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Evaluation of Perception of Use of a Gamified Platform from the Student Perspective: An Approach for Studying Unified Modeling Language

Felipe A. FEICHAS[1], Rodrigo D. SEABRA[2]

[1]*Institute of Systems Engineering and Information Technology, Federal University of Itajubá Itajubá/MG, Brazil*

[2]*Institute of Mathematics and Computing, Federal University of Itajubá Itajubá/MG, Brazil*

email: feichas2000@gmail.com, rodrigo@unifei.edu.br

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Abstract. This research discusses the use of a gamified web platform for studying software modeling with Unified Modeling Language (UML). Although UML is constantly being improved and studied, many works show that there is difficulty in teaching and learning the subject, due to the complexity of its concepts and the students' cognitive difficulties with abstraction. There are challenges for instructors to find different pedagogical strategies to teach modeling. The platform proposed allowed students to complement their UML knowledge in an environment with game elements. From the results, it can be concluded that the platform obtained great acceptance and satisfaction of use. Most of the students participating in the research were satisfied with the usability of the platform, reporting a feeling of contribution of the tool to studying the content, in addition to pointing out the satisfaction of using gamification as a pedagogical strategy.

Keywords: unified modeling language, software modeling, software engineering, gamification.

1. Introduction

This work aims to contribute to the development of skills inherent to software modeling with UML, a concept that encompasses a set of techniques required for students in Computer Science, Computer Engineering, Software Engineering (SE) and Information Systems courses. However, due to its importance, the results of this research can be extended to several other courses that teach the topic. The difficulties of many students with the concepts related to software modeling can affect their professional activities, presenting difficulties in real and more complex projects (Huang and Distante, 2006; Silva, 2020).

Software modeling is the ability to abstract a real system through models, facilitating the understanding of its functionalities, structures, and behaviors before implementing it (Guedes, 2018). Therefore, abstraction is one of the most important skills for students of computing and the like, as it provides a greater level of detail of specific problems or for understanding concepts (Hazzan and Kramer, 2007).

Unified Modeling Language (Rumbaugh *et al.*, 2004) is the language most used internationally by the higher education sector to design software systems using models. It is not a programming language, but a modeling language to support software engineers to create visual representations of real-world situations (Guedes, 2018). Although software modeling with UML is well explored, many studies show that the teaching and learning of the topic is a difficult process due to the complexity of its concepts (Sien, 2011; Bera, 2012; Lethbridge, 2014; Reuter *et al.,* 2020; Silva, 2020). Moreover, many students generally face difficulties in understanding the syntax and semantics of models (Ma, 2017; Chourio *et al.,* 2019; Reuter *et al.,* 2020), structuring information in models (Reuter *et al.,* 2020; Silva, 2020), and applying generalization/specialization relationships (Ma, 2017; Reuter *et al.,* 2020; Silva, 2020).

One of the factors for the quality of a developed software is the detailing of the models in the system modeling stage, and it is important that the difficulties are solved or minimized during the modeling teaching process. Otherwise, students' conceptions of systems in models will incompletely or incorrectly correspond to what is being developed (Ma, 2017; Sien, 2011).

Several authors state that the traditional teaching paradigm of the subject can contribute to the difficulties presented by students (Szmurło and Śmiałek, 2006; Silva, 2020). Most courses also use the traditional teaching method centered on the teacher, with lectures and dialogues, aiming to present the modeling concepts (Al-Tahat, 2014). Furthermore, the complexity of the content makes it difficult to change the teaching resources used by the instructor to meet a new type of more dynamic student, resulting in inefficient teaching and learning of the content (Capuano *et al.*, 2012).

According to Bera (2012), learners generally find it difficult to solve problems that do not have a defined solution or that are vague or ambiguous. For students to learn to solve software modeling problems, it is necessary to create an environment that provides more practical experiences, such as simulations, real projects, dramatizations, case studies or other types of experiential learning activities (Kurkovsky *et al.*, 2019). Therefore, the traditional method of lectures may not be the most effective, because students, in certain cases, do not have the chance to actively participate in the teaching-learning process, feeling unmotivated to learn (Al-Tahat, 2014). In the current context and considering the high level of integration between society and technology, there is an interest in the study of new teaching-learning methods to increase student motivation and engagement. Laroza and Seabra (2015) observed that UML teaching can be conducted using extra-class pedagogical tools, which go beyond traditional classes, providing students with greater knowledge gains in the learning process of the subject.

Based on these considerations, instructors need to use new pedagogical strategies to challenge students to feel more motivated and engaged with the learning process (Dichev and Dicheva, 2017). A promising approach in this direction, which has gained prominence since 2010, is teaching/learning through gamification (Deterding *et al.*, 2011). According to Dichev and Dicheva (2017), gamification in teaching is a strategy that aims to increase motivation in learning and student engagement using game elements in an educational environment. The aim is to use the motivational and involvement potential of game elements to motivate students in the learning process (Deterding *et al.*, 2011), aiming to make complex contents more accessible, facilitating the learning process (Dichev and Dicheva, 2017).

Therefore, the use of gamification as a pedagogical strategy is believed to motivate positively, with a didactic platform that uses game elements to contribute to the study of software modeling with UML. Some studies in recent years have explored gamified environments in the context of education and have shown benefits in terms of student motivation and engagement. Some examples are the works by Hamari *et al.* (2014), Santos *et al.* (2016), Feichas *et al.* (2021) and Saleem *et al.* (2022). There are also several works focusing on the application of gamification to software engineering disciplines, as in Poffo (2016), Diniz *et al.* (2017) and Nascimento (2019).

Porto *et al.* (2021) developed a systematic mapping with the initiatives and challenges of using gamification in higher education. The authors organized the application of gamification by SE topics and identified that there are many research opportunities in different subjects, such as software modeling, the object of study of this research.

Based on the above, this research aims to analyze the behavior and engagement of students from the data generated during the period of use of the gamified environment proposed for studying the UML. In addition, through questionnaires, the acceptance and satisfaction of using the platform were investigated, regarding usability, study of content and gamification and satisfaction. We thus sought to achieve the main benefits provided by gamification cited in the literature, mainly in relation to the motivation and engagement of students. As a direct contribution to this research, a gamified platform was made available for studying software modeling with the UML, evaluated from the student perspective.

The paper is structured as follows: Section 2 presents the background. Section 3 details the platform developed and the research methodology used. Section 4 provides and discusses the results. Finally, Section 5 presents the final considerations of the study.

2. Background

2.1. *Teaching Software Engineering*

According to Sommerville (2016), SE is a discipline with core aspects of the software creation and development process, from the stages of analysis and definition of requirements to the stages of operation and maintenance. Due to its importance, the teaching of higher education is increasingly essential for training professionals inComputing (Almi *et al.*, 2011). Therefore, according to ACM/IEEE (2013), among the subjects of computing courses, SE is presented as one of the most important. In addition, success in the teaching-learning process of the contents is fundamental for turning students competent professionals.

The SE discipline is generally offered in undergraduate courses in computing and the like, as well as in graduate programs, technical and technological courses (Coutinho *et al.*, 2019). In the Computing area, there are groups that discuss and elaborate curricula and guidelines for teaching and training in the area, such as the Brazilian Computer Society (SBC) and the international groups Institute for Electrical and Electronic Engineers (IEEE) and Association for Computing Machinery (ACM).

Some works have explored the difficulties in teaching and learning higher education subjects (Prikladnicki *et al.*, 2009; Sien, 2011; Gimenes, 2015; Ouhbi; Pombo, 2020). One of the factors for the difficulty of students is the traditional approach to teaching, highlighting that it should be more student-centered to increase engagement and motivation and, consequently, improve learning (Prikladnicki *et al.*, 2009). Therefore, to better prepare students in SE, it is necessary to seek different means of teaching and learning, aiming to enable comprehensive knowledge in all the concepts of the area.

2.2. *Software Modeling*

Software modeling is a fundamental topic in higher education teaching, being one of the main steps involved in software development (Paige *et al.*, 2014). In this context, it is essential that students develop the ability to model and to produce reliable and robust software (Agner *et al.*, 2019).

According to Guedes (2018), software modeling consists in creating models by abstracting a real system, with the purpose of describing structural or behavioral aspects of the software. Blaha and Rumbaugh (2006) define models as an abstraction of something that helps understanding before building it. Abstraction is a trivial mental skill that makes it possible to solve complex problems. For the Object Management Group (OMG), modeling is the design of software applications before coding. Modeling is one of the fundamental activities in software development, allowing a better understanding of its functions and states (Guedes, 2018).

According to the ACM/IEEE (2014) curriculum guidelines for undergraduate SE courses, students should be able to recognize the importance of abstraction and modeling for software architecture, design, and specification.

Software can be represented in different aspects, using different diagrams, with static and dynamic models (Booch *et al.*, 2012). Kramer (2007) states that modeling is the most important technique for software engineering students, promoting comprehension, reasoning, and abstraction skills, to build models that help to understand and analyze large and complex problems. Among the skills, according to Hoare (1972), abstraction is the most powerful tool available to the human intellect for understanding complex phenomena. Hazzan and Kramer (2007) point out that abstraction is something so difficult to teach that, to get around the problem, the solution is to use modeling languages that provide a fixed and standardized structure to express certain aspects of a domain or idea.

Difficulties related to students' modeling skills have motivated research on methods and tools, as well as modeling languages, such as UML, which facilitate teaching the subject.

2.3. *Unified Modeling Language*

UML (OMG, 2017) is the most and widely used graphical modeling language (Störrle, 2017; Agner *et al.*, 2019), being supported and managed by the Object Management Group (OMG) as the standard object-oriented analysis and design language. UML provides a standard template for elaborating systems architecture projects, and can be used for the observation, creation, specification, and documentation of artifacts that use complex software projects (Booch *et al.*, 2012).

In summary, UML is seen and used as a graphical notation to provide support for software development and maintenance, as an essential part of the software creation process (Guedes, 2018). UML is not a development methodology, that is, it does not specify the project stages and the steps in the development of the software, but it helps to define the characteristics of the system, its requirements, states, and the dynamics of the processes with the graphic diagrams. Finally, its diagram models offer the possibility to visualize the elements of the system architecture, such as flows, business rules, components, actors, database schemas, language commands used and reusable software components.

In its current version, 2.5.1, the UML (OMG, 2017) includes 14 types of diagram models, classified into two categories: structural and behavioral. Seven diagrams represent structural information and seven others represent behavioral information. By applying the different views of UML, a better understanding of the system can be obtained (Störrle, 2017; Guedes, 2018).

Since UML is the most used modeling language in the software industry (Guedes, 2018), most universities in the world that offer courses in Computing and the like adopt UML as a graphical language for teaching software modeling. The modeling discipline aims mainly to enable the student to model and abstract to support software development in several domains (ACM/IEEE, 2014).

Despite its importance, UML modeling is considered a difficult-to-teach-and-to-learn discipline compared to other software engineering disciplines. There are several studies that report the difficulties of students when learning modeling with UML diagram models, due to the complexity of their concepts (Sien, 2011; Ma, 2017; Reuter *et al.* 2020; Silva, 2020), and others related to cognitive difficulties of students with abstraction (Bera, 2012; Reuter *et al.* 2020; Silva, 2020), such as difficulty in structuring information in models (Reuter *et al.* 2020; Silva, 2020); difficulty in understanding the syntax and semantics of the models (Ma, 2017; Reuter *et al.* 2020; Silva, 2020); difficulty in correctly applying generalization/specialization relationships to models (Ma, 2017; Reuter *et al.* 2020; Silva, 2020).

It is important to seek pedagogical tools and resources to offer students a more dynamic and in-depth learning, in addition to developing a fun and motivating teaching-learning environment (Petri and Chiavegatti, 2015; Ouhbi and Pombo, 2020).

2.4. *Gamification*

The term gamification began to be used from 2010, with the idea of encouraging people, and has gained popularity with the belief that gamification has the potential to change behaviors, increase motivation and engagement, and improve the learning process (Dichev and Dicheva, 2017). Such benefits are seen as arising from the ability of gamification to increase the motivation of users to perform specific tasks by implementing mechanisms originated from game design (Huotari and Hamari, 2012). Gamification is thus a promising method or methodology, becoming increasingly explored in industry (Zichermann and Cunnungham, 2011) and in academia (Dichev and Dicheva, 2017).

According to the basic definition of Deterding *et al.* (2011), gamification is defined as the use of game design elements in a non-game context, that is, the main idea of gamification is to apply the motivational power of games using their elements to non-gaming environments.

Huotari and Hamari (2012) emphasize that gamification is more than a simple implementation of game elements in a non-game context. For them, gamification refers to the process of improving a service by developing gamified experiences to support the creation of value for the user. For Sailer *et al.* (2017), the focus of gamification is to increase motivation and stimulate the performance of a certain task. Kapp (2012), in turn, presents a definition of gamification that is best suited to the learning area. The author defines that gamification is the use of mechanics, aesthetics, and game-based thinking to motivate action, engage people, stimulate learning, and solve problems.

Game mechanics work as a means of motivating players to contribute to engagement within the gamified environment. Engagement corresponds to the time the player spends in the environment, and the level applied by the player is an essential factor to verify the success of the gamified environment (Zichermann and Cunnungham, 2011).

2.5. *Gamification in Teaching*

Although gamification is used in various contexts, in recent years it has gained attention in educational settings (Hamari *et al.*, 2014). Among the pedagogical strategies in the current context, gamification appears to be a promising instrument, and can be considered a new reading of the playful culture (Martins *et al.*, 2018). This is because gamification aims to involve students, making them feel more engaged and motivated than when they are exposed to more traditional teaching-learning methods (Kapp, 2012).

There is great concern among education experts about how to make learning more interesting for students (Martins *et al.*, 2018). It should be noted that low student involvement and lack of motivation are the main difficulties faced by instructors (Lee and Hammer, 2011). For these reasons, gamification has been explored mainly in education (Dichev and Dicheva, 2017).

When applying a gamified environment to the classroom, the focus is to increase students' motivation in the learning process and/or transform tedious activities into fun (Dichev and Dicheva, 2017). Kapp (2012) points out that gamification, when used correctly, has the potential to engage, educate and inform. Hamari *et al.* (2014) emphasize that applied gamification as a learning resource constitutes a means that can expand not only the student's knowledge, but also their ability to cooperate and communicate with colleagues regarding the understanding of the learning content. Gamification in education applies game-like rule environments, player experiences, and cultural profiles to shape student behavior (Lee and Hammer, 2011).

As a result, students can overcome inherent learning challenges, both learning and achieving better academic performance (Kapp, 2012). The potential of games as educational tools has grown as interest in the gamification method grows, drawing the attention of educators and institutions towards increasing student engagement and experience with learning (De-Marcos *et al.*, 2016).

2.6. *Related Works*

Currently in the literature, there are some works with gamified environments applied to education in software engineering disciplines.

Poffo (2016) used gamification to motivate students in a gamified environment for teaching software engineering. The author applied the hypothetical-deductive and applied research methods and the knowledge was used for elaborating the gamified teaching environment. By the qualitative and quantitative evaluation of the environment by the students, their motivation with the use of the environment was verified. A positive contribution to learning was obtained, in which most students considered that the gamified solution contributed to content learning.

Su (2016) developed a gamified environment for evaluating the effects of gamification on software engineering teaching. In the study, 107 undergraduate students participated in two classes. Students performed various tasks in the environment by using game elements: points, progress bar, missions, time, rounds and awards. As a result, students felt more motivated with the application of gamified teaching and showed an improvement in their academic performance.

Diniz *et al.* (2017) applied gamification to motivate and guide undergraduate students to cooperate in open-source software projects. The authors used the following game elements: missions, points, ranking and levels. 17 undergraduate students participated in the research. The results showed that students felt motivated and oriented to collaborate with the project. The feedbacks were observed to be especially useful to guide the students and the points kept the students engaged with the project.

Based on related works, the gamification strategy has shown to be applied to different disciplines in computing courses and has kindled the interest of researchers in the development of tools, with game resources, to increase student engagement and motivation, to contribute to the teaching-learning process. Likewise, the motivating factor of this research is to help students in the study of software modeling with UML, in which some type of difficulty with the study of the content has often been demonstrated or reported.

3. Method

3.1. *PGE-UML Platform*

PGE-UML is an online web platform, with gamification resources, available for access outside the classroom, that is, at home or in other environments where students and instructors have devices with Internet access. It has great flexibility for use on large screens, such as desktops (Fig. 1), or small screens of mobile devices, such as smartphones (Fig. 2). Its interface was planned and developed to provide students with a simple and pleasant environment.

The process of creating the gamified environment to promote the study was directed towards achieving two main objectives. First, to provide an environment in which stu-

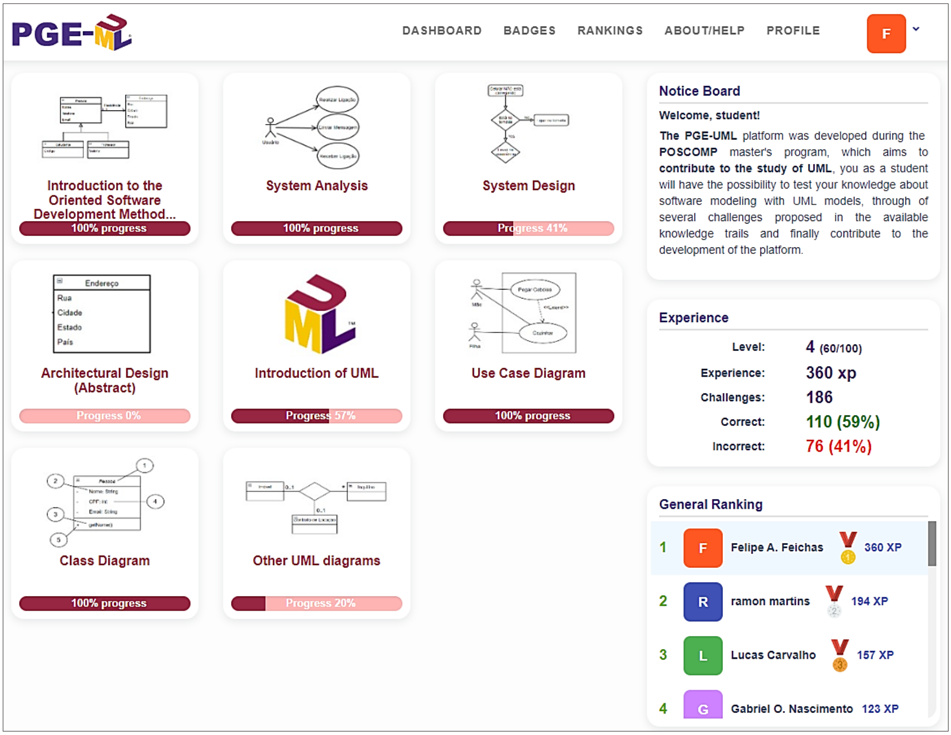

Fig. 1. PGE-UML main screen (dashboard). Source: The authors.

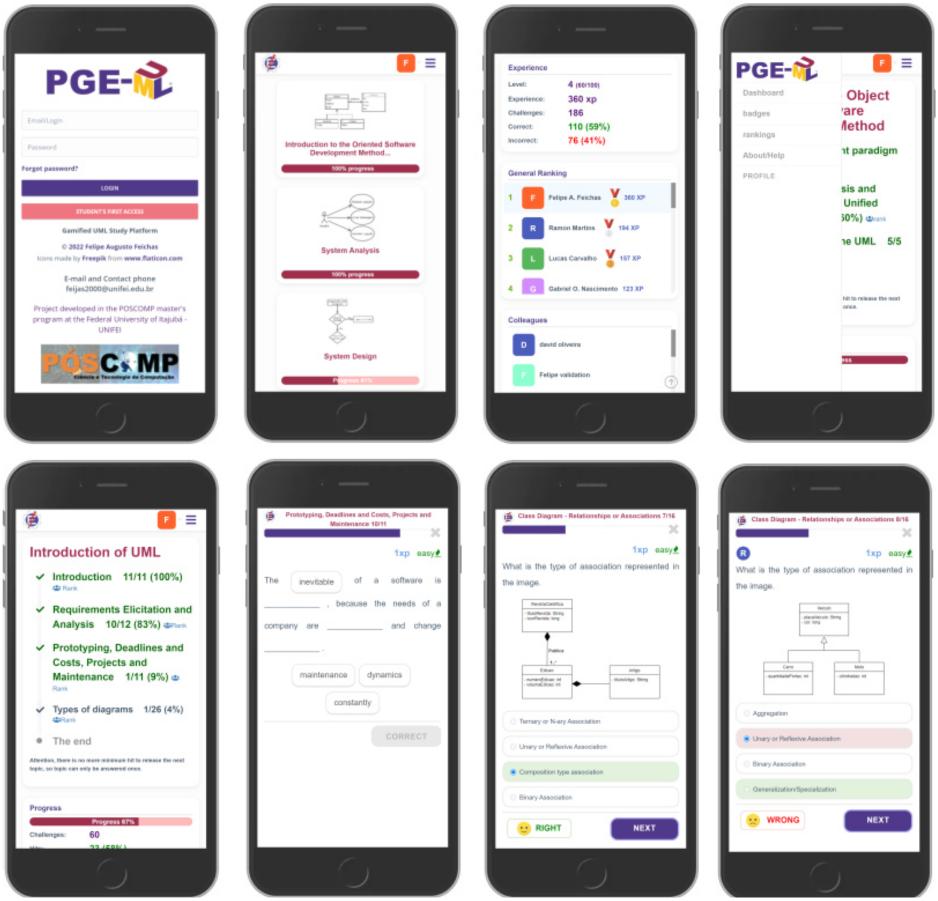

Fig. 2. Mobile version of the platform. Source: The authors.

dents can observe the effect of their actions and learning while developing the activities. Second, to use the environment as a complement to the traditional teaching method, transforming the class into a motivating and engaging experience (Kapp, 2012).

For developing the environment, the script by Alves (2015) was adopted, which consists of a step-by-step guide for the development of learning solutions with gamification, aiming to ensure the use of game thinking in the teaching process. This process consists of seven steps: (i) know the business and learning objectives; (ii) define behaviors and tasks that will be targets of this solution; (iii) know your players; (iv) recognize the type of knowledge that will have to be taught; (v) ensure the presence of entertainment; (vi) use appropriate tools; and (vii) make prototypes.

The proposed tool contains two profiles: (i) that of the instructor, who registers classes and students, monitoring their progress; (ii) that of the student, who participates in the activities.

The basis of fun in the environment is the application of game elements, such as points, badges, leaderboards, feedbacks, and challenges, on a web platform. With this information, students can compare their progress with that of other students (Fig. 3), thus encouraging competition. The application of these elements is expected to modify the behavior of students, aiming to intensify their motivation to study the content.

Another important aspect for stimulating students is represented by the knowledge trails (Fig. 4), which consist of sequences of phases and topics with varying challenges and degrees of difficulty, providing a challenging environment.

The knowledge that can be worked on in the environment is theoretical and practical, employing challenges such as ‘quiz’ (Fig. 5), ‘gap(s)’ (Fig. 6), ‘select the correct image’ (Fig. 7), ‘video-based answer’, ‘image-based answer’, ‘true or false’ (Fig. 8), ‘form the sentence’, ‘pair relation or ordered selection’, among others.

The idea is that from theoretical challenges, as well as practical exercises, learners reinforce what was learned in the classroom, improving, and practicing their knowledge, in addition to receiving feedback on it. Martins *et al.* (2018) claim that problem-solving is one of the ways to achieve higher levels of student learning motivation and engagement.

In general, the use of PGE-UML for studying content occurs in a sequence of seven steps:

- Initially, the lecturer accesses the platform and registers the class.
- Upon completion of registration, the lecturer provides the access form to students. The platform allows the lecturer to add students or provide a code for them to perform the first access.

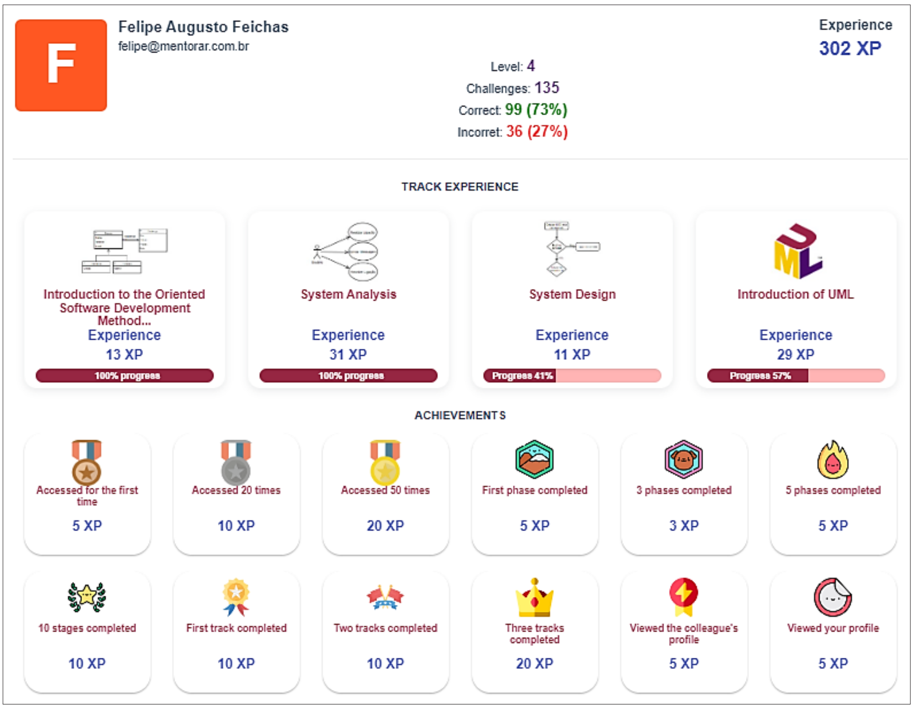

Fig. 3. Student information and progress. Source: The authors.

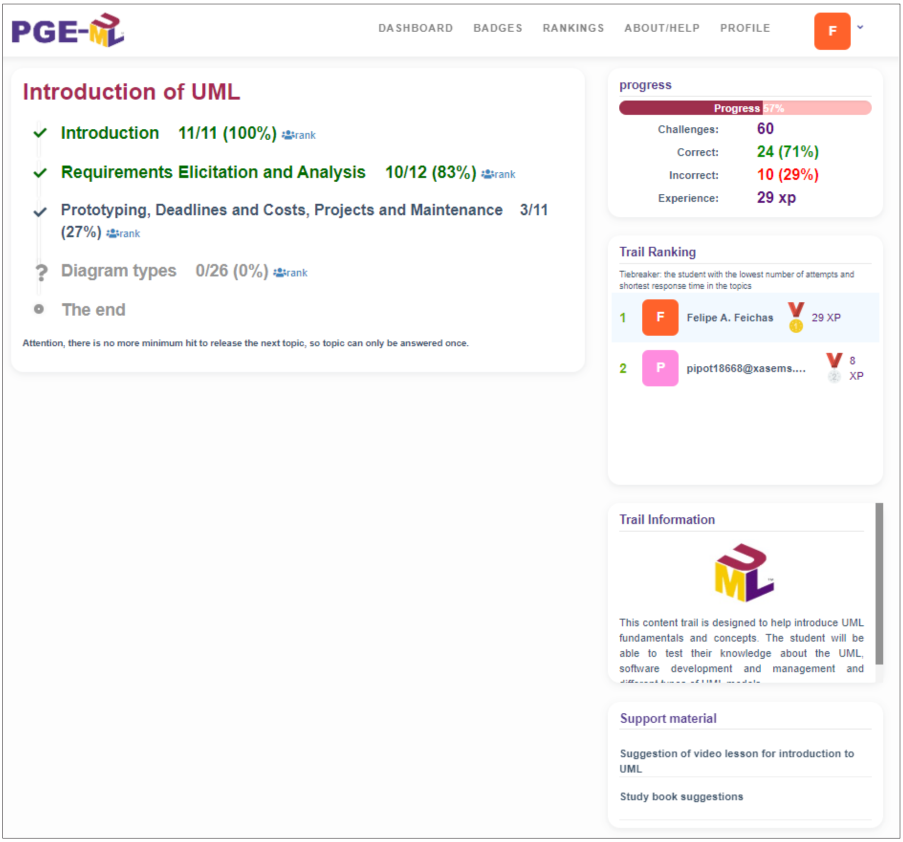

Fig. 4. Knowledge trail example. Source: The authors.

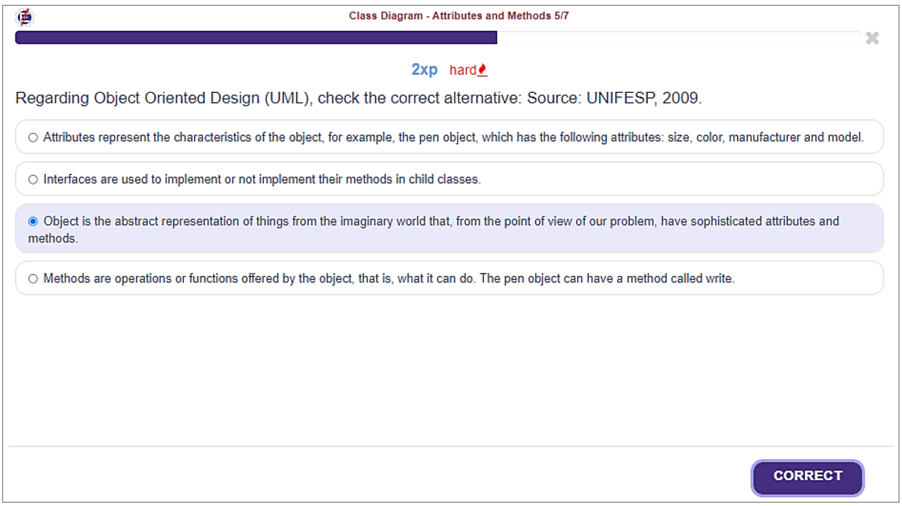

Fig. 5. ‘Quiz’ challenge. Source: The authors.

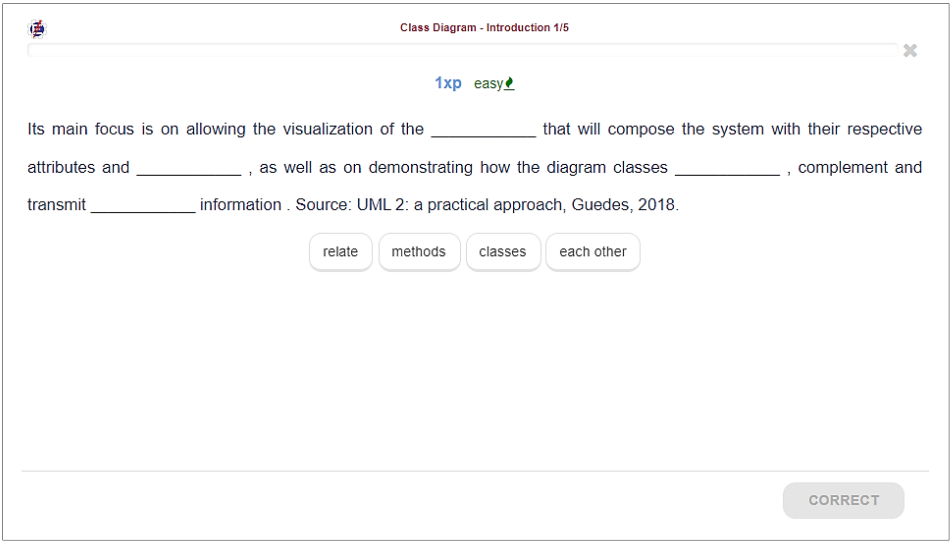

Fig. 6. ‘Gaps’ challenge. Source: The authors.

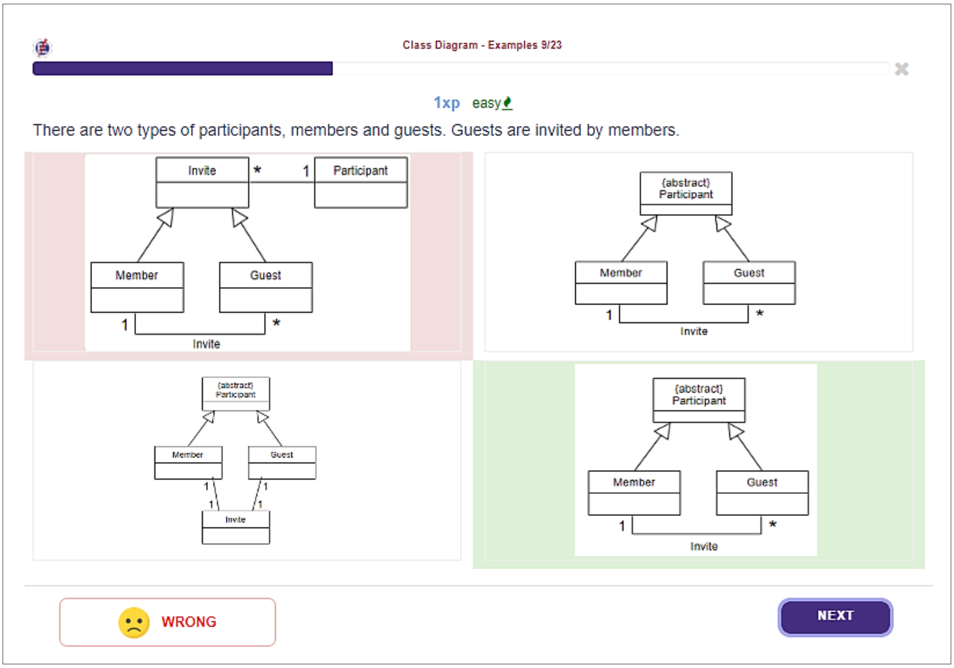

Fig. 7. ‘Select the correct image’ challenge. Source: The authors.

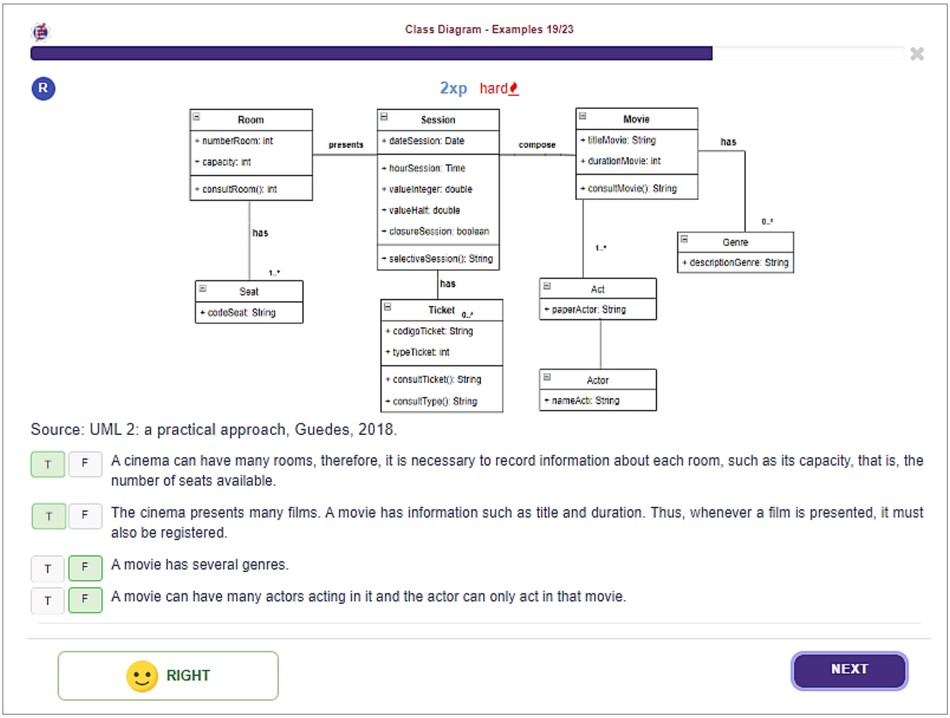

Fig. 8. 'True or false' challenge based on the image. Source: The authors.

- During the class, the lecturer asks the students to access the platform, explaining the functioning and rules of the environment.
- Students access the platform and check the available trails.
- The lectures are delivered and then the trails are made available, leaving it to the lecturer to choose which ones will be made available to the students.
- Students perform the trails, which can be performed in class, or after class, in another location.
- Students who finish the trails receive points and badges, and can track their positions on the leaderboard, as well as their achievements.

The PGE-UML platform developed in this research can be accessed by the following link: uml.cvs.com.br.

3.2. *Participants and Method Description*

After developing the proposed platform, a case study was conducted during the first semester of 2022, involving 25 volunteer students enrolled in the Object-Oriented Computing II course at the Federal University of Itajubá. Students were exposed to PGE-UML for 12 weeks. In conducting the case study, the presentation of the platform with the professor responsible for the discipline was defined, as well as a brief overview of gamification for increasing student interest. The presentation took place in a computer-teaching laboratory at the university, as students could use computers with Internet access. Access could also occur by mobile devices or notebooks. In this presentation, the objective of the research was clarified, and that the participation of students in the study would not cause any interference with the grades obtained in the discipline.

After this brief presentation, a space was opened for possible clarifications. After resolving the doubts, a Free and Informed Consent Term was given to the students who agreed to participate in the research, highlighting the initial purpose of the study in question, as well as the anonymity and use of the data collected only for research purposes. It is worth mentioning that this research followed the ethical precepts determined by Resolution No. 510 (Brasil, 2016), of April 7, 2016.

Before starting to use the platform, participants were asked to answer the Class Knowledge Questionnaire. This questionnaire presented 10 questions for obtaining profile data and a self-assessment of the students regarding their availability for the study, their knowledge regarding the content and their level of interest in games. Identifying the profiles of the students in the class was of great relevance to the study, for better understanding the results and verifying whether gamification was a viable option for the context.

The platform was made available for students to use as the course content progressed. Knowledge trails were released so that they could play, reinforcing the content learned in the classroom. The contents of the trails were reviewed with the course instructor and released in the following order, with their respective topics:

- **Track 1** – Introduction to the object-oriented software development method: OO development paradigm, software analysis and design and the Unified Process, and modeling and UML.
- **Track 2** – System analysis: analysis and specification of requirements, use cases, specification and modeling of software design elements (architecture, classes and objects).
- **Track 3** – Introduction to UML: introduction, elicitation and requirements analysis, prototyping, deadlines and costs, projects and maintenance, and types of diagrams.
- **Track 4** – Use case diagram: introduction, characteristics (actors, forms, representations and associations) and examples.
- **Track 5** – Class diagram: introduction, attributes and methods, relationships or associations and examples.

During this period, logs were captured to record the interactions and behaviors of the students automatically, from the moment they logged into the platform. After the period of use, the students were asked to answer the "Questionnaire for Evaluating the Use of the Platform" (Table 1). The questionnaire consisted of 14 multiple-choice questions, divided into three categories: *usability*, *content study, gamification and satisfaction*. This questionnaire sought to investigate the acceptance and satisfaction of use by the students participating in the case study using a five-point Likert scale, with responses ranging from 'strongly disagree' to 'strongly agree'.

Table 1

Questionnaire to evaluate the use of the platform. Source: The authors

Focus in	ID	Question
Usability	Q1	It was simple to access and learn to use PGE-UML for the first time.
	Q2	The platform is easy to use.
	Q3	The design (graphical interface, layout, challenges, etc.) of the platform is clean and pleasant.
	Q4	The platform information is well organized.
	Q5	The texts used on the platform are readable.
Content Study	Q6	The content presented in the knowledge trails is challenging for me.
	Q7	The content on the platform was relevant to my interests.
	Q8	It is clear to me that the content is related to the discipline.
	Q9	The platform contributed to my studies compared to other activities.
	Q10	Other students could benefit from using the platform to learn software modeling with UML.
Gamification and Satisfaction	Q11	The platform promotes a moment of competition with the scoring system.
	Q12	I had fun with the gamified environment.
	Q13	I would rather learn with gamification than in any other way.
	Q14	I would recommend the gamified platform to be used in other disciplines.

4. Results

From the information collected, it can be identified that, at the end of the intervention, of the 25 participating students, most identified themselves as male (92%) and aged between 19 and 24 years old (84%). This information points to a trend in computing courses in relation to gender and age. Due to this homogeneity, possible differences in behavior related to gender and age were not explored in this research.

Since the PGE-UML is a web platform, whose purpose is to be used in the classroom or outside the classroom, it was relevant to identify the level of availability of students' time and their daily dedication to studies. It can be observed that practically half of the students carry out some [other/professional/...] type of activity (48%) and the others only study (52%). Although a part carries out activities in addition to studies, most answered that they study one or more hours a day at home, on average (96%). Therefore, there was the opportunity for these students to use the platform, in addition to class time, as an extra-class resource.

Another objective of the platform is to assist students in the study of the topic. Thus, it was relevant to examine previous experience and difficulties with the subject to assess the importance of the platform as a study assistance tool. More than half of the students (68%) were observed to have a previous notion of the theme. Almost half had already applied UML to other subjects or at work (48%). Considering the students' experience with the content, more than half (52%) did not express difficulties with the content.

Regarding the students' interest level regarding the use of electronic games, aiming to analyze the students' profiles and find important factors to support or not the use of the platform with gamified resources, it can be observed that all the students like games, being that 78% spend one to three hours a day playing games. In addition, 78% play on smartphones and on computers, that is, the same devices used to access the platform. Finally, 88% of the students found it interesting to use game elements for the study. In this context, the possibility of applying a didactic web environment, with gamification resources is noticeable, once it is accessible on desktops or smartphones, to increase the participation and engagement of students in studying in or outside the classroom.

The analysis of the logs of interactions, behaviors and the time spent by students with PGE-UML showed engagement with the platform and dedication to completing the trails. Of the accesses, 59.6% occurred during classes. 94% of the knowledge trails were observed to have been completed and 56% of the proposed emblems conquered. As for the challenges made available, 98% were responded to. Of these, 91% were answered correctly, and most students obtained a percentage of correct answers above 80%. Finally, it is understood that the achievement indicators showed motivation to complete the proposed activities. As a result, it is understood that there was a possible influence of gamification on student motivation.

Regarding the answers to the Platform Use Assessment Questionnaire (Fig. 9), in terms of usability, all the students agreed that PGE-UML was easy to access and learn for the first time (Q1), and all of them fully agreed that it was easy to use (Q2). Most students agreed that the platform had a clean and pleasant design (Q3), that the information was well-organized (Q4), and the texts were readable (Q5). Therefore, as to usability, in the grouped value of the questions, 95.2% fully or partially agreed with this criterion. In view of these results, as most students were in favor of the statements, the data show a great acceptance of the gamified environment by the students.

Regarding the content study category, considering the students' previous experience with the topic, more than half of the students (72%) agreed that the content was challenging (Q6), with a percentage of neutral responses being observed. It is understood that due to the students' previous experience with the content, a greater level of difficulty in the challenges is necessary to try to further increase the students' motivation. Still on the study of the topic, the majority (92%) agreed that the content presented was relevant to their interests (Q7), all the students agreed that the content presented was related to the topic (Q8), and the majority (84%) agreed that the PGE-UML contributed to the development of knowledge compared to the other activities of the discipline (Q9). It is believed that due to this feeling of contribution, the vast majority (92%) agreed that other students could benefit from using the PGE-UML (Q10), indicating that students felt satisfied with the use of the platform for the study. Considering the grouped value of the five questions of the content study, 88% of the students agreed with the statements. This indicates that the vast majority considered the study by PGE-UML to be positive, and that the platform directly contributed to the students in building their knowledge.

Regarding gamification and satisfaction, most participants agreed (92%) that PGE-UML promoted a moment of competition with the scoring system among students (Q11). Regarding entertainment, 68% agreed with this aspect (Q12). This shows that most students experienced the feeling of fun provided by using the gamified environ-

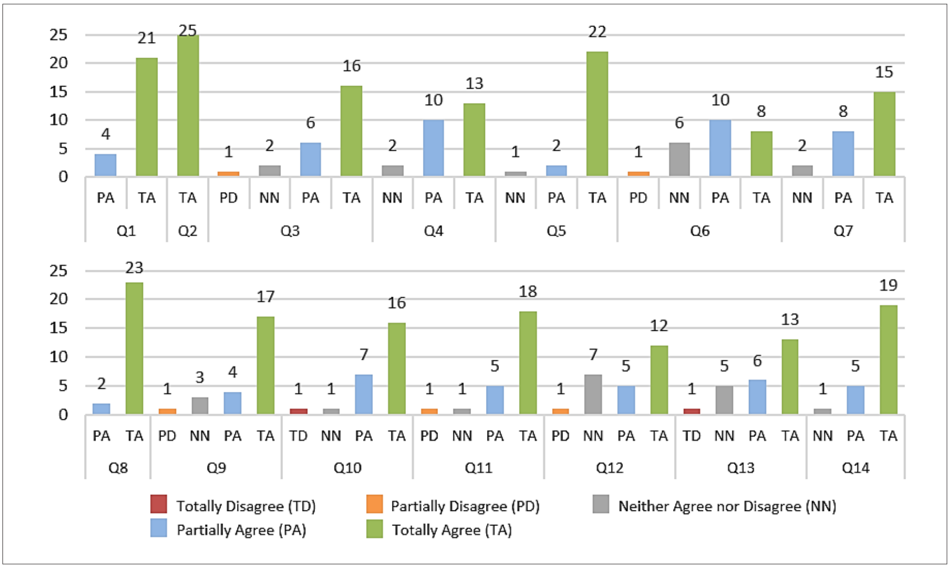

Fig. 9. Frequencies of answers to questions on the platform usage evaluation form. Source: The authors.

ment. However, as some students expressed not having experienced this feeling, it might be necessary to explore other forms of challenges to increase the number of students who may experience it. Regarding learning through gamification rather than using another way (Q13), most students agreed (76%) with the question. In addition, 96% of learners would recommend using PGE-UML in other subjects (Q14). This result again shows the acceptance and satisfaction of using the platform for the study, as a complement to the traditional teaching method. Therefore, 83% of the participants expressed agreement on the grouped value of the gamification and satisfaction category. This result suggests that PGE-UML achieved its main objectives: to promote a feeling of a gamified environment, actively engage students in the process, besides contributing to motivate and encourage the study of software modeling with UML.

Note that the students expressed satisfaction with the use of the platform, pointing out that it can be used by other students in the study of UML and recommending that it be used in other disciplines, leading to the conclusion that there was acceptance and satisfaction on the part of the students in using the platform. As indicated by Kapp (2012) and verified from the answers, when using the gamified environment as a complement to the traditional teaching method, the class becomes a motivating and engaging experience.

4.1. *Data Analysis*

The analysis of the data from the questionnaire to evaluate the use of the platform permitted to calculate some statistical indicators, presented in Table 2. According to the

Table 2
Descriptive research data. Source: The authors

Categories	Questions	Minimum	Maximum	Average	Median	Standard deviation	Variance
Usability	Q1	4	5	4.84	5	0.374	0.14
	Q2	5	5	5	5	0	0
	Q3	2	5	4.48	5	0.823	0.677
	Q4	3	5	4.44	5	0.651	0.423
	Q5	3	5	4.84	5	0.473	0.223
Content Study	Q6	2	5	4	4	0.866	0.75
	Q7	3	5	4.52	5	0.653	0.427
	Q8	4	5	4.92	5	0.277	0.077
	Q9	2	5	4.48	5	0.872	0.76
	Q10	1	5	4.48	5	0.918	0.843
Gamification and Satisfaction	Q11	2	5	4.6	5	0.764	0.583
	Q12	2	5	4.12	4	0.971	0.943
	Q13	1	5	4.2	5	1.041	1.083
	Q14	3	5	4.72	5	0.542	0.293

data presented, analyzing each question, it was found that the median varied between 4 and 5. The standard deviation was between 0.277 and 1.041, showing a variation in the answers, mainly in questions Q8 and Q13. This variability indicates that the students gave different answers to the same questions.

Fig. 10 presents the grouped answers of the students for the category's usability, content study, gamification and satisfaction. Regarding the usability category and considering the grouped value of the five questions, the evaluations received the following percentages: 77.6% 'completely agree', 17.6% 'partially agree', 4% 'neither agree nor disagree' and 0.8% 'partially disagreed'. In general, the data analysis suggests that PGE-UML had good acceptance regarding the usability of the platform.

The evaluations of the content study category and considering the grouped value of the five questions yielded the following percentages: 63.2% 'completely agreed', 24.8% 'partially agreed', 9.6% 'neither agreed nor disagreed', 1.6% 'partially disagreed' and 0.8% 'strongly disagreed'. Adding the opinions of those who 'totally agreed' and 'partially agreed', 88% of the students agreed with the questions about the study of content by the platform.

In the gamification and satisfaction category and considering the grouped value of the four questions, the evaluations were as follows: 62% 'completely agree', 21% 'partially agree', 14% 'neither agree nor disagree', 2% 'partially disagreed' and 1% 'strongly disagreed'. Adding the responses of the participants who 'totally agreed' and 'partially agreed', 83% of the students agreed with the use of gamification, showing good satisfaction with PGE-UML.

Table 3 presents the descriptive data grouped in relation to the category. Analyzing the data, it was observed that the median value in all the categories was 5, and it can be

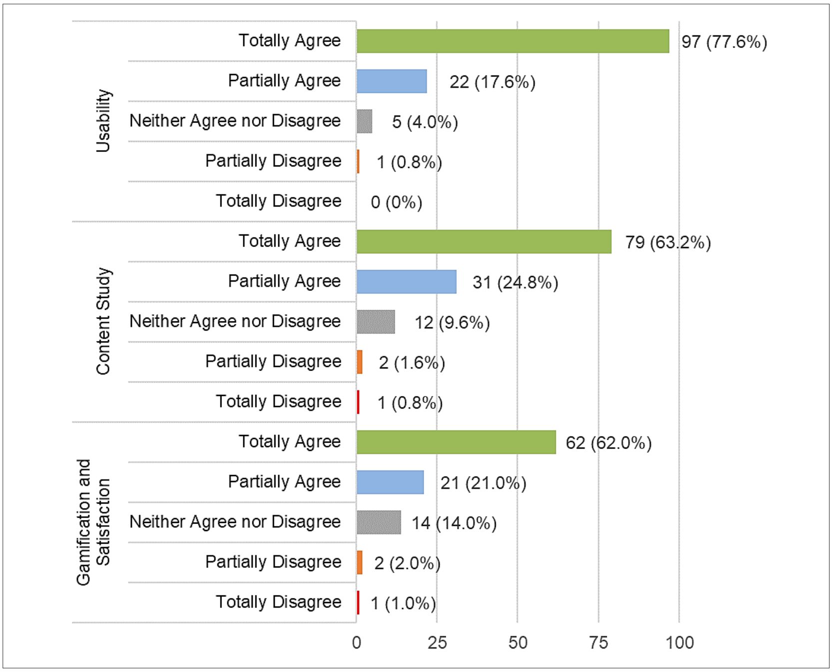

Fig. 10. Frequency of assessment responses by category. Source: The authors.

Table 3

Descriptive data grouped by category. Source: The authors

Categories	Minimum	Maximum	Average	Median	Standard deviation	Variance
Usability	2	5	4.72	5	0.576	0.332
Content Study	1	5	4.48	5	0.799	0.638
Gamification and Satisfaction	1	5	4.41	5	0.877	0.769

concluded that the students agreed with the questions applied. The standard deviation was between 0.576 and 0.877, showing that there was a variation in the responses.

Table 4 presents the general descriptive data of the questionnaire, without grouping by category or question. It appears that from of the result of the general median, it can be concluded that the students agreed with the questions presented.

This result suggests that the use of the PGE-UML, with its gamification resources, reached a good level of acceptance and satisfaction by the students, because, when comparing the median obtained (5 – 'totally agree') with the values of the Likert scale adopted, it was identified that the students agreed with the questions. Therefore, it can be considered that the PGE-UML contributed to engage and to motivate students regarding the study of content.

Table 4

General descriptive data. Source: The authors

Description	Values
Number of students	25
Number of questions	14
General number of responses	350
Minimum value	1
Maximum value	5
Average	4.545
Median	5
Standard deviation	0.762
Variance	0.580

4.2. *Reliability Analysis*

To measure the reliability of the platform evaluation questionnaire, Cronbach's Alpha was applied to assess the internal consistency of the questions. The instrument also checks whether there was coherence in the variation of the responses of the students participating in the study. According to Pereira (2001), Cronbach's Alpha determines the relationship between covariance measures and internal variances. The alpha coefficient varies between 0 and 1, which means that the higher the value close to 1, the greater the internal consistency of the questions evaluated. The alpha coefficient can be understood as the squared correlation, being the supposed real measure of the event studied. Malhotra (1996) defines that the minimum acceptable value for Alpha is 0.6, while George and Mallery (2003) proposed a scale of values in which 0.6 is questionable, 0.7 is acceptable, 0.8 is good and above 0.9 is excellent.

To calculate Cronbach's Alpha coefficient, the IBM SPSS Statistics software was used. First, it was applied to all the fourteen questions of the questionnaire, but in question Q2, as all students 'totally agree', the variance is equal to zero, making it necessary to remove the question. Therefore, calculations were performed on thirteen questions and the overall result was 0.855, which means good consistency, as shown in Table 5.

Despite the high level of reliability in the general context of the questionnaire, presenting a good consistency, it is essential to analyze the individual influence of each question. Table 6 presents the results if each question is removed.

As can be seen in Table 6, even if a question is removed, the alpha coefficient remains above 0.8, which means that none of the questions disagrees with the questionnaire.

Table 5

Overall reliability. Source: The authors

Cronbach's Alpha	Cronbach's Alpha based on standardized items	Number of items
0.855	0.862	13

Table 6

Cronbach's alpha statistics if an item is excluded. Source: The authors

Cronbach's Alpha if item is excluded	
Q1	0.856
Q3	0.836
Q4	0.847
Q5	0.858
Q6	0.828
Q7	0.835
Q8	0.848
Q9	0.843
Q10	0.834
Q11	0.864
Q12	0.834
Q13	0.849
Q14	0.846

4.3. *Correlations*

When calculating the Pearson correlation between the platform evaluation questionnaire questions, applying the Microsoft Excel 2019 data analysis correlation, 10 occurrences with r coefficient greater than 0.6 were found. Due to the limited number of students, this coefficient value is considered a strong correlation.

As shown in Table 7, no occurrences were found with negative r coefficients lower than -0.5; therefore, there were no significant negative correlations. In question Q2,

Table 7

Correlations between the questions in the platform evaluation questionnaire. Source: The authors

Questions	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14
Q1	1.00													
Q2		1.00												
Q3	-0.01		1.00											
Q4	-0.04		0.37	1.00										
Q5	-0.15		0.53	-0.03	1.00									
Q6	0.26		0.53	0.44	0.31	1.00								
Q7	0.18		**0.60**	0.52	0.28	**0.73**	1.00							
Q8	0.27		0.54	0.43	0.22	0.52	0.47	1.00						
Q9	0.37		0.30	**0.64**	-0.21	**0.60**	**0.64**	0.34	1.00					
Q10	0.59		0.29	0.40	-0.10	0.52	0.47	**0.64**	**0.68**	1.00				
Q11	-0.09		0.25	-0.13	0.39	0.19	0.02	0.04	-0.01	0.23	1.00			
Q12	0.17		**0.60**	0.44	0.41	**0.64**	0.49	0.50	0.27	0.31	0.12	1.00		
Q13	0.09		0.56	0.17	0.15	0.28	0.27	0.49	0.07	0.37	0.37	0.59	1.00	
Q14	0.59		0.03	0.25	-0.02	0.44	0.31	0.40	0.47	**0.70**	0.12	0.30	0.33	1.00

there was a particularity; as all students ‘totally agreed’, it was not possible to verify correlations with the other questions.

The first two correlations that can be observed are between questions Q3 and Q7 ($p = 0.001$) and Q3 and Q12 ($p = 0.001$), indicating that there is a correlation between the quality of the design (graphical interface, layout, challenges, etc.) of the PGE-UML and the students’ interest in the content presented in the knowledge trails and in the level of fun provided by the platform. A gamified environment with an attractive, efficient, and functional design can thus be observed to directly influence students’ interest in its content, as well as providing a sense of fun with the environment.

Another correlation was found between questions Q4 and Q9 ($p < 0.001$). The quality of the presentation of texts on the platform contributed to the students’ study compared to other activities of the discipline. For this reason, an environment with clear and legible texts interfered with the relevance of PGE-UML for students regarding the study of the content.

The next correlations observed are between questions Q6 and Q7 ($p < 0.001$), Q6 and Q9 ($p = 0.001$) and Q6 and Q12 ($p < 0.001$), indicating that the level of difficulty of the challenges presented in the knowledge trails correlated with the degree of relevance of the content for students (Q7) and the feeling of contribution of the platform to the study compared to other activities of the discipline (Q9). The level of difficulty of the challenges is positively correlated with students’ enjoyment of the PGE-UML (Q12). In this sense, it was possible to verify the importance of the gamified environment being challenging for students, as well as the levels of difficulty of the challenges on the trails. A challenging environment has a direct positive impact on fun, content relevance and acceptance of the platform by students.

The relevance of the content presented on the platform for students (Q7) is correlated with the feeling of contribution of the platform to the students’ study, compared to other activities of the discipline (Q9) ($p < 0.001$). The increase in the content relevance level is thus strongly correlated with the platform contribution to the intensification of the study of the research participants.

The level of students’ perception of whether the content presented on the platform is related to the content of the discipline (Q8) is positively correlated with the degree of recommendation of PGE-UML for other students to benefit from the use of the platform, aiming to learn software modeling with UML (Q10) ($p < 0.001$). The quality of the content presented clearly had a direct impact on the recommendation of the platform for other students to learn software modeling with UML using PGE-UML.

The feeling of contribution of the platform to the study of content (Q9) is correlated to the degree of recommendation of the PGE-UML for other students to learn software modeling with UML using the tool (Q10) ($p < 0.001$), indicating that the greater the contribution of the platform to the study of content, the greater the recommendation of the platform to the students’ colleagues.

Finally, the recommendation to use the platform to learn software modeling with UML (Q10) is correlated to the recommendation to use PGE-UML in other disciplines (Q14) ($p < 0.001$), indicating that the acceptance level of the platform for learning UML has a direct impact on its recommendation for use in other disciplines.

5. Final Considerations

The main motivation of this research is that the modeling of software with UML is considered complex for students to learn and for professors to teach. In addition, it is difficult for instructors to find different pedagogical strategies to improve the teaching of the subject. Seeking to alleviate these difficulties, this work presented the PGE-UML, a gamified platform directed to the study of the theme. Gamification has the main benefits of increasing motivation in learning and engagement using game elements. With this, the purpose of the platform is to use the motivational and involvement potential to encourage students in the study process.

One of the PGE-UML differentials is represented by the knowledge trails, which consist of sequences of phases and topics with several theoretical challenges and practical exercises, so that students reinforce what was learned in the classroom, improving and practicing their knowledge, besides receiving feedback on it. The gamified environment has leaderboards, a scoring system and badges for achievements for fostering competition, as they allow the student to follow the progress of other participants, along with the high availability of use, in an online environment, available in different resolutions and devices, such as notebooks or smartphones.

By interactions, it was possible to analyze the behaviors and engagement of students participating in the research. The data showed that they accessed the platform both during and after class hours. The logs showed that the students completed most of the knowledge trails available in the period. Hence, the analysis showed the engagement in using PGE-UML, the result of an active participation of the students in the study of the content. Finally, PGE-UML was concluded to contribute to the study of the content, and great acceptance and satisfaction by the students was verified in the use of the gamified environment.

As future work, a case study is suggested, to apply the platform to a larger sample of students, in different classes and in the long term, seeking to better investigate how different students experience and react to gamified learning by using. Also proposed is to evaluate the possible gain in the teaching-learning process provided using PGE-UML with a control group, to quantitatively determine if its use promotes a significant increase in students' performance.

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F.A. Feichas was born in Itajubá, Minas Gerais, Brazil, in 1987. He received the B.S. degree in Information Systems from the Federal University of Itajubá (UNIFEI), Itajubá, Brazil, in 2014 and the M.S degree in Computer Science from the Federal University of Itajubá (UNIFEI), Itajubá, Brazil, in 2022. Since 2014, he has been working on the development of mentoring and professional training platforms. Currently, he is a partner at the startup CVS Sistemas, Brazil. He has authored three journal articles. His research focuses on informatics in education.

R.D. Seabra was born in Marília, São Paulo, Brazil, in 1982. He received the B.S. degree in Computer Science from the Centro Universitário Eurípides de Marília (UNIVEM), Marília, Brazil, in 2003, and the Ph.D. degree in Science from University of São Paulo (USP), São Paulo, Brazil, in 2009. He is currently a professor at the Institute of Mathematics and Computing of the Federal University of Itajubá (UNIFEI), working in undergraduate and graduate courses. He is the author of 90 complete works distributed in specialized journals, proceedings of events and book chapters. His research interests include informatics in education, human-computer interaction, virtual reality and software engineering.