE/ACM curriculum [21].

As a way to validate and evaluate the proposal of the gamified framework, it was used in the most difficult content of the subject, Homogeneous Data Structures, according to a survey carried out by [22] and the participant observation that took place at this university [23].

VI. The Gamification Design: The Gamified Framework

The gamified framework consists of a set of game elements arranged in two basic documents: teaching plan and gamified spreadsheet. The bases that allowed us to develop the list of requirements for product design were: the survey [22], the participant observation carried out at the researchers' university [23], the gamification structure by [14] and a systematic literature review [24]. The elements were subdivided into the following groups: characteristics, practices, rewards and teaching resources and strategies.

The characteristics define the gamification, and have the following elements: (i) content, which identifies the content / subject to which it will be treated (Homogeneous Data Structure - array and matrix - according to the content pointed out in the survey [22] as the most difficult to teach and learn), (ii) goals, which are the teaching and learning objectives (to enable students of the subject to develop and analyze algorithms using Homogeneous Data Structure, based on the identification, implementation and tests in this type of structure), (iii) rules that define the limits and growth of players in the environment (application of bonuses and penalties for behavior, bonuses granted per class, punctuation for developed practices, application of avatars, application of medals and ranking), (iv) feedback that is the way in which the player will receive his / her progression in the game (making the gamified spreadsheet available to students at the beginning of each class and via the virtual classroom, in addition to all the lists of challenges and exercises used at home, were results are available), and (v) characters that shows the participants involved in the gamified environment (Master is a Researcher / Professor with knowledge in gamification, Mentor is the Professor of the subject, Coach for monitoring problem solving, ScorePlay / Judge for the development of the class score and Players who are students).

Practices are the forms adopted for teaching and evaluating content, they are: (i) initial conversation, an

introductory moment of the elements that made up gamification for players, (ii) theoretical and practical class, teaching about the content and soon afterwards a practical exercise of algorithms, (iii) Dojo Randori, a safe programming environment, where a pilot and co-pilot paired together to develop an algorithmic solution presenting to the audience, (iv) Programming Laboratory (LAB), evaluative activity with questions of greater difficulty done in pairs and with the aid of a computer;, (v) theoretical test, assessment of individual learning, and (vi) feedback class, when players were questioned and could suggest improvements to the framework.

The rewards are worked to reinforce positive behaviors and inhibit negative ones, they are: (i) bonuses, granted for positive behaviors, defined in the rules, (ii) penalties, withdrawal of bonuses for negative behavior, (iii) star resource, daily conversion of bonuses, (iv) point, concession by answering questions about the contents, (v) medals, awarded to the best placed in the item point and star resource, and (vi) avatar, symbolic representation granted by the players' daily progression.

The teaching resources and strategies adopted in gamification: (i) list of challenges, questions about the contents, (ii) exercise list for home, list aimed at exercising outside class hours, (iii) coaching, assistance given to players through tips for solving challenges, (iv) mentoring, resolution made by the professor or monitor of the subject with the student ensuring the understanding of the challenges, and (v) Scoreplay / Judge, character responsible for assigning and / or removing students' points and / or bonuses in the gamified spreadsheet

The teaching plan is the document containing each of the game elements described, it is the base document that contains the description of the contents, activities and rules of the gamification that will be executed and accompanied by the spreadsheet. They are detailed: the identification of the subject, the contents that will be worked on, teaching and learning objectives, the desired skills and competences, the schedule of classes, the description of the activities carried out in the classroom, and the planning and description of the gamified process (rules for scoring, granting an avatar, bonus, penalties, acquiring a star resource, converting points and assigning stars to grade in the subject) [25].

The gamified spreadsheet, on the other hand, is the instrument used during the classes to collect information about the students' performance and behavior. The rules of the game served as a basis for the organization of the spreadsheet tabs and their programming in an automatic and integrated way. That is, as the values were being filled out, the spreadsheet calculated the star resource for the behavior and the score to indicate the corresponding avatar. The spreadsheet was programmed to generate indexes and automatic conversions, for more detailed information about automation and the framework as a whole, see in [25].

A. Evalutaion of the Gamified Framework

After the conception and development of the first version of the gamified framework, we understood that it would be necessary to undergo an expert evaluation, so that they could identify points for improvement and notes on the strategy for working with gamification and algorithms in the product. We chose to use peer review, as it is a mechanism for evaluating and validating proposals through an analysis carried out by experts. It can be defined as “the most effective and efficient mechanism to guarantee the quality, reliability, integrity and consistency of academic literature” [26]. The peer review of the gamified framework took place in three stages, namely: planning, conducting and analyzing.

As reviewers, four professors / researchers were chosen, from two different specialties: Algorithms, two professors who have already taught the subject; Gamification, two researchers involved in research on the specialty of gamification. For the review itself, there were two product presentation and evaluation sessions. One for each group of specialists, where the review forms and the gamified teaching plan were distributed. In each session, the expert responsible for gamification explained to the experts: (i) the review procedures, (ii) the use of the product by the characters involved, and (iii) the functioning of the gamified spreadsheet.

After carrying out the evaluation, the data were systematized and discussed among the authors to generate or not change the product, as well as the strategy adopted for its implementation. As a result of the peer review, the requests made by the experts considered relevant to the work were implemented, with a direct impact on the teaching plan and spreadsheet. After that moment we had the first version of the gamified framework for Algorithms or equivalent subject.

VII. The Use of the Gamified Framework: The Experiment

The experiment with the use of the gamified framework was the way found to evaluate and validate our proposal. The context of realization was the Algorithms course, with a 60-hour workload, offered to freshmen in the first academic semester of 2018, by the Faculty of Computing of a Federal University in Brazil, specifically in the period in which the content of Homogeneous Data Structures (array and matrix) was addressed.

In order to guide and analyze the execution of the experiment, we elaborated a guiding question for the experiment: *Does the use of gamification assist the engagement of the class and collaborate for learning about the content of homogeneous data structures?*

A. Planning

The planning took into account the teaching plan and the gamified spreadsheet [25]. The planning items are described in Scenario and Characters. Regarding the Scenario, the classroom is one of the most important core of gamification, since it was the scene of the experiment and the game. The classes took place in a computer lab, containing: magnetic board, intended for explanation, multimedia projector, and computers for professors and students. On the day of the theoretical test, the students went to another location, without access to the internet and without using the computer. As for the Characters, this is an undergraduate class from the Bachelor of Computer Science course at a Federal University in Brazil, comprising 20 students, a monitor, the professor of the subject and an trainee, responsible for gamification.

B. Development of Lessons

According to the teaching plan, the experiment counted eight lessons, as described below.

Lesson 01, which aimed at an initial conversation about gamification, in which the teaching plan was presented, in presentation format, containing: the goal, rules and characters of gamification. It was also explained how students would earn points and bonus, as well as the schedule of classes.

In Lessons 02 and 03 the theoretical and practical approach (ATP) was adopted with the content of homogeneous data structures. In the second class, the array content was worked on and in the third one, matrices were addressed. The explanation was structured as follows: the concept, a metaphor, the implementation in the Pascal language, and, finally, the students were invited to resolve questions regarding the content.

For the theoretical and practical classes we have as an example of one of the challenges present in the list for which students would need to solve: *Develop an algorithm that reads from the user a set of numbers from a square matrix of order 3 and presents the stored numbers to the user. Rule of constitution of square matrix: number of columns = number of lines*.

Every time the student solved a question in class he / she scored, as indicated in the teaching plan. It is worth noting that this same issue was adopted in the traditional classes of the subject, which was recognized in the future for a possible point of concept.

In Lessons 04 and 05 the Randori Dojo technique was applied, which is an activity performed in pairs in a safe programming environment. The students had an initial period of ten minutes to check and analyze the proposed question. After this period, one student took over as the first pilot and after seven minutes there was an exchange for another student, until all students participated in the activity. The co-pilot position was optional, reserved in case any student wanted to help the pilot in coding. After three minutes of the pilot coding, the audience could interact with him / her, as well as the copilot volunteering to help. As a necessary material, a computer and a multimedia projector were used.

In Lesson 06 there was the practice of LAB with pairing, a technique in which students were divided into pairs by lot, to solve four computational problems based on algorithmic solutions, from the homogeneous data structures content. The guidelines were given by the characters: master and mentor, right at the beginning of the practice. As an established rule, internet access was not allowed, however coaching was allowed as a way to help the pairs. The material used was a computer for each pair. This practice was adapted from the framework proposed in [14].

In Lesson 07 the students were submitted to an evaluative activity in order to verify and analyze the knowledge and the acquired knowledge: a theoretical test containing four subjective questions, in which two questions were about array and two were about matrices.

In Lesson 08 students answered questions regarding the gamified framework, in order to record feedbacks about the approach to the teaching and learning process. No score was awarded for that day, only a bonus.

Collaboration was one of the guiding elements of the gamification proposal, as it understands the need to motivate students in the class to a practice that is increasingly present in the job market, that is, teamwork. In this study, as already mentioned, the objective was to score, bonus and evaluate the knowledge acquired on the content of Homogeneous Data Structure. For this, as already informed, the teaching plan and the gamified spreadsheet were used.

As students acquired scores, the electronic spreadsheet provided generated automatic daily avatars, according to the standard established in the rules present in the teaching plan. Regarding the bonus, the student could win or lose it, according to already established criteria. Per day, the bonus element could generate up to three stars resources.

One of the instruments that enabled feedback to students about the progress in gamification was the availability of the gamified spreadsheet in the extended classroom, as well as its presentation at the beginning of each class. The spreadsheet allowed students to view their progress within the gamified content in the subject.

C. Execution

The development of the research took place with the collection of the marks already attributed previously in the subject for the content chosen by base, in the case of homogeneous data structures and the execution of the experiment. A complete account of the execution of the experiment, as well as the analysis of quantitative and qualitative data can be found in [27].

Thus, we divided the results and discussion into two groups: Teaching methodologies – using SWOT matrix (Strenghts, Weaknesses, Opportunities, Threats) Daily; and data on bonuses and penalties. The first group was collected by means of structured notes of the perceptions of the researcher responsible for conducting gamification, with contributions suggested by the professor and the subject's monitor, as well as audio recordings, previously approved by the participating students and monitor. The second group was collected using a gamified spreadsheet divided into tabs referring to daily bonuses and penalties, plus the judge's / scoreplay's perceptions.

In the context of our experiment, at the end of each gamified class we made a conversation circle aimed at building the SWOT matrix. The participants involved at that time were: the professor responsible for the subject, the monitors, the researcher who was developing the experiment and the judge / scoreplay.

At the time, by means the SWOT analysis matrix, it was possible to identify through the professor's speech and the researcher's perception in the classroom that the students were adapting well to gamification and were enjoying it. As much as possible, points of improvement were identified within the framework.

In general, regarding the methodologies used in the experiment, the students stated that the use of a gamified classroom for teaching the content of data structure in the Algorithms subject was very valid. Through the approach, the students had the necessary theoretical and practical view of the subject. It is worth mentioning that all points raised by the gamification characters were widely discussed and systematized in this research in order to improve the gamified framework for the teaching and learning process in the Algorithms subject. The qualitative results in detail can be viewed in [25].

Quantitative data supported qualitative data in order to evaluate the gamified framework to develop the next version as well as for the next uses. Similarly, quantitative results can be seen in [27].

In general, the points element allowed students to provide positive feedback on their progress within the gamified content. However, we suggest some suggestions for the next version, such as: (i) allowing greater freedom in the practice of Dojo, through the attribution of points only for the collective code developed in the room, and (ii) define a rule for attempted scoring in LAB practice.

Regarding the analysis of the behavior of students throughout the classes, the class that uses the Dojo Randori reached the largest number of reach of the star resource. In the practice of feedback, which we imagine to be the day on which the most stars would be distributed, was tied with the first theoretical and practical class. So, it is important to have a future discussion of new ways to collect information from students about the framework, during the feedback class. In general, on the element of stars, none of the students achieved the 3 stars, a daily goal. We can identify new forms of bonus, or remove the bonus limitations in order to allow students to achieve the daily goal for the component in the next uses of the gamified framework.

Finally, another gamification element used in order to analyze the performance of students in relation to content and participation was the medal. For the reported experiment, the categories: Power and Participative were adopted. The first refers to the number of points that the student had accumulated during the gamification, that is, the performance. The second medal indicated the student with the greatest number of stars, that is, the one who most participated in the process. In general, the medal element was added to the framework in order to stimulate competition among students. However, in the feedback class they reported collaboration as a central element. The point of improvement would be the availability of prizes for the first places in the medals, in order to encourage students.

VIII. VALIDATION OF FRAMEWORK

The validation of the framework happened in two ways described here: (i) by the evolution and the analysis of the students' grades inside the classroom, that is, in the context of the same subject and with the same participants, and (ii) by comparing the performance of students' grades in the gamified subject with the grades obtained in the subject without gamification.

In Fig. 1 we have the grades of the Algorithms subject in relation to the gamified content. In the image we can see how many points the students accumulated in the course of the proposed approach, how many stars and the conversion of these elements to the grades, presented in a tab of the online gamified spreadsheet. Throughout the game the student was following the points acquired in his / her learning process and the conversion to the grade in the subject.

Members	Total Points	Total Grades	Total Stars	Grade Conversion	Final Content Grade
Student 01	141,75	1,42	4	0,0	1,42
Student 02	415	4,15	3	0,0	4,15
Student 03	593,75	5,94	9	0,5	6,44
Student 04	966,5	9,67	9	0,5	10,17
Student 05	977,75	9,78	9	0,5	10,28
Student 06	945,5	9,46	7	0,5	9,96
Student 07	898	8,98	9	0,5	9,48
Student 08	748,75	7,49	9	0,5	7,99
Student 09	565,25	5,65	8	0,5	6,15
Student 10	603,75	6,04	7	0,5	6,54
Student 11	851,75	8,52	5	0,5	9,02
Student 12	958,5	9,59	10	1,0	10,59
Student 13	934,75	9,35	7	0,5	9,85
Student 14	537,75	5,38	5	0,5	5,88
Student 15	667,75	6,68	5	0,5	7,18
Student 16	506,25	5,06	8	0,5	5,56
Student 17	116,75	1,17	2	0,0	1,17
Student 18	421,75	4,22	5	0,5	4,72
Student 19	693,75	6,94	7	0,5	7,44
Student 20	504,25	5,04	3	0,0	5,04

Fig. 1. Student grades on the use of the gamified framework.

The first way adopted to validate the use of the framework to support the teaching and learning process of algorithms comes from an analysis of the progression of students during the course. For this, we collected the grades from the first and second tests, through participant observation [23]; in addition, we aggregate an image in order to perform the analysis (see Fig 2).

The Fig. 2 portrays that several students have gained considerable performance, as is the case with students: 03, 04, 07, 08, 09, 12, 15, 18 and 20. Some others maintained their performance and reported, through the feedback class, the excellent experience of working with gamification. According to one of the students, “Having contact with collaboration in the classroom, refers to skills in the job market”. Thus, on the first day of class, we emphasize the games elements that we would work with in the classroom. So, the experience of working with gamification was a success when looking at the progression of students' performance in the subject and also at the information reported in the feedback class.

It is worth mentioning that some students had a loss of performance in the gamified content, as was the case with students: 11 and 16. They portrayed the researcher individually in the feedback class, their disagreement with collaboration and fear of speaking in public, for this reason they did not participate in the Dojo and LAB activities, which had a score value for the subject. For this situation, what was said and discussed in the first class, initial conversation, was again reaffirmed to the students, where market practices would be with emphasis on the proposed approach to the subject, especially public speaking and collaboration for development of work.

Fig. 3 represents the grades (PR) collected from the Algorithms subject offered by the same Faculty of Computing in 2016. The students in the third assessment, which is equivalent to the content of homogeneous data structure, obtained a lower performance than the other grades. We have as an example the following students: 02, 04, 06, 08, 09, 10, 11.12, 13, 15, 16, 17, 19 and 20. At this point, when we analyze the relationship to the data collected through the experiment with those of participant observation [23], we observed that gamification helped students in their performance in relation to the subject. Therefore, when it comes to comparing and validating the gamified approach compared to what is adopted in the subject, we indicate the success of our proposition.

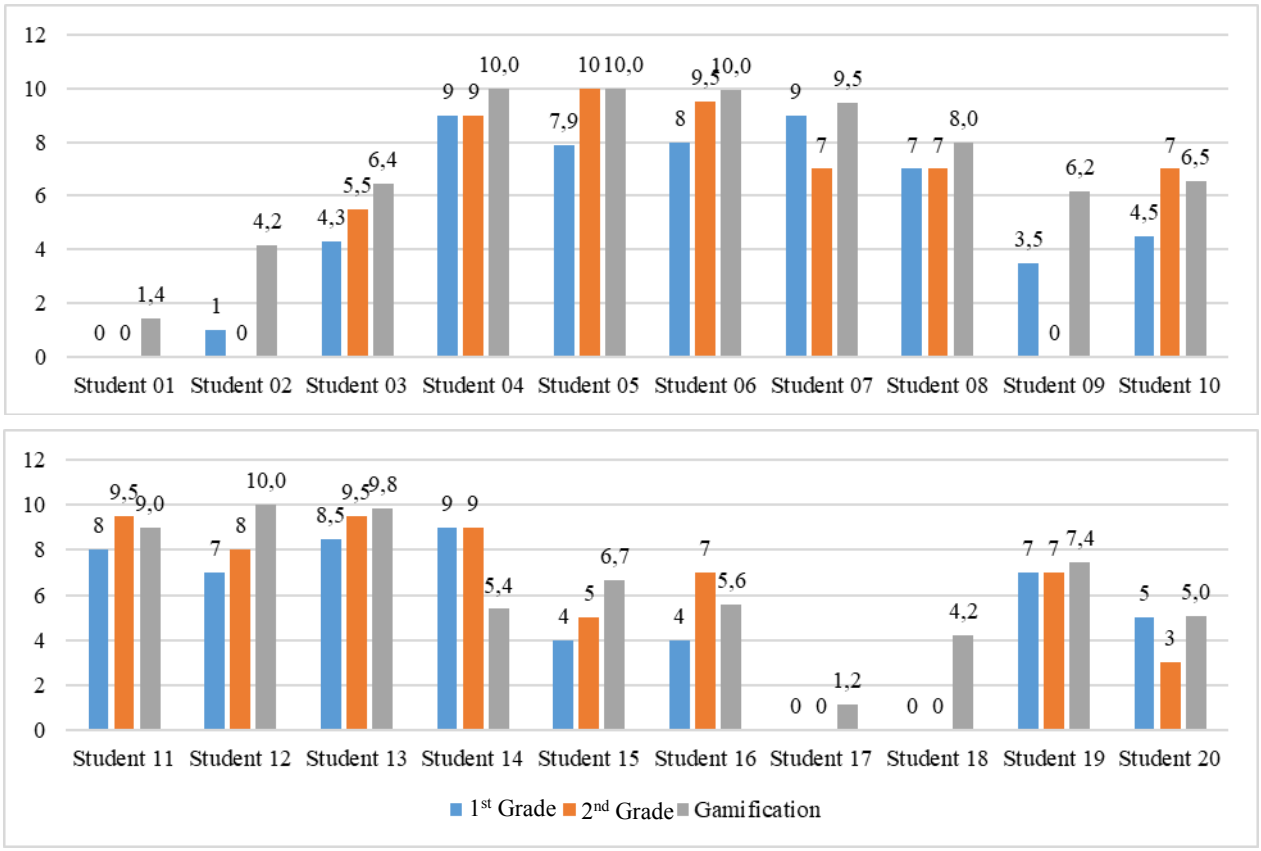

Fig. 2. Presentation of student performance in the entire subject.

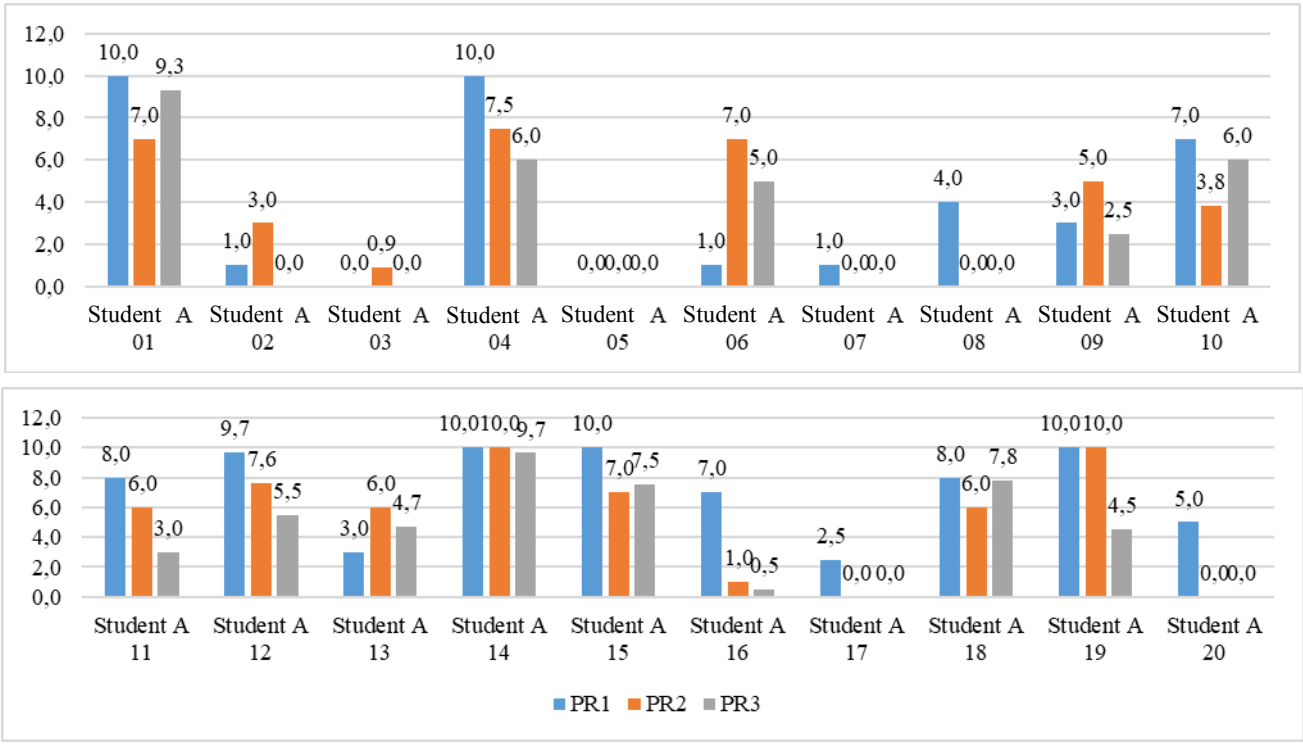

Fig. 3. Presentation of student performance in the Algorithms subject offered in 2016.

The analysis with a different group of people does not allow us to identify the progression of a student within the subject, but when we work with more complex content than the previous one and that student performed better, we can identify a gain in knowledge. Regarding the comparison of two classes, this work adopts such a comparison because it is something advocated by the literature as a way to validate and evaluate new teaching methodologies, as presented in [24]. In relation to this analysis, it is possible to identify the acceptability and learning of students in one class in relation to another and not from person to person. It is noteworthy that the group to which the experiment was being carried out managed to have better performance, whose teaching through gamification was one of the main factors.

It should be noted that for the validation the same content and activities were adopted for both classes. In addition, it is worth informing that the professor maintains the knowledge base with information about the subject in the Moodle environment. Only the presentation layout is changed. Therefore, it was easy to replicate the content and activities for the classes.

Regarding the comparative results between classes, it was only possible to carry out from the grades obtained, since the professor does not keep information about how students answered the questions contained in the theoretical tests, unlike how it was performed within the experiment using gamification.

Therefore, we can infer that the gamified framework for the teaching and learning process of the Algorithms subject is characterized by success, as it allows students to gain performance, in addition to engaging them in the knowledge of the subject contents, being valid for use in other contents, as well as in the entire subject.

IX. Conclusion

The Algorithms or equivalent subject is an important curricular component for the continuity of students in undergraduate courses in Information Technology, with special emphasis on software development. Within the literature and at a Federal University in Brazil, we can see high rates of failure and dropout in the subject. In addition, we found several difficulties for both teaching and learning within this curricular component.

The gamified framework for the Algorithms or equivalent subject is an alternative to the teaching and learning process, which provides greater performance, as well as a motivation for students to be interacting in their learning process. The validation method through the analysis of the yields adopted by the participants in the classroom and a control group is possible to infer the success of the gamification for the content of homogeneous data structure in the Algorithms subject.

The results of each stage of the research, more specifically the experiment and the validation of the gamified approach, made it possible to answer the focus question, as well as to reach the general objective outlined. Among the main results achieved, we highlight:

- Greater participation of students in the classroom,
- Greater collaboration between students when solving the challenges proposed in the classroom,
- Greater commitment to solving exercise lists,
- Improvement in the performance of most students with regard to the evaluation grade,
- Use of dynamic and playful classroom practices,
- Timely feedback on students' progress in the subject,
- Acceptance of the approach by the students.

The gamified framework as a product proposal for this research, after all the changes, proved to be adequate and timely to mitigate teaching and learning problems in the Algorithms or equivalent subject. However, it also has limitations perceived mainly during the experiment carried out in an offered Algorithms subject in the Bachelor of Computer Science course at the Faculty of Computing at a Federal University in Brazil. Examples are:

- The professor to make an appropriate use of the framework needs a minimum infrastructure of resources, which is not always available, such as: computer lab, monitor support and a person to act as judge / scoreplay,
- The proposed framework does not assume the presence of students with disabilities and with an introverted temperament, but it is not known whether it is a product limitation or the gamified approach itself.

As future works for the research on screen we register: the use of the framework with other contents of the Algorithms subject, the generation of an automated tool to assist the professor and students in the course of gamification, and comparing performance with the use of the tool and not just the spreadsheet with the gamified teaching plan.

Acknowledgment

The authors of this paper would like to thank the students of the class who allowed the experience of a new experience in the teaching and learning process of the Algorithms subject.

References

[1] Brazilian Computer Society, “Reference Syllabus for undergraduate courses in Bachelor of Computer Science and Computer Engineering”. Brazil, 2005.

[2] M. Dias Júnior and L. Mercado, “The Importance of the Simulation Teaching Strategy for the Discipline of Algorithms”. In: *5º Congresso Ibero-Americano em Investigação Qualitativa (CIAIQ),* 2016, pp. 85 - 94.

[3] Brazilian Computer Society, “Training references for undergraduate courses in Computing”. Brazil, 2017.

[4] Y. Bosse and M. A. Gerosa, “Failures and dropouts in the subjects of introduction to the programming of the University of São Paulo: A preliminary study”. In *XXIII WEI–Workshop sobre Educação em Informática.* Recife, julho 2003.

[5] M. M. Giraffa and M. C. Mora, “Dropout in the subject of algorithm and programming: a study from the intervening factors in the student's perspective”. In *Congresos CLABES*, 2013.

[6] V. Ramos, R. Wazlawick, M. Galimberti, M. Freitas, and A. C. Mariani, “The Comparison of the World Reality of Programming Teaching for Beginners with the National Reality: Systematic review of the literature in Brazilian events”. In *Brazilian Symposium on Computers in Education (Simpósio Brasileiro de Informática na Educação-SBIE,* Vol. 26, No. 1, 2015, p. 318.

[7] S. Deterding, D. Dixon, R. Khaled, and L. Nacke, “From game design elements to gamefulness: defining gamification”. In *Proceedings of*

the 15th international academic MindTrek conference: Envisioning future media environments, 2011, pp. 9-15.

[8] K. M. Kapp, "The Gamification of Learning and Instruction: Game-based Methods and Strategies for Training and Education". 1st ed. [S.l.]: Pfeiffer & Company, 2012. ISBN 1118096347 9781118096345.

[9] G. L. K. Timmermann and F. J. González, "Mediations that teachers and students establish with the content of the course Algorithms discipline: case study". *Anais dos Workshops do V Congresso Brasileiro de Informática na Educação (CBIE 2016)*, Uberlândia, 24 a 27 Outubro 2016, pp. 1295 - 1305.

[10] M. L. Fardo, Gamification Applied in Learning Environments". RENOTE. Revista Novas Tecnologias na Educação, v. 11, 2013, pp. 1.

[11] S. Tanaka, M. Vianna, Y. Vianna, and B. Medina, "Gamification: Como reinventar empresas a partir de jogos", 2013.

[12] W. Li, T. Grossman, and G. Fitzmaurice, "GamiCAD: a gamified tutorial system for first time autocad users". In *Proceedings of the 25th annual ACM symposium on User interface software and technology* (pp. 103-112). ACM, 2012.

[13] Y. K. Chou, "Actionable gamification: Beyond points, badges, and leaderboards". Octalysis Media, 2017.

[14] I. S. Elgrably and S. R. B. Oliveira, "Gamification and Evaluation of the Use the Agile Tests in Software Quality Subjects: the Application of Experiments". 13th ENASE - Evaluation of Novel Approaches to Software Engineering, Madeira, 2018.

[15] E. D. Santos and S. R. B. Oliveira, "Gamification as a Support Tool to Support Technique Teaching Analysis of Points by Function in a Graduate Class: A Case Study". In: *15th CONTECSI - International Conference on Information Systems and Technology Management*, 2018.

[16] K. Werbach and D. Hunter, "For the win: How game thinking can revolutionize your business". Wharton Digital Press, 2012.

[17] S. Freitas, T. Lima, E. Canedo, and R. L. Costa, "Gamification and evaluation of student engagement in an undergraduate technical subject". In *Brazilian Symposium on Computers in Education (Simpósio Brasileiro de Informática na Educação-SBIE)*,Vol. 27, No. 1, 2016, pp. 370.

[18] W. M. Monteiro, T. M. Oliveira, and D. J. S. Martins, "Gamification in Education: Possibilities for teaching programming". *Revista Tecnologias na Educação*, v. VII, n. 13, 2015.

[19] A. P. Falcão, M. D. Leite, and M. M. Tenório, "Support tool for classroom teaching using gamification and game design". In *Brazilian Symposium on Computers in Education (Simpósio Brasileiro de Informática na Educação-SBIE)*. Vol. 25, No. 1, 2014, pp. 526.

[20] L. Gonçalves, G. Giacomazzo, F. Rodrigues, and B. Macaia, "Gamification in Education: a conceptual model to support planning in a pedagogical proposal". In *Brazilian Symposium on Computers in Education (Simpósio Brasileiro de Informática na Educação-SBIE),* Vol. 27, No. 1, 2016, pp. 1305).

[21] Association For Computing Machinery/ Institute Of Electrical And Electronic Engineers, "Computer engineering curriculum in the new millennium". *IEEE transactions on Education*, 2003, pp. 456-462.

[22] J. A. S. Quaresma, M. K. Eliasquevici, and S. R. B. Oliveira, S. R. B. "A Study about the Subject of Algorithms or Equivalent of the Under Graduation Courses Regarding Education, Learning and Content : A Survey Application". In: *15th CONTECSI - International Conference on Information Systems and Technology Management*. São Paulo, 2018.

[23] J. A. S. Quaresma, S. R. B. Oliveira, and M. K. Eliasquevici, "A Participant Observation for the Understanding of the Interaction between students, professors and content in the algorithms subject". In: 12th International Conference of Education, Research and Innovation, 2019, Seville, SPAIN. 12th International Conference of Education, Research and Innovation - ICERI 2019, 2019. pp. 426-436.

[24] J. A. S. Quaresma, M. K. Eliasquevici, J. Menezes, and S. R. B. Oliveira, "Gamified Approaches to Teaching and Learning in Discipline Algorithms: A Systematic Literature Review". In: *16th CONTECSI - International Conference on Information Systems and Technology Management*. São Paulo, 2019.

[25] J. A. S. Quaresma, M. K. Eliasquevici, and S. R. B. Oliveira, "A Gamified Framework for Teaching and Learning of Algorithms or Equivalents Subject". In: *16th CONTECSI - International Conference on Information Systems and Technology Management*. São Paulo, 2019.

[26] L. Nassi-Calò, "Peer review: modalities, dos and dons". Scielo em perspectiva. *Scielo em Perspectiva*, 2015.

[27] J. A. S. Quaresma, M. K. Eliasquevici, and S. R. B. Oliveira, "An Experimental Evaluation of the Use of a Gamified Framework for the Algorithms and Equivalent Subject". In: *27º WEI – Workshop Educação em Informática*. Belém, 2019.