FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Applying Gamification to Teaching-Learning Techniques in Higher Education: an Engineering Case Study

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MSc in Informatics Engineering and Computing

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Resumo

A tecnologia tornou-se a força motriz das tarefas quotidianas, destacando-se na educação, especialmente após a pandemia, que obrigou a uma mudança para um modelo virtual *online*. Com isto, a educação superior tradicional revelou dificuldades em manter o interesse dos estudantes, levando ao aumento do insucesso académico e, consequentemente, da taxa de abandono universitário.

Por outro lado, os jogos provaram ser capazes de manter níveis elevados de motivação e envolvimento e reduzir o cansaço experienciado na resolução de problemas complexos, quando comparados com um exercício análogo de aprendizagem. Assim, a comunidade académica tem demonstrado um interesse crescente na exploração e adoção de gamificação - integração de elementos, mecânicas e estruturas típicas de jogos em outras áreas de atividade - no processo de aprendizagem para melhorar estas estatísticas.

Neste contexto, o presente trabalho visou desenvolver um método inovador para o processo de ensino-aprendizagem no ensino superior utilizando técnicas de gamificação, tais como pontuação, classificação, competição entre pares, trabalho em equipa e prémios, em duas fases.

A primeira fase envolveu uma revisão sistemática da literatura acerca da gamificação no ensino superior. No total, foram encontrados 558 artigos que, após filtragem, resultaram numa lista de 31 referências a ser analisadas.

A segunda fase consistiu na conceptualização, desenvolvimento e validação do protótipo de um método de ensino-aprendizagem através de design centrado no utilizador. Para este efeito, três modelos foram criados: o primeiro com exercícios para estudo autónomo ou aulas práticas, o segundo com desafios para resolver durante as aulas teóricas ou em casa, e o último com um fórum onde os estudantes podem colocar as suas dúvidas e responder às questões dos outros. Os modelos foram validados através da realização de testes de usabilidade com 26 estudantes e 11 professores da Faculdade de Engenharia da Universidade do Porto (FEUP), que aferiram os efeitos dos elementos de gamificação na motivação e no desempenho académico dos estudantes.

Através destes testes, foi possível verificar os elementos mais efetivos na motivação e no desempenho dos estudantes em cada situação testada, como a introdução de medalhas (4,95/5) para os estudantes que respondem corretamente no fórum, ou a existência de feedback imediato (4,9/5) nos exercícios.

Este trabalho proporciona valor para os estudantes, tornando as suas tarefas mais apelativas e dignas de envolvimento e melhorando os seus resultados, bem como para os professores, facilitando a retenção da atenção dos seus estudantes. Este trabalho adiciona também valor através da submissão de um artigo de revisão sistemática da literatura, bem como a futura submissão de um artigo completo de estudo de caso. Por último, a produção de um ranking com as classificações dos diferentes elementos de jogos em relação à motivação e ao desempenho académico cria diretrizes para futuras abordagens semelhantes.

Palavras-chave: Design Centrado no Utilizador, Envolvimento, Motivação, Desempenho Académico, Gamificado, Inovação

Classificação ACM: Applied Computing -> Education -> Interactive Learning Environments

Abstract

Technology has become the driving force of every day-to-day task, notably education, especially after the pandemic, which forced a shift to an online-based, digital model. With this, traditional higher education revealed difficulties in keeping students motivated and interested, which led to an increase in academic failure and, consequently, in the university dropout rate.

On the other hand, games have been proven to successfully sustain high levels of motivation and engagement and reduce the fatigue experienced when solving complex problems, compared to an analogous learning exercise. Hence, the academic community has shown an increasing interest in exploring and adopting gamification – the integration of game elements, mechanics and structures in other areas of activity – into the learning process to improve these statistics.

In this regard, the present work aimed to develop an innovative higher education teaching-learning method using gamification techniques, such as point scoring, leaderboards, peer competition, teamwork and awards, in two phases.

The first phase involved a systematic review of the literature on gamification in higher education. In total, 558 articles were retrieved, which, after filtering, resulted in a list of 31 references to be analysed.

The second phase consisted of conceptualising, developing and validating the prototype of a teaching-learning method through user-centred design. For this purpose, three models were designed: the first with exercises for autonomous study or practical classes, the second with challenges to be solved during theoretical lectures or as homework, and the last one with a forum where students can ask their doubts and answer each other's questions. The validation of the models took place through usability tests performed with 26 students and 11 professors from the Faculty of Engineering at the University of Porto (FEUP), in which the effects of gamification elements on student motivation and academic performance were assessed.

Through these tests, it was possible to identify the most effective elements in motivating students and improving their performance in each scenario, such as the introduction of badges (4.95/5) for students who answer correctly in the forum or the existence of immediate feedback (4.9/5) on exercises.

This research provides value for students by making their tasks more appealing and worthy of engagement and improving their results, as well as for professors by making it easier to keep their students' attention. It also adds value through the submission of a systematic literature review article to be published, as well as the future submission of a full case study article. Lastly, the production of a ranking with the motivation and learning performance ratings of the different game elements creates guidelines for similar future approaches.

Keywords: User-Centred Design, Engagement, Motivation, Learning Performance, Gamified, Innovation

CCS Concepts: Applied Computing -> Education -> Interactive Learning Environments

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This work was a result of conjoined forces from several people to which I am immensely thankful.

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I extend this acknowledgement to FEUP. Their unwavering support and resources were essential in enabling the successful elaboration of this work. In this context, I highlight those who dedicated their time and effort in participating in testing the prototypes and providing valuable advice and suggestions, as they made this Dissertation possible.

I would also like to mention TU Wien, where I studied during my Erasmus semester, for opening my horizons to the vast influence that gamification can exert on the teaching-learning process.

I take this opportunity also to thank all my friends, especially my "Turtles", who have been with me since the very beginning of my degree, throughout (almost) sleepless nights, working, celebrating or gaming, and had to listen to me complaining through several nights about projects that didn't work because of a missing semicolon.

Lastly, I want to dedicate this work to my family, especially my dear parents and brother, as without their unconditional support and motivational speeches, I wouldn't have gotten to where I am right now, let alone finish this Dissertation.

Thank you all, and be proud, because this work is also yours.

Henrique Pereira

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Abbreviations and Symbols

F2F	Face-to-Face
FEUP	Faculty of Engineering of the University of Porto
GBL	Game-Based Learning
LMS	Learning Management System
SLR	Systematic Literature Review

Chapter 1

Introduction

1.1 Context

In the current world, technology is the driving force of the most basic day-to-day tasks. A particular case where this can be seen is in the education area. Each year, new software or tools are introduced to classrooms worldwide [5]. This digitisation has been forced to exponentially increase during the pandemic due to the general shift from a F2F (face-to-face) to a fully, later becoming hybrid, virtual classroom model [14, 26].

In the case of higher education, the alliance between this constant innovation and the lack of interaction in a virtual classroom have contributed to the traditional classroom model (a lecturer speaking over a PowerPoint presentation or writing on a board) becoming obsolete, leading to a more challenging job for professors and a more monotonic and difficult one for students. This has been developing into a significant factor in the decrease in academic performance and the increase in the university dropout rate in multiple places worldwide [8, 12, 33].

1.2 Motivation

To confront these statistics, a trend has been developing in the academic community regarding the use of gamification - the integration of game elements, mechanics and structures in other areas of activity – in education [2]. While used predominantly for entertainment, games have successfully sustained high levels of motivation and engagement and reduced the fatigue experienced when solving complex problems compared to an analogous learning exercise [2]. Despite being more explored in school systems, gamification is now being taken into universities to increase student engagement and improve information retention [13].

Multiple gamification elements, such as points, leaderboards and awards [1], and techniques, of which competition [34] and cooperation [1, 7] are examples, have already been explored and documented in the existing bibliography. The effects of these gamification methods have also been studied when applied simultaneously with other standard academic procedures: group work, hybrid courses, problem-based learning [7], and mobile learning [10].

Some of the effects commonly associated with these gamification techniques are significant learning performance improvement [5], easier information retention [24], increase in motivation [1, 31], development of soft skills [4, 5], more constant engagement, more frequent use of learning materials [3, 8], and increased satisfaction with lectures, exercises and study [13, 24]. More specifically, some gamified tools and activities also improved confidence [32], learning recommendations [30], and student collaboration [31].

On the other hand, using gamified elements also positively affects lecturers by enhancing class dynamics and activity [34], increasing student participation [8] and attention retention [32] and automating tasks such as assessment [4, 29] and personalised advice [30].

However, the effects on both professors and students can also be harmful. For example, gamification had an adverse impact on some students when the elements used, such as scoreboards or puzzles and riddles, made them feel demotivated when they ranked low or increased their stress and decreased their performance when the complexity level and design were inadequate [19, 22, 28].

On the side of professors, there are a few possible disadvantages associated with the need for good planning: diminished impact in the teaching of highly complex concepts [19], low completion rate due to difficulty and design problems [22], need for personalisation of exercises for each student and clear instructions [33]. Additionally, the use of technology needs well-established rules to be effective [32].

1.3 Objectives

Based on the literature review and all the factors mentioned above, gamification requires further exploration in higher education. Therefore, this paper aimed to study the effects of an innovative gamified teaching-learning method on university professors and students.

This innovative approach followed a user-centred design, always focusing on the needs of both students and lecturers. Two design loops took place, continuously surveying the target population and using their feedback to improve the prototype.

The method prototype also considered factors that need to be deeply explored. An example of this is customisability, leading the method to mould into the professors' requirements to avoid an extensive adaptation period, and allowing them to shape it for their students, to increase its effectiveness in improving motivation and learning performance.

Hence, the main objective was applying the previously mentioned innovative gamified approach to teaching and learning. Its consequent goals were improving students' learning performance, satisfaction and motivation with the course; facilitating the teaching task by reducing the burden of keeping students motivated and automating time-consuming tasks such as feedback generation, assessment and grading; following an evolutive approach during the development against user requirements; and achieving customisability of the final method to lecturers' preferences and students' needs.

1.4 Hypothesis and Research Questions

Keeping in mind all of the aspects mentioned above, the central hypothesis placed for this work is as follows:

> *"It is possible to achieve higher student motivation and learning performance through a user-centred, customisable, gamified teaching-learning method, thereby enhancing class dynamics and lowering the effort needed from professors."*

Based on the hypothesis presented above, this work was guided by the following research questions:

RQ1: *Is it feasible to follow a **user-centred** approach to develop a gamified teaching-learning method to increase students' motivation and learning performance?*

The user-centred, customisable and evolutive approach is the focal point of the innovative gamified teaching-learning method intended to be developed, which aimed to improve students' academic experience.

RQ2: *Is it possible to enhance **student participation and class dynamics** using a user-centred gamified teaching-learning method, easing the lecturers' burden of keeping students engaged?*

The teaching-learning method attempted to increase student participation and engagement, which would relieve the pressure that demotivation and lack of interaction pose for professors.

RQ3: *Is it feasible to make the teaching-learning method **easy to use**, adapting it to the lecturers' preferences and reducing their adaptation period and effort?*

One of the methodology's primary goals was to ease professors' adaptation and usage of the new technology.

RQ4: *Is it feasible to allow professors and students to **customise** the gamified teaching-learning method to improve its suitability for the latter?*

The customisability of the method by the professors and students was essential for the latter's motivation and learning performance to increase.

1.5 Document Structure

The bases for this project are further discriminated in Chapter 2 (State of the Art), which presents the existing work, technologies and main characteristics of the approaches used to tackle the same problem. In Chapter 3 (Methodology), the methodology followed during the development process is described in further detail, and the timeline of the tasks performed is presented. Chapters 4 (Iterative Design: First Loop) and 5 (Iterative Design: Second Loop) detail the procedure behind

each of the design loops, as well as the usability tests performed and feedback received. Lastly, in Chapter 6 (Conclusions and Future Work), the main conclusions drawn from the work are summarised, and the future objectives for this project are discussed.

Chapter 2

State of the Art

This chapter presents an overview of the current state of gamification in higher education. As background research to this study, an SLR (Systematic Literature Review) was executed regarding the topic of the project, with the procedure and key findings being introduced below.

2.1 Systematic Literature Review

The SLR was performed through Scopus and Web of Science articles. The step-by-step procedure for this SLR follows the PRISMA 2020 statement [25] and is represented through the fluxogram in Figure 2.1 and further described ahead.

Firstly, a search on both these databases was performed using the following query:

- Title, abstract or keywords (containing a conjunction of the following terms):
  - "gamification" or "game-based" or "gamified"; AND
  - "teaching" or "learning"; AND
  - "higher education" or "university";
- Subject area (at least one of the following):
  - Computer Science;
  - Engineering;
  - Business;
  - Mathematics;
  - Economics;
- Publishing year: from January 2017 to January 2023;
- Document type: article;
- Language: English.

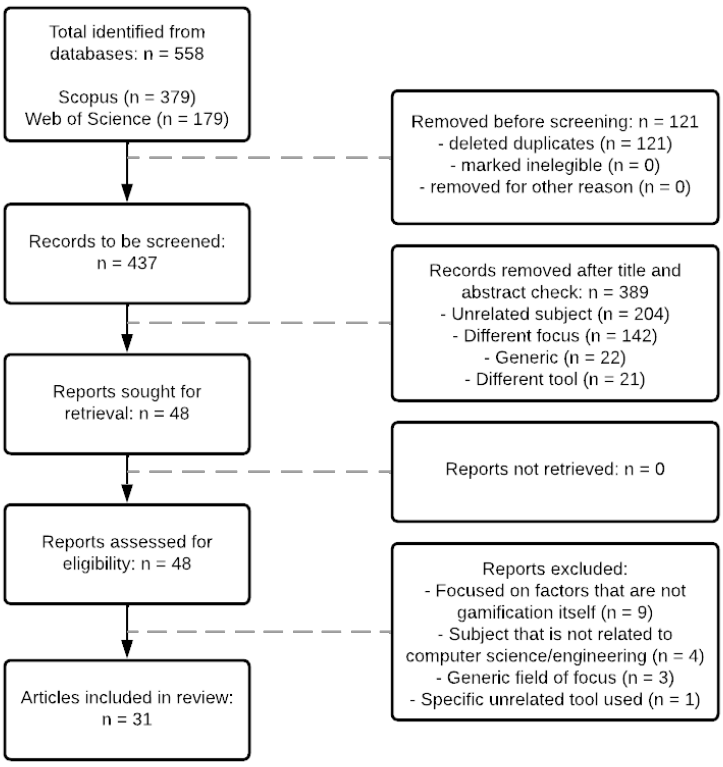


Figure 2.1: PRISMA diagram of the SLR procedure

This search yielded a total of 558 articles, 379 being retrieved from Scopus and 179 from Web of Science. From this collection, 121 records were duplicates, with references present in both databases, and were therefore deleted.

For the resulting 437 records, the title and abstract were analysed to find the ones that better fit the requirements. These were refined during this process, as the decision to exclude results related to Business, Management or Economics was made, focusing on Informatics Engineering.

The publishing year of each article was also summarised in Figure 2.2, which shows an increasing trend in the investigation of gamification, demonstrating the pertinence of this work.

This analysis followed the criteria shown in Table 2.1, resulting in 389 exclusions.

Table 2.1: Exclusions by Title and Abstract

	Exclusion Criterion	Number of exclusions
EC1	Unrelated subject	204
EC2	Different focus	142
EC3	Generic	22
EC4	Different tool	21

EC1 refers to every topic not directly related to Informatics Engineering (not in the Computer Science, Mathematics or Programming fields).

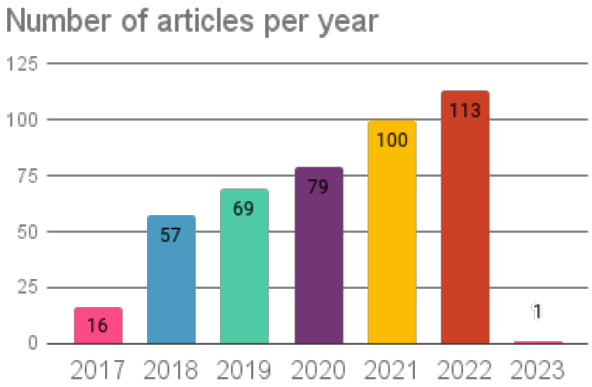


Figure 2.2: Number of articles per year before filtering

EC2 is related to the analysis of different criteria, whether these are too specific (e.g. only a particular population being analysed) or diverge from the topic (e.g. the effects of distance learning and techniques implemented).

EC3 comprises articles that are too generic in field or engagement techniques.

EC4 regards the use or the study of the use of different tools (e.g. already existing games).

The full-text versions of the 48 resulting articles were retrieved. After a more in-depth inspection, following the criteria shown in Table 2.2 for excluding 17 more articles.

Table 2.2: Exclusions by Full Text

	Exclusion Criterion	Number of exclusions
EC1	Unrelated subject	4
EC2	Different focus	9
EC3	Generic	3
EC4	Different tool	1

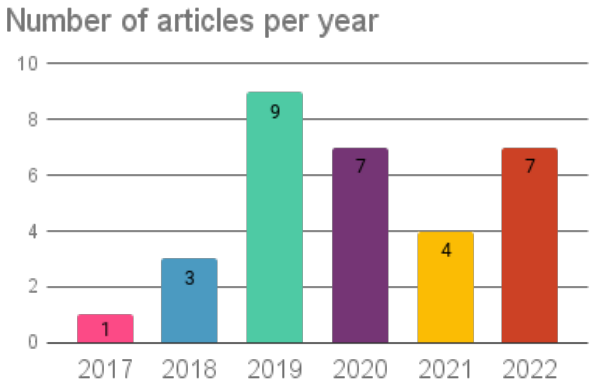


Figure 2.3: Number of articles per year

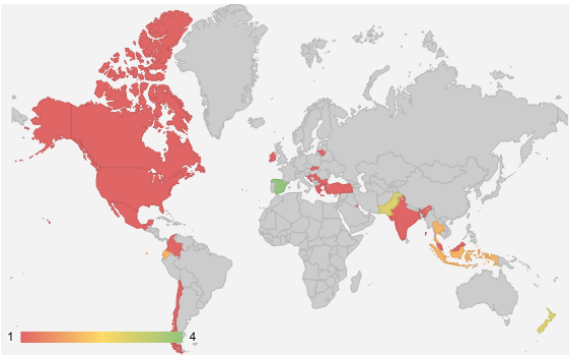


Figure 2.4: Number of articles per country

The final bibliography was further studied, consisting of 31 articles organised per publishing year and country as seen in Figures 2.3 and 2.4, respectively. These focused predominantly on disciplines such as Programming and Information Science, as Figure 2.5 represents.

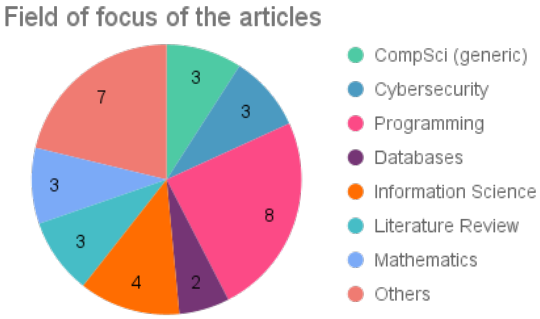


Figure 2.5: Number of articles per field

2.1.1 Literature Review

The bibliography comprised three literature reviews on gamification in higher education, one targeting Computer Science specifically [22], focusing on the significant advantages of gamification but also on the aspects that need improvement [5, 19], exposed in the sections ahead.

2.1.2 Framework Proposal

Alghamdi and Younis [2] idealised a framework relative to the use of computer games in cybersecurity for higher education, focusing on the use of animation for knowledge delivery and gamification for knowledge assessment.

2.1.3 Applied Solutions

The remaining bibliography focused on the development of specific applied teaching-learning methods for various subjects, such as Programming [9, 10, 20, 23, 28, 29, 30, 33], Information Science [11, 17, 18, 24] and Mathematics [26, 27, 32].

Each of the authors adopted a distinct methodology for their research, using different games, applications or game elements or combining them with other teaching-learning techniques and obtaining divergent results, summarised in the following sections.

The essential findings of the SLR are enumerated in the following categories: definition, advantages, disadvantages, prevailing elements, existing methods and associated techniques.

2.2 Gamification

García-Iruela *et al.* [12] define *gamification* as the use of game mechanics in environments that do not have entertainment as the main objective, which is supported by the definition used in [3], whose authors describe it as the insertion of computer game elements into systems that are not game-based.

In the Educational field, Boytchev and Boytcheva [4] define gamification as converting educational content and processes unrelated to games into game-based ones. Castillo-Parra *et al.* [5] add the goal of achieving better pedagogical results.

Gamification in education can be defined as using game elements, mechanics or content in non-game-based educational environments to achieve better teaching-learning results.

Additionally, some of the literature addresses GBL (*Game-Based Learning*), defined by Cengiz *et al.* [6] as an approach that provides learning through games with satisfaction and interest in the learning activity as crucial goals. In this sense, GBL can be distinguished from gamification because the first involves a complete game as a pivotal point.

However, GBL is most commonly applied through the use of *serious games* [9, 27, 33], defined by Bernik *et al.* [19] as computer games having learning as its primary purpose, as opposed to entertainment. Therefore, when mentioned ahead, gamification will also comprise GBL and serious games.

Gamification has been predominantly advantageous for students and lecturers overall. In 2.6, we can see that more than 60% of the analysed bibliography had only positive results. However, almost 30% of it had simultaneously positive and negative results. The reasons for these, as well as the principal elements and techniques applied, are enumerated in the following sections.

2.3 Advantages of Gamification in Higher Education

Gamification has been used with distinct objectives regarding the increase in students' performance, the most common ones being increasing their motivation [1, 9, 16, 23, 31] and learning performance [3, 9, 11, 30]. However, the analysed studies also show that the use of these techniques has also helped students in several other factors, such as soft skill development [4, 5], engagement and frequency of study [3, 8, 28], satisfaction and enjoyment [13, 24, 28].

Despite being a matter of less focus overall, some authors also mention the positive effects of these techniques for lecturers. Apart from severely reducing the burden of keeping students engaged, gamification helps teachers by improving class dynamics and activity [17, 34], increasing

student participation, involvement and attention retention in the lectures [8, 32] and automating time-consuming tasks such as assessment and evaluation [4, 29], personalised recommendation [30] and feedback [6].

It is worth noting that there have been conflicting results regarding the effects of gamification depending on the student's previous gaming experience. Daungcharone *et al.* [9] detected no difference between the group with experience with video games and those without it regarding learning achievement and motivation. Furthermore, Oktaviati and Jaharadak [22] mention that gaming experience does not relate to the effect of the gamified application on learning performance, but it influences motivation. However, Cengiz *et al.*'s work [6] shows a positive correlation with the students' gaming experience but also correlates age with effectiveness, the latter being higher in younger audiences. This correlation could also explain the first one because younger people are typically more used to gaming elements.

2.4 Disadvantages of Gamification in Higher Education

Across the reviewed literature, some specific adverse effects of gamification were also detected. This is the case of [19], in which the low-ranking students felt stress and demotivation due to poor scoreboard results, or [22, 28], where students felt demotivated by the inadequate difficulty and design. Moreover, Zorrilla Pantaleón *et al.* [34] mentions that some students are not attracted by these techniques.

It was also noted that lecturers also suffer negative consequences of gamification, with consequences such as lower effectiveness in teaching highly complex concepts [19], need for effort and extensive planning [27], need for personalisation, targeting and clear instructions in exercises [33] and need for well-established rules regarding the use of technologies [32].

2.5 Gamification Elements

The main gamification design elements [1, 12, 29] used are the following:

- **Points/rewards:** similar to grades in the educational system [6], they are the basic form of encouraging students' motivation [1], rewarding for and evaluating their learning performance [12], and can be used to allow progression [8]. Possible point variations are experience points, redeemable points, skill points or karma points [21];
- **Badges:** distinction for a student's achievement or milestone [12], one of the preferred elements by students [34];
- **Leaderboards:** table showing ranks of students, usually based on points or level [12], one of the most effective elements in learning performance and motivation for high-ranking students [34], yet highly prejudicial for low-ranking ones [19], which can be avoided through anonymity [18];

- **Levels:** progress tracking feature, usually based on experience points or number of tasks satisfied [1], some may be blocked until a previous level is completed [12];
- **Challenges/missions:** collections of tasks that have to be performed to gain points or other rewards [12];
- **Time limit:** time set to complete a specific task, can reduce performance if inadequate [28];
- **Instant feedback:** immediate response or scoring after the completion of a task [12], students can see what they do wrong and, if that's the case, correct it in future attempts [29].

2.6 Existing Methods

Despite being more vastly applied in schools, gamification is also being inserted into a higher education context. Multiple examples of this are subject to discussion throughout the bibliography, diverging into different branches and techniques.

The most recurrent example is the insertion of the lecture contents into complete games. These can be escape/breakout games [6, 27], mobile games [9, 10, 31] or role-playing games [32], among others [8, 33].

The researchers also appointed the use of 3D modelling [4] and animated [2] environments that allow a certain level of immersion of the students.

The authors also mention the use of gamification for both in-class, such as discussions [1] or rewarded participation [7], and out-of-class activities, especially independent study [34].

Another method commonly used by the authors to introduce gamification into classroom tasks is the adaptation of LMSs (Learning Management Systems), of which Moodle is the prime example [3, 12]. However, Milenković *et al.* [21], Rojas-López *et al.* [28] and Tasadduq *et al.* [29] go one step further and create their own gamified course management tools.

Similarly, Marín *et al.* [20] developed a gamified platform that simulates a compiler to liken the students' C programming lessons to a fun problem-solving assignment.

Finally, the use of questionnaire-based applications, such as Kahoot! [17, 18, 24], Quizizz [26] or even original ones [30], is also a standard target of review in the references.

The results obtained relative to motivation and learning performance through the application of the methods described in the different articles can be observed in Figure 2.6.

2.7 Association with Different Techniques

In the bibliography, part of the distinct approaches consisted of applying gamification associated with other techniques, and they achieved different effects with these.

Ahmad *et al.* [1] measured the effects of gamification in group work, which revealed that these techniques provide more satisfaction when used individually or in small (n=7) groups than in larger (n=24) ones. It also showed that the grades improved more in individual and small than in larger group settings.

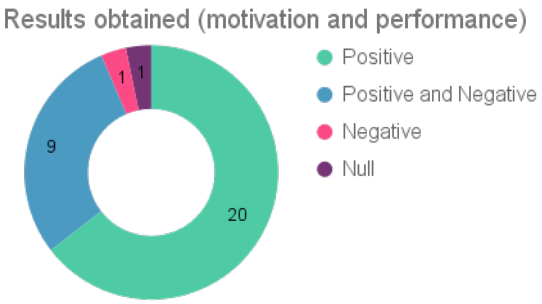


Figure 2.6: Results obtained per article identified in the selected literature

Clarke *et al.* [7] compared the simultaneous application of gamification, collaborative learning, problem-based learning and social interaction to the traditional lecture-style approach, getting overall positive results in exam grades from the experimental group, with LES (Learning and Engagement Strategies) in F2F classes.

A mobile game-based approach to C programming learning was researched by Daungcharone *et al.* [9, 10]. The results of these studies indicate that a mobile game-transformed lecture-based system causes a significant improvement in learning and an increase in motivation. However, the fully game-based approach with no lectures achieved the most interest among students.

Additionally, Licorish and Lötter's [17] results evidenced that the application of gamified tools permits timely breaks in the learning process, allowing students to refresh, which contributes to strengthening their concentration afterwards.

Lastly, Pratiwi *et al.* [26] approached gamification techniques in an online Discrete Mathematics course setting. Their results show that students had a favourable opinion of online game-based learning.

2.8 Conclusions

After the SLR, it can be concluded that different gamification implementations in higher education have distinct effects. However, some common denominators can be found across the bibliography.

Gamification benefits university students in several dimensions, including learning achievement, motivation, interest, engagement, confidence, soft skills and the development of frequent study habits. It also reduces the lecturers' burden of keeping students interested, enhances the class activity and dynamics and automates time-consuming tasks, such as evaluation and feedback.

However, the methods used must be perfected to avoid penalising a section of students or wasting planning effort and time. This includes personalisation and targeting to ensure every student has access to favourable content and techniques.

The most common bibliography examples of the application of these techniques are in F2F classes (gamified discussion and participation), out-of-class activities (tools for independent study),

complete games (breakout/escape, mobile, role-playing, platform, among others), interactive activities, adapted LMSs and questionnaire-based applications.

It can also be associated with other learning and engagement techniques, such as group work, problem-based learning and timely breaks, to contribute to the common goal of ensuring positive consequences in terms of motivation and learning performance.

Chapter 3

Methodology

Besides not being widely applied in higher education, gamification needs to be more developed and investigated. From the conclusions drawn in the previous chapter, the most impactful characteristics yet to be inserted into gamification teaching-learning techniques are personalisation and targeting.

In this regard, the proposed solution is based on the development of an innovative, **user-centred, evolving, customisable** teaching-learning method. This solution focuses on these three key aspects, detailed in the following sections. The procedure adopted is also further described in this chapter.

3.1 User-Centred Design

User-centred design is the first essential aspect that needs to be further explored with gamification in higher education, and it was applied in the development of the solution. The primary focus on the users' requirements characterises this design technique, meaning the development of the method should take place keeping the perspective of both students and professors in mind.

In this approach, the work begins with an analysis of the context in which the project is introduced, in this case, gamification in higher education. Then, as represented in Figure 3.1, the target population has to be involved through a requirement survey, from which a set of requirements has to be drawn.

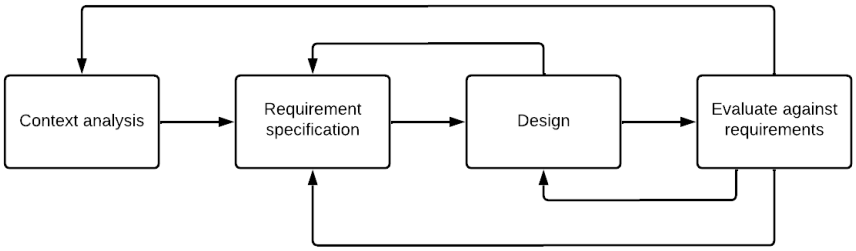


Figure 3.1: User-Centred Design

From these requirements, a prototype can be developed to fit the needs of the users behind them. This prototype should then be tested and evaluated against these same requirements as long as they need to be improved. This can lead to a need for some fixes in the design, a refactoring of the requirements or even a new, more extensive context analysis.

This looping process should only stop when the current design is considered to fit the pre-chosen requirements and no other requirements are added. This is an ideal situation which is not always applicable in real-world scenarios since new requirements are constantly being created, leading to a continuously evolving prototype/version.

3.2 Customisability

The lack of personalisation is one of the most common defects detected by the authors in the bibliography. Hence, one of the primary goals of the method developed is to be as customisable as possible for both lecturers and students.

For lecturers, one of the most significant obstacles to using a new technology or teaching method is the adaptation time needed. Through the availability of customisable features, different types of activities or forms of evaluation and assessment, the ease of managing the students' details and results and the provision of tutorials for each of the available tools, lecturers have an easier time being introduced to this innovative method.

On the other hand, students react differently to each gamified teaching-learning method employed, as referred to by many authors in the bibliography. This distinct response can be due to the gamification elements used, the types of exercises, the evaluation techniques, or even just the layout. Confronting the need to adapt these to each student, no one understands their needs better than their lecturers. Therefore, the teachers have tools available to create their exercises to suit the students' preferences.

Furthermore, the students can adapt the gamification elements themselves to better fit their needs, customising their profile/team elements, as well as activating or deactivating certain gamification elements they may not want.

3.3 Procedure

Following the user-centred approach in an iterative fashion, as described above, the requirements and feedback given by the target population are the core drive of the project. Hence, after the initial literature review as a context analysis, the work started with a survey to both samples of the target population for requirements specification.

The survey consisted of a short group of questions related to the participants' demographic data and more detailed questions about their experience and their preferences regarding gamified teaching-learning approaches. The questions and responses to these surveys, issued using Google Forms (https://www.google.com/forms, last accessed in June 2023), are presented in Appendixes A and B and further discussed in the next Chapter.

The requirements specified by both sets of participants were then used for the design and evaluation of a prototype of a gamified programming teaching-learning app (Codyglot, with its final version available here, last accessed in June 2023) using Figma (https://www.figma.com, last accessed in June 2023), incorporating several academic features and gamification elements.

As aforementioned, the development and evaluation of this prototype were done through an iterative process consisting of two loops. Both of these loops were composed of three stages: design, testing, and feedback. The design stage, in Figma, was focused on the previously received requirements/feedback, integrating the most commonly wanted features and game elements into the models created. In the first iteration, a total of seven models were created based on three main variants. For the second loop, these seven alternatives were joined into three models, one per variant, with the preferred elements of each of the original ones.

The variants consisted of different use cases relative to three distinct scenarios. The first one was created by adopting an exercise-based approach, which students could use either during practical classes or during autonomous study. The professors have access to the students' data and results, being able to see their progression in the exercises and thus give them more personalised feedback and assistance.

The second alternative focuses on a challenge-based app, adopting a gamified evaluation format. These challenges could serve as checkpoints or breaks during theoretical classes, as well as opportunities for autonomous study at home. Despite the correction being automatic, the professors can still manually change the evaluation of the students' responses.

The last scenario is a forum to be used as a support tool for communication among students and professors. The aim of this forum is for the first to expose their questions regarding course contents while their peers are entrusted with the task of replying to their doubts, receiving a reward in exchange. The professor has the ability to view the students' questions and can also contribute to the responses (when there are none or the existing ones are unsatisfactory). This way, they can also aid the students in a more interactive and motivating way.

These three variants of the app could all be used parallelly, as they involve different tasks, features and scenarios. Ahead, this study focuses on the effect of these gamification elements in each of the described stages of the teaching-learning process in a curricular unit. All three involve actions from the students, the professors and interaction between both parties.

The testing phase took place in person, as two series of usability tests were performed with the participants using Figma's interactivity tools and their mobile phones, with a high diversity of operating systems, sizes and other specifications. During the two loops, both lecturers and students were submitted to the application and given a series of tasks that they had to classify using a 5-point Likert scale [15] regarding four different criteria: simplicity, understandability, effects on student motivation and effects on student performance. The affirmations inherent were "The task was easy to perform.", "I understood what the task represented and how it worked.", "This task would improve the motivation of a student.", and "This task would improve the academic performance of a student", and the data is collected in numerical form from 1 (Strongly Disagree) to 5 (Strongly Agree). They also had to use a Likert scale to evaluate some additional affirmations specific to

each model. For evaluation purposes, an average value of 4 (Agree) or above was considered satisfactory for each of the affirmations.

Lastly, the feedback recollection stage consisted of a summary of the feedback received and consequent refactoring of the requirements previously conceived. In the first loop, this feedback was applied to improve the models used in the second round of testing.

The progression of the prototypes of distinct variants through input from the target population led to an increase in confidence in the features and gamification elements implemented and their pertinence in the context in which they are applied.

3.4 Project Timeline

The tasks performed during this work, represented below through a Gantt diagram (Figure 3.2) from October 2022 to June 2023, were as follows:

1. **SLR:** The systematic literature review of the existing gamification in higher education, resulting in the State of the Art presented and discussed in Chapter 2.

2. **Requirement analysis:** The analysis of the target population's needs. After a short brainstorming period, an initial questionnaire was posed to the student and professor communities to learn about their experience with gamification in higher education and their preferences regarding such teaching-learning methods. These were then schematised into a list of requirements, organised by frequency, based on the questionnaire responses.

3. **Incremental prototype development:** After the initial requirement analysis, the prototype development started with an initial design. This phase was mostly simultaneous with the validation, focusing on the final user's needs by repeatedly testing the prototypes developed.

4. **Validation:** The prototype was exposed to the population's scrutiny through usability tests on two different occasions to obtain feedback and resulted in an adaptation of the requirements and models. The conclusions drawn thereof were the pivotal factor of this work.

5. **Production of the Dissertation:** The Dissertation report was produced during the entire process, from the systematic literature review to the final validation results and conclusions drawn.

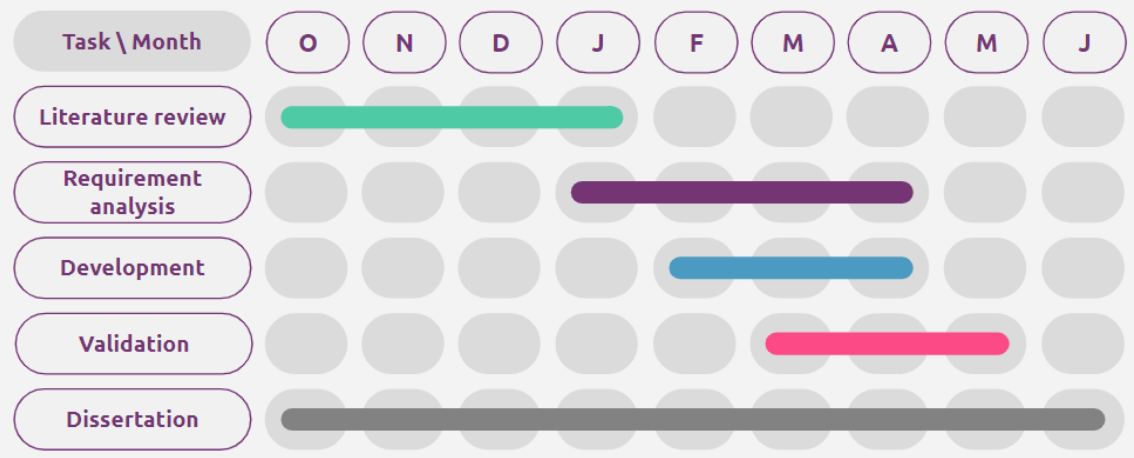


Figure 3.2: Gantt diagram of the project timeline

3.5 Conclusions

This work adopted a user-centred, iterative approach in the development of a customisable teaching-learning app using Figma. An initial survey was done to analyse the requirements of both students and lecturers to be implemented in the designs.

During the iterative development loops, the models were based on the requirements obtained and then validated by performing usability tests with the target population. The feedback from the participants was then summarised and used to either improve the first set of prototypes or evaluate the prototypes in both loops.

Chapter 4

Iterative Design: First Loop

In this chapter, the first design iteration is described, as well as the first round of usability tests performed with students and professors, and the feedback received is summarised.

4.1 Requirement Specification

4.1.1 Student Survey

A total of 115 engineering students from several degrees at FEUP answered the survey. The questions included in this survey can be found in Appendix A.

This group of students spanned from ages 17 to 46, with the majority falling between 18 and 23. The participants primarily take part in bachelor's or master's degrees in Informatics, Civil, and Mechanical Engineering, most of them revealing proficiency in video games and gaming elements.

The survey revealed that most students had an average interest and motivation in their lectures and a lower one in studying autonomously. This finding corroborated the previously established theory drawn from the literature review that students find higher education and studying to be monotonous and difficult activities [8, 12, 33].

Moreover, 80% of the participants had previous exposure to gamified and game-based teaching-learning methodologies, despite being limited in scope - 66 out of 92 experimented only with Kahoot! (https://kahoot.com/, last accessed in June 2023). However, the answers evidenced that under 14% of the surveyees use gamified learning approaches regularly. These participants emphasized that these tools were characterised by their inherent fun and dynamic nature, as well as their ability to foster an interactive, engaging learning environment, breaking the flow of the study or the lecture with an entertaining pause, while more than half of them did not find any notable disadvantages on them.

According to the expectations, the participants exhibit signs of demotivation, dissatisfaction and a certain degree of disinterest in their lectures and studies. Consequently, it is unsurprising that they reveal a significant interest and openness in trying innovative teaching-learning methods.

The students expressed their desire for several key features in the app. Their primary focus was on promoting interaction among fellow students, both through healthy competition and collaboration, as well as with the professors. Additionally, they sought features that would motivate them to be more engaged in their lectures and their autonomous study, provide support for their learning process, and facilitate the review of key concepts. Regarding the topic they would prefer, an overwhelming majority of students chose programming.

4.1.2 Professor Survey

This survey was answered by 23 professors across different Engineering degrees, aged 30 to 69. The questions included in this survey can be found in Appendix B.

When asked about their experience with videogames and gaming elements, the majority selected average or below. Furthermore, 52% of the surveyees had never used a gamified approach in their lectures or courses, but 21 of the 23 mentioned they were open to trying an innovative gamified approach. The majority of these cited a lack of knowledge about gamification as the primary reason, highlighting the importance of spreading awareness and information about the available gamification tools.

Both groups of professors, regardless of their prior knowledge of gamified teaching-learning methods, identified several advantages associated with these tools. They highlighted the importance of promoting student engagement and motivation, facilitating interactivity, and enabling effective assessment of students' comprehension of the concepts taught.

On the other hand, the lecturers that do not use these tools cited the challenges associated with their setup and preparation, including the effort and time consumption, as well as their lack of knowledge of gamified tools in higher education as the main drawbacks that hinder the adoption of such methods.

This is in line with their perspective that preparing and giving lectures, as well as giving feedback on exercises and assignments, are highly demanding tasks, requiring substantial time and effort to complete.

Similar to the students, when asked about their desired features, the professors stressed the importance of promoting student engagement through exercises, instant feedback, and effective content dissemination. Furthermore, they expressed the need for tools that enable efficient evaluation and organization of course data. They also selected programming as their preferred topic.

4.2 First Prototypes

Taking into consideration the initial requirements received from both professors and students, the development phase involved using Figma to implement three main variants, each encompassing various sub-variants incorporating different gamification elements and features.

4.2.1 Exercises

The first app variant was created by adopting an exercise-based approach, featuring a progression of levels that corresponded to different topics covered in the lectures. These exercises consisted of a variety of question formats, including multiple-choice and open-ended questions. Students receive immediate feedback on their responses through visual notifications.

4.2.1.1 Features

This variant contains exercises with instant feedback as its main feature, given through a change of colours in the selected answer, indicating whether it is correct. If the answer selected is incorrect, the correct answer is highlighted and a tip is shown, as seen in Figures 4.1 and 4.2.

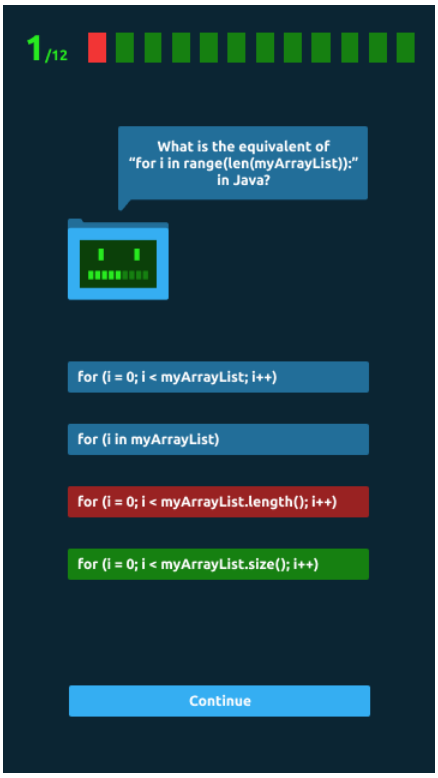


Figure 4.1: Incorrect multiple choice question

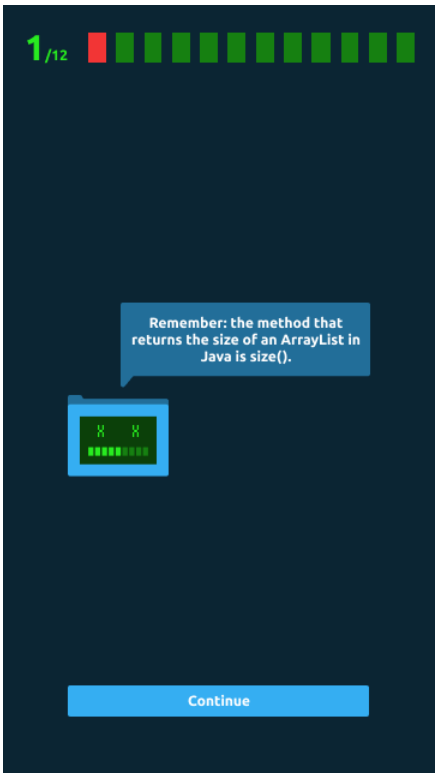


Figure 4.2: Feedback on incorrect answer

Moreover, the students can also access a theoretical lecture associated with each level provided by the professor, which can consist of a slide presentation, a video, or any other file format. An example of the lecture content is shown in Figure 4.3, and the professor can make their selection as depicted in Figure 4.4.

4.2.1.2 Gamification Elements

In order to evaluate the impact of the different game elements within the exercise-based approach, three sub-variants were developed. These alternatives enable the assessment of the effects of each

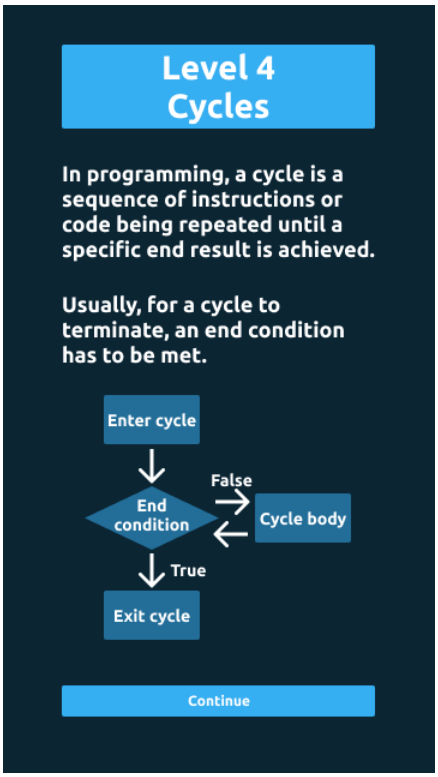


Figure 4.3: Theoretical content

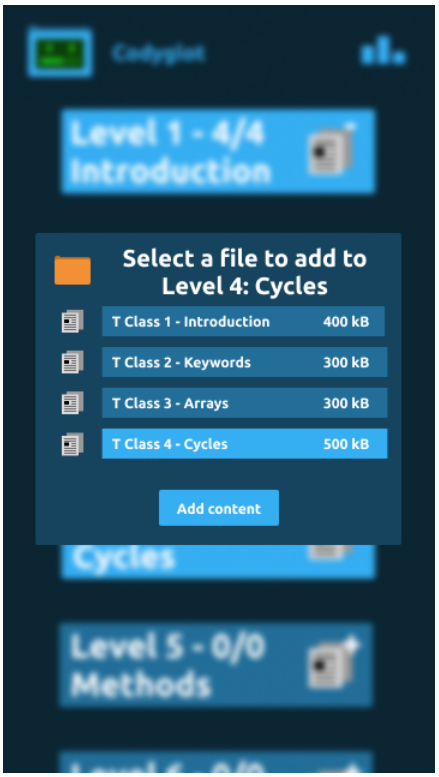


Figure 4.4: Add theoretical content

distinct gamification component in this scenario.

The first alternative revolves around the implementation of a point system and a leaderboard (Figures 4.5 and 4.6), in which exercises are introduced through a set of levels. Each level contains twelve exercises, each awarding one point on the leaderboard. It also includes instant feedback on the responses. To avoid causing demotivation among lower-ranking students, only the top 5 positions of the leaderboard are publicly displayed. However, the professor has access to the complete leaderboard, allowing them to personalise the support given to each student.

The second alternative includes a more clear level progression, with each level completed rewarding the student with a collectable key that can be used to unlock further levels (Figure 4.7) as a way of assuring the retention of the students' engagement and motivation. It also introduces a limited number of lives, which are reduced with every incorrect answer (Figure 4.8), up to a limit of three lives lost, at which point the student has to restart the level. This element was added to enforce at least a majority of correct answers before progressing to the next level.

Much like the first one, the last model also incorporates a point-based leaderboard. The distinction, however, lies in the implementation of teams (Figure 4.9), in which each student contributes with their own points towards a collective group score (Figure 4.10). The students also have the opportunity to purchase boosters for their teammates with their own points. These boosters grant their affected teammates double the number of points they achieve in the next 24 hours, as explained in Figure 4.11. The availability of this purchasable gift and the existence of a "virtual economy" promotes cooperation rather than competition within the team through social pressure.

Figure 4.5: Point leaderboard (as visible for students)

Figure 4.6: Full leaderboard (visible only for professors)

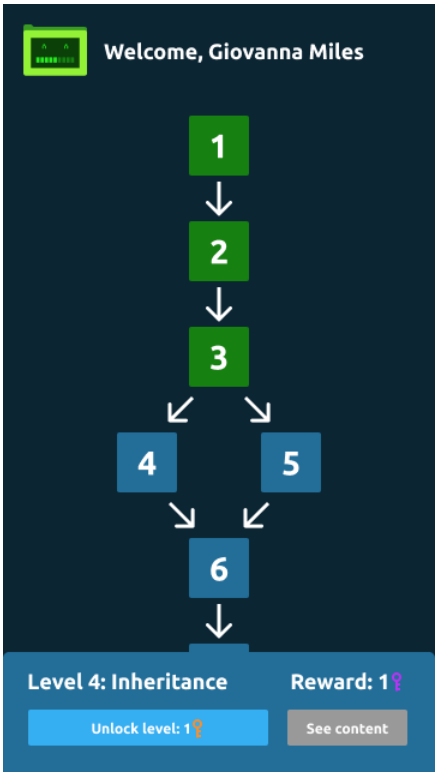


Figure 4.7: Unlockable levels

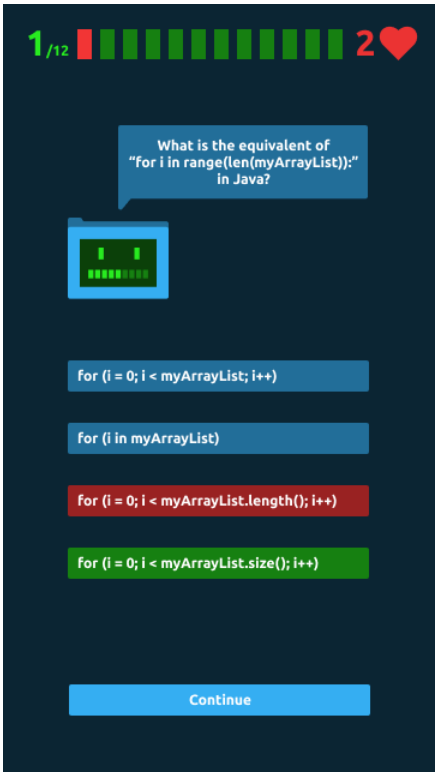


Figure 4.8: Limited lives

Figure 4.9: Team leaderboard

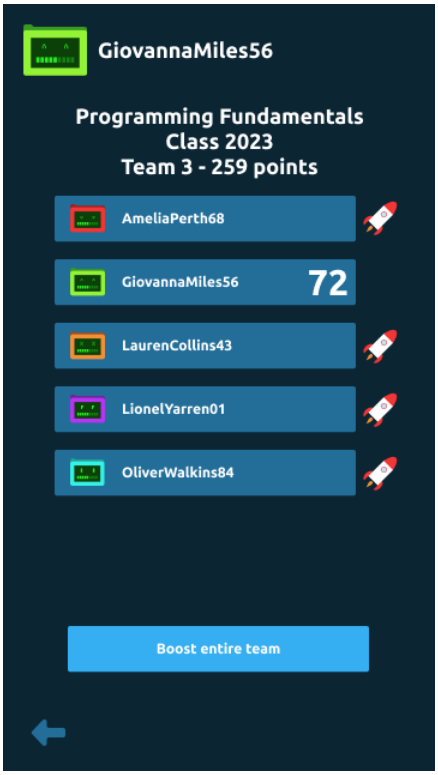


Figure 4.10: Team statistics

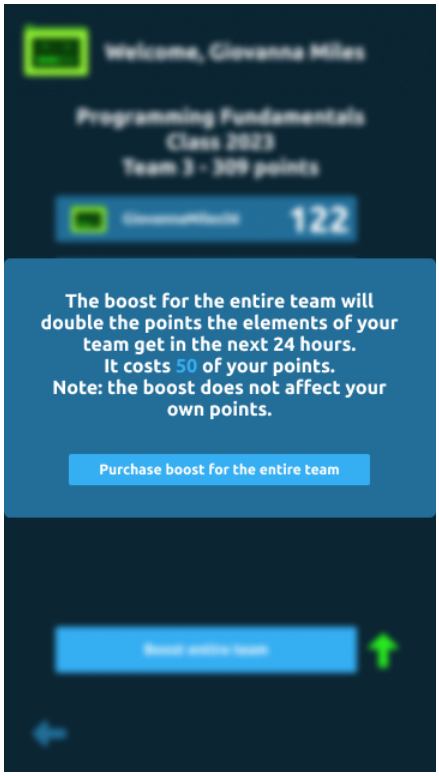


Figure 4.11: Booster purchase

4.2.2 Challenges

The second variant focuses on a challenge-based app that allows evaluation. After completing the challenges, a leaderboard is generated based on the order in which students submitted their correct answers, adding a competitive element to the experience.

4.2.2.1 Features

Challenges function as checkpoints to assess the students' comprehension and assimilation of the course contents. Through these weekly exercises (Figure 4.12), the professors can quantify the students' performance through a leaderboard (Figure 4.13).

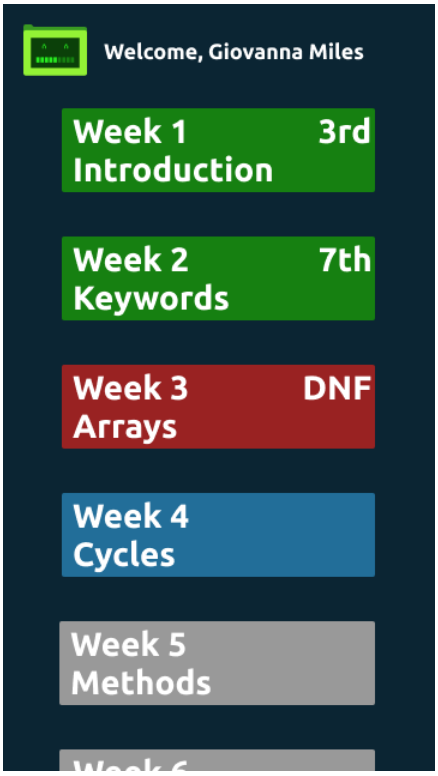


Figure 4.12: Weekly challenges

Figure 4.13: Challenge leaderboard (visible only for professors)

The two versions consist of an immediate-feedback challenge, done in real-time, in which the students can see their peers' incorrect answers (Figure 4.14), and a delayed-feedback challenge, more complex and to be solved autonomously at the students' own pace (Figure 4.15).

4.2.2.2 Gamification Elements

The two sub-variants integrate a few common elements: both alternative formats of challenges include leaderboards. For the real-time challenges, a student's place on the leaderboard is based on the time spent in comparison to the peers' response time. For the delayed challenges, however,

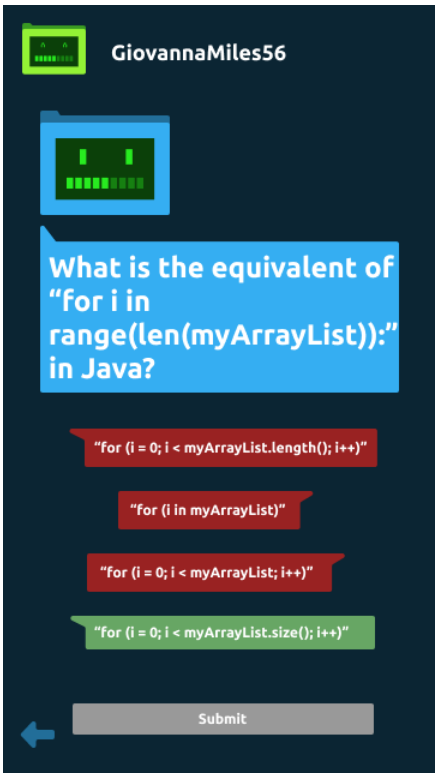


Figure 4.14: Real-time challenge

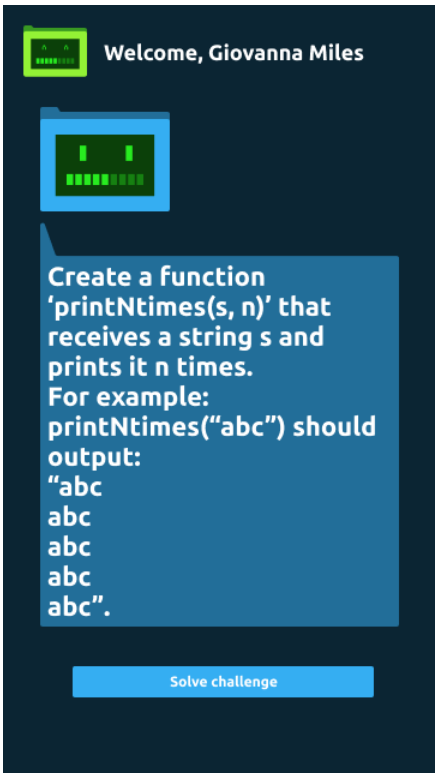


Figure 4.15: Delayed challenge

since the students have only one attempt, it depends on the order of the answers, as well as on whether the solution is correct.

The first alternative relies primarily on instant feedback, both on the student's responses and their peers', distinguishable by the direction in which the arrow is pointing, as visible in Figure 4.14. It also incorporates the element of anonymity from the attempts of the other students, which are not identified.

The second model applies, through a due date pre-selected by the professor, the effect of a timed task, creating pressure on the students to submit their solution before the deadline (Figure 4.16). This due date is shown on the unsolved challenges from a limit of three days, in order to remind the students of the deadline. The time used to resolve the challenge is not measured, as this would induce their stress levels to rise and their motivation to decrease.

4.2.3 Forum

The third and final variant consists of a forum that enables students to submit their questions related to the course contents. Then, their peers have the opportunity to respond to these questions and are incentivised with rewards for providing correct answers. This interactive forum encouraged knowledge sharing and collaboration among students, leading to a supportive learning community in the course.

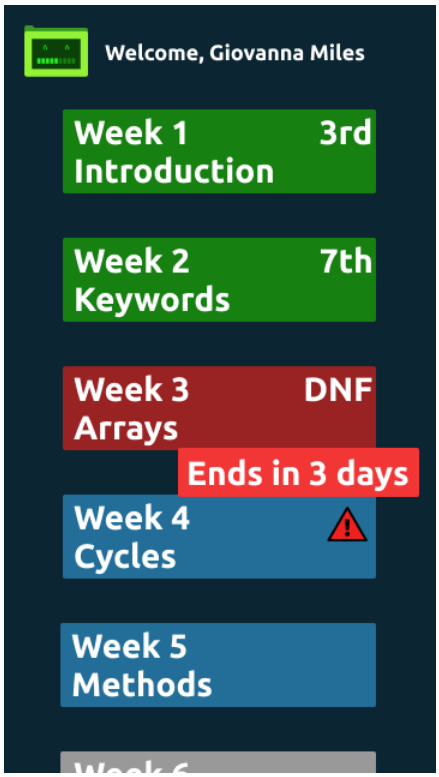


Figure 4.16: Challenge due date

4.2.3.1 Features

Both models have an equal question-based system in which the students can ask and reply publicly, allowing their peers to also view and benefit from them (Figure 4.17).

In the first alternative, the professor assumes a validation role, having the final authority to determine the correctness of the answers on a certain topic by awarding the person who answered correctly.

In the second one, however, this validation role is transferred to the students, who can vote on the answers they consider correct. Meanwhile, the professor keeps the role of a moderator, with the ability to close and reopen topics as necessary (Figure 4.18).

4.2.3.2 Gamification Elements

The concept of the forum in itself engulfs two gamification elements: social pressure, which encourages students to actively participate in assisting their peers, and cooperation, promoting a collaborative environment.

The first version contains badges awarded by the professors for the correct answers as a form of direct feedback (Figure 4.19). This does not prevent them from being able to reply as well, in case no student responds within a certain time frame. These badges are then displayed on the students' profiles as a way of keeping track of their achievements.

Figure 4.17: Forum feed

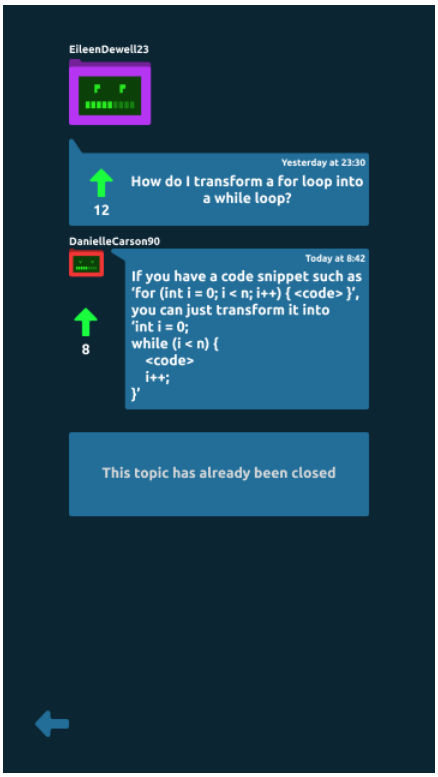


Figure 4.18: Closed topic with votes

The alternative with mutual feedback applies a voting relationship that contributes to an "honour" system, known as credibility, which is publicly displayed in the student's profile, accessible to other students and the professor, as seen in Figure 4.20. Additionally, there is a relative leaderboard for the students' credibility values. This is displayed exclusively on the profile of the top 10% students in the class, ensuring that lower-ranking students are not adversely affected by this element. The voting system also introduces an element of anonymity to this model, as they get the chance to express their opinion without the fear of being put to shame if the answer they voted for is wrong.

4.3 Feedback

During the usability tests, both students and professors were given a set of tasks for each prototype that tested each possible feature. The participants, consisting of 14 students and 4 professors, were asked to classify each task in terms of simplicity, comprehensibility, effects on motivation and learning performance using a Likert scale, as well as a few model-specific affirmations (as described in further detail in Section 3.3). The full results of these tests are available in Appendix C.

The simplicity ratings for each task were consistently very high, with the average score being above 4 for all tasks. Similarly, the understandability ratings only got close to 4 on the first task ("Open theoretical content 4") for students. Based on these findings, we can conclude that

Figure 4.19: Profile with badges

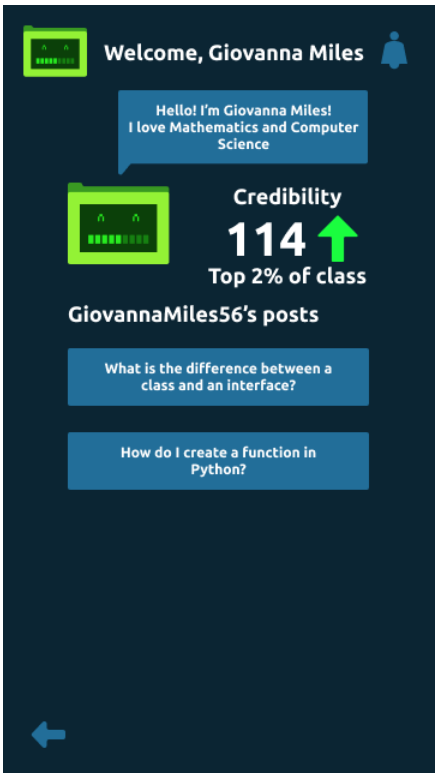


Figure 4.20: Profile with credibility

the majority of techniques employed in the development and available features are simple and intuitive for both professors and students.

Regarding learning performance, the only negatively highlighted element was the disclosure of others' credibilities, justified by the bias it can introduce to those students' answers, as they may be mistakenly preconceived to be less correct than others'.

Regarding motivation, the features and gamification elements that received the least optimal ratings were as follows:

- the limited lives in exercises: 3.6 - due to losing interest when having to repeat exercises;
- the internal leaderboard in team-based exercises: 3.1 - due to causing negative relations between the teammates;
- the social pressure in team-based exercises: 3.6 - for similar reasons to the previous;
- the leaderboard in both challenges: 3.0 and 3.2, respectively - while students appreciated having an evaluation of their solution, they would rather have an objective gamified rating than it depending on the other students;
- the visibility of others' credibility in the mutual feedback forum: 2.7 - it can generate a bias when receiving a response from someone with low credibility.

The time constraint imposed on the challenges, which are intended to be completed as homework, also received an average neutral rating (2.9) in terms of inducing stress. However, the rating for that gamification element in motivation increase was 4.2. This indicates that the tradeoff has to be further tuned to ensure that stress does not inadvertently result in the opposite effect.

Furthermore, the lack of instant feedback led to a poor rating in delayed feedback challenges, both by students (3.4), who expressed demotivation in waiting for the results, and professors (3.3), who felt overwhelmed by the manual process of providing feedback for each solution and the restriction to only one attempt per student.

When asked whether they agreed that the social aspect of the forum provided a healthy pressure to participate in the professor-based forum, the students gave it a rating of 3.8 (partially agree), probably due to the contribution between students being more noticeable in the second model.

On the other hand, in the mutual-feedback alternative, they gave a neutral rating to the affirmation "The lack of direct feedback from the professor takes away reliability from the answers", meaning that even though they valued the students' efforts to validate each others' answers, they still felt the need to have a "seal of approval" from the professors.

Upon being questioned about feeling humiliated when posting their questions publicly in the forum, the majority of students disagreed yet had an opinion very close to neutral (2.6), evidencing the need for stronger motivation to participate.

The feedback given by the lecturers involved was significantly positive, only having two negative ratings: the previously mentioned lack of automatic feedback in delayed challenges (3.3) and the leaderboard in challenges (3.3), which was also a shared perspective among the students.

Lastly, the distinction between L.EIC (Bachelor's in Informatics Engineering and Computing) and M.EIC (Master's in Informatics Engineering and Computing) students and those enrolled in other degrees is rather inconclusive. The only notable difference is that related to the leaderboards, both external and internal to the team. Students enrolled in informatics degrees found the competition created by the leaderboards to be more demotivating and more harmful to their performance than the rest of the student base, maybe due to a more ambitious and challenging environment.

4.4 Conclusions

From the surveys, we could conclude that most of the students and lecturers wanted a programming teaching-learning app with tools to retain students' attention, promoting interaction among students as well as between students and professors and imposing a pause in the flow of the lectures/study. Thus, the app should provide an interactive, dynamic way for the students to review key concepts while still simplifying the professors' tasks of evaluation, assessment and organisation of the course.

The app was then designed as three variants to serve the purposes of aiding students in content review through exercises with immediate feedback, evaluating the students' performance through

gamified challenges created by the professors and providing easier management of these evaluation data, and mediating the interactions between both and delegating them to the other students through a forum.

These three variants were divided into seven sub-variants, each containing distinct game elements, in order to assess the effects of each of these in the described scenario. Similarly, they also incorporated a variety of features, to see which would be more well-received by both professors and students parallelly to the gamification components.

Chapter 5

Iterative Design: Second Loop

In this chapter, the data retrieved through the surveys, the usability tests, and comments from participants will be discussed in further detail.

5.1 Second Prototypes

After analysing the feedback received, the sub-variants were joined through the choice of the highest-rated features and gamification elements and the removal of the lowest-rated ones. Hence, the changes made to the prototypes are described in this section.

Apart from model-specific changes, there were also some general fixes, such as resizing buttons and fonts, as well as changing some colours to make the models more uniform and intuitive.

5.1.1 Exercises

The exercise models with unlockables and teams were merged, the theoretical content and reward interfaces were made more intuitive, and the key usage and number of keys needed were changed to make it more engaging and intuitive.

Moreover, achievements were added to the profile (Figure 5.1) and the internal leaderboard was removed (Figure 5.2), as suggested by several testers.

Lastly, the ability to review the exercises at the end of each level was given to the students (Figure 5.3), the correct/incorrect options were highlighted more strongly, the leaderboard and team icons were changed, and an option was added for the leaderboard to be deactivated (Figure 5.4) since the discrepancy in ratings was really high in the first round of feedback. After deactivating the leaderboard, only the personal score and the team score are displayed (Figure 5.5).

Some further feedback was provided, such as adding a placement test to avoid students having to do exercises about contents they already know, but that idea was dropped since it would not be applicable to a university course, and allowing second chances on multiple choice questions or changing the public top 5 to a top 3, which most participants rejected when posed with that alternative.

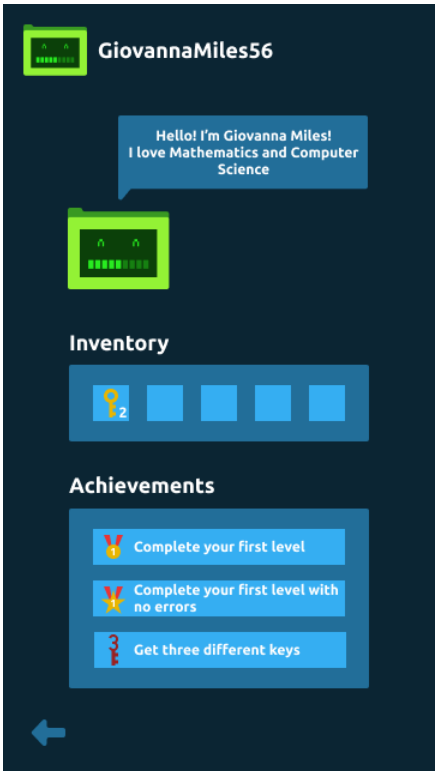


Figure 5.1: Profile with keys and achievements

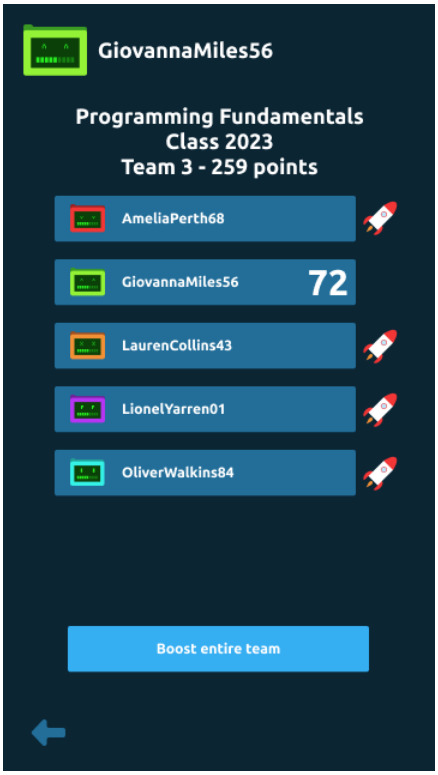


Figure 5.2: Team details with active booster

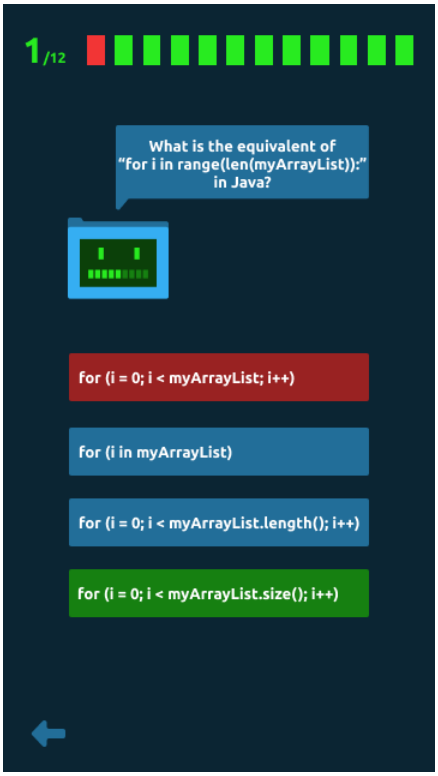


Figure 5.3: Exercise review

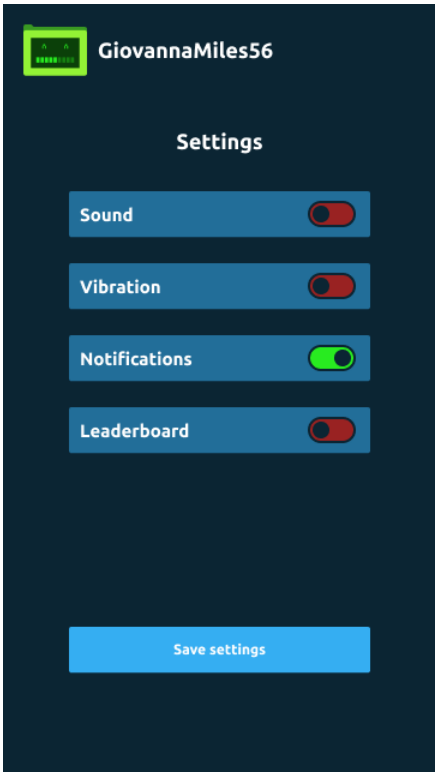


Figure 5.4: Leaderboard setting

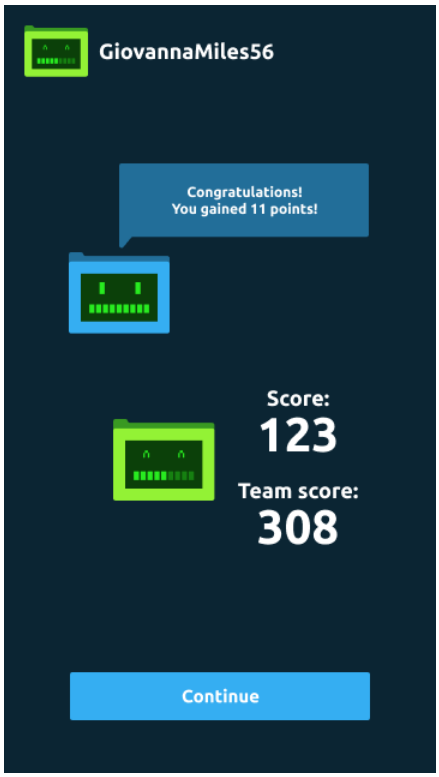


Figure 5.5: Score with deactivated leaderboard

5.1.2 Challenges

For the challenge variant, the general feedback was that both versions are equally important. Therefore, they were also merged into a single one. The "delayed-feedback" version was transformed into a different version of instant-feedback, since this was extremely valued. Hence, a permanent due date was added to the "homework" challenges while they are not completed, symbolised by a yellow triangle (Figure 5.6), which changed to red when there were only 3 days left. By then, a notification was also sent to the students to remind them of the activity. This does not apply to real-time challenges, which take place in person during lectures.

Furthermore, the leaderboard aspect was changed to stars (Figure 5.6), since the evaluation self-notion was more important than a relative ranking. This evaluation is done in two distinct ways: for real-time challenges, students have three attempts to solve the challenge, and each incorrect attempt reduces the number of stars achieved by one (up to a total of three stars lost); for complex challenges, students have a single attempt to solve them, so the evaluation is performed through a set of unit tests and the stars are attributed according to the percentage of unit tests passed. Despite the leaderboard being removed for the students, it is still visible to the professors (Figure 5.7), and even students who were incorrect are included so that the lecturers can have an overview of the students' knowledge level. The students are also allowed to review a challenge after they've completed it, showing their own attempts, as well as the correct answer, in case they did not get it correct (Figure 5.8).

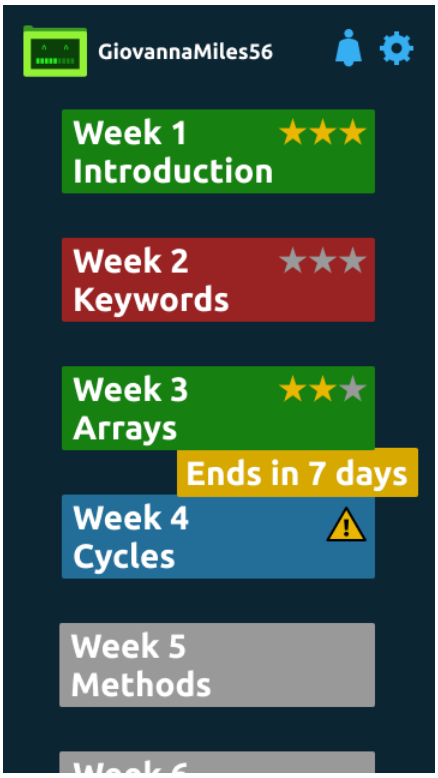


Figure 5.6: Challenge level select with due date

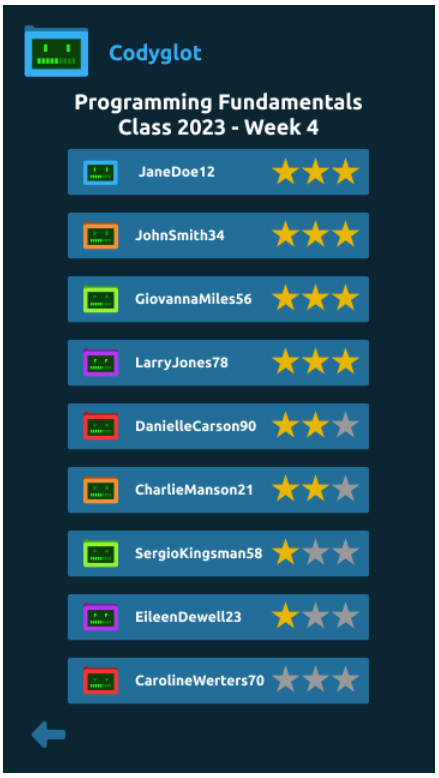


Figure 5.7: Star leaderboard

Additionally, to make the answer display more user-friendly in real-time challenges, a division was added between the student's answers and their peers', as visible in Figure 5.9.

Some minor adjustments also took place, such as keeping the question visible while the challenge is being answered and replacing "DNF" ("Did Not Finish") on the challenges that were not completed before the due date with "-".

Other feedback, such as showing the leaderboard position as a pop-up instead of in the level and changing "Pending" to "Awaiting Evaluation" on the delayed-feedback challenges, was not applicable since those features were removed.

5.1.3 Forum

In the forum, both forms of feedback were added to the new model (Figure 5.10). Thus, the second prototype contained both the voting system among the students and the badges, of which new types were added (Figure 5.11) to give the professors the ability to add different forms of feedback to each answer. In addition, the badges now identify which professor gave them, to allow students to reach out to them for related doubts.

As desired by the majority, the topics were set to remain open even after an answer was determined as correct by one of the professors so that other students could ask further related questions or send different answers that may also be considered correct.

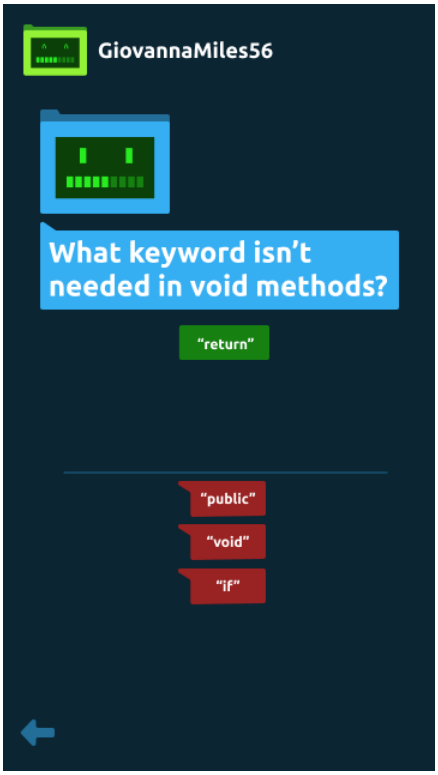


Figure 5.8: Review of a challenge

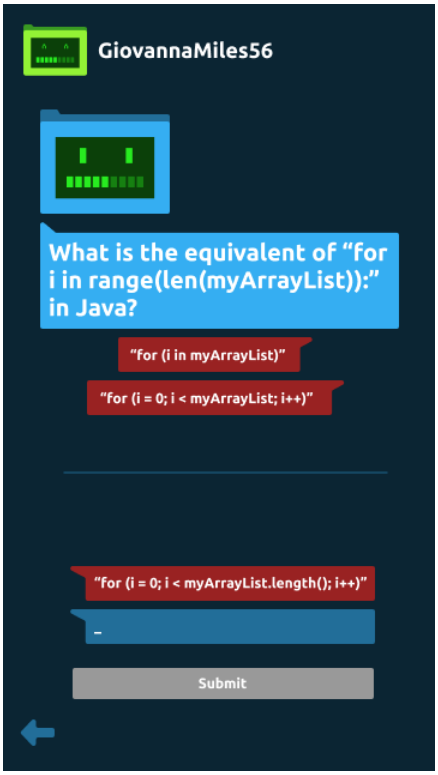


Figure 5.9: Real-time challenge

Figure 5.10: Forum with both systems

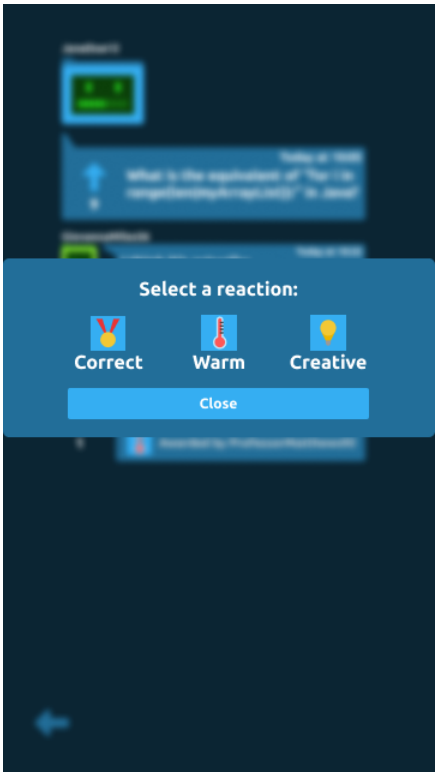


Figure 5.11: Badge types

Moreover, credibility was removed as suggested since, in the opinion of the interviewees, it led to demotivation or bias in the answers of students with the lowest credibility values. Because of this change, other suggestions related to credibility were not applicable.

Finally, the questions were separated because some testers mentioned it looked too similar to a "chat room" or messaging system. However, to avoid them looking more like messages, neither the reply button nor the text field at the bottom, both suggested by students, were added to the forum.

Other suggestions that were rejected include highlighting "hot streaks" (a high number of medals in a short time period), dismissed because both students and professors found it excessive to add more gamification elements and features, and making questions anonymous since it is useful for the professors to be aware of who posts questions on a certain topic to give them more personalised support.

5.2 Feedback

After the application of the aforementioned changes, a new round of usability tests took place with the three updated models, one for each variant. In this second round of tests, there was a total of 30 participants, 21 students and 9 professors. The full results can be found in Appendix D.

This set of 30 participants contained 9 students and 2 professors with previous knowledge about the app, already present in the first iteration of usability tests, and 19 unbiased participants who were experimenting with the app for the first time. This way, the features can be tested against the previous versions, as well as independently.

The students involved in the first phase mentioned that the prototypes highly improved, and the feedback was almost totally positive. The star mechanic added to the challenges (to replace the leaderboard) was the only element that received a lower rating in motivation (3.9), as only the first attempt counts for the number of stars. However, a suggestion made by one of the students was that when a student repeats a challenge after the first attempt, they can get more stars, while the professor can still access the first solution submitted. This supports the conclusion that it is possible to enhance student participation and class dynamics using a user-centred gamified teaching-learning method, confirming **RQ2** (Section 1.4).

Furthermore, the increase in motivation and learning performance caused by the combination of different types of exercises and the introduction of personalisable settings (such as the optional leaderboard) attest that allowing customisation of the gamified teaching-learning method by professors and students improves its suitability, answering **RQ4** (Section 1.4) affirmatively.

The professors, averaging 45 years old, had an incredibly positive evaluation, with every rating averaging 4.5 or higher for all parameters and a maximum number of average errors per task of 0.167. This endorses **RQ3** (Section 1.4) by reaffirming the simplicity and intuitiveness of the teaching-learning method. Despite that, some feedback was still given, such as adding a podium to the challenges at the end of the semester with the highest number of stars or adding what class/lecture the students should review when they get a challenge wrong.

The feedback given could still be used to improve some minor details, meaning the app could always be somewhat improved. However, for the sake of this project, the gamification elements were deemed successful through the feedback given in the second round. Hence, **RQ1** (Section 1.4) was confirmed, as a user-centred approach was successfully used to develop a gamified teaching-learning method to increase students' motivation and learning performance.

5.3 Gamification Ratings

This section contains the ratings for the effects of each game element on the motivation and learning performance of students in each of the variants. For this model-specific ranking, the student affirmation ratings were directly used. When not applicable, the value corresponds to an average between the professor and student ratings. The discarded elements from the first loop are also included for comparison purposes. For more detailed results of the usability tests, consult Appendixes C and D.

5.3.1 Motivation

Table 5.1: Exercise Motivation Ratings

Exercises	
Immediate feedback	4.9
Achievements	4.9
(Unlockable) Levels	4.8
Team leaderboard (optional)	4.7
Teams	4.6
Points	4.6
Gifting/Boosters	4.4
Single leaderboard*	4.2
Lives*	3.6
Internal team leaderboard*	3.1

Table 5.2: Challenge Motivation Ratings

Challenges	
Instant feedback (on all answers)	4.8
Anonymity	4.6
Time Limit	4.4
Competition	4.4
Stars	4.2
Delayed feedback*	3.3
Leaderboard*	3.1

* - elements that were removed after the first iteration.

Table 5.3: Forum Motivation Ratings

Forum	
Profile	5.0
Badges	4.9
Voting system	4.8
Cooperation	4.4
Anonymity	4.2
Public social network (credibility)*	2.7

5.3.2 Learning Performance

Table 5.4: Exercise Learning Performance Ratings

Exercises	
(Unlockable) Levels	5.0
Immediate feedback	4.9
Team leaderboard (optional)	4.8
Single leaderboard*	4.8
Teams	4.7
Gifting/Boosters	4.6
Points	4.6
Achievements	4.5
Lives*	4.0
Internal team leaderboard*	3.6

Table 5.5: Challenge Learning Performance Ratings

Challenges	
Stars	5.0
Instant feedback (on own answers)	4.8
Competition	4.4
Instant feedback (on other's answers)	4.3
Leaderboard*	4.1
Delayed feedback*	4.1

Table 5.6: Forum Learning Performance Ratings

Forum	
Badges	5.0
Cooperation	4.9
Voting system	4.8
Public social network (credibility)*	3.8

* - elements that were removed after the first iteration.

Note: The elements that were not included in the Learning Performance subsection were deemed not to have a direct impact on students' learning performance, or their impact was not studied directly, being exclusively a target of study in regard to their effect on motivation.

5.4 Conclusions

Although the prototypes could still be improved, given the fact that some of the ratings were still below "Good" (considered to be 4 on the Likert scale), the results were deemed satisfactory for the sake of this Dissertation.

Through the two cycles, it was possible to iteratively improve the prototypes and achieve better ratings in terms of motivation and learning performance, as well as make them more intuitive and simple to use. This way, a better result was achieved for both students and professors.

Finally, two rankings of the effects of different game elements in distinct scenarios were created, with the goal of providing guidelines for similar approaches designed in the future.

Chapter 6

Conclusions and Future Work

In this chapter, we revisit and answer the hypothesis and research questions formulated for this project, draw the final conclusions, present the main contributions, and discuss possible future steps.

6.1 Answering the Hypothesis and Research Questions

In Section 1.4, the hypothesis behind this project was introduced:

> *"It is possible to achieve higher student motivation and learning performance through a user-centred, customisable, gamified teaching-learning method, thereby enhancing class dynamics and lowering the effort needed from professors."*

This hypothesis focused on 4 main points: creating a user-centred, gamified teaching-learning method, making it customisable by both students and professors, using it to increase student motivation and learning performance and lowering the effort needed from professors on their tasks.

Revisiting our research questions, we confirmed that: **RQ1:** the teaching-learning method developed in this project had as base concept a user-centred approach, based on two different iterations of design, testing and feedback, that led to a successful improvement on its effects on motivation and learning performance; **RQ2:** it enhanced students' motivation to participate and provided dynamism to the lectures; **RQ3:** professors (and students) gave it a very high rating in both simplicity and understandability across all features, ensuring the adaptation period is short for new users; **RQ4:** professors and students have the capability to customise the method in a certain degree, and their feedback indicates this improves students' motivation and learning performance.

As all research questions occasioned by the hypothesis have been affirmatively answered, the hypothesis is hereby confirmed by the experimental results, as we conclude the user-centred, customisable, gamified teaching-learning method developed causes an improvement in student motivation, learning performance, participation and lecture dynamics, thereby lowering the effort needed from the lecturers in their tasks.

6.2 Final Conclusions

This work intended to study the effects of gamification in higher education and design an innovative, gamified teaching-learning method to increase student motivation and learning performance, facilitating the professors' tasks.

After an extensive analysis of the existing bibliography in the field and a brainstorming period, significant conclusions were drawn. Gamification is a promising way of providing motivation and engagement factors for university students, thereby helping the improvement of grades and learning outcomes. Hence, gamification could answer the recent increase in university student demotivation, failure and dropout rates.

Nevertheless, gamification is not a well-demarcated recipe; several parameters need tuning to make sure it doesn't have adverse effects. Thus, user-centred development was proposed as a technique to adapt the method to the target population. In this context, a survey was conducted with both professors and students, concluding that the majority of them desired a gamified programming teaching-learning app that could help students review key concepts, retain their attention and promote interaction between students and lecturers while simplifying the tasks of the latter.

The gamified teaching-learning method, developed and tested in two iterative loops, consisted of three variants of programming learning apps: exercises, challenges and a forum, each incorporating distinct features and game elements. Through usability tests performed with both target populations, an assessment of the effects of the different game elements in each scenario was done, resulting in two rankings, one based on motivation and the other one on learning performance.

The improvement in the results obtained for both lecturers and students allows the conclusion that the user-centred approach is advantageous in the development of gamified teaching-learning tools, not only for the participants involved in both phases but also for unbiased participants who experienced only the improved model.

Despite the positive results, this work contains some possible limitations regarding the validity of the results, as these may have been affected by the reduced size of the sample of students and professors, especially in the first iteration of usability tests. However, the points created during that first stage were mostly confirmed later through a second, more populated phase, removing most of the bias from the first round.

The homogeneity of the participants may also have influenced these results (despite being from different degrees and having very widespread ages, they were all from engineering degrees, and it may not transfer as well to other contents). However, both the student sample and the professor sample contained multiple individuals enrolled in Bachelor's and Master's degrees not highly related to Programming, such as Civil, Environmental, and Mining and Geo-Environmental Engineering.

6.3 Main Contributions

Firstly, this research project contributes to making students' tasks more appealing and worthy of engagement, provoking an improvement in their academic results. On the other hand, it makes it easier for professors to keep their students' attention and interact with them.

Additionally, this research has achieved significant milestones: an article based on the SLR performed for this project has already been submitted for publishing in an international journal, presenting the key findings regarding the current state of the art of gamification in higher education; and a case study article, including the experimental testing of the prototypes and their corresponding results, is under development to be submitted to an international journal.

Lastly, two rankings of the gamification elements were produced, one based on their effects on motivation and the other based on their effects on learning performance for each of the scenarios. These rankings serve as valuable resources for the creation of a set of guidelines for the future development of similar approaches.

6.4 Future work

After the completion of this dissertation, many tasks can still be executed to achieve improved results. During the second round of feedback, despite the remarkable results, the participants still provided suggestions to improve certain details that otherwise could have adverse effects on both the motivation and the learning performance of the students.

Furthermore, new features, gamification elements and scenarios could be incorporated to study different combinations and their conjoined influence on all metrics evaluated in this project.

Given the positive outcome of the prototypes tested, but keeping in mind the homogeneity of participants involved in the usability tests performed during this study, the method could later be tested and expanded into different higher education branches.

Another possible path to adopt in the future is the integration of the game elements targeted by this work into already existing entities, such as Moodle (https://moodle.up.pt/, last accessed in June 2023), as this would require an even shorter adaptation period for both students and professors to these elements, easing their introduction into mainstream higher education.

References

[1] A. Ahmad, F. Zeshan, M.S. Khan, R. Marriam, A. Ali, and A. Samreen. The impact of gamification on learning outcomes of computer science majors. *ACM Transactions on Computing Education*, 20(2), 2020.

[2] M.Y. Alghamdi and Y.A. Younis. The use of computer games for teaching and learning cybersecurity in higher education institutions. *Journal of Engineering Research (Kuwait)*, 9(3):143–152, 2021.

[3] A. Bernik, D. Radošević, and G. Bubaš. Achievements and usage of learning materials in computer science hybrid courses. *Journal of Computer Science*, 15(4):489–498, 2019.

[4] P. Boytchev and S. Boytcheva. Gamified evaluation in steam for higher education: A case study. *Information (Switzerland)*, 11(6), 2020.

[5] B. Castillo-Parra, B.G. Hidalgo-Cajo, M. Vásconez-Barrera, and J. Oleas-López. Gamification in higher education: A review of the literature. *World Journal on Educational Technology: Current Issues*, 14(3):797–816, 2022.

[6] M Cengiz, KU Birant, P Yildirim, and D Birant. Development of an interactive game-based learning environment to teach data mining. *INTERNATIONAL JOURNAL OF ENGINEERING EDUCATION*, 33(5):1598–1617, 2017.

[7] P.J. Clarke, D.L. Davis, I.A. Buckley, G. Potvin, M. Thirunarayanan, and E.L. Jones. Combining learning and engagement strategies in a software testing learning environment. *ACM Transactions on Computing Education*, 22(2), 2022.

[8] J.C. Cuevas-Martínez, A.J. Yuste-Delgado, J.M. Perez-Lorenzo, and A. Triviño-Cabrera. Jump to the next level: A four-year gamification experiment in information technology engineering. *IEEE Access*, 7:118125–118134, 2019.

[9] K. Daungcharone, P. Panjaburee, and K. Thongkoo. A mobile game-based c programming language learning: Results of university students' achievement and motivations. *International Journal of Mobile Learning and Organisation*, 13(2):171–192, 2019.

[10] K. Daungcharone, P. Panjaburee, and K. Thongkoo. Implementation of mobile game-transformed lecturebased approach to promoting c programming language learning. *International Journal of Mobile Learning and Organisation*, 14(2):236–254, 2020.

[11] R.K. Dixit, M. Nirgude, and P.S. Yalagi. Employ gamification to make "i&cs" more interesting. *Journal of Engineering Education Transformations*, 32(2):55–60, 2018.

[12] M. Garcia-Iruela, M.J. Fonseca, R. Hijon-Neira, and T. Chambel. Gamification and computer science students' activity. *IEEE Access*, 8:96829–96836, 2020.

[13] H. Hosseini, M. Hartt, and M. Mostafapour. Learning is child's play: Game-based learning in computer science education. *ACM Transactions on Computing Education*, 19(3), 2019.

[14] Eva Jacobs, Oliver Garbrecht, Reinhold Kneer, and Wilko Rohlfs. Game-based learning apps in engineering education: requirements, design and reception among students. *European Journal of Engineering Education*, pages 1–34, 2023. doi: 10.1080/03043797.2023.2169106.

[15] Ankur Joshi, Saket Kale, Satish Chandel, and D Kumar Pal. Likert scale: Explored and explained. *British journal of applied science & technology*, 7(4):396, 2015.

[16] M. Jurgelaitis, L. Čeponienė, J. Čeponis, and V. Drungilas. Implementing gamification in a university-level uml modeling course: A case study. *Computer Applications in Engineering Education*, 27(2):332–343, 2019.

[17] S.A. Licorish and A.L.J. Lötter. When does kahoot! provide most value for classroom dynamics, engagement, and motivation?: Is students' and lecturers' perceptions. *Journal of Information Systems Education*, 33(3):245–260, 2022.

[18] S.A. Licorish, H.E. Owen, B. Daniel, and J.L. George. Students' perception of kahoot!'s influence on teaching and learning. *Research and Practice in Technology Enhanced Learning*, 13(1), 2018.

[19] D. Maryono, Budiyono, Sajidan, and M. Akhyar. Implementation of gamification in programming learning: Literature review. *International Journal of Information and Education Technology*, 12(12):1448–1457, 2022.

[20] B. Marín, J. Frez, J. Cruz-Lemus, and M. Genero. An empirical investigation on the benefits of gamification in programming courses. *ACM Transactions on Computing Education*, 19(1), 2019.

[21] I. Milenković, U. Šošević, D. Simić, M. Minović, and M. Milovanović. Improving student engagement in a biometric classroom: the contribution of gamification. *Universal Access in the Information Society*, 18(3):523–532, 2019.

[22] R. Oktaviati and A.A. Jaharadak. The impact of using gamification in learning computer science for students in university. *International Journal of Engineering and Technology(UAE)*, 7(4):121–125, 2018.

[23] M. Ortiz-Rojas, K. Chiluiza, and M. Valcke. Gamification through leaderboards: An empirical study in engineering education. *Computer Applications in Engineering Education*, 27(4):777–788, 2019.

[24] H.E. Owen and S.A. Licorish. Game-based student response system: The effectiveness of kahoot! on junior and senior information science students' learning. *Journal of Information Technology Education: Research*, 19:511–553, 2020.

[25] M. J. Page, J. E. McKenzie, P. M. Bossuyt, I. Boutron, T. C. Hoffmann, C. D. Mulrow, et al. The prisma 2020 statement: an updated guideline for reporting systematic reviews. *Systematic Reviews*, 10(1):89, 2021.

[26] Pratiwi, Rusmono, and M.A. Suparman. Games based learning on discrete mathematics in the new normal. *Academy of Entrepreneurship Journal*, 27:01–18, 2021.

[27] A. Queiruga-Dios, M.J.S. Sánchez, M.Q. Dios, V.G. Martínez, and A.H. Encinas. A virus infected your laptop. let's play an escape game. *Mathematics*, 8(2), 2020.

[28] A. Rojas-López, E.G. Rincón-Flores, J. Mena, F.J. García-Peñalvo, and M.S. Ramírez-Montoya. Engagement in the course of programming in higher education through the use of gamification. *Universal Access in the Information Society*, 18(3):583–597, 2019.

[29] M. Tasadduq, M.S. Khan, R.M.A. Nawab, M.H. Jamal, and M.T. Chaudhry. Exploring the effects of gamification on students with rote learning background while learning computer programming. *Computer Applications in Engineering Education*, 29(6):1871–1891, 2021.

[30] C. Troussas, A. Krouska, and C. Sgouropoulou. Collaboration and fuzzy-modeled personalization for mobile game-based learning in higher education. *Computers and Education*, 144, 2020.

[31] Waseemullah, AK Kazi, MF Hyder, and FA Basit. Animated game-based learning of data structures in professional education. *INTERNATIONAL JOURNAL OF COMPUTER SCIENCE AND NETWORK SECURITY*, 22(8):1–6, 2022.

[32] S.A. Zabala-Vargas, L. García-Mora, E. Arciniegas-Hernández, J. Reina-Medrano, B. de Benito-Crosetti, and A. Darder-Mésquida. Didactic strategy mediated by games in the teaching of mathematics in first-year engineering students. *Eurasia Journal of Mathematics, Science and Technology Education*, 18(2), 2022.

[33] D. Zhao, C.H. Muntean, A.E. Chis, G. Rozinaj, and G. Muntean. Game-based learning: Enhancing student experience, knowledge gain, and usability in higher education programming courses. *IEEE Transactions on Education*, 2022.

[34] M.E. Zorrilla Pantaleón, D. García-Saiz, and A. de la Vega. Fostering study time outside class using gamification strategies: An experimental study at tertiary-level database courses. *Computer Applications in Engineering Education*, 29(5):1340–1357, 2021.

Appendix A

Student Survey

This appendix showcases the questions in the initial survey done to the student population at FEUP and the responses submitted by the participants.

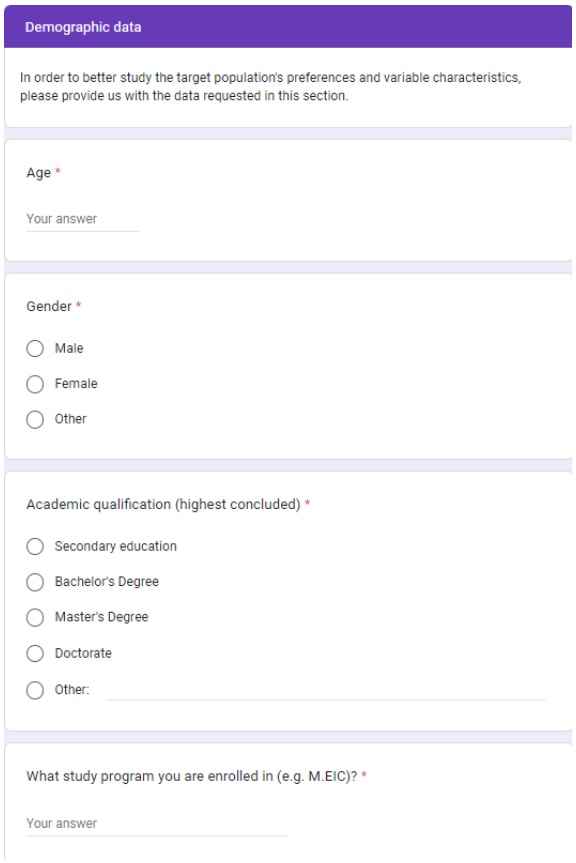
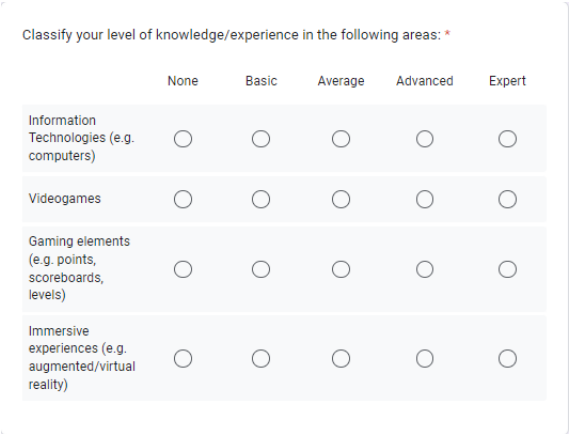


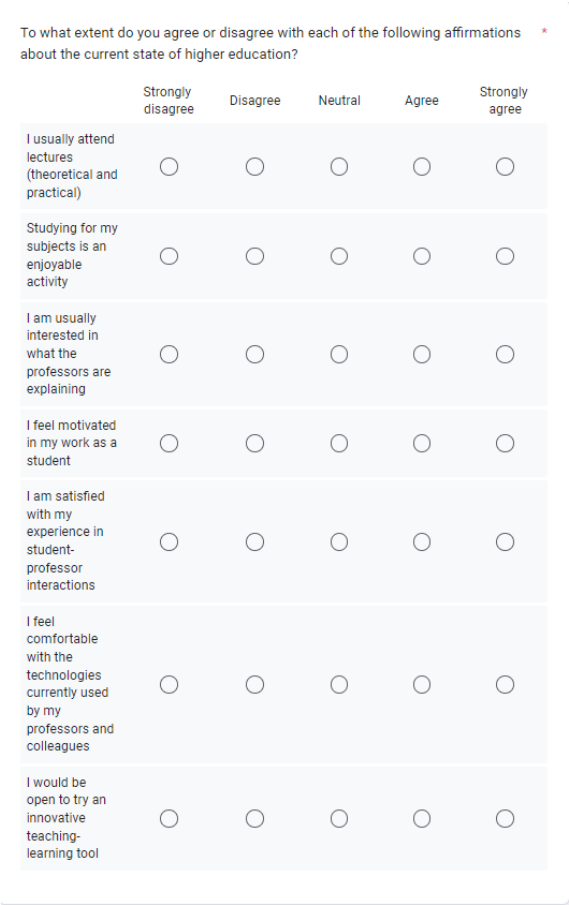
Figure A.1: Student demographic data



Classify your level of knowledge/experience in the following areas: *

	None	Basic	Average	Advanced	Expert
Information Technologies (e.g. computers)	○	○	○	○	○
Videogames	○	○	○	○	○
Gaming elements (e.g. points, scoreboards, levels)	○	○	○	○	○
Immersive experiences (e.g. augmented/virtual reality)	○	○	○	○	○

Figure A.2: Student experience - 1



To what extent do you agree or disagree with each of the following affirmations about the current state of higher education? *

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I usually attend lectures (theoretical and practical)	○	○	○	○	○
Studying for my subjects is an enjoyable activity	○	○	○	○	○
I am usually interested in what the professors are explaining	○	○	○	○	○
I feel motivated in my work as a student	○	○	○	○	○
I am satisfied with my experience in student-professor interactions	○	○	○	○	○
I feel comfortable with the technologies currently used by my professors and colleagues	○	○	○	○	○
I would be open to try an innovative teaching-learning tool	○	○	○	○	○

Figure A.3: Student experience - 2

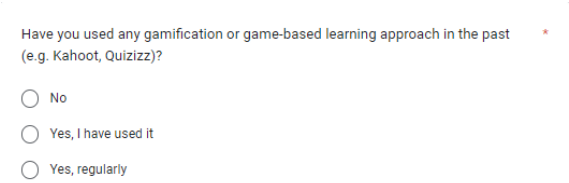


Figure A.4: Student experience - 3

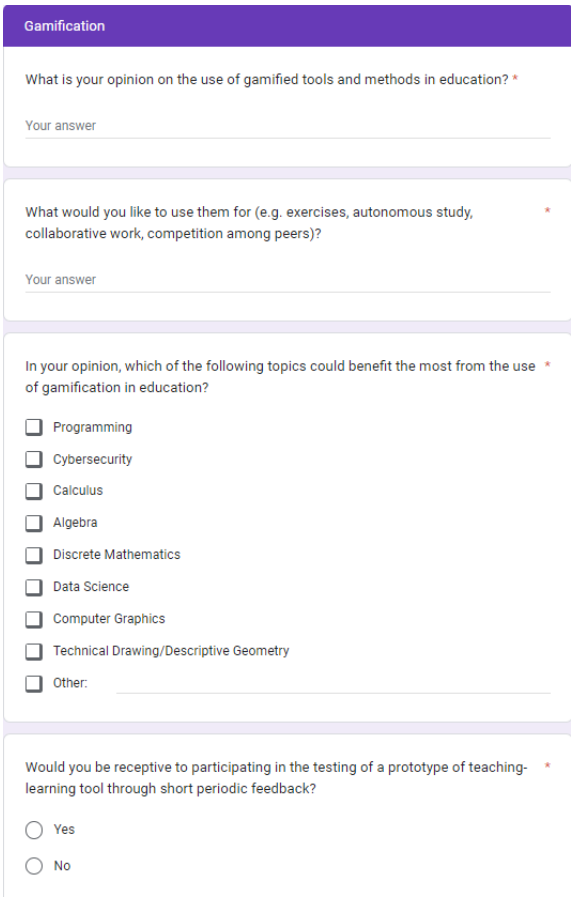


Figure A.5: Student no gamification experience

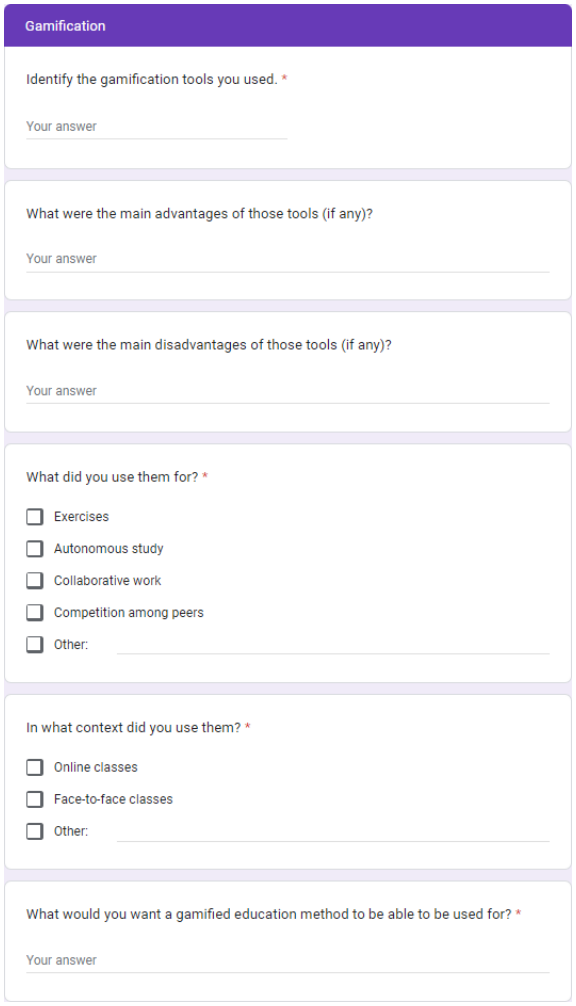


Figure A.6: Student gamification experience - 1

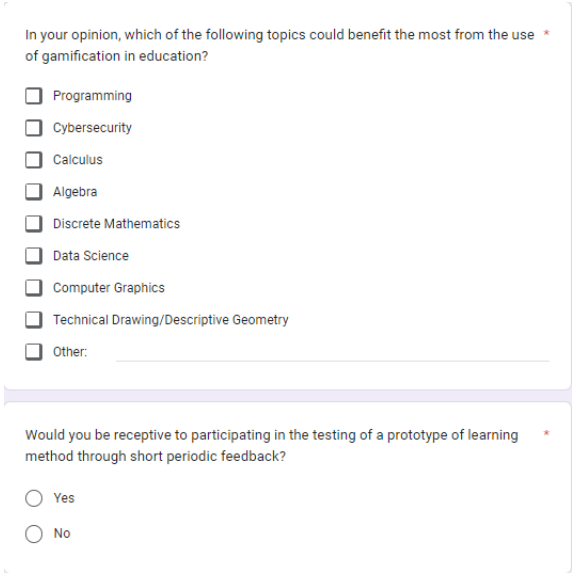


Figure A.7: Student gamification experience - 2

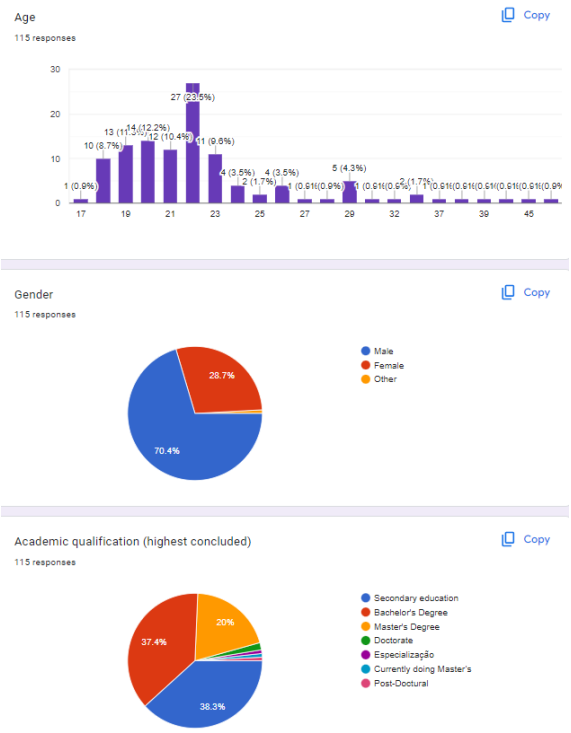


Figure A.8: Student demographic data answers

Figure A.9: Student experience answers - 1

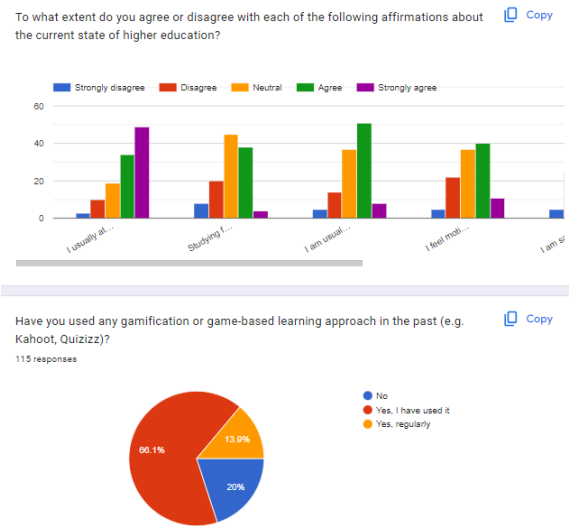


Figure A.10: Student experience answers - 2

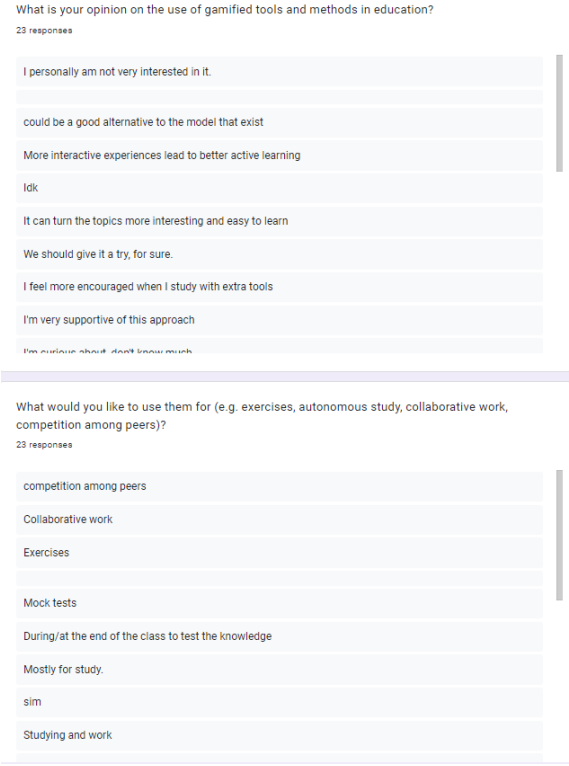


Figure A.11: Student no gamification experience answers - 1
Note: in text-answered questions, only the first responses are shown

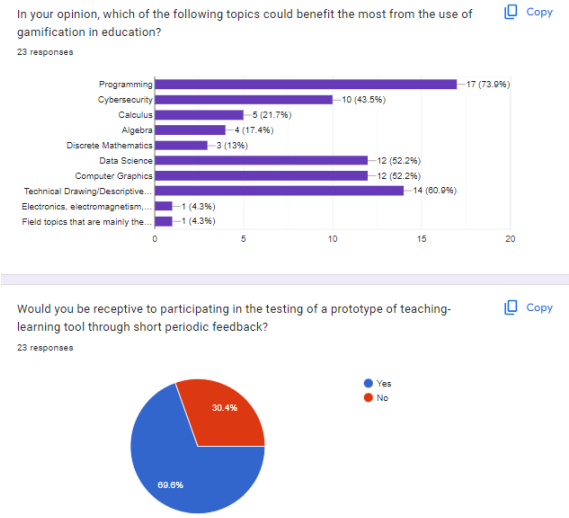


Figure A.12: Student no gamification experience answers - 2

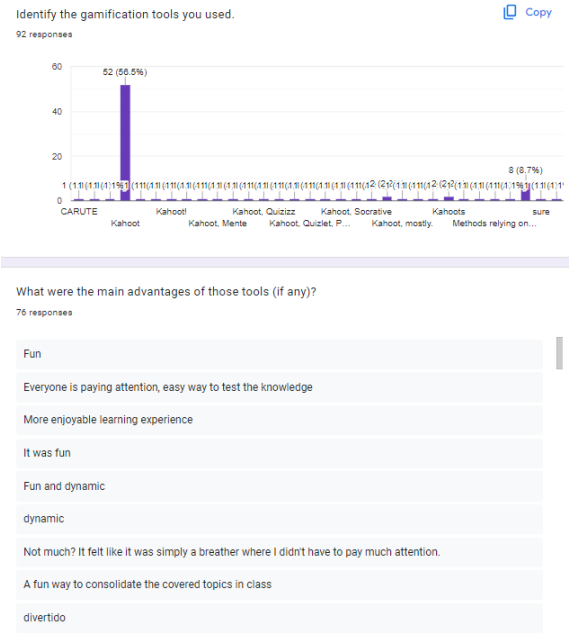


Figure A.13: Student gamification experience answers - 1

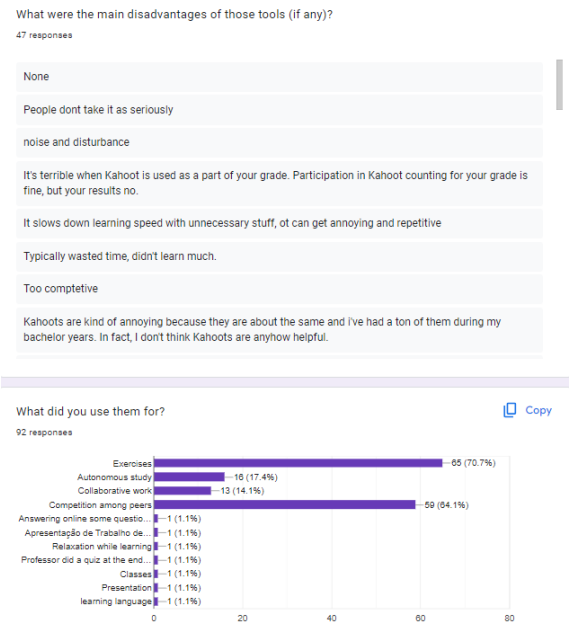


Figure A.14: Student gamification experience answers - 2

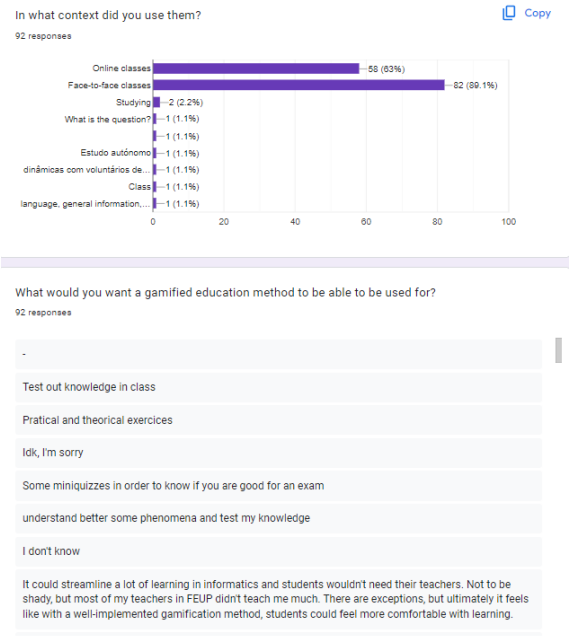


Figure A.15: Student gamification experience answers - 3

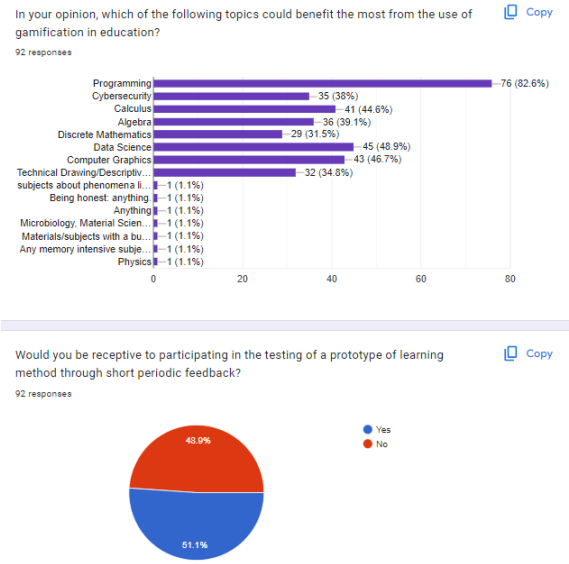


Figure A.16: Student gamification experience answers - 4

Appendix B

Professor Survey

This appendix showcases the questions in the initial survey done to the professor population at FEUP and the responses submitted by the participants.

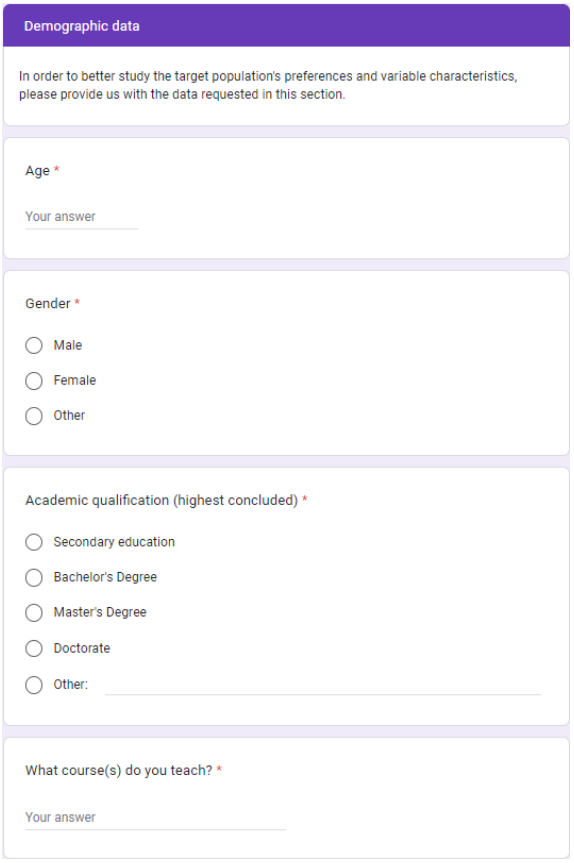
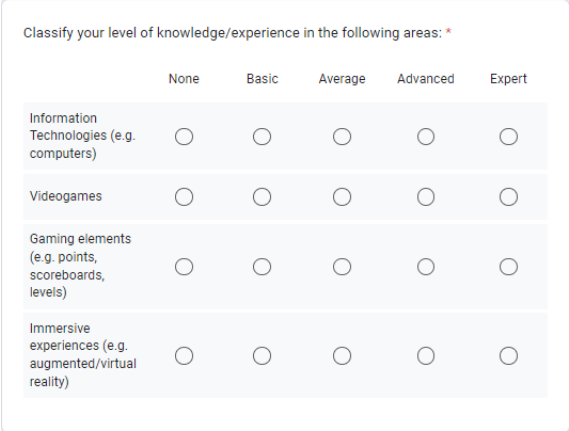


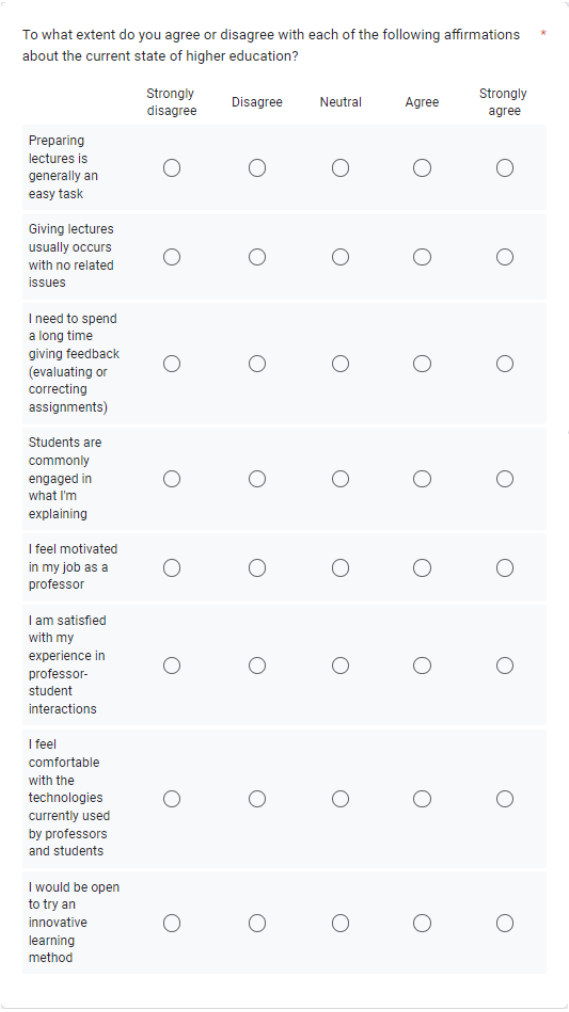
Figure B.1: Professor demographic data



Classify your level of knowledge/experience in the following areas: *

	None	Basic	Average	Advanced	Expert
Information Technologies (e.g. computers)	○	○	○	○	○
Videogames	○	○	○	○	○
Gaming elements (e.g. points, scoreboards, levels)	○	○	○	○	○
Immersive experiences (e.g. augmented/virtual reality)	○	○	○	○	○

Figure B.2: Professor experience - 1



To what extent do you agree or disagree with each of the following affirmations about the current state of higher education? *

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Preparing lectures is generally an easy task	○	○	○	○	○
Giving lectures usually occurs with no related issues	○	○	○	○	○
I need to spend a long time giving feedback (evaluating or correcting assignments)	○	○	○	○	○
Students are commonly engaged in what I'm explaining	○	○	○	○	○
I feel motivated in my job as a professor	○	○	○	○	○
I am satisfied with my experience in professor-student interactions	○	○	○	○	○
I feel comfortable with the technologies currently used by professors and students	○	○	○	○	○
I would be open to try an innovative learning method	○	○	○	○	○

Figure B.3: Professor experience - 2

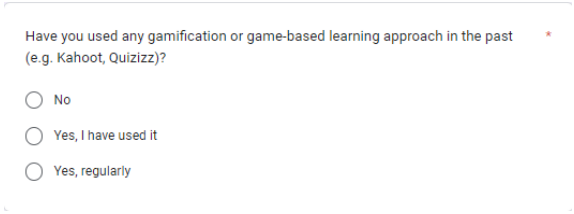


Figure B.4: Professor experience - 3

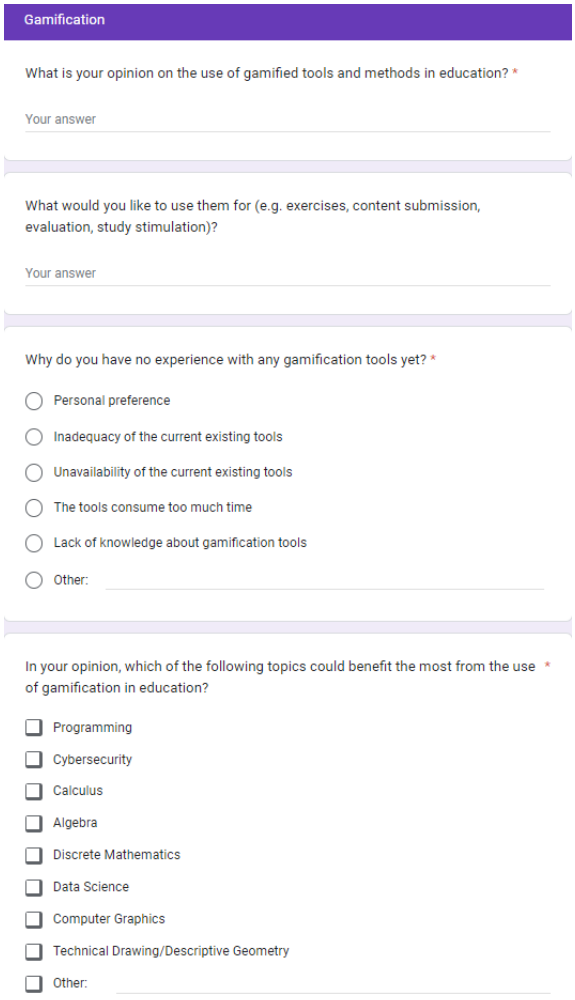


Figure B.5: Professor no gamification experience - 1

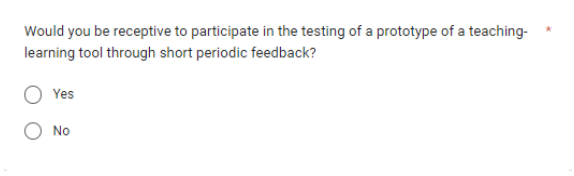


Figure B.6: Professor no gamification experience - 2

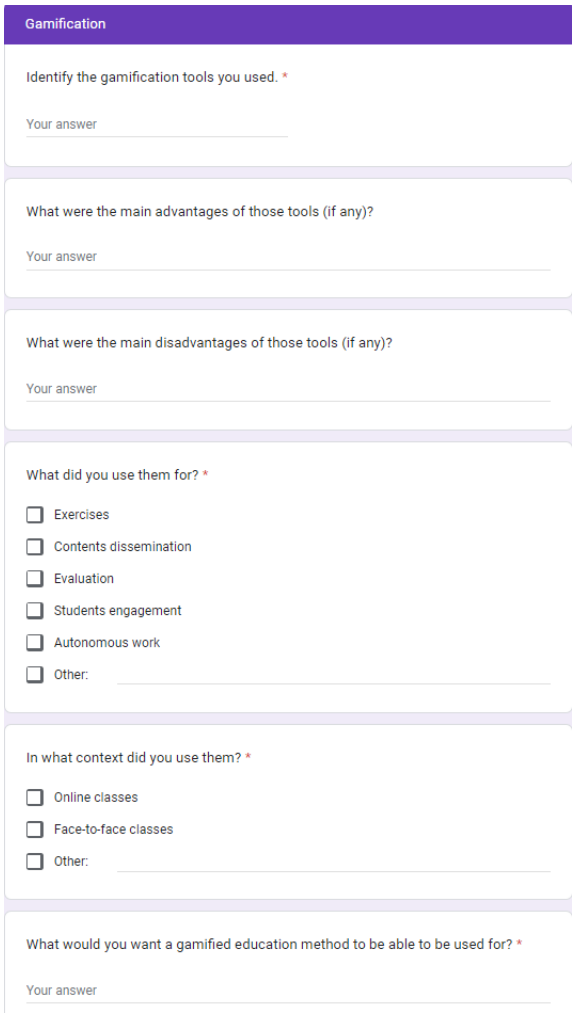


Figure B.7: Professor gamification experience - 1

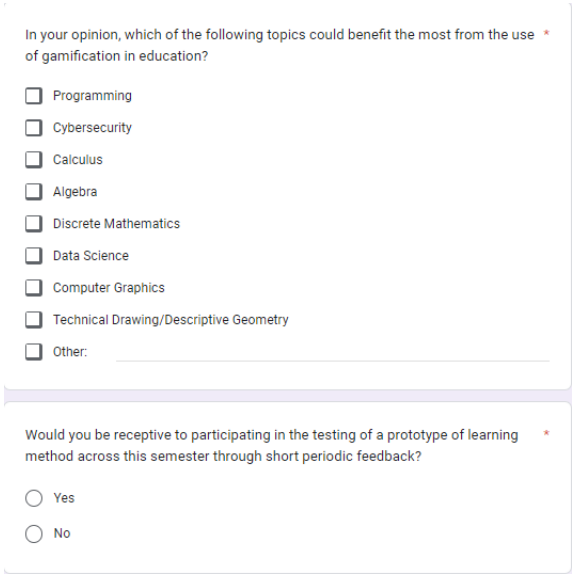


Figure B.8: Professor gamification experience - 2

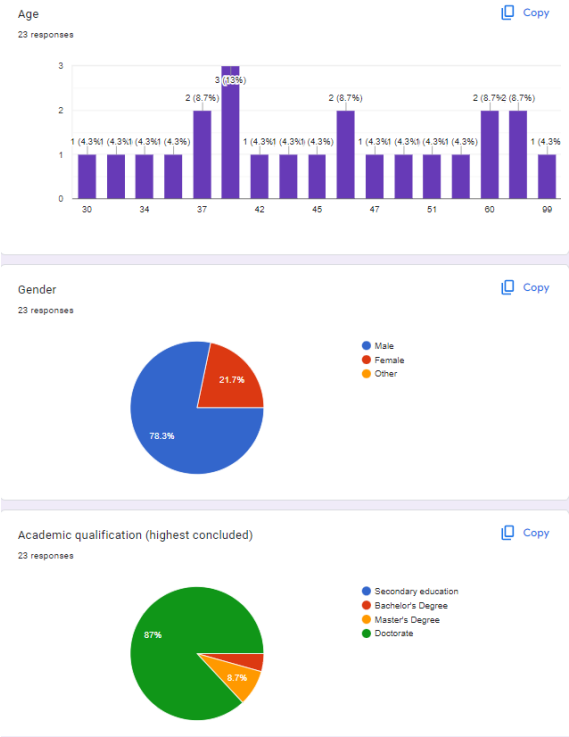


Figure B.9: Professor demographic data answers

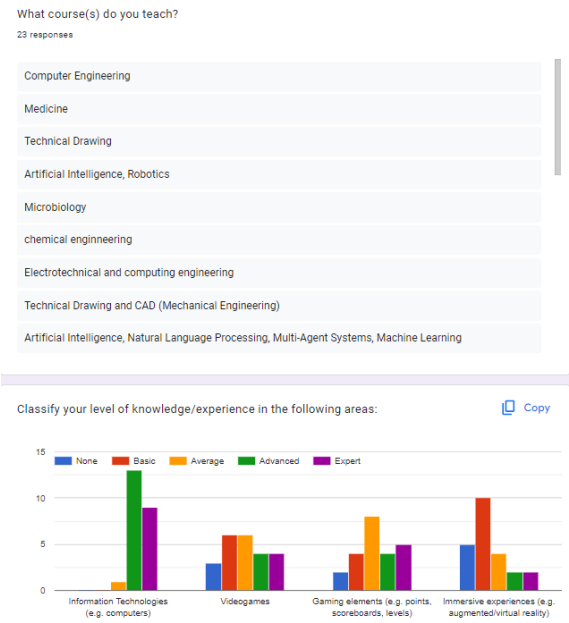


Figure B.10: Professor experience answers - 1
Note: in text-answered questions, only the first responses are shown

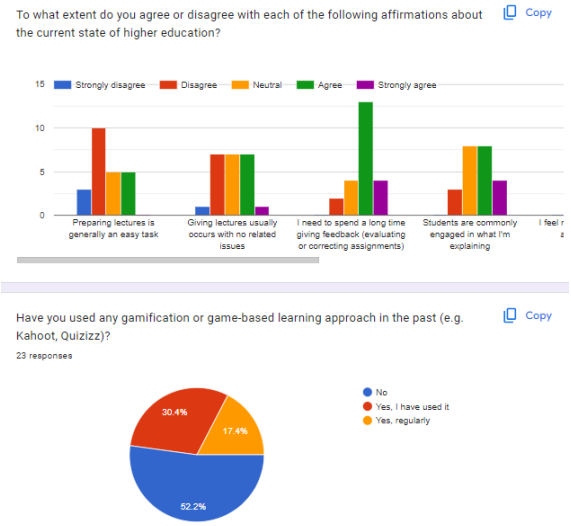


Figure B.11: Professor experience answers - 2

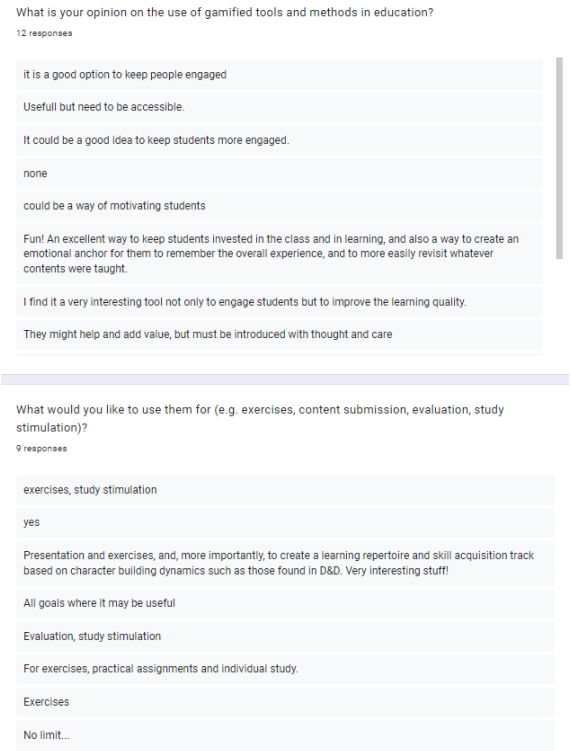


Figure B.12: Professor no gamification experience answers - 1

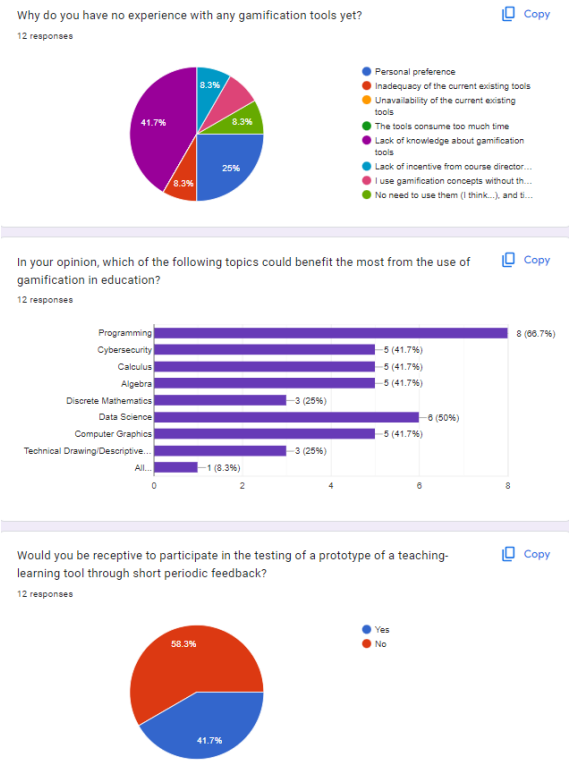


Figure B.13: Professor no gamification experience answers - 2

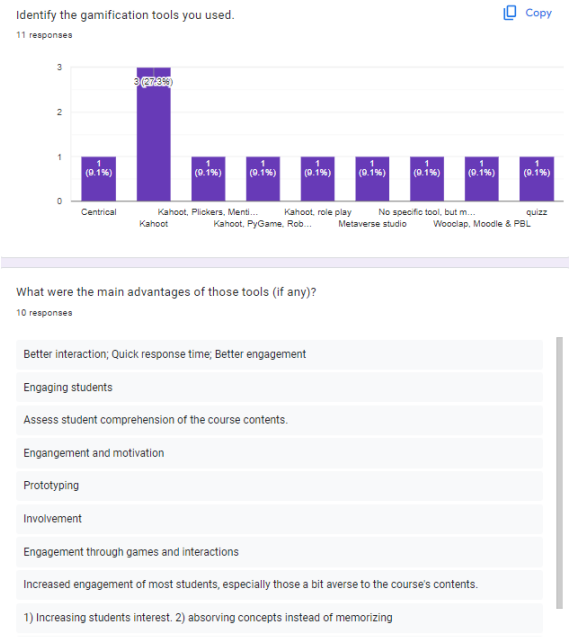


Figure B.14: Professor gamification experience answers - 1

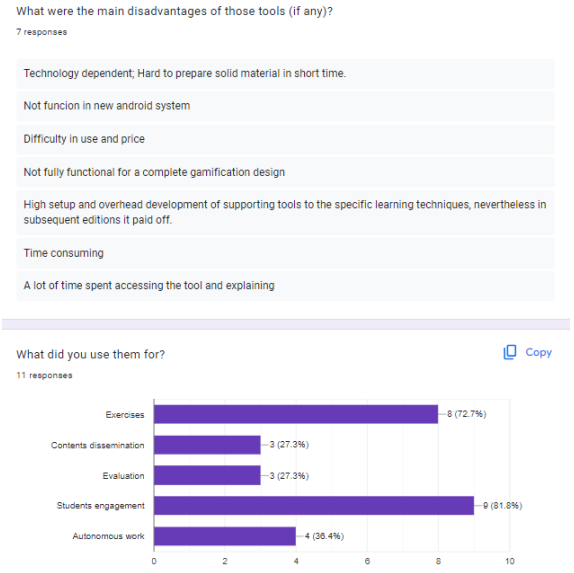


Figure B.15: Professor gamification experience answers - 2

Figure B.16: Professor gamification experience answers - 3

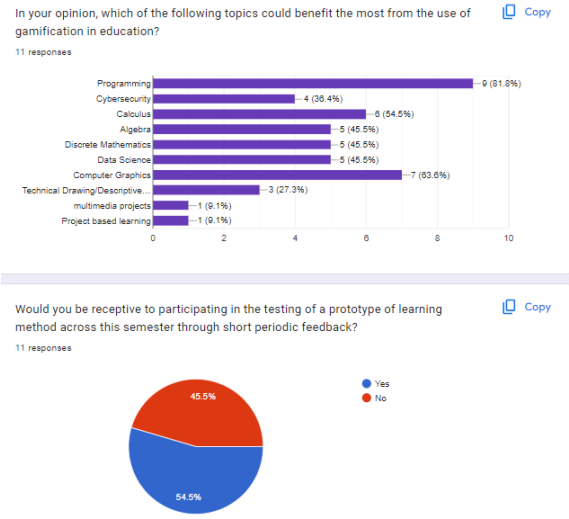


Figure B.17: Professor gamification experience answers - 4

Appendix C

Usability Tests: First Loop

This appendix shows the results of the usability tests during the first loop. These include the Likert ratings for the tasks and the model-specific affirmations.

Average ratings per task		Simplicity (1-5)	Understandability (1-5)	Motivation (1-5)	Learning (1-5)	# of errors
Leaderboard	Open theoretical content 4	4.929	4.143	4.071	4.929	0.286
	Start level 4	4.929	4.857	-	-	0.143
	Solve multiple choice exercise	5.000	4.929	4.857	4.857	0.000
	Solve coding exercise	5.000	4.500	4.929	4.929	0.000
	See results and top 5 leaderboard update	5.000	5.000	4.714	4.786	0.000
Unlockables	Open theoretical content 3	5.000	4.929	4.857	5.000	0.000
	Start level 3	5.000	5.000	4.929	5.000	0.000
	Solve multiple choice exercise	4.929	5.000	4.071	4.643	0.000
	Solve coding exercise	5.000	4.929	5.000	5.000	0.071
	See reward received	5.000	5.000	4.286	4.643	0.000
	Unlock next level	5.000	5.000	-	-	0.000
	Open inventory (profile)	5.000	4.714	4.357	4.214	0.000
Team	See team leaderboard update	5.000	5.000	4.429	4.500	0.071
	Open team stats	5.000	5.000	4.286	4.500	0.000
	Activate a booster	5.000	4.786	4.500	4.500	0.000

Figure C.1: Student exercises

Instant	Select week 4	5.000	5.000	-	-	0.000
	Answer incorrectly	5.000	5.000	4.786	5.000	0.000
	See others' wrong answers	5.000	4.571	4.429	4.000	0.000
	Answer correctly	5.000	5.000	5.000	4.857	0.000
	See personal classification	5.000	4.857	4.214	4.143	0.000
Delayed	See the due date	5.000	5.000	4.714	4.571	0.143
	Open challenge 4	5.000	5.000	-	-	0.071
	Submit challenge answer	4.857	5.000	4.643	4.714	0.143
	See pending result	5.000	5.000	-	-	0.000
	Complete challenge 5	5.000	5.000	4.643	4.643	0.000
	See both results	5.000	4.857	4.000	4.071	0.000

Figure C.2: Student challenges

Professor	Select class from list	5.000	5.000	-	-	0.000
	Scroll through feed	5.000	4.929	-	-	0.000
	See closed topic	5.000	4.929	5.000	4.714	0.000
	See open topic	5.000	4.929	-	-	0.000
	Post solution	5.000	5.000	-	-	0.000
	Open notification menu	5.000	5.000	-	-	0.071
	Open post from notification	5.000	5.000	-	-	0.000
	See profile with new badge	5.000	5.000	4.857	4.857	0.143
	Open post from badge	5.000	5.000	-	-	0.000
Mutual	Select class from list	5.000	5.000	-	-	0.000
	See profile and credibility	5.000	5.000	4.500	4.214	0.000
	Scroll through feed	5.000	5.000	-	-	0.000
	See closed topic	5.000	4.929	-	-	0.000
	See open topic	5.000	5.000	-	-	0.000
	Post solution	5.000	5.000	4.714	4.500	0.000
	Vote for topic	5.000	5.000	-	-	0.000
	Open notification menu	5.000	5.000	-	-	0.071
	Open post from notification	5.000	5.000	-	-	0.000
	See profile with updated credibility	5.000	5.000	4.500	4.071	0.143
	See someone else's profile with lower credibility	5.000	5.000	2.714	3.643	0.214

Figure C.3: Student forum

Model	Affirmation	Average rating
Leaderboard	Levels motivate me to continue learning	4.714
	Points are a good reward for correct answers	4.500
	The leaderboard affects me negatively due to competitiveness	1.929
	The instant feedback helps me keep track of my mistakes	4.786
Unlockables	Unlocking new levels is an incentive to keep advancing	4.571
	The inventory is helpful to keep track of what levels I can unlock	4.214
	The rewards are distracting from the main purpose of learning	1.571
	The existence of limited lives is demotivating from learning	2.357
Team	The existence of teams is prejudicial to my individual performance	1.357
	The purchase of gifts being limited to individual points makes it a waste	1.571
	The gifting of boosts incentivises cooperation	4.500
	The internal leaderboard of the team can influence the relations between peers negatively	2.929
	The pressure to avoid being last in my team is too high	2.429
Instant	I am negatively affected when my wrong answers are shown anonymously	1.429
	The instant feedback on everyone's answers helps me find the correct answer	4.786
	Getting a low score on the leaderboard reduces my motivation	3.000
	Challenges would be a good way of interrupting theoretical teaching-learning moments	4.929
Delayed	The lack of instant feedback makes me less motivated to check my result	2.643
	The time constraint makes me more motivated to complete the challenge	4.214
	The time constraint causes an increase in my stress levels	2.857
	Getting a low score on the leaderboard reduces my motivation	2.786

Figure C.4: Student affirmations 1

Professor	Badges are not a good enough reward for helping my peers	1.571
	The feeling of cooperation for problem-solving makes me more motivated to participate in the forum	4.357
	The social aspect of the forum pressures me to aid other students	3.786
	I feel humiliated posting my questions publicly	2.571
Mutual	Having my credibility as a public value makes me more motivated to participate	4.071
	The lack of direct feedback from the professor takes away reliability from the answers	3.357
	I feel empowered by being able to vote on the answer I think is correct	4.500
	The anonymity of votes makes me more motivated to use this tool	4.714

Figure C.5: Student affirmations 2

Average ratings per task		Simplicity (1-5)	Understandability (1-5)	Motivation (1-5)	Learning (1-5)	# of errors
Leaderboard	Add theoretical content 4	5.000	5.000	5.000	5.000	0.750
	Add stage to level 4	4.500	4.750	5.000	5.000	0.000
	Create multiple choice exercise	4.500	4.750	4.750	4.000	0.500
	Save level	5.000	4.500	-	-	0.000
	Publish level	4.750	5.000	-	-	0.500
	See classrooms	5.000	5.000	-	-	0.250
	See class leaderboard	5.000	4.750	4.250	5.000	0.000
Unlockables	Create level 10	4.250	4.750	5.000	5.000	0.000
	Rename and add reward	5.000	5.000	4.667	5.000	0.000
	Add theoretical content	5.000	5.000	-	-	0.000
	Add multiple choice exercise	4.667	5.000	-	-	0.667
	Save level	5.000	5.000	-	-	0.000
	Publish level	5.000	4.667	-	-	0.000
	See classrooms	5.000	5.000	-	-	0.000
	See class leaderboard	5.000	5.000	-	-	0.000
	Check inventory (profile)	5.000	5.000	-	-	0.000
	Add new class (invite students)	5.000	5.000	-	-	0.000
Team	See class leaderboard	5.000	5.000	5.000	5.000	0.000
	See team leaderboard	5.000	4.500	4.500	5.000	0.500

Figure C.6: Professor exercises

Instant	Select classroom	5.000	5.000	-	-	0.000
	See current week	5.000	4.750	5.000	5.000	0.500
	Mark answer as correct	4.250	5.000	-	-	0.000
	Close challenge	5.000	5.000	5.000	5.000	0.000
	Create new challenge	5.000	5.000	-	-	0.000
	Write prompt and correct answer	5.000	5.000	-	-	0.000
	Open challenge	5.000	5.000	-	-	0.000
	See leaderboard of closed challenge	5.000	5.000	4.000	5.000	0.000
Delayed	Select classroom	5.000	5.000	-	-	0.000
	See current week	5.000	5.000	5.000	5.000	0.000
	Mark answer as correct	4.750	5.000	3.250	5.000	0.000
	Mark answer as incorrect	5.000	5.000	3.250	5.000	0.000
	Create new challenge	5.000	5.000	-	-	0.000
	Write prompt	5.000	5.000	-	-	0.000
	Select due date	5.000	5.000	-	-	0.000

Figure C.7: Professor challenges

Professor	Select class from list	5.000	5.000	-	-	0.000
	Scroll through feed	5.000	5.000	-	-	0.000
	See closed topic	5.000	4.750	5.000	5.000	0.000
	See open topic	5.000	5.000	5.000	5.000	0.000
	See open topic again	5.000	5.000	5.000	4.750	0.000
	Award badge to correct answer	5.000	5.000	5.000	5.000	0.250
	See profile with new badge	5.000	5.000	4.500	5.000	0.000
	See post from badge	5.000	5.000	-	-	0.000
Mutual	See closed topic	5.000	5.000	5.000	5.000	0.250
	See open topic	5.000	5.000	5.000	5.000	0.000
	See open topic again	5.000	5.000	5.000	5.000	0.000
	Close topic	5.000	5.000	-	-	0.500
	See profile with credibility	5.000	4.750	5.000	5.000	0.500

Figure C.8: Professor forum

Appendix D

Usability Tests: Second Loop

This appendix shows the results of the usability tests during the second loop. These include the Likert ratings for the tasks and the model-specific affirmations.

Average ratings per task		Simplicity (1-5)	Understandability (1-5)	Motivation (1-5)	Learning (1-5)	# of errors
Exercises	Open settings	5.000	5.000	-	-	0.000
	Change leaderboard settings	5.000	5.000	5.000	5.000	0.000
	Open content	5.000	5.000	4.857	5.000	0.048
	Start level	5.000	5.000	-	-	0.000
	Solve multiple choice exercise	5.000	4.905	5.000	5.000	0.000
	Solve coding exercise	5.000	4.952	4.905	5.000	0.000
	Review lesson	5.000	5.000	5.000	5.000	0.000
	See score update (or leaderboard)	5.000	5.000	5.000	4.952	0.000
	See profile	5.000	4.952	4.952	5.000	0.048
	Unlock level 4	5.000	5.000	5.000	5.000	0.000
	See score/leaderboard	5.000	4.905	5.000	5.000	0.000
	Activate a booster	5.000	4.762	4.381	4.619	0.000
Challenges	Check due date	5.000	5.000	4.905	4.810	0.095
	Start week 3	5.000	5.000	4.952	5.000	0.000
	Answer incorrectly	5.000	5.000	-	-	0.143
	See other people's answers	5.000	4.905	4.381	4.429	0.000
	Answer correctly	5.000	5.000	4.810	4.857	0.000
	See result	5.000	4.952	4.571	4.952	0.000
	Complete challenge 4	5.000	5.000	4.619	4.905	0.048
	Review week 2	5.000	5.000	4.857	4.952	0.000

Figure D.1: Student exercises and challenges

Forum	Open profile	5.000	4.905	4.905	5.000	0.000
	Scroll through feed	5.000	4.952	-	-	0.000
	See answered question	5.000	5.000	4.905	4.905	0.000
	See open topic	5.000	5.000	5.000	5.000	0.000
	Post solution	5.000	5.000	-	-	0.000
	Open notification menu	5.000	5.000	-	-	0.095
	Open post from notification	5.000	5.000	-	-	0.000
	See profile with new badge	5.000	5.000	5.000	5.000	0.048
	Open post from badge	5.000	5.000	-	-	0.000

Figure D.2: Student forum

Model	Affirmation	Average rating
Exercises	The leaderboard being optional for myself boosts my motivation	4.381
	The immediate feedback on the exercises keeps me engaged	4.905
	The achievements distract me from the main purpose of learning	1.476
	The points are a good reward for correct exercises	4.571
	The privacy of the internal team leaderboard affects me negatively	1.762
	Unlocking a new level keeps me motivated	4.810
Challenges	The instant feedback on others' answers helps me find the right answer	4.333
	The time constraint makes me more motivated to complete the challenge	4.429
	The quality-based score of the response is more useful than time-based	4.810
	Losing stars with wrong answers makes me less motivated to participate	2.143
Forum	The different kinds of badges are useful to express different feedback	4.857
	The voting system added to the badges reinforces the motivation	4.810
	Being able to reply to a question after it was already answered helps me learn better	4.857
	I feel humiliated posting my responses publicly	1.857
	The anonymity of votes makes me more motivated to use this tool	4.238

Figure D.3: Student affirmations

Average ratings per task		Simplicity (1-5)	Understandability (1-5)	Motivation (1-5)	Learning (1-5)	# of errors
Exercises	Create level 10	5.000	4.667	-	-	0.000
	Rename and add reward	5.000	5.000	5.000	5.000	0.000
	Add theoretical content	5.000	5.000	4.667	4.833	0.167
	Add multiple choice exercise	5.000	5.000	5.000	5.000	0.167
	Save level	5.000	5.000	-	-	0.000
	Publish level	5.000	5.000	-	-	0.000
	See classrooms	5.000	5.000	-	-	0.000
	See class leaderboard	5.000	5.000	4.500	4.500	0.000
	Open team leaderboard	5.000	5.000	5.000	5.000	0.000
	Check profile	5.000	5.000	5.000	5.000	0.000
	Add new class (invite students)	5.000	5.000	-	-	0.000
Challenges	Select classroom	5.000	5.000	-	-	0.000
	See current week	5.000	4.667	5.000	5.000	0.000
	Mark answer as correct	5.000	5.000	-	-	0.000
	Close challenge	5.000	5.000	5.000	5.000	0.000
	See challenge leaderboard (private for students)	5.000	4.667	5.000	4.667	0.000
	Create new challenge	5.000	5.000	-	-	0.000
	Write prompt	5.000	5.000	-	-	0.000
	Add unit tests	5.000	5.000	5.000	5.000	0.000
	Select due date	5.000	5.000	5.000	5.000	0.000

Figure D.4: Professor exercises and challenges

Forum	Select class from list	5.000	5.000	-	-	0.000
	Scroll through feed	5.000	5.000	-	-	0.000
	See answered topic	5.000	5.000	5.000	5.000	0.000
	See open topic	5.000	5.000	-	-	0.000
	Award warm badge	5.000	5.000	5.000	5.000	0.000
	Reopen topic	5.000	5.000	-	-	0.000
	See profile	5.000	5.000	5.000	5.000	0.048
	Award correct badge	5.000	5.000	5.000	5.000	0.000
	See profile again	5.000	5.000	-	-	0.000

Figure D.5: Professor forum