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Pervasive Games for Education

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Abstract

Teaching is a complex process that requires a high degree of effort and motivation, particularly in STEM areas such as programming. Several teaching methodologies have been developed in order to increase students' motivation. In this work, we propose a solution based on pervasive games that make learning more fun and adapts to the context of the student. This solution is composed of an authoring tool for the teacher, a mobile location-based game and a server that provides integration of both.

This dissertation falls within the scope of the European project BEACONING (*Breaking educational barriers with contextualized pervasive and gameful learning*), which aims to enhance learning through gamification methods and pervasive games, adapted to each student, in order to enable a learning process "anywhere and anytime.".

The present dissertation will focus on the development of the authoring tool that enables the teacher to gamify lesson plans and to adapt them to different locations and students. Since the focus of BEACONING is the STEM area, a gamified lesson plan for the teaching of introductory programming was developed. This plan is going to merge one game narrative with a mix of mini-games and will be capable of enhancing the defined learning objectives. A specific mini-game for programming was also developed in order to provide an automatic assessment of programs developed in the scope of the game.

In this case study, the developed game for the teaching of programming will be playable on mobile devices and web, and its narrative is based on adventure and location-based games. Preliminary tests will be carried with students from the Master in Informatics, in order to assess the potential of this approach to the courses in Introductory programming. We have also conducted one focus group to explore the potential of this solution in other STEM areas.

Resumo

O ensino é um processo complexo que requer um elevado grau de esforço e dedicação, particularmente em áreas STEM tal como a programação. Várias metodologias de ensino têm sido desenvolvidas no sentido de incrementar a motivação dos estudantes. Neste trabalho é proposta uma solução baseada em jogos pervasivos que torna a aprendizagem mais divertida e adaptada ao contexto de cada estudante. Esta solução é composta por uma ferramenta de autoria para o professor, um jogo baseado na localização e um servidor capaz de integrar ambos.

Esta dissertação enquadra-se no âmbito do projeto europeu BEACONING (*Breaking educational barriers with contextualized pervasive and gameful learning*), que pretende potenciar a aprendizagem através de métodos gamificados e jogos pervasivos, adaptados a cada estudante, de modo a proporcionar um processo de aprendizagem "em qualquer lugar em qualquer altura".

A presente dissertação irá focar o desenvolvimento da ferramenta de autoria que possibilita ao professor a gamificação de planos de estudo, e a sua personalização a diferentes localizações e perfis de estudantes. Sendo o contexto do projeto BEACONING a área do STEM, foi desenvolvido um plano de estudos gamificado para aprendizagem dos fundamentos da programação. Este plano integra uma narrativa de jogo e um conjunto de mini-jogos que potencie os objetivos de aprendizagem definidos. Um mini-jogo para a programação foi desenvolvido para possibilitar correção automática de código no âmbito do jogo.

No caso específico, o jogo desenvolvido para o ensino da programação funcionará em dispositivos móveis e na web, e as narrativas serão baseadas em jogos de aventura e em jogos baseados na localização. Foram feitos testes preliminares com estudantes do Mestrado em Engenharia Informática, de modo a testar o potencial desta abordagem para unidades curriculares sobre introdução à programação. Foi também realizado um focus group para explorar o potencial desta solução em outras áreas do STEM.

Acknowledgements

At the end of this Dissertation, I must express my gratitude to everyone that supported me throughout my year of study and the writing and development of this dissertation.

I would like to start thanking my supervisor, António Coelho, and to my co-supervisor, João Jacob, for their continuous help and guidance at every stage of the dissertation.

I would then like to thank Rui Nóbrega and João Jacob once more for the allowance to use and modify work of their authoring in my dissertation, and also every BEACONING partner for their direct and indirect involvement in the authoring tool.

I would also like to thank every person that took part in the tests that were performed in the scope of this dissertation and also every person who contributed to the Game Jam.

At last, I can never thank enough to my family, including my girlfriend, and friends who provided a great support and aid during my years of study and the writing of this dissertation.

João Faria

"Games have power. Games have the power to teach, to train, to educate. Games have the power to bring people together—young, old, and in between. Games have the power to reveal and build character. Games have the power to retain and promote health. Games have the power to heal. On the other side of the force, gambling games have the power to enrich or to bankrupt."

[MC05, chap. Foreword]

Contents

1 Introduction **1**
- 1.1 Context . . . 1
  - 1.1.1 BEACONING . . . 2
- 1.2 Goals/Objectives . . . 2
- 1.3 Motivation . . . 3
- 1.4 Dissertation Structure . . . 3

2 Related Work **5**
- 2.1 Introduction . . . 5
- 2.2 Serious games . . . 5
  - 2.2.1 Military games . . . 6
  - 2.2.2 Educational games . . . 7
  - 2.2.3 Examples . . . 7
- 2.3 Conclusions/Summary . . . 10

3 Methodologies **11**
- 3.1 First approach . . . 11
  - 3.1.1 Architecture . . . 12
  - 3.1.2 Mockups . . . 12
  - 3.1.3 Prototype . . . 15
  - 3.1.4 Technologies . . . 16
- 3.2 Architecture . . . 17
  - 3.2.1 Authoring Tool . . . 18
  - 3.2.2 Programming Mini-game . . . 18
  - 3.2.3 Location-based Game . . . 19
  - 3.2.4 Back-end Server . . . 19
- 3.3 Evaluation and Validation . . . 19

4 Implementation **21**
- 4.1 Technologies . . . 21
- 4.2 Authoring Tool . . . 22
  - 4.2.1 Back-end . . . 22
  - 4.2.2 JSON Files . . . 23
  - 4.2.3 User Interface . . . 29
  - 4.2.4 Integration . . . 32
- 4.3 Programming Mini-game . . . 33
  - 4.3.1 Back-end . . . 33
  - 4.3.2 User Interface . . . 34

4.4 Location-based Game . . . 35
4.4.1 Game architecture . . . 36
4.4.2 Back-end . . . 37
4.4.3 XML . . . 37
4.4.4 Game Interface . . . 39
4.5 Back-end Server . . . 41

5 Preliminary Evaluation and Results **43**
5.1 Informatics students . . . 44
5.1.1 GLP . . . 44
5.2 Informatics teachers . . . 44
5.3 Game Jam focus group . . . 45
5.3.1 Authoring Tool Usability Testing . . . 45
5.3.2 Pervasive Game Usability Testing . . . 48
5.3.3 Example of a GLP . . . 50
5.3.4 Conclusions . . . 52

6 Conclusions and Future Work **53**
6.1 Completed objectives . . . 53
6.2 Main Challenges . . . 54
6.3 Future Work . . . 54

References **55**

A Time traveler (GLP programação) **57**

B Game Jam Tutorial **73**

C Authoring Tool Documentation **79**

D Game Jam Consent Form **89**

E SUS Form **91**

F Game Jam Graphs **93**

G Game Jam Sample Files **113**

H Authoring Tool Sample Schemes **121**

List of Figures

2.1 America's Army training test. . . . 6
2.2 Math Blaster problem solving. . . . 8
2.3 Code Combat game. . . . 9
2.4 Codin Game programming interface (gameplay). . . . 9

3.1 UML Component Diagram depicting the proposed Beaconing Authoring Subsystem, its components, and services provided and consumed. . . . 12
3.2 First approach to the learn view of the authoring tool. . . . 13
3.3 First approach to the game plot view of the authoring tool. . . . 14
3.4 First approach to the play view of the authoring tool. . . . 15
3.5 First approach to the assessment view of the authoring tool. . . . 16
3.6 First approach to the prototype of the authoring tool. . . . 17

4.1 Authoring Tool glps database table . . . 22
4.2 Authoring Tool glps database table sample from Game Jam . . . 22
4.3 Authoring Tool . . . 30
4.4 Authoring Tool image 2 . . . 31
4.5 Mini-game exams table . . . 34
4.6 Mini-game evaluations table . . . 34
4.7 Programming Mini-game web page . . . 35
4.8 Location-based game table . . . 37
4.9 Location-based game table sample from Game Jam . . . 37
4.10 Location-based game screen-shot 1 . . . 39
4.11 Location-based game screen-shot 2 . . . 39
4.12 Location-based game screen-shot 3 . . . 40
4.13 Location-based game screen-shot 4 . . . 40
4.14 Back-end server diagram . . . 41

5.1 SUS Authoring Tool Question 2 . . . 45
5.2 SUS Authoring Tool Question 2 Counting . . . 45
5.3 SUS Authoring Tool Question 3 . . . 46
5.4 SUS Authoring Tool Question 3 Counting . . . 46
5.5 SUS Authoring Tool Question 7 . . . 46
5.6 SUS Authoring Tool Question 7 Counting . . . 46
5.7 SUS Authoring Tool Question 8 . . . 47
5.8 SUS Authoring Tool Question 8 Counting . . . 47
5.9 SUS Authoring Tool Question 9 . . . 47
5.10 SUS Authoring Tool Question 9 Counting . . . 47
5.11 SUS Authoring Tool Score . . . 48

5.12 SUS Game Question 9 49
5.13 SUS Game Question 9 Counting 49
5.14 SUS Game Score 49
5.15 Sample Game Jam GLP 51

Abbreviations

LMS	Learning Management System
STEM	Science, Technology, Engineering and Mathematics
SG	Serious Games
FEUP	Faculty of Engineering of the University of Porto
WWW	*World Wide Web*
GLP	Gamified Lesson Plan
BEACONING	Breaking educational barriers with contextualized pervasive and gameful learning
LGB	Location-Based Game
AT	Authoring Tool
BES	Back-End Server
PMG	Programming Mini-Game
MG	Mini-Game
UX	User Experience
SUS	System Usability Scale
FPRO	"Fundamentos da Programação" course
GBL	Game Based Learning

Chapter 1

Introduction

Teaching is a complex process that requires a high degree of dedication and abstraction. Several teaching methodologies have been developed in order to increase students' motivation [CKXG11]. It is intended to develop a game compatible with mobile devices that make learning programming more fun and adapts to the context of the student. To this end, a pervasive game capable of being configured to adapt to spatial, temporal, social and functional context will be developed in order to enable a learning process "anytime, anywhere".

In this first chapter the context where the dissertation is inserted, the goals, the motivation and the structure will be detailed.

1.1 Context

Since this dissertation is being undertaken in the Informatics course, there will be a focus on programming tuition as the example given.

One of the focus of this dissertation is the creation of a lesson plan for the teaching of programming through a pervasive, context-aware game. This is to be achieved through GBL (Game Based Learning), where the student will learn the lesson plan's subjects through a pervasive game. In order to have a context-aware game, the teachers will have the need to customize and adapt the game to each student or class, hence there is a need for an authoring tool capable of this.

The dissertation is integrated with a European project named BEACONING (*Breaking educational barriers with contextualized pervasive and gameful learning*), this project aims to develop a gameful experience for study plans using pervasive, context-aware methodologies. In this regard, there was a contribution to the project by creating an authoring tool for customization and gamification of lesson plans.

1.1.1 BEACONING

BEACONING [H20] stands for "*Breaking Educational Barriers with Contextualized, Pervasive and Gameful Learning*" and will focus on 'anytime anywhere' learning by exploiting pervasive, context-aware and gamified techniques and technologies, framed under the Problem-Based Learning approach. This European project has three big aims:

1 **Integrate technological, pedagogical and social perspectives** using pervasive, context-aware and gamified approaches ensuring that the BEACONING platform engages a community of learners.

2 **Develop, implement and validate a platform that** utilizes gamification, pervasive gaming, procedural game content generation, game authoring, human-computer interfaces, learning analytics and a problem-based learning model and that is usable, adaptable, extendable and sustainable.

3 **Explore and measure the level of engagement, effectiveness and impact** that the BEACONING platform provides towards incentivising learners and promote acquisition and transfer of knowledge and skills, and also validate and provide an exploitation and business plan for the platform adoption.

This project counts with 15 partners from 9 different countries.

1.2 Goals/Objectives

The main goal of this dissertation is the creation of one solution for pervasive, gamified lesson plans with the ability to adapt to each student's context. A GLP (Gamified Lesson Plan) for programming tuition will be created as an example of the tool's potential and for evaluation purposes.

In order to achieve this goal, several objectives will be met, such as:

- The development of an authoring tool to adapt the lesson plan to each teacher's needs and objectives, and to customize the game experience to each student.
- The development of one location-based, pervasive game that is capable of being customized through the authoring tool.
- The development of one mini-game that will be used in code-related exercises, such as automated assessment of code, also customized in the authoring tool.
- The development of a lesson plan focused on the introduction to programming.
- Validate the UX of this solution.

1.3 Motivation

As mention before, tutoring is a complex process, that requires hight dedication and abstraction. Serious games have shown to aid the learning process improving results in terms of learning, skill enhancement, motivation and engagement of the learners[CBM+12]. With the supplement of pervasive methodologies, the learning process can be more immersive [HLMR07] and the enjoyment of the students can be increased even more [Jeg07], thus leading to an even better learning experience [Plø14].

1.4 Dissertation Structure

In relation to the structure of this dissertation, there are 4 chapters other than this one.

The next chapter 2 is related to the state of the art and presents related work. The chapter 3 is related to the problem definition and to the proposed methodologies to solve it. Chapter 4 defines the work done to solve the problems previously defined. Chapter 5 shows the tests performed to validate the solution and conclusions based on those tests. The last chapter 6 tells the conclusions of this paper, the main challenges and any possible future work.

Chapter 2

Related Work

2.1 Introduction

In this chapter, there will be an introduction to the subjects comprising the dissertation and the state of the art thereof. Additional mention will be made about related work in the same field of study and what problems are still open.

There are 5 main subjects the dissertation focuses on: serious games, pervasive games, authoring tools, programming tuition and programming or coding games.

- **Serious games** are games whose intention is to make the player learn something throughout the game-play. Learning while playing is far easier than learning through a more serious context, like in a classroom.
- **Pervasive games**, on other end, use the context where the player is inserted to enhance the player experience. It can use its spatial, temporal, social and functional context to grant a learning process "anytime, anywhere".
- **Authoring tools** consist on tools that allow customization and adaptation of content that has been previously created by someone else, allowing a quick access to a customized resource that would have taken a long time to create from scratch.
- **Programming tuition** consists on methods or lesson plans to teach programming to a crowd of learners.

2.2 Serious games

Serious games can be defined as games whose purpose is more than just entertainment. Although entertainment is issued carefully in any game, since games need to be fun, in serious games it

needs to be planned even more carefully because the game must guarantee that the player will meet the game's purpose while also allowing a fun experience [RCV09].

Serious games can be divided into several sub-categories: military games, government games, educational games, corporate games, health-care games and political, religious and art games [SJB07].

2.2.1 Military games

Since serious games offer the possibility to train dangerous or hazardous situations and environments in a secure and safe way, this is the perfect scenario for military training. Also, many skills can be taught only by doing, and many lessons can be learned only through failure. Military games are an example of the use of serious games in a more complex and serious context. These games focus on the improvement of the skills of the player, hence training either recruits in their competencies or officers in battle planning [MC05].

This sub-category of serious games has the particularity of having violence, which is usually never possible to have in serious games, since they typically aim at passing a knowledge or ideal.

2.2.1.1 America's Army

One example of one of the most popular serious game ever created is America's Army, a game created with the intention of attracting new recruits to the army, in order to counter the falling recruitment [ZMW+03].

The game is remarkable for its similarity with the real world combat. The recruits that gained interest in the army through the game already had some minor training, gained in the game, and only needed to deepen their knowledge, granting them and advantage towards recruits with no previous contact with the military.

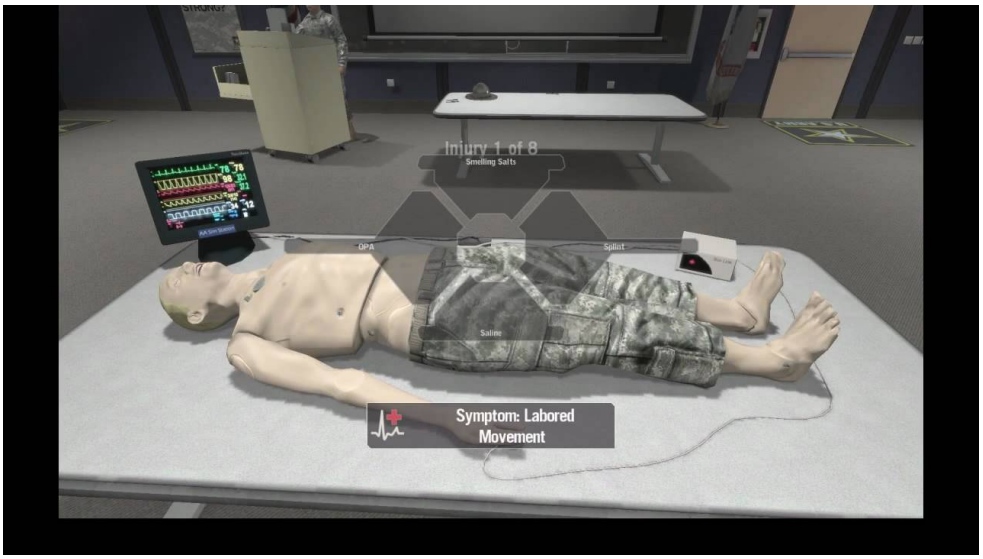


Figure 2.1: America's Army training test.

As it can be seen in Figure 2.1, the game includes initially a training that the player must play through and pass in order to play the game. In the image, one of the tests is displayed where the player must know, based on the symptoms, what is the problem and which health aid should be applied.

This game was a success in both increasing the number of recruits in the army and in people playing it. In 2006 the game had already 17 million downloads and over 4 million registered users. The recruitment through this game achieved recruiting costs 85% cheaper [SJB07].

2.2.2 Educational games

There are two kinds of educational games: edutainment games and game-based learning. Edutainment is the simplest way of gamifying education, this kind of game just covers the lesson plan with some entertainment from games [Res04]. Serious games are commonly mistaken with Edutainment games. Edutainment games are defined by the Entertainment Software Rating Board (ESRB) as those that "provide users with specific skills development or reinforcement learning within an entertainment setting" where "skill development is an integral part of product" (Entertainment Software Rating Board, 2007). Although all edutainment games are serious games, the other way around isn't true, since serious games encompass every game whose purpose is more than just entertainment [RCV09].

The second kind of educational games, game-based learning, differs from edutainment in the sense it starts with the lesson plan and then creates a game that fits the plan, balancing both the gaming experience and the ability to retain the knowledge and apply it in the real world. These second kind of education games are more powerful and offer gains both in the learning and the entertainment of the player. Unlike edutainment, game-based learning offers the full potential of games [Res04][EN11]. This type of educational games is where this dissertation is inserted.

2.2.2.1 Math Blaster

A good example of an educational game is Math Blaster, this game is a perfect example of what edutainment is. The player is rewarded with game content when he does the "boring" learning part. In this particular case, the player gains bullets when he answers math exercises correctly and then he is allowed to do the fun part of shooting things with the earned bullets. This is the typical case where the game doesn't make the player like the subject the game focus on, it just covers the educational content with a game [Bru99].

As it can be noted in the Figure 2.2, the player is required to use math to solve the equation in order to progress in the game.

2.2.3 Examples

Serious games have been used for many purposes. The main being education, there are a few examples of applications of serious games for the teaching of programming.

Figure 2.2: Math Blaster problem solving.

In the following subsections, there will be presented serious games and platforms of serious games that were created with the intention of teaching programming.

2.2.3.1 Code Combat

CodeCombat [coda] is a platform for students to learn computer science while playing through a real game. This platform allows students to play through real code instead of drag-and-drop blocks and indirectly programming.

This game, shown in Figure 2.3, is based on programming a hero to collect gems and defeat enemies, while also meeting objectives like a maximum number of functions. This game is good at combining the education with the gameplay. Since different items have different methods, the player will see the attacks and possible ways of movement directly related to the game and not to the programming itself.

2.2.3.2 Codin Game

CodinGame [Codb] is another example of a game that allows a player to improve their programming skills through gameplay. This game, in particular, works with many different programming languages and it requires the player to create outputs to solve the game. These outputs must follow a set of defined rules so that the game objective is met throughout all defined tests.

As it can be seen in figure 2.4 the player has at the top right of the window a usual programming interface where the code must be written, on the top left there is a graphical representation of the gameplay, which works like a cinematic created by the game. The objective is to make the character, based on the rules defined, solve the game. On the bottom left corner is the output of

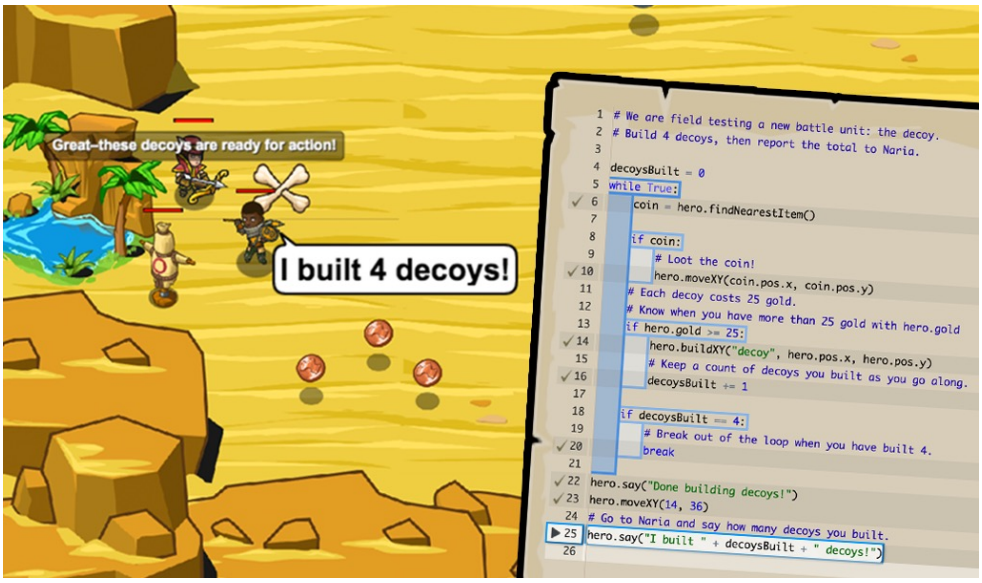


Figure 2.3: Code Combat game.

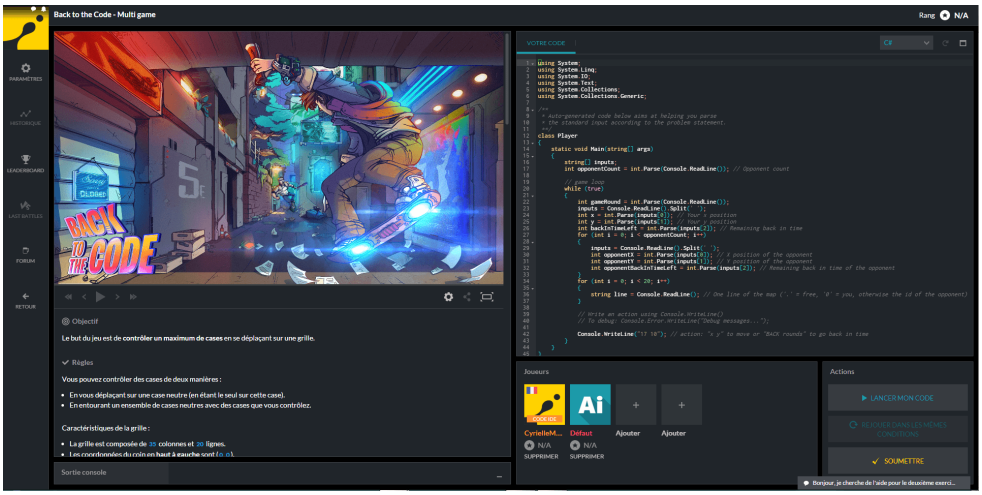


Figure 2.4: Codin Game programming interface (gameplay).

the code and extra info about the state of the game per tick. At the bottom right corner, the button to run the tests and to submit the solution can be found, in order to submit the solution all of the tests must be successful.

Every game can be customized and created as the teacher wants, leading to a lot of freedom and different stories during the gameplay.

2.2.3.3 ITyStudio

This platform is somehow similar to the BEACONING platform in the sense it allows the creation of e-learning games for teaching. It differs in the fact it is not context-aware, pervasive nor it has

procedural content generation for disabilities.

2.3 Conclusions/Summary

In summary of the state of the art, several solutions and research exist in all of the areas this dissertation is inserted. It can be concluded that both, serious games and pervasive games, contribute to better results in terms of learning and education than current standard teaching.

Although, as it was already pointed out, there are already some solutions for teaching that use GBL, there is still a lack of tools that allow adaptation of the game to each individual student or even to a whole class.

Chapter 3

Methodologies

Previously we have had a look at what already exists in the area and also what subjects this dissertation addresses. Now a full overview of the problem, together with the methodology used to solve it is going to be presented.

3.1 First approach

In the beginning of this dissertation some ideas were still fuzzy, but with time a lot were settled. In this subsection, the first approach to the problem will be explained, together with the initial idea of how the project would unroll. In the next section, the actual approach and divergences will be explained.

Initially, as it was intended and because the BEACONING platform aims to deliver a context-aware gamification of lesson plans, it could be understood that the teacher was supposed to access a list of already created lesson plans, presented in a repository, and select the one he thinks that suits the most. After selecting and loading the lesson plan, the teacher could just press next and deploy the game for his students or customize it to better fit his class. When deciding to customize the plan, the teacher should be able to freely change the activities, the quests, the missions or even the game plot. There should be total freedom in the adaptation of the lesson plan, or at least close to total since some inputs and number of activities could be mandatory or have boundaries because of the selected game plot.

As of the design of the mini-game, the initial idea was to create a code-based mini-game, capable of validating code from different languages. This was the basis of the mini-game, but it could be further improved to allow variants. Some of them could be passing a code with a bug for the student to find it, or to create the code indirectly through some visual content.

It was also required the creation of a location-based, pervasive game that would be customized through the authoring tool and capable of launching the code-based mini-game.

Furthermore, there was the intention to create a lesson plan for introductory programming that uses these tools. This plan would be based on the "Fundamentos da Programação", a Programming 101 course at FEUP, so the main difficulty is to create a game plot that fits the course program.

It was also desired that the authoring tool had integration with at least one LMS, which, in this case, would be Moodle since FEUP uses it as its LMS.

3.1.1 Architecture

The architecture of the authoring tool, present in figure 3.1, consisted, hitherto, of a high-level representation of the beaconing authoring subsystem and its projected integration with the remaining BEACONING platform subsystems and third party systems.

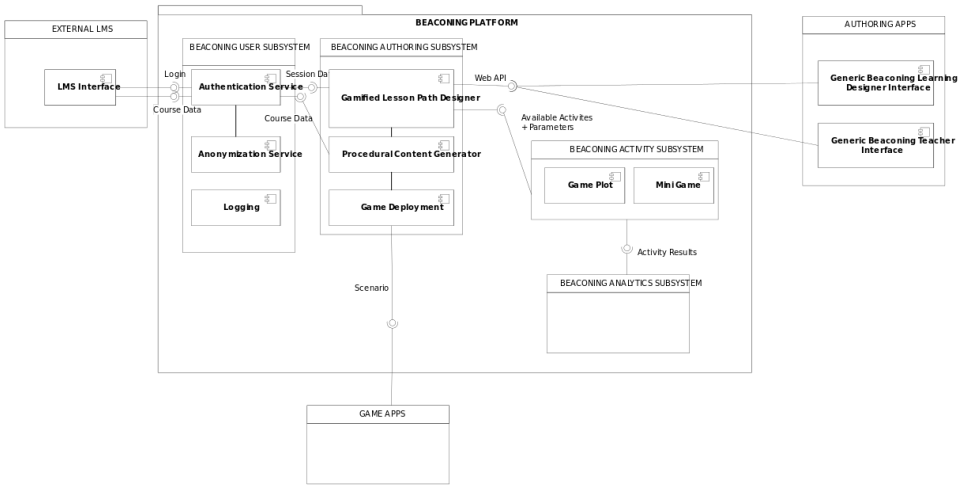


Figure 3.1: UML Component Diagram depicting the proposed Beaconing Authoring Subsystem, its components, and services provided and consumed.

The subsystem relies on the authentication and/or user subsystems (such as an LMS) to provide both permissions and data that can be used for the creation of procedurally generated content. Third party applications can, via a web API, create or instantiate lesson plans through the gamified lesson plan designer, through the inclusion of quests, missions and activities with varying learning goals and weights. These activities (such as games) provide a list of available parameters that can be adapted to fit each individual learners' needs. The personalized game configuration is then made available to a gaming application.

3.1.2 Mockups

In a first approach, several mockups have been created, related to the authoring tool. These mockups weren't final and they were going to be further edited and improved.

In the following subsections, they are going to be presented and detailed.

3.1.2.1 Learn view

The Learn view is where the teacher can create and/or customize the gamified lesson plan. In this view, he will not only be capable of adding missions, quests and activities, but also tailor them to each student, location or context.

Each element in this view is collapsible, facilitating the understanding of the lesson plan and increasing the ease of use for the teacher.

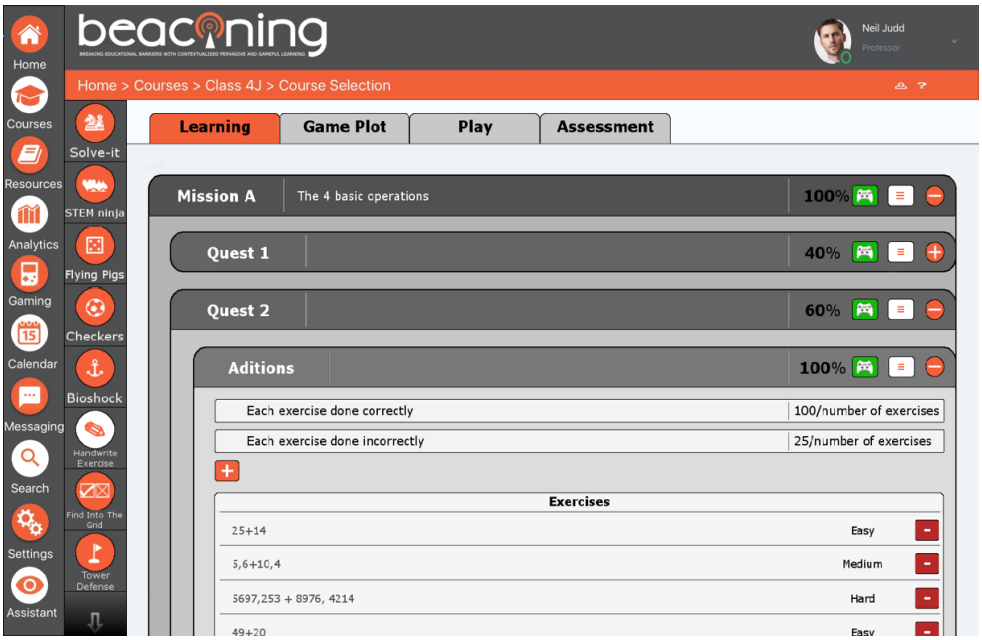


Figure 3.2: First approach to the learn view of the authoring tool.

As noted in the Figure 3.2, the teacher can define weights to each mission, quest and activity in order to customize the lesson plan. Also, further customization can be achieved through the details of the mission/quest/activity, which can be accessed through the white buttons on the right-hand side.

On the left, there is a vertical bar with the existing mini-games (orange background) and the existing non-gamified activities (white background), such as an handwrite exercise made in the classroom. To add one of these activities to a quest the teacher can drag it from the menu and drop it on top a quest area. Activities can have several assessments, such as “exercise done correctly” and “at least one right”, meaning it isn’t just a right/wrong evaluation. The panel presented in Figure 3.2, which is relative to exercises inside an activity, differs between activities. In the case of a location-based game, its content will be related to selecting locations on a map.

3.1.2.2 Game Plot view

The Game Plot view is where the teacher can cross over the game plot with the lesson plan, merging and connecting the activities defined in the lesson plan with the challenges created that appear during the gameplay.

Figure 3.3: First approach to the game plot view of the authoring tool.

As it can be noted in the Figure 3.3, the approach for the view is similar to the Learning view. The game plot, the levels and the challenges are all collapsible, providing a simple and easier interaction with the tool.

In terms of customization, the teacher can change the text that precedes the challenge, in order to adapt it to the context of the student and can connect challenges with activities.

3.1.2.3 Play view

This view is the most recent one of the authoring tool, it has been updated and edited in the begin of February during a BEACONING meeting in Madrid. This view allows several paths in the lesson plan, allowing different students to have different experiences while playing the game, but still ending with the same level of learning in each of the subjects.

As it can be seen in Figure 3.4, the teacher can select a minimum and a maximum number of activities in each quest, as well as the weight each one will have. The player must be able to reach at least 100% of each of the contents. Although each possible gameplay path must reach 100%, it is possible that it exceeds this percentage. The possibility to have over 100% of each content was introduced to ensure every student is subjected to a minimum amount of learning material, while

Figure 3.4: First approach to the play view of the authoring tool.

leaving the possibility to do some "extra" exercises, reaching, this way, over 100% of the content the extra exercises relate to.

3.1.2.4 Assessment view

The Assessment view holds the link between activities and the competencies the student is supposed to acquire. This is the view where the teacher can select how much of each competence, defined in the lesson, should be rewarded for every activity the student does. The student is rewarded with the competence depending on the results he obtain in the exercise. This evaluation of the results is made through learning analytics.

As noted in the Figure 3.5, This matrix-like view, similar to the Play view, allows the teacher to insert in the matrix cells the amount that a given competence should grant a player for the conclusion of the corresponding activity.

3.1.3 Prototype

As a complement to the mockups developed, a prototype capable of showing the Learning view working was developed. This prototype demonstrates the interaction with this view. The intent of developing the prototype as a complement to the mockups was for demonstration purposes in the BEACONING Madrid meeting.

As it can be seen in Figure 3.6, the prototype includes a collapsible view of missions, quests and activities and present several types of assessments for the activities.

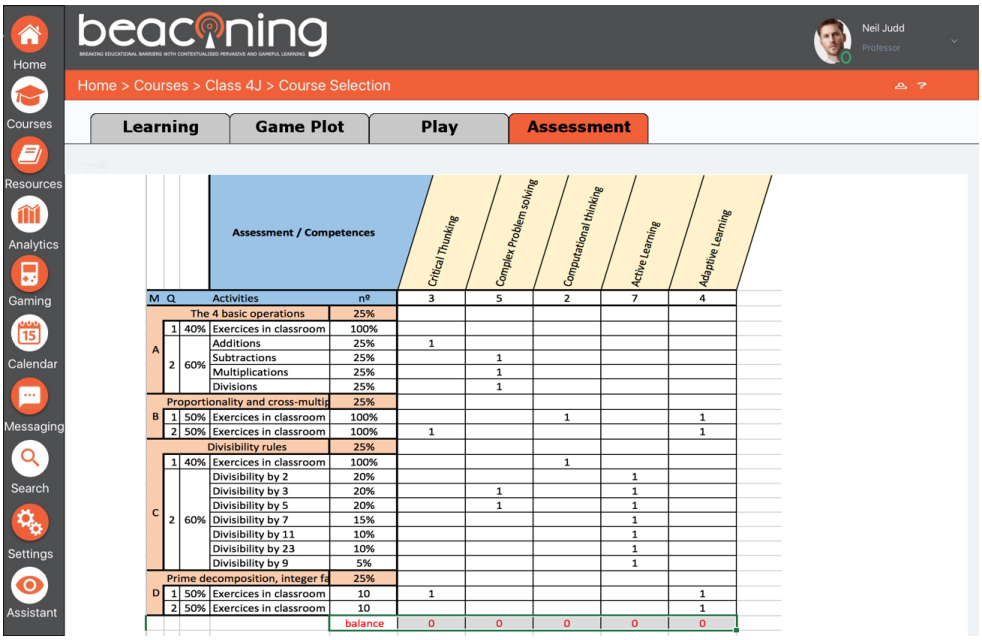


Figure 3.5: First approach to the assessment view of the authoring tool.

As mentioned above, the exercises area depends on the kind of activity selected. If the teacher chooses, for instance, a location-based mini-game, the teacher will be presented with a map requesting some locations the students have to go to complete the mini-game.

3.1.4 Technologies

The first phase technologies that were selected for the development of the authoring tools were:

- Laravel (PHP + SQL)
- Blade (HTML)
- CSS
- Bootstrap
- Apache
- JQuery

Laravel and Apache were used for the back-end of the authoring tool and the server. Blade, CSS, Bootstrap and JQuery were used to create the front-end of the tool, so that it could be dynamic and flexible. All of these technologies offer good flexibility, stability, scalability and ease of use, hence their choosing. All of the communication from the authoring tool to other external tools/APIs, such as the games and the analytics presented in the BEACONING platform will be made using JSON.

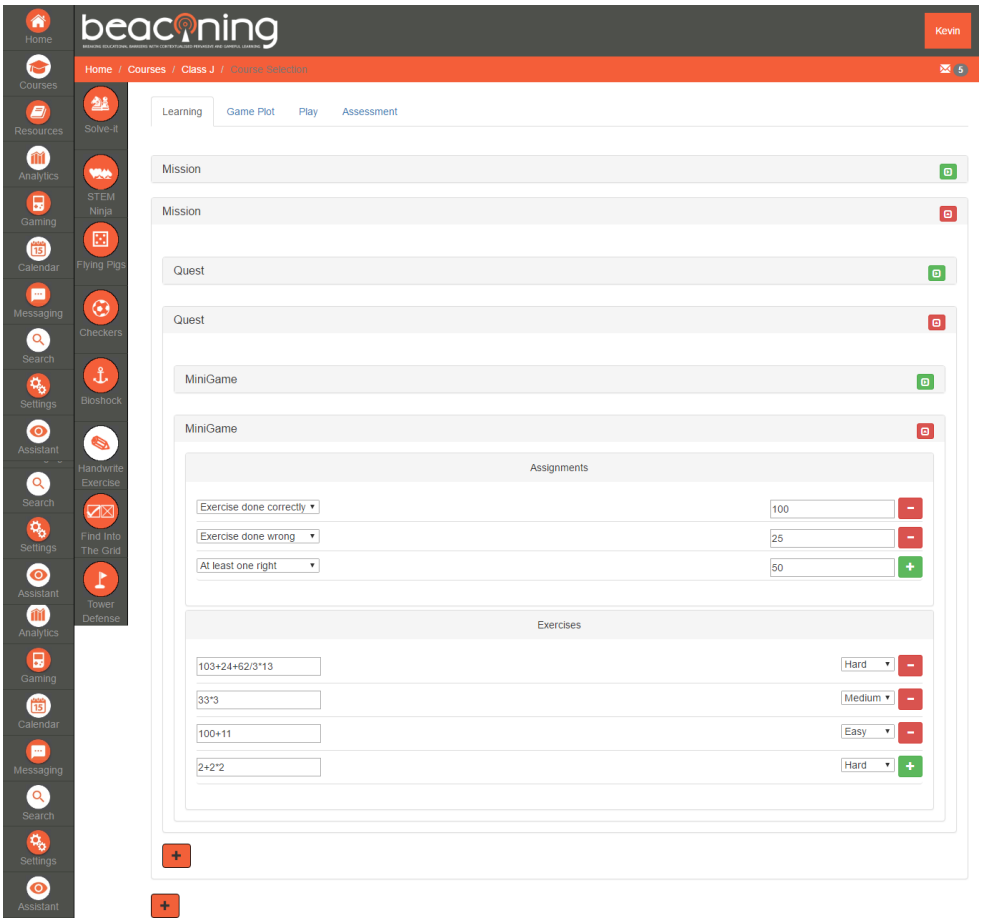


Figure 3.6: First approach to the prototype of the authoring tool.

3.2 Architecture

The project developed over the course of this dissertation can be broken into four parts. All of them are linked in order to work as one, giving the teacher the most convenient way to create a lesson plan that fits his needs while also giving the students a game where they can have fun learning through a pervasive and contextualized game.

The first part of the project is the authoring tool. This tool has been developed in the scope of BEACONING, as previously mentioned. This authoring tool allows a teacher to create a lesson plan and gamify it. The plan can then be deployed for the students to play.

The second part is the auto-corrector mini-game. Although the auto-corrector was not developed from scratch, there was an adaptation of one tool capable of auto-evaluating Scheme code. This tool is currently being used in the "Fundamentos da Programação" course to evaluate students' exam grades.

The third part is a location-based game. The game was also an adaptation of a previously made game called "Invicta", that had interest points in some locations on a map that were either a dialog or a quiz. This game was adapted and modified in order to fit this dissertation needs. Although the

base game was used, most of it was modified, leaving not much more than the graphical elements and the game logic. In the scope of this dissertation, the game is also capable of launching the PMG (Programming Mini-Game) for the students to solve some problems using programming.

The fourth and last part of the project is the server that links all of the other components and works as a bridge.

Additionally, there was also made an example of a GLP (Gamified Lesson Plan) that would use all of these different tools in order to teach programming in the most efficient and fun way.

3.2.1 Authoring Tool

The authoring tool uses the architecture initially defined in the first approach. The mockups have changed and there is already an implementation of the authoring tool with a new look, designed by a BEACONING partner (Hands Free Computing [HFC]). There are two users of the authoring tool, the teacher and the learning designer. The last one creates a generalized GLP without any student in mind. This GLP will then be edited by the teacher and customized to his needs. The learning designer has access to all of the options the teacher has in the authoring tool, except for the deployment of the GLP and the selection of the target students. The tool is capable of saving GLPs for easy access and edition. It is linked with a server, to which it makes POST calls to send the game configuration (XML) and the mini-game configuration (JSON+SCM+CSV). The authoring, as of the current state, is only using the Learning view presented in the first approach mockups. The GLP is composed of several missions, in which there are several quests. In each quest, there should be one or several Challenges, which represent points in the game where some action is performed, and in each of those Challenges, there is a list of Activities. These Activities represent a mini-game that is launched to the user. Although in the BEACONING project the teacher and the learning designer are not supposed to change the game plot nor to have several Activities per Challenge, in the authoring tool this is possible, making it as much universal as it can be, allowing integration with other types of systems easily. The AT should also be capable of giving an order to the Challenges taking place in the game, for the student to follow the lesson plan, therefore inside a quest, the challenges need a system capable of linking them to each other in order to make a path. In this dissertation, a graph was implemented where each Challenge is a Node, with an input point and one output point that can make any kind of combination to generate several possible paths. Further explanation can be found in the next chapter 4.

3.2.2 Programming Mini-game

The mini-game is based on an auto-corrector of scheme code. This auto-corrector is the current tool used in FPRO to evaluate the assessments of the students. There is a component used to present the wording of an assignment, which represents one or several exercises to the student. this wording is represented by a JSON file. The auto-corrector receives a CSV file representing the solution to the assignment and two SCM files, one given by the teacher containing the right solution and one given by the student containing his answer. If both SCM give the same solution

based on the CSV, the student has the exercise correct. Initially, the teacher needs to provide the CSV, the SCM and the JSON. These components interact to each other when an assignment is evaluated, through an executable file that take the files as arguments. The evaluation of the solution is a grade that goes from 0 to 100, although in the scope of a game the exercise should be considered as correct or incorrect to decide if the student can proceed in the story or not. A simple example of this would be unlocking a door, where the student either unlocks the door or fails to unlock. He can't unlock it partially and continue his journey.

3.2.3 Location-based Game

The location-based game uses the already made game "Invicta". In extension to its functionalities, the game is now capable of launching a web page, have several active pins on the map and have an order of executions, granting the player several possible paths. The web page launched on some pins allows external tools and mini-games to be used in this location-based game. The coding mini-game is an example of a game that is launched through the web. The mini-games can also be "required", meaning the player has to succeed in order to continue the game, e.g. unlocking a door. The location-based game must be customized through the AT, therefore the game configuration must come from a file hosted on the web, in this case, a XML, which is already being used in the Invicta game. This way the game only needs to be installed once in the mobile device and any games created can be played, this gives much more comfort to the student than having to download and install a different game each time he wants to play a new game. The game must also be capable of sending feedback about player actions to the web so that the teacher can know where the student is in the lesson plan and what answers the student gave to multiple choice quizzes.

3.2.4 Back-end Server

This server must be capable of connecting all the different components and host the database and the files. Every of the other parts should connect to the server to retrieve and save the files and information they use. In this project, the back-end server holds the database with the games and the programming assignments, while the GLPs are saved in the AT server.

3.3 Evaluation and Validation

To evaluate the system three test groups were prepared, one with students from the Informatics course, one with teachers from the Informatics course and one during a Game Jam that uses by base the System developed during the course of this dissertation.

To gather feedback about the system, there are some SUS questionnaires for each of the groups that can provide useful data and information after being collected and processed. This processed data indicates the usability of the system from the users' point of view.

Giving some extra detail about the testing groups:

- Informatics students - This test group will use the GLP created on this dissertation and will be evaluating the LBG and the PMG. The tests aim to understand the potential of a pervasive GLP for teaching, specifically the teaching of programming.
- Informatics teachers - This test group will be using the AT for creating one GLP. During and after the tests feedback will be collected to evaluate the AT in its potential to easily and conventionally create a GLP.
- Game Jam - This test group are the attendees of a Game Jam that took place at FEUP. They were required to use the system that was implemented in this dissertation to create their own GLP and then play each other GLPs. This group GLPs were created in the area of STEM, as opposed to the one created in the scope of this dissertation which focuses on the teaching of programming. The group aims at testing both the AT and the LBG to understand its potentials and limitations when used freely by individuals.

The validation is based on the SUS score obtained from the testing groups. Through the score it is possible to know if a system should be considered acceptable or not, based on user opinion. Further explanation of how the tests were made and their details can be found in Chapter 5.

Chapter 4

Implementation

Following the previous chapter's methodology, the implementation is going to be presented. Here will be defined the used technologies, the implemented data structures, web services, authoring tool, mini-game and location-based game.

This chapter will be divided into 5 sections, the first being the selected technologies and why are these the best ones available, the second being the authoring tool with its components, the third will be the programming mini-game, the fourth will be the location-based game and the fifth and last one will be the back-end server that keeps most of the files and information and links the different components.

4.1 Technologies

The final technologies used in this dissertation and its components were the same as the ones initially defined, plus some others required to create other tools apart from the authoring tool. The total list of used technologies is as follows:

- Laravel (PHP + SQLite)
- Blade (HTML)
- Bootstrap (CSS)
- Apache
- JQuery (JavaScript)
- Unity3D (C#)
- Java
- JSON, XML

As mentioned in the previous chapter 3, all of these technologies offer good flexibility, stability, scalability and ease of use, hence their choosing. Laravel allowed an easy implementation of a

server with its structure partially done, reducing the time needed for its implementation and giving a more stable solution.

The location-based game was implemented using Unity, therefore, the selected scripting language was C#. The decision to use C# instead of JavaScript was based on the already implemented functionalities of "Invicta" game. The mini-game was implemented on the web but uses an executable file (.exe) created using Java. All of the files in the authoring tool are saved in the JSON format, this allows easy modification using JQuery and JavaScript from a web server. The file representing the game is a XML file. The decision to use this format instead of JSON is based on the fact that "Invicta" game was already using it, so rather than adapting the tool to read a JSON file, the authoring tool converts the gamified lesson plan to XML.

4.2 Authoring Tool

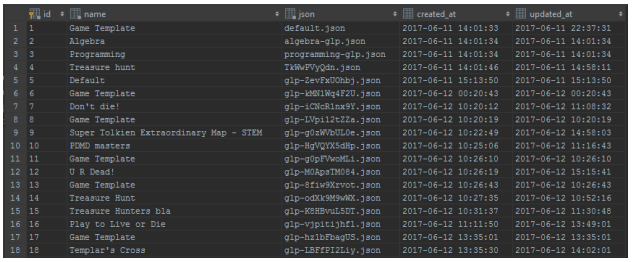
The Authoring Tool was mostly developed in the scope of BEACONING. Consequently, its architecture, user interface and behavior were all defined, architected and implemented alongside this dissertation. This introduced some limitations and some structure that is not ideal. In that regard, the implementation that was specifically made a certain way to fit BEACONING will be pointed out. Some content was adapted to better fit other components that are present in this dissertation, allowing a better and easier integration across each other.

The AT was implemented as a website that has only one view, that view being the AT. There is a fully implemented back-end, that allows the creation, modification, loading and save of GLPs.

4.2.1 Back-end

Due to the lack of core-services in the current state of the BEACONING project, there was a need to implement a back-end in the AT to support the missing features the core-services were supposed to have, such as the saving of the GLPs together with all the files associated with them and the different API routes to manipulate them.

Figure 4.1: Authoring Tool glps database table



	id	name	json	created_at	updated_at
1	1	Game Template	default.json	2017-06-11 14:01:33	2017-06-11 22:37:31
2	2	Algebra	algebra-glp.json	2017-06-11 14:01:34	2017-06-11 14:01:34
3	3	Programming	programming-glp.json	2017-06-11 14:01:34	2017-06-11 14:01:34
4	4	Treasure hunt	TkWwFVyQdn.json	2017-06-11 14:01:46	2017-06-11 14:58:11
5	5	Default	glp-2evFxO0hbj.json	2017-06-11 15:13:50	2017-06-11 15:13:50
6	6	Game Template	glp-kNN1Wq4F2U.json	2017-06-12 00:20:43	2017-06-12 00:20:43
7	7	Don't die!	glp-iCNcR1nx9Y.json	2017-06-12 10:20:12	2017-06-12 11:08:32
8	8	Game Template	glp-LVp1IrZZe.json	2017-06-12 10:20:19	2017-06-12 10:20:19
9	9	Super Tolkien Extraordinary Map - STEM	glp-g0aWWbILOe.json	2017-06-12 10:22:49	2017-06-12 14:58:03
10	10	PDMD masters	glp-HgVQYX5dBp.json	2017-06-12 10:25:06	2017-06-12 11:16:43
11	11	Game Template	glp-g0pFVWoMLi.json	2017-06-12 10:26:10	2017-06-12 10:26:10
12	12	U R Dead!	glp-M0ApaTM084.json	2017-06-12 10:26:19	2017-06-12 15:15:41
13	13	Game Template	glp-8fiw9Xrvot.json	2017-06-12 10:26:43	2017-06-12 10:26:43
14	14	Treasure Hunt	glp-odXk9M9wWX.json	2017-06-12 10:27:35	2017-06-12 10:52:16
15	15	Treasure Hunters bla	glp-K5HBvuL5DI.json	2017-06-12 10:31:37	2017-06-12 11:30:48
16	16	Play to Live or Die	glp-vjpit1jhf1.json	2017-06-12 11:11:50	2017-06-12 13:49:01
17	17	Game Template	glp-hz1bFbagUS.json	2017-06-12 13:35:01	2017-06-12 13:35:01
18	18	Templar's Cross	glp-LBFfPI2Liy.json	2017-06-12 13:35:30	2017-06-12 14:02:01

Figure 4.2: Authoring Tool glps database table sample from Game Jam

Each GLP is an entry in a database table called g_l_ps, shown in figure 4.1, and contains the ID which is the primary key, a name, a JSON which is the path to the JSON file containing the configuration of the GLP and created_at and modified_at timestamps.

The back-end also handles the creation, save and update of GLPs and all the files involved. In this regard, there is a PHP Controller that modifies the database and the files.

These files represent a gamified lesson, composed of missions with several quests. There is also a file representing each quest, which contains several challenges and each challenge contains several activities. These activities also have a file of their own, since they can be saved separately from the GLP. The schema of the mini-game and the configuration are also saved in JSON format.

The ideal would be to store all of the JSON files in the same JSON instead of giving paths to files where the rest of the GLP components are. It is not implemented this way since BEACONING project will have core services that are going to save this files. Also, since BEACONING aims at being open to third parties, these files are all separated instead of grouping all the information in a single file, this way allowing either to use other authoring tools, other challenge customizing tools or even other mini-game authoring tools. The mini-game uses a configuration and a schema that came from URLs since the game can use third party mini-games, as it is happening in BEACONING, prior to the core services implementation.

Due to the BEACONING project, the mini-game schema and their configuration are saved in separated JSON files to allow easy exportation to foreign tools and to ease the integration with third party mini-games. Although in one regard this can be good because it allowed an easier integration with the other tools developed in this dissertation, it required a second server to store such files, therefore, for the prototype of the AT modified specifically for this dissertation, it was opted to modify the behavior into saving the files locally.

4.2.2 JSON Files

The JSON files used by the authoring tool to represent mini-games have both a schema and a Configuration, being the configuration one instance of the schema.

To ease the development of the tool and to improve its flexibility and scalability, the forms to edit, in the Authoring Tool, elements represented by a JSON are generated from the element schema, this way to integrate a third-party tool, only one schema is required.

Next there will be presented the different JSON files existing in the AT.

4.2.2.1 GLP

The GLP JSON file has been modified to include a map and its coordinates in latitude and longitude from top left corner to right bottom corner, allowing the location-based game to use different maps in different games.

```
1 {
2     "id": "9",
```

```
    "name": "Super Tolkien Extraordinary Map - STEM",
    "mapSrc": "http://i.imgur.com/mxw0Bg1.jpg",
    "mapTop": "41.17993",
    "mapLeft": "-8.599401",
    "mapBottom": "41.176017",
    "mapRight": "-8.592907",
    "missions": [
        {
            "id": "The Lord of the Rings",
            "name": "The Fellowship",
            "description": "",
            "skills": "English",
            "quests": [
                {
                    "id": "1",
                    "name": "The Hobbit's Journey",
                    "graph": "graph-km1zfje6eo.json"
                }
            ]
        }
    ]
}
```

As seen in the above code, the GLP is identified by its id and contains a name and a list of missions. Each mission has an id used to identify it. This ID is currently not being used, but in the future of BEACONING can be used to copy a mission from a different GLP into another, by referring to this id. It also has a name, a description and the skills granted from playing the mission. These features came from BEACONING platform and are requirements. in this dissertation, they are ignored and not used. At last, there is a list of quests presented inside the mission, each of them having an id, not being used and for the same purpose of the mission's id, a name and a path to a file containing the graph of the mission.

4.2.2.2 Quest

The JSON file of the quest has also been adapted to better fit this dissertation. Similarly to the GLP JSON, there has been the addition of coordinates to locate points in a location-based game and also some extra fields to use extra functionalities of the game. These extra fields will be addressed shortly.

```
{
    "quest": {
        "challenges": [
            {
                "id": "0",
                "name": "The Shire",
                "x": "25",
```

```
                "y": "38",
                "lat": "-8.598619611566065",
                "lon": "41.17873813595241",
                "type": "normal",
                "executeonce": "true",
                "pinid": "1",
                "activities": [
                    {
                        "name": "Dialog Box",
                        "configuration": "/samples/configurationy855b6ouz.json",
                        "schema": "/samples/invicta-dialog.json",
                        "resources": "",
                        "minigame": "true"
                    },
                    {
                        "name": "Multiple Choice",
                        "configuration": "/samples/configuration8ltbdp72r.json",
                        "schema": "/samples/invicta-options.json",
                        "resources": "",
                        "minigame": "true"
                    }

                ]
            }
        ],
        "connections": [
            {
                "source": "1",
                "target": "2"
            },
            {
                "source": "0",
                "target": "3"
            }
        ]
    }
}
```

The JSON file present before is part of a JSON file from one quest from the Game Jam that will be addressed later in chapter 5. As it can be noted each quest has a list of challenges. Since in the scope of this dissertation the challenges are also points on the map, they have been added two fields: "lat" and "lon", in order to give them a location on the map. In the website, these locations are converted to coordinates above the map calculated from the map corner's coordinates. The fields "type", "executeonce" and "pinID" were also added for extra functionalities. The "type" of the pin identifies if it is a hidden pin or a regular pin. Each of these types will be addressed later for further explanation. The "executeonce" identifies if the player can play the same pin again in the case he reaches it more than once. The "pinID" identifies the pin both on the website map and

on the game. Also, the pin has an ID that is not used, just like previous ID's in JSON files and a name. The fields "x" and "y" are the location of the box containing the challenge in the graph view of the AT. The last field is the list of activities, which can be mini-games or exercises. In this particular case, they can also be dialog boxes, since in the BEACONING project the authoring of dialog boxes were not yet architected/implemented. Each of these activities has a name, a configuration file, a schema file, a resources file and a boolean indicating if it is a mini-game or an assignment. This last field is not used currently and will only be implemented in a later stage of BEACONING. The resources maps to a file that needs to be provided alongside the schema. These resources are the options and default values of some of the schema's fields. They came from a separate file instead of being fields in the schema because of the BEACONING project partners requirements. At the bottom of the file is a list of the connections between the different challenges. These connections are a separated list with "source" and "target" to allow any possible combination to be created. Although in the BEACONING project a limitation of the input and output of a challenge being a 1-1 connection, the AT allows any combination so that any third party application that supports it will be able to implement it, like the case of the location-based game implemented in this dissertation.

4.2.2.3 Activity

Lastly, there is the JSON file for the activities. In the location-based game, only three activities are implemented. A programming mini-game, an options quiz and a dialog box. Because the instances of these activities are extremely simple, having only one or two fields, their schemes will be presented instead.

```
{
  "$schema": "http://json-schema.org/draft-04/schema#",
  "type": "object",
  "properties": {
    "text": {
      "type": "string",
      "form_input_type": "TEXT_AREA",
      "form_label": "Text",
      "form_description": "Text to be presented"
    }
  }
}
```

The previous schema belongs to the dialog box. It is a JSON file with only one field which is the "text" of the dialog box. This text is then presented in the game.

```
{
  "$schema": "http://json-schema.org/draft-04/schema#",
  "type": "object",
```

```
  "properties": {
    "url": {
      "type": "string",
      "form_input_type": "TEXT_INPUT",
      "form_label": "Url",
      "form_description": "Url to the play"
    },
    "id": {
      "type": "integer",
      "form_input_type": "TEXT_INPUT",
      "form_label": "Exam ID",
      "form_description": "ID of the exam to be launched"
    },
    "required": {
      "type": "boolean",
      "form_input_type": "BOOLEAN_SELECTION",
      "form_label": "Required",
      "form_description": "The web exam has to be done correctly to continue?"
    }
  }
}
```

This second JSON file is the programming mini-game. It takes an URL to the game being launched, the id of the programming exercise and a boolean that indicates if the exercise has to be done correctly in order to advance in the game. Since this exercise is run from the back-end server and is launched from an URL, any kind of third party mini-game that is run from an URL can be created this way. The only limitation would be the use of a back-end call to verify if the game has been done correctly, which could just be unchecked and such feature would not be used.

```
{
  "$schema": "http://json-schema.org/draft-04/schema#",
  "type": "object",
  "properties": {
    "title": {
      "type": "string",
      "form_input_type": "TEXT_INPUT",
      "form_label": "Question",
      "form_description": "Text of the question"
    },
    "url": {
      "type": "string",
      "form_input_type": "TEXT_INPUT",
      "form_label": "Save link",
      "form_description": "Url for the api to save the result"
    },
    "answers": {
      "type": "array",
```

```
      "items": {
        "type": "object",
        "properties": {
          "text": {
            "type": "string",
            "form_input_type": "TEXT_INPUT",
            "form_label": "Answer text",
            "form_description": "Text to present in the answer"
          },
          "iscorrect": {
            "type": "boolean",
            "form_input_type": "BOOLEAN_SELECTION",
            "form_label": "Right answer",
            "form_description": "The answer is correct?"
          }
        }
      }
    }
  }
}
```

This third and last JSON file represent the schema of an options quiz. The quiz has a "title" which represents the question, an URL in case the answer of the quiz is to be saved for later evaluation and a list of answers to the question. Each answer has a text containing the answer and a Boolean to identify if the answer is correct or incorrect.

4.2.2.4 External JSON

The Authoring Tool is producing one more JSON file, that is not saved in the back-end of its own server but rather on the back-end server containing the games. The reason is that the back-end server is also the host of the programming mini-game, so when the AT produces the wording of the programming assignment, it is saved to that server instead of the AT server.

```
{
    "game_id": "1",
    "displayed_game_name": "Programming",
    "lang": "en",
    "game_description": "Coding games for Dr.Scheme",
    "user_token": "schema_token",
    "timeout": "60",
    "pausable": "false",
    "accessible": "false",
    "questions": [
        {
            "question_text": "Faca um programa que some a sequencia de Fibonacci
                nas primeiras 10 iteracoes.",
            "question_image_url": "",
```

```
            "skippable": "",
            "timeout": "",
            "lang": "scheme",
            "answer_text_template": ""
        }
    ]
}
```

This is a sample of one programming mini-game, where most of the fields are from the BEACONING mini-game's schema. Most of the fields are not used in the dissertation. The ones used are the "displayed_game_name", the "game_description", the "timeout" but only for evaluation purposes and the questions list. On each question the used fields are the "question_text", the "lang" that has been added to fit the context of the dissertation and represents the programming language, in the specific case, only "Scheme", and the last field is the "answer_text_template" which was also added and is used to provide some text already written in the answer box.

4.2.3 User Interface

The visual of the interface of the AT was developed by partner HFC ("Hands-Free Computing"). It was then implemented and integrated into the already-existing AT. Some adjustments were made to their mockups in order to fit components that were not present, for example the quest's graph. To the prototype developed in the scope of this dissertation, there were further modifications like the insertion of a map with pins and also the addition of the extra activities. These extra modifications will be addressed further in this document.

In figure 4.3, one can see the authoring tool interface. The components presented in the view are the following:

1. GLP name. This represents the name of the GLP. It can be right clicked to edit the name.
2. Mission name and number. This shows the mission number and has the name under it. It can be right clicked to edit the name, the description and the skills.
3. Quest name. The quest can also be right clicked to edit the name and the JSON file where the quest is stored. This was created this way to allow quests to be used across Missions or even across GLPs.
4. Add Quest button.
5. Add Mission button.
6. Save GLP button. This button saves the GLP and any currently open quest and activity.
7. Submit Game button. This button submits the game as a XML to the back-end server. Upon successfully saving the game, the AT pop-ups the game ID, so that the students can play the created game on Android App by simply inserting the ID of the game in the main menu.

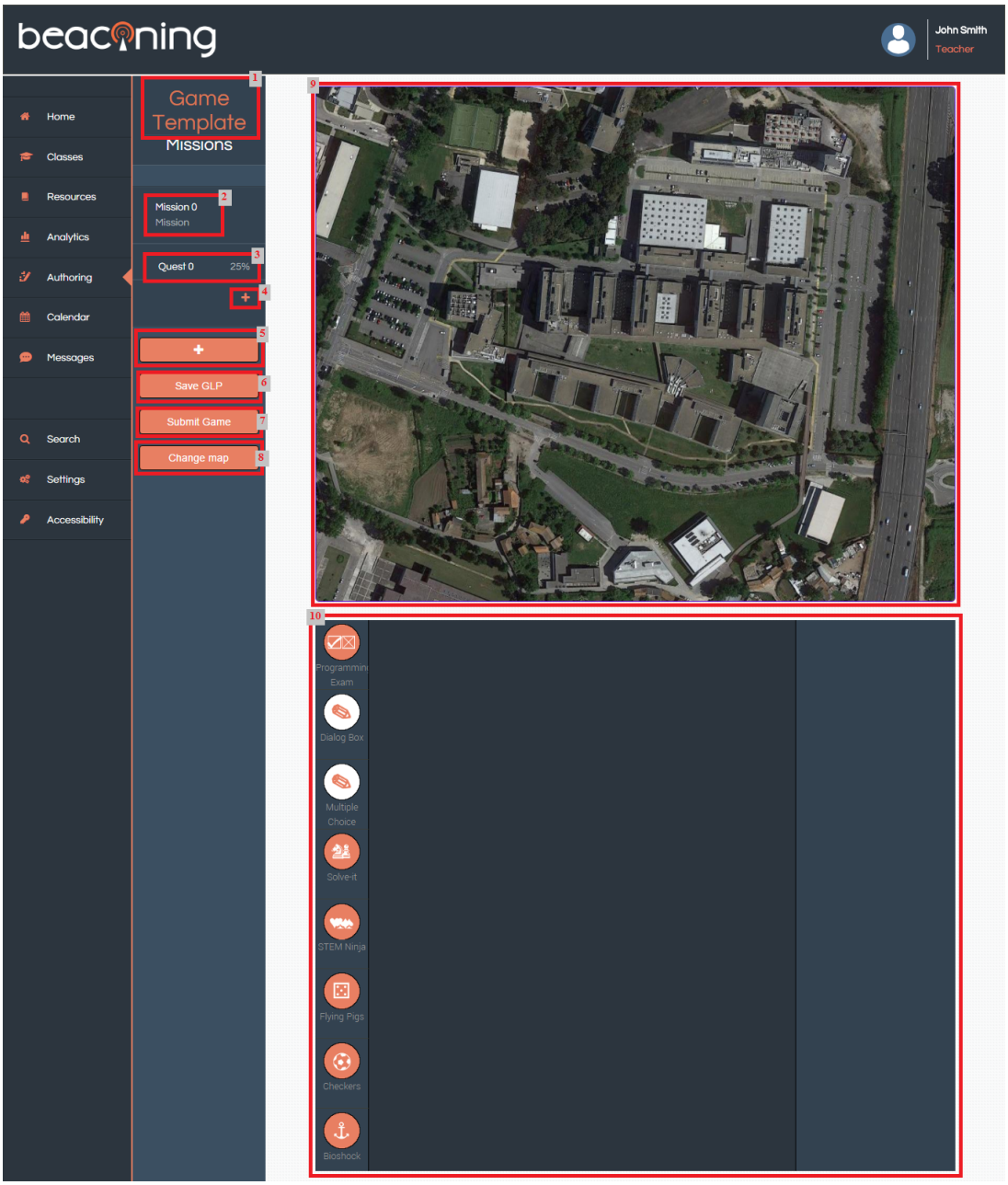


Figure 4.3: Authoring Tool

8. Change Map button. This button allows the edition of the map image. It requires an URL to the new map and 4 coordinates corresponding to the latitude and longitude of both the top left point of the map and the bottom right point.

9. Map. Here the Teacher has access to the map where he is going to create pins and also the pins. The pins can be dragged across the map to relocate them.

10. Quest graph.

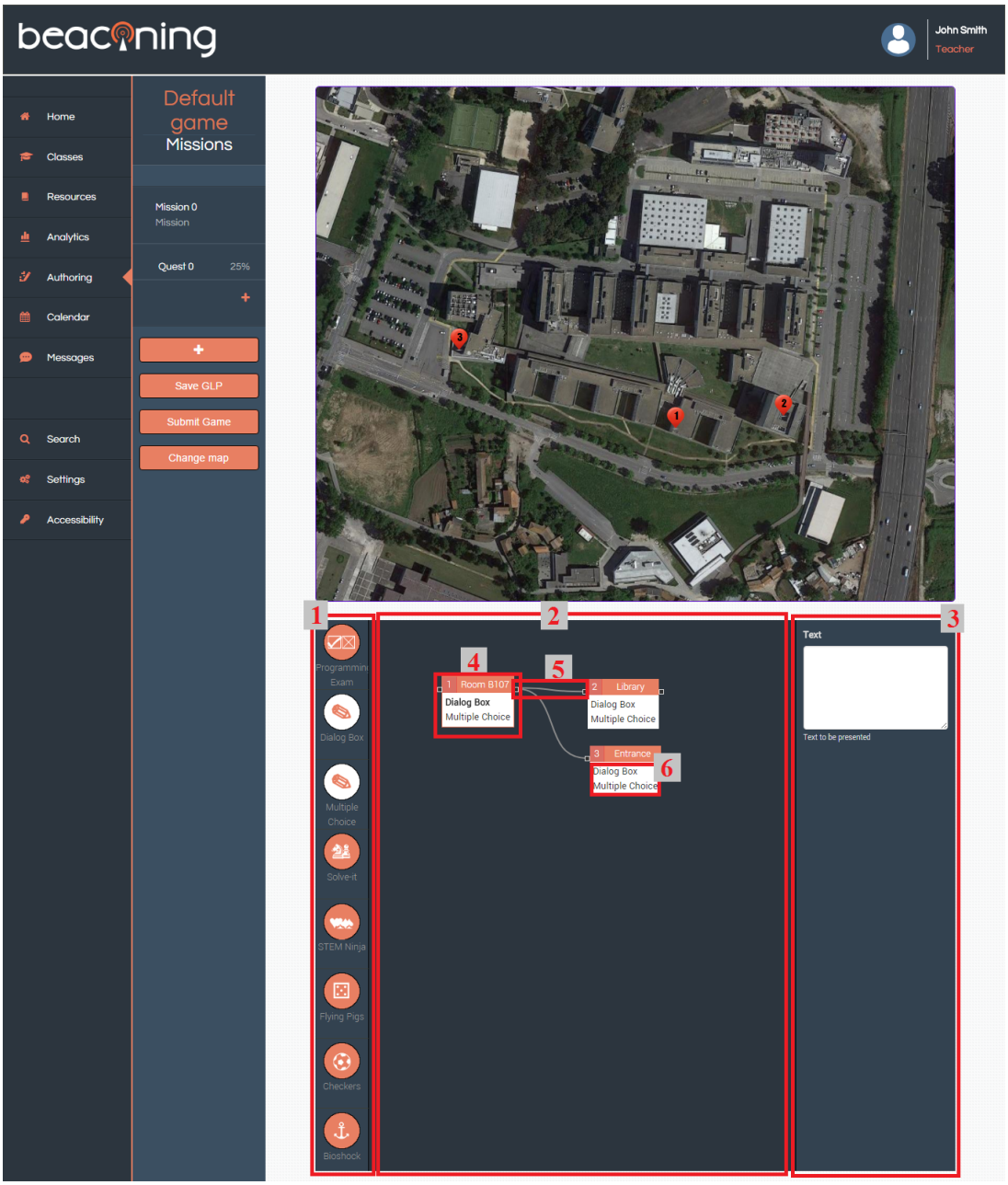


Figure 4.4: Authoring Tool image 2

In figure 4.4 we can see some elements already created on the graph. The graph view can be explained in more detail. The elements presented in it are:

1. The list of the activities available in BEACONING plus the three activities added for the prototype of this dissertation.

2. The graphical view of the quest with the nodes.

3. The edition panel. This is where the edition of activities take place, once one is selected in the graph.

4. A node on the graph. This node represents a pin on the map. Each time a pin is placed, through a left click, a new node appears on the graph, each node can be dragged to another part of the graph and can be linked to other nodes through input or output connectors.

5. A connection between two nodes. The connections don't have any rules other than not connecting one node to itself.

6. The activities of a node. They can be added to a node by dragging from the left list and dropping over the node.

To remove any element from the quest or the map one is required to right click it. A dialog box should pop up for confirmation and upon acceptance, the element is removed.

Each quest has one graph, the Lesson Plan follows the order of the quests inside each mission, so the starting points are all the nodes in the graph of the first quest inside the first mission that has no inputs and the ending points are all the nodes from the last quest from the last mission that have no connections on the output. The linking between quests is made through linking all the nodes without connections in the output from the first quest to all the nodes without connections in the inputs of the following quest. In this sense, each quest's graph must have at least one node with an empty input and one node with an empty output. The modifications are auto-saved upon several conditions, those being:

- Save GLP button saves any opened mini-game, any opened quest and the entire GLP.
- Upon closing a quest or swapping to another the entire quest plus any open mini-game are saved.
- Upon unselect a mini-game or selecting another, the mini-game is saved.

Further explanation and some examples of the AT capabilities can be found in the Appendix document "AT documentation".

4.2.4 Integration

The integration from the AT to the other components of this dissertation was made through the back-end server. The AT generates a XML file when submitting a game to the server and sends it via a POST call, which gets later a return with the ID of the created game. This is one of the two interactions from the AT with other components, the other being the loading and submission of the programming mini-game from and to the back-end server. The programming assignment will be addressed further ahead in this document, in its corresponding section. To author the programming assignment, once it is selected in the authoring tool, the details show at the edition panel, there will be presented the URL to the web page to run the assignment, the id of the assignment and a

boolean to indicate if it is required. To author the assignment itself the teacher has to type the ID and press the button under it that says "Edit Exam". Once pressed, a modal window will open with a form to edit the assignment details. in case the ID was empty, the form will have all the fields empty. After submitting the new assignment, the field of the form that asks for the assignment ID will be automatically filled with the new created assignment ID.

4.3 Programming Mini-game

The programming mini-game was adapted from an already existing tool made to auto-correct Scheme code, currently being used at "Fundamentos da Programação" course and created by João Jacob. This tool was made using Java and is capable of evaluating assignments given a CSV file with the assignment, a SCM file with the correct solution and a SCM file with the student's solution. The program compares the results of calling a function from the teacher SCM file and the student SCM file, if they are the same the student has the exercise correct and is given the indicated points, otherwise, that exercise has a grade of 0.

This tool was adapted to better fit in this dissertation. The output of the tool has been modified to only give the score and an optional field, when executing the file, giving the entire report of the assignment, with details of what was done correctly and incorrectly. There was also a modification to remove the messages the tool was sending to both the students of the course and the teachers, when assignments are evaluated. The last modification was the adaptation to evaluate a single file instead of an entire folder of answers, this way it can evaluate one answer from one student instead all the answers from the entire class.

After these modifications on the tool itself, a executable file was generated with all of the libraries and it was placed on a server, which is the back-end server that links all the dissertation's components. Through this executable, the server is capable of evaluating Scheme code by giving the path to the evaluation files.

At last for the programming mini-game, a web page was created to play the game, together with a full back-end to support it. This was the initial component of the back-end server, before linking the components of the dissertation. The wording of the assignment was also added in the form of a JSON file. JSON has been the selected data type because the AT was going to generate it, and everything was already being saved as a JSON, so only a schema was required to create a form capable of creating and editing a programming mini-game.

The components of the back-end related to the mini-game will now be addressed by sections.

4.3.1 Back-end

The back-end of the Mini-game has two tables, one for the assignments and one for the answers. It has several functions for create/delete/update assignments and evaluations and also to evaluate an answer, review an answer (this gives a full report), get the grade from an answer or a student and two functions to get the sheet with grades from every student, one gives the best grade each student got on the assignment, the other gives the last grade each student obtained.

Figure 4.5: Mini-game exams table

Figure 4.6: Mini-game evaluations table

In figure 4.5 and figure 4.6 we can see the tables that were used in the back-end of the mini-game.

The exams, presented in figure 4.5, have a primary key id and a unique name. The uniqueness of the name was for a easier management of the assignments through a back-office. There is a "timeLimit" which is only used for grading and three hashes each one referring to one of the files. The three files, as pointed before, are the CSV with the evaluation, the SCM file containing the correct solution to the problems and the JSON file with the assignment wording. In the database, the use of a hash was opted to simplify the track of modifications in these files upon editing. If the hash generated from the entire file content is different from the one present in the database, the file has been modified, so the file is rewritten and the database hash is updated, this way the access to the disk can be minimized.

The evaluations, presented in figure 4.6, have an id as primary key, an exam as a foreign key, which is the assignment it refers to, a user that is a string that identifies the student that answered the assignment, the grade he obtained, the submission, which is a string containing the SCM code. This is duplicated since the SCM file has also to be written for the auto-corrector executable to access it. There is also the time taken for the student to complete the assignment.

4.3.2 User Interface

The website developed to run a mini-game was made as simple as it could be while providing a good user experience.

As it can be seen in figure 4.7, there is a timer at top left corner of the page which indicates elapsed time. The title and the description of the game are on the top of the form and then each

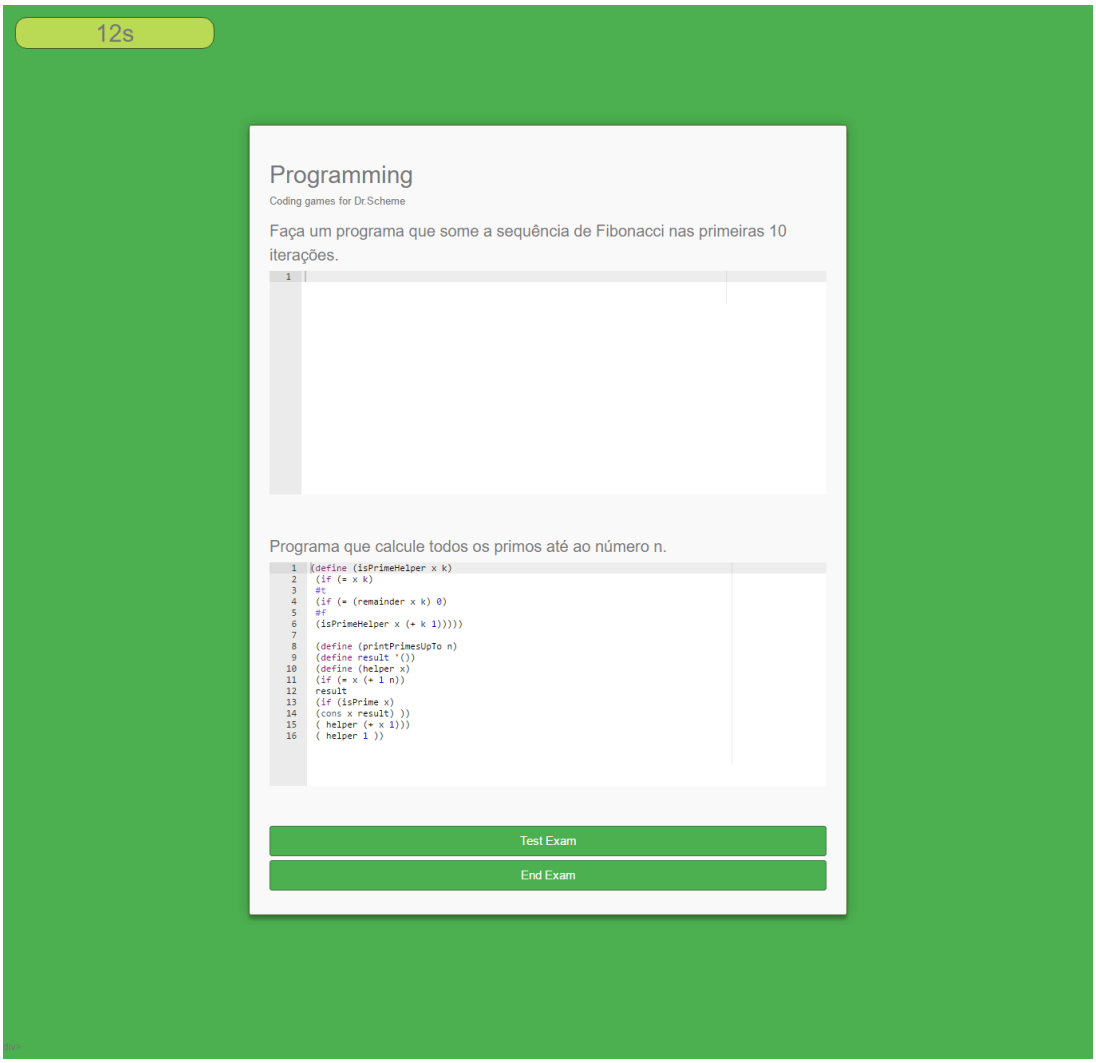


Figure 4.7: Programming Mini-game web page

question is presented in a list. For each question, there is the title and a coding box. This box has Scheme highlight features, making it very effective to aid students.

At the end of the assignment, there are two buttons, the first one evaluates the assignment and gives the student feedback about the correctness of his solution. Notice that there is no grading from "required" programming mini-games, therefore the answer is either right or wrong. The second button submits the assignment and redirects the user to a page that indicates he can return to the game (location-based game).

4.4 Location-based Game

The location-based game was adapted from an already developed game called "Invicta". The original game was a Unity project that used GPS location and was based on placed marks on the map of the "Invicta" city, which is the city of Porto in Portugal. The game had some points being

shown, the user had to walk to them and open them. There could be dialogs or/and multiple choice quizzes inside each mark. This game was created by João Jacob and Rui Nóbrega.

Since the game was imported into a much newer version of Unity, most of it was broke and had to be fixed. After fixing the original game, a lot of modifications took place, leaving not much more than the logic of the game untouched.

The modifications started with adding the programming mini-game to the game, making it launch a web page where the mini-game was. After achieving this, the creation of the game XML and its modification took place in order to generate it through the AT. After the AT could successfully generate the game XML, the XML was hosted at the back-end server used by the programming mini-game. A table to host the game was created and some services to publish and retrieve the game were also created. After these, the game was adapted into having a sequence of points on the map, instead of showing all at the same time, then allowing each point to have a list of other points to follow him, then adding hidden points and repeatable points. There were visual fixes, in terms of items sizes, change the map and its locations, zoom limits, added a player pin to the map, change pin behavior to only become active when the player is near and modifying the game to allow a PC version that could be controlled with the keyboard. One more modification was the capability to load the game from the server through an ID given in the main menu, this way the game only needs to be installed once and all the games created by the authoring tool can be played from the same App as long as the back-end server doesn't change its IP address. There was also the addition of logging every player action to a server, through some scripts and server previously created by João Jacob. It was opted to reuse these already implemented features instead of creating a new logging table on the back-end to save time since those were already working.

Now a brief introduction to the game and its features will be presented.

4.4.1 Game architecture

The game is a Unity project, composed of several scripts who coordinate all the functions. These scripts can be divided into a few sections:

- Camera controllers - these scripts control the camera and its GUI components.
- Challenge scripts - these scripts control the different types of challenges and their behavior when executed. The challenges are only executed once the player opens a pin on the map.
- Content loader - this script loads the content from the XML to the game. It requests the XML from the back-end and then loads its content into the game.
- Location services - this script is responsible for the player location and tracking. It is also through it that the PC version is capable of moving using the keyboard.
- Pin scripts - these scripts are responsible for the management, position and behavior of the map pins. The manager selects which pins are active, the position places them on the map

and the behavior selects the challenges when they are opened and decides when the pin should be considered done.

The pins on the map can have two types: hidden or normal. A normal pin is presented in the map when active and the player can see it and activate it when near. The hidden pin is not present in the map and the player has an indicator in the game that shows the distance to the closest hidden pin. The pin becomes visible when the player is near it. The pins can also be executed one or several times in the case they become active again. If a pin can be executed once every time it is reached his activities are reset. The programming challenges can be required. If they are, the player can only continue the game once he successfully completes them.

4.4.2 Back-end

The game back-end was developed in the back-end server already containing the assignments, this way no other server hosting data was needed. The back-end has one database table called games and several functions to add/delete/update the games.

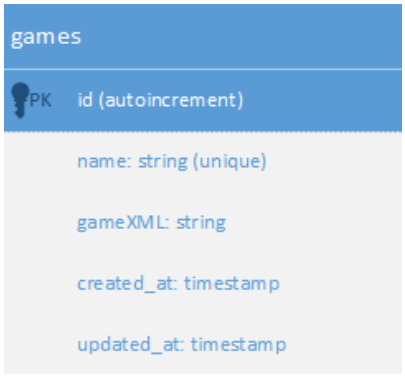


Figure 4.8: Location-based game table

Figure 4.9: Location-based game table sample from Game Jam

As seen in figure 4.8 and figure 4.9, the table contains an auto-incrementing ID as primary key, a unique name for easier recognition when listing all the available games and the game's XML, representing the game for the students to play.

The back-end is also responsible for the edition of the games, therefore there are some PHP functions that access the database for updating games' information. The game XML is composed of checkpoints that are points on the map. Inside each of the checkpoints, there are one or more challenges. Each challenge can be a narrative challenge, a web challenge or a multiple choice quiz.

4.4.3 XML

The game XML follows the implementation of the "Invicta" game, with some extra information and additional challenges.

```
<invicta map="/images/FEUP.png" top="41.17993" left="-8.599401" bottom="41.176017"
    right="-8.592907">
   <game>
      <checkpoints>
         <checkpoint pointId="3" lon="41.17757149380705" lat="-8.594628268865128"
             image="Rose" name="Laat" type="normal" executeOnce="true">
            <challenges>
               <challenge type="narrative">
                  <narrative value="Welcome! My name is Laat, I have a scroll but
                      before I give it to you I will need some proof that you are
                      allowed to read it." />
               </challenge>
               <challenge type="question">
                  <question value="What weights more, 1Kg of gold or 1Kg of water?"
                       url="http://56b2304c.eu.ngrok.io/api/saveResult">
                     <answer value="The gold" isCorrect="false" />
                     <answer value="The water" isCorrect="false" />
                     <answer value="They weight the same" isCorrect="true" />
                  </question>
               </challenge>
               <challenge type="webchallenge">
                  <webchallenge value="http://drscheme-autocorrector-ws.dev/play/1"
                       required="false">
                  </webchallenge>
               </challenge>
            </challenges>
         </checkpoint>
      </checkpoints>
      <connections>
         <connection source="1" target="3" />
         <connection source="3" target="2" />
      </connections>
   </game>
</invicta>
```

Above is the example of part of one game XML generated by the Authoring Tool. The XML starts with an "Invicta" tag with the map and the coordinates of top-left and bottom-right corners. Then it has a game with a list of checkpoints. In each checkpoint there is an id, a latitude, a longitude, the image of the point, its name, which will be used as the text of the label, the type of point and a boolean indicating if it should be executed only once. Inside a checkpoint is a list of challenges, that can be "narrative", "web challenge" or "question" (multiple choice quiz). The narrative challenge has only the text. The web challenge has the URL to the back-end, the assignment id and the boolean indicating if it is required. The question challenge has the question and all of the answers with their text and the boolean indicating if they are correct.

4.4.4 Game Interface

The game interface will now be presented.

Figure 4.10: Location-based game screen-shot 1

In figure 4.10 we have the main menu of the game, where the player can select the ID of the game he wants to play and then must select "Adventure Mode" to start the game. This main menu came from the "Invicta" original game and the only modifications were the replacement of one button with an input field for the game ID and the back-end associated with it.

Figure 4.11: Location-based game screen-shot 2

In figure 4.11 the gameplay is presented. This is the default map of the game, a map of FEUP that has been "aged" using image edition techniques. The player is located at the glowing dagger that is stabbed on the ground, and the flowers are the pins on the map that are currently active. They have a label associated with them. Once a player is near one, they start changing size from small to big and other way around, indicating they are in range.

Figure 4.12: Location-based game screen-shot 3

In figure 4.12 an example of a multiple choice quiz is given. The buttons on the quiz answers change size according to the size of the input text, this way any given answer size is fit inside them.

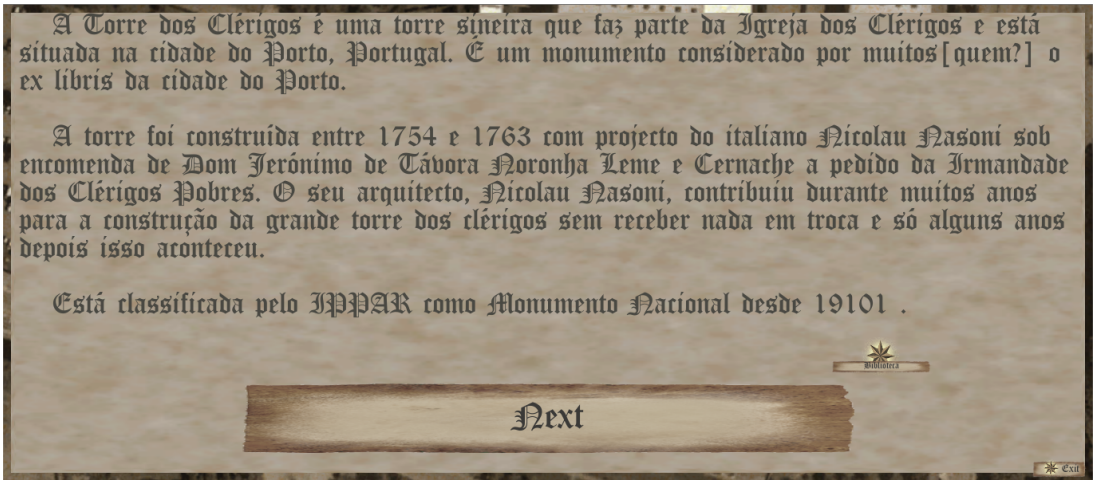


Figure 4.13: Location-based game screen-shot 4

This figure 4.13 shows the dialog box with some text in it. The text presented is from one of the markers of the Invicta game.

The view of the programming mini-game has already been presented before since the game launches a web page. In the game, it is only shown a page with the indication to follow web page instructions, and continue to play the game when instructed.

4.5 Back-end Server

The back-end server was already explained in parts throughout this Chapter, one piece at a time. Now a full and deeper understanding of the server will be presented, together with the integration of the different components.

The back-end server is hosting the auto-corrector of Scheme, together with all its routes, functions and solving web page. It also hosts the table with all of the games used by the location-based game, once again along with the routes and functions associated with it.

The bridge between all of the different components of the system is this back-end server, there is no other connection between any component that doesn't use this server as a middle point.

The diagram with the server and its components is as follow:

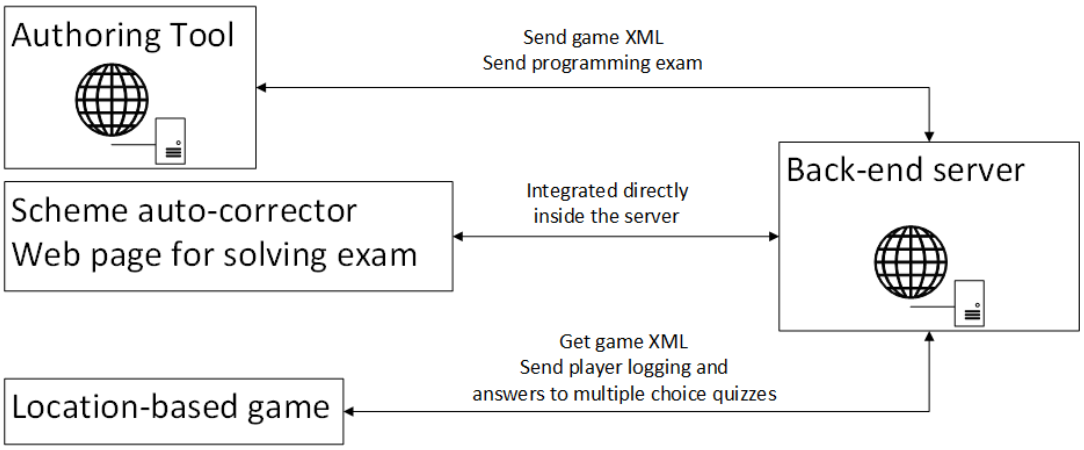


Figure 4.14: Back-end server diagram

As it can be seen in figure 4.14, the connection between the Back-end Server and the different components is as follows:

- Authoring Tool - The AT has a server of its own, where all the data about GLPs is stored. It is connected to the BES to send the game XML when submitting the game, which has a return with the ID of the game for later use in the LBG, and to send and retrieve a programming assignment from and for authoring.

- Programming Mini-Game - The PMG is built inside the BES, but since the auto-corrector itself is an external executable file that is run from PHP console, it can be seen as a separate component. All the data about the assignments and their evaluation is inside the BES, together with the web page for the student to play and solve the assignment. Once he submits it, the BES runs a PHP command that executes the auto-corrector and gets its return to save on the database.

- Location-Based Game - The LBG integrates the BES by retrieving the game XML to be used and by sending a logging of the player actions, together with the player quizzes answers.

The game also launches the web page for the assignment using the BES. After solving the assignment the return to the game must be made manually when instructed.

Chapter 5

Preliminary Evaluation and Results

Although this dissertation focus on pervasive games for teaching, since it has been wrote in the scope of a Master's degree in Informatics, the tests were aimed at teaching programming, specially the teaching of Scheme following the lesson plans of "Fundamentos da Programação" course. The tests were aimed to understand the ease of use and the efficacy of the authoring tool to create a gamified lesson plan for teaching and the fun and effectiveness of the game as a learning tool that has the potential to make the student have fun while learning. The usability testing was based on SUS [BKM09], giving a good and accurate measure of the effectiveness, the efficiency and the satisfaction of the system. Three tests were planned, one with students from the course Master in Informatics and Computing Engineering, with the first cycle of studies complete, therefore they are already graduated in Informatics and so considered experts. The second group was planned to target teachers from the Master in Informatics and Computing Engineering, that had already been teachers of the course "Fundamentos da Programação". The last group was a focus group from a Game Jam that happened at FEUP and was not focused on programming but on STEM.

The Game Jam was the first group being tested, Therefore, with some of the feedback obtained both from the inquiries and from the attendees in person, there were upgrades and enhancements to both the authoring of the gamified lesson plans and to the game itself.

For each of the groups, only the most interesting and distinguished questions will be addressed specifically, the ones with regular results without anything special to mention will only be addressed in an overall view.

To evaluate the user experience, standard SUS questionnaires were given. Each composed of 10 questions, rated from 1 to 5 where 1 means "Strongly Disagree" and 5 means "Strongly Agree". We will analyze each of the components of the system separately for a deeper understanding of the results.

In some charts, there is a red horizontal line representing the mean of the answers. The mean was chosen over the median since the results must go from 1 to 5, hence the non-existence of significant outliers that could affect the mean.

5.1 Informatics students

This tests will be performed with graduate students from the Master in Informatics and Computing Engineering course and will aim at understanding how powerful a game can be to teach the player something and how good and efficient is the solution described in this dissertation. The lesson plan is based on the "Fundamentos da Programação" course and a handcrafted game plot was created to fit part of this plan. The game plot has some alternative paths that give different students a different experience of the game, allowing them to talk about the game at the end and giving them a more immersive experience, where their actions have a difference in the game. Although there are several points where students can take different paths, the learning material and the exercises will always be the same, granting that the player will learn everything specified in the lesson plan.

The test starts with a brief explanation of the game and its features and after the student is ready to play the game he can install the app and start the game. Feedback about the location of the student and current state in the game is collected in real-time.

Due to the context of the students, it was opted to create the story and the wording of the questions in Portuguese, this way any misunderstanding or bad interpretation could be avoided.

5.1.1 GLP

The GLP was composed of only one Mission, with some quests, each encompassing some primary points in the story.

As it can be seen in the Appendix A, there is a total of 19 assignments, where the last three of them are adaptations of the same exercise, therefore the player will only resolve one of them. The fourth from last exercise is optional, being an extra exercise the player can solve in case he opts by it. In the middle of the game, the player has to find the correct point on the map, among 5 points. One of them continues the game while the others are wrong and require the player to keep looking by giving an extra hint. Due to this point, there are four exercises that are complementary and one that is the one leading to the solution. These 5 exercises have the same subject and use the same function. Each one of them requires the player to calculate the area of a geometric figure, therefore the player can solve just one to learn the subject.

5.2 Informatics teachers

The test performed with teachers is aimed at testing the authoring tool to better understand its potential and limitations. The group will have a total of 4 teachers, all of them with previous experience at teaching scheme in "Fundamentos da Programação" course. Although this focus group is rather small, it is composed of experts, and so with an adequate dimension.

This test has two stages. In the first one, the teachers are asked to follow a tutorial and are given a small questionnaire at the end, gathering some feedback from the first impressions of the tool. In the second stage, they are required to create some content using the AT and some feedback

is gathered right after each of the steps. At the end of this stage, some extra feedback is collected, followed by a SUS questionnaire to evaluate the usability according to professionals.

5.3 Game Jam focus group

This focus group comes from a Game Jam that took place at FEUP whose theme was location-based games. The participants were mostly composed of students of a Digital Media Doctoral program. There were proximately 13 persons attending to the Game Jam but only 8 stayed during the entire Game Jam, leaving only 8 persons in the focus group that was evaluated.

The Game Jam was composed of 3 stages. In the first one, they had to follow a tutorial to learn how the authoring of the GLP works and then test the game they created during the tutorial. This stage is meant to give some knowledge of the authoring tool and to show its features, potentials and limitations. After following this tutorial and playing the game the attendees know enough of the system to create their own GLP with their own lesson plan and their own game plot.

In a second stage, after completing the tutorial the entrants were asked to create a gamified lesson plan for STEM using the authoring tool and then submit it to the game server. In this stage, a few feedback and impressions were obtained, particularly in relation to implementation limitations and bugs that had not been detected earlier. Also, during this stage, the participants had access to a Windows testing tool that allowed them to play the game using keyboard arrows, this way they could test the game to make sure they were creating a playable GLP.

In the third stage they played the games they have created in stage two. This stage was good to understand the actual fun and immersion a game can give, while also teaching something.At the end of this stage, two forms were given to evaluate both the authoring tool and the game.

5.3.1 Authoring Tool Usability Testing

There is a total of 9 bars in the following graphs, each one of them represents one user's answer. A total of 9 persons answered the questionnaire.

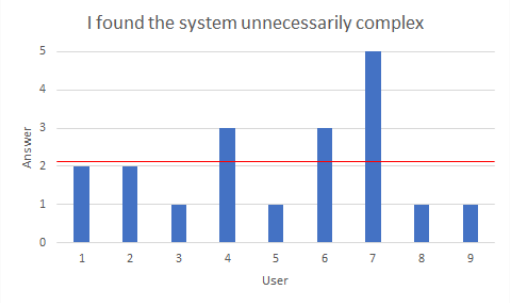


Figure 5.1: SUS Authoring Tool Question 2

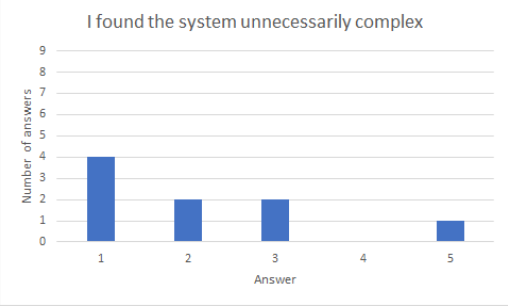


Figure 5.2: SUS Authoring Tool Question 2 Counting

As it can be observed in figure 5.1 and figure 5.2, this question had a mean of 2.25, this represents a small tendency to consider that the AT is not an unnecessarily complex tool. As it can

also be observed in the graph, only one person considered the authoring tool to be more complex than it should. The person who strongly agreed mentioned as an observation that too many mouse clicks and drags were required to create a GLP. This is rather contradictory from the feedback obtained from other people since several asked for an extra click when deleting content in order to confirm the deletion. As other observation the same person suggested the addition of a CSV importer to load multiple-answer quizzes, this could also be a reason to strongly agree since it would be easier to just load a CSV with the information rather than manually copy-pasting the questions and answers and adding extra answers manually.

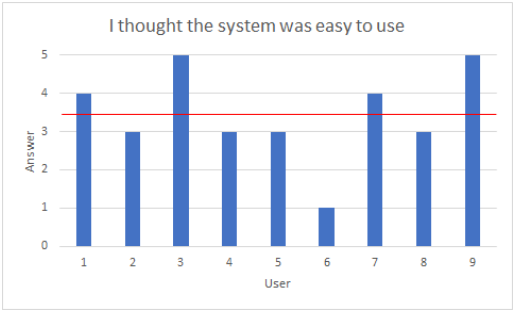


Figure 5.3: SUS Authoring Tool Question 3

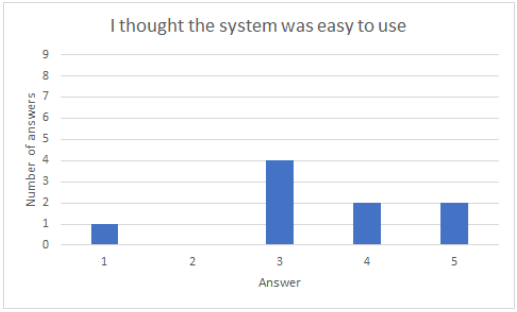


Figure 5.4: SUS Authoring Tool Question 3 Counting

As it can be observed in figure 5.3 and figure 5.4, in this answer there was an average of 3.25, meaning most agreed that the AT was easy to use.

As noticed in the previous question, there was only one answer that was negative. The person who answered it left no extra comments on the tool, but it's the one who had the lowest SUS score among all.

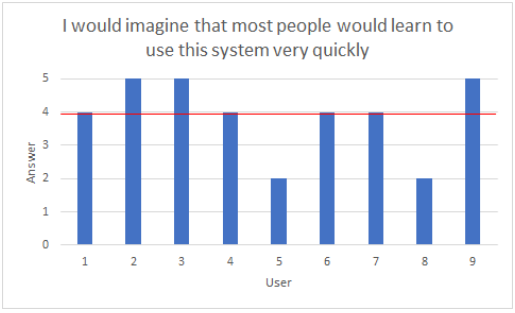


Figure 5.5: SUS Authoring Tool Question 7

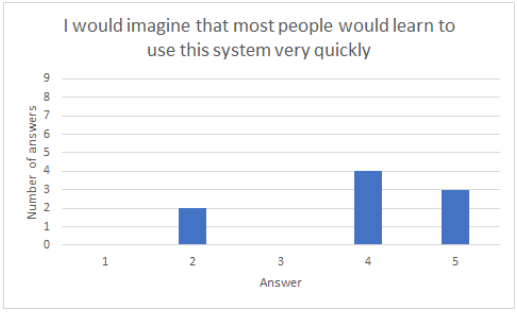


Figure 5.6: SUS Authoring Tool Question 7 Counting

As it can be observed in figure 5.5 and figure 5.6, this question is particularly interesting when related to the previously presented one, question 3, since the person who strongly disagreed that the system was "easy to use" answered that "the system can be learned to use very quickly". This is rather contradictory since a system that is hard to use hardly can be learned to use quickly.

As it can be observed in figure 5.7 and figure 5.8, we can only notice one answer above neutral (3), since this is the same person who strongly agreed that the system is unnecessarily complex

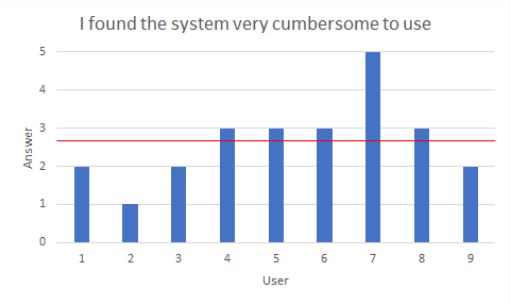


Figure 5.7: SUS Authoring Tool Question 8

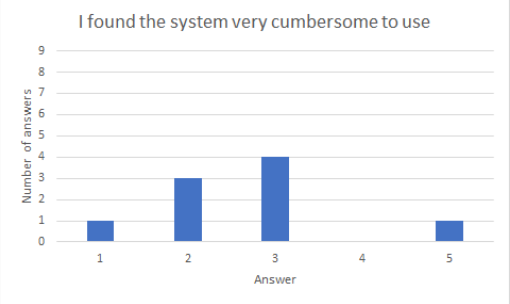


Figure 5.8: SUS Authoring Tool Question 8 Counting

this answer is consistent. Both this and question 2 can be related in a way they evaluate how hard the system is to use.

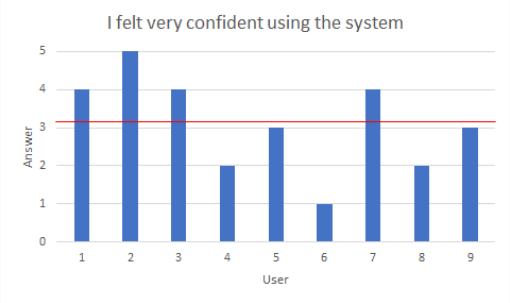


Figure 5.9: SUS Authoring Tool Question 9

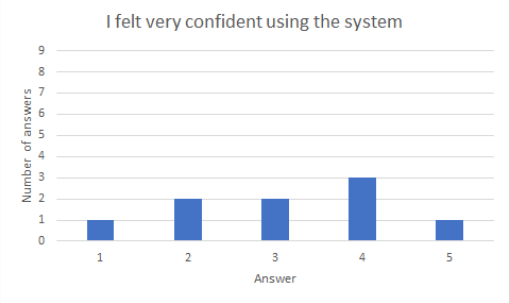


Figure 5.10: SUS Authoring Tool Question 9 Counting

As it can be observed in figure 5.9 and figure 5.10, this question is particularly interesting since there was at least one answer in every option, from "strongly disagree" to "strongly agree". Focusing on the "Strongly Disagree" answer, the person who selected is also the person who thought the system was not easy to use, making this a consistent answer. Since there was no extra feedback, there is no observation on why it was not easy to use.

5.3.1.1 SUS Score

The SUS score is the final score of each of the answers to the questionnaire, this gives an overall information on how well each of the persons rated the AT.

As noted in figure 5.11, the mean of the SUS score for the AT was 63.06, this is under the mean score for a web interface, which is 68.2 [BKM09]. This score, under 68.2, means the system needs to be improved and the system is currently on a state that is not final.

It is important to mention that in the BEACONING project, there were delays in the integration between partners and in the services, which limited the results, contribution to a lower SUS Score than expected. These delays are being resolved and some of the flaws are being fixed.

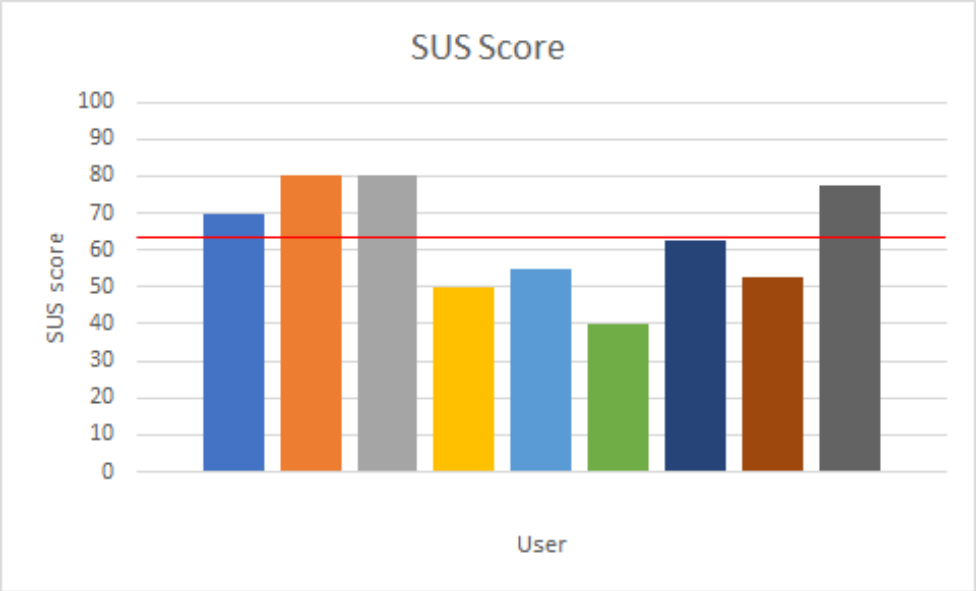


Figure 5.11: SUS Authoring Tool Score

5.3.1.2 Overall feedback

Other than the SUS questionnaire, there was also some feedback obtained during the development of the GLPs, mostly bugs that happened in the AT, some of them even drove some people to quit the Game Jam. The most relevant ones were:

- Pressing the "Enter" key during the editing of a challenge makes the page refresh, losing all the progression since the last saving of the GLP (which some people were not doing).
- When the previous bug happens, it was no longer possible to save the GLP, so the user was forced to refresh the page and start all over again from the last save.
- There was the lack of a confirmation dialog when deleting items, which led some people to mistakenly remove items from the GLP and having to remake them all over again.
- The lack of auto-save on every modification of the GLP, even graphically rearrangement of the elements on the graph.

From the additional observations, there was also mentioned the lack of an "undo" in the AT to recover last made modifications, the addition of a load option for some type of challenges and the option to save the GLP to a file in order to allow offline edition.

5.3.2 Pervasive Game Usability Testing

There is a total of 7 bars in the following graphs, each one of them represents one user's answer. A total of 7 persons answered the questionnaire.

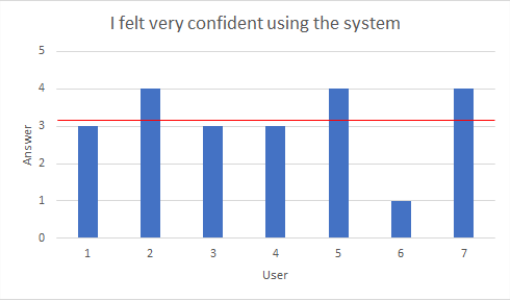


Figure 5.12: SUS Game Question 9

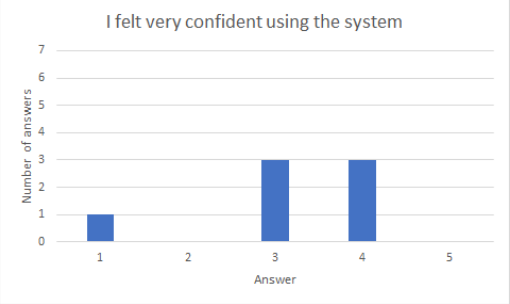


Figure 5.13: SUS Game Question 9 Counting

As it can be observed in figure 5.12 and figure 5.13, one can notice an outlier, while all the other answers were either neutral or positive. The person who gave the "strongly disagree" answer had the lowest SUS score among all answers, meaning it was a person who had a really bad experience with the game.

This person was also the only person giving a negative answer in some of the other questions, but since those answers were close to the mean, they could not be called outliers, so the questions were not mentioned.

5.3.2.1 SUS Score

The SUS score is the final score of each of the answers to the questionnaire, this gives an overall information on how well each person rated the Game.

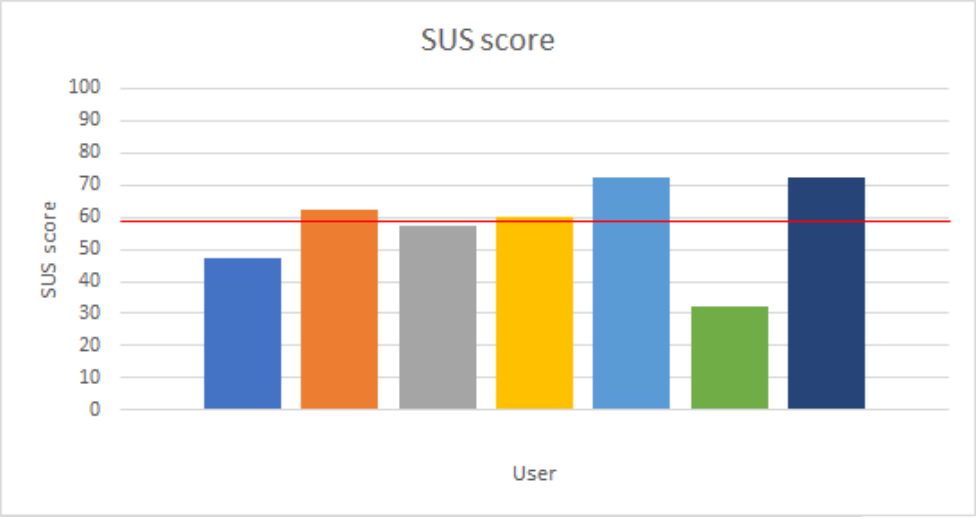


Figure 5.14: SUS Game Score

As present in figure 5.14, the mean of the SUS score for the Game was 57,86, this is under the mean score for a cell phone application, which is 65.9 [BKM09]. This score, under 65.9, means the system needs to be improved and the system is not acceptable. It should be particularly noted

that one of the persons had a really low score, pulling the mean to a much lower value than it would be without that answer (62.08).

5.3.2.2 Overall feedback

Other than the SUS questionnaire, there was also some feedback obtained during gameplay. There were only three relevant informations, which can be the cause for a low SUS score.

The first was the lack of a proximity meter, that could indicate how far we are from a hidden point. This is rather important since the player must know where the point is, from the hints the game developer gave. In the case the player didn't figure where is the hidden point, he will be "lost" and would need to walk randomly around to find the point.

The second relevant feedback was the sudden end of the game, or even unplayable game. Although this is a relevant feedback it is not really related to the game but to the AT, since those games were created "incorrectly", making the game unplayable at some points.

The third feedback, that is probably the cause of the very low SUS score, was the low range for triggering the pins on the map. One person, in particular, placed all of the pins inside buildings, and because the range to trigger was rather low (8 to 9 meters), to trigger them he had to be inside the building. This is difficult to achieve since the game uses GPS location, which is imprecise inside buildings. Therefore the game would be close to unplayable, justifying why one of the answers had a SUS score of 32.5, even though this was due to a mistake on the pins placement and not exactly a flaw of the game, but rather a limitation.

But overall the users were able to create very imaginative games as is shown in the following example.

5.3.3 Example of a GLP

An example of one GLP developed during the Game Jam is the "Super Tolkien Extraordinary Map - STEM" which was based on the LOTR ("The Lord of The Rings" [Tol55]) map. In this particular GLP, the team changed the map to the LOTR map and placed pins in there. The coordinates of the pins are still placed on the same spot as they would be on the regular map, so from one side to the other, there is exactly the same distance by foot.

From figure 5.15, showing one of the GLPs created in the Game Jam, it can be seen that the GLP has only one mission and one quest. The quest has 8 Challenges and 4 out of the 8 have mini-games. In this case, every challenge has one dialog box and a multiple answer quiz. The flow of the game is as follows, following the order of the pins:

- The shire
  - Welcome, young halfling! I am very pleased you have chosen to embark on this amazing journey.
  - Hobbiton has 11 other halflings. Your adventure needs 1/4 of the population to be successful. How many friends should you bring? (4, 8, 2, 3), right answer: 3.

Figure 5.15: Sample Game Jam GLP

- Ringwraiths
  - You have been waylaid by RingWraiths on horses, you must hide to avoid them.
  - The Wraiths ambushing you. If their horses run at 9km/h and you run at 3km/h, and you start with 6km of advance, how many minutes would they need to catch up to you? (30minutes, 2 hours, 1 hour), right answer: 1 hour
- Bree. This pin is hidden.
  - You have arrived to Bree, and can finally enjoy some rest and comfort. Or can you?!?

  - 1+1? (1, 2), right answer: 2.

- Rivendell
  - <empty dialog box>
  - <empty quiz>
- Attack at Redhorn pass. This pin is hidden
- The mines of Moria
- Lorien
- Down the river

The game auto-skips any pin that has no mini-games inside, therefore only the 4 first pins appear on the map, and the last one has an undefined behavior since it contains an empty quiz. One empty dialog box is just a window with a button saying "next".

5.3.4 Conclusions

From this group of tests, some important bugs were found and there was the possibility to fix them before the remaining two groups, the Informatics students group and the Informatics teachers group, test the tool.

The SUS scores obtained were somewhat low scores, making it important to make some changes suggested by the users in order to improve the tool and reach an acceptable level of user experience.

All the graphs containing details of each questionnaire, whisker box graphs related to each questionnaire, the GLPs and the game XMLs can be found in the Appendix of the dissertation. There can also be found there the consent agreement to use the material created by them on the present dissertation and the SUS questionnaire used.

Chapter 6

Conclusions and Future Work

Serious games for education is an emerging area that has been researched and developed lately, but its integration with pervasive, context-aware methodologies, in the large scope of mobile learning, is an emerging trend, and specific tools are required to help teachers.

This Dissertation proposed and implemented a solution that fills the lack of adaptation and awareness from current GBL solutions through an authoring tool capable of customizing the Lesson Plans for every student's needs and context, while also increasing the engagement and immersion of the student through a pervasive, location-based game.

6.1 Completed objectives

As of the end of this dissertation, a complete solution for the presented problem and objectives was developed and tested.

In the scope of BEACONING, an Authoring Tool was created and used for this dissertation after passing through some modifications and adaptations. During the development of the project, delays and limitations took place and the time consumed into its creation was exponentially bigger than expected initially. This Authoring Tool is fully capable of customizing the Gamified Lesson Plan, the Location-Based Game and the Programming Mini-Game.

Using the already existing Scheme auto-corrector a Programming Mini-Game was created, this Mini-Game is capable of evaluating the answer of a student to an assignment, giving a grade. It is possible for the teacher to obtain all the grades of every student for each assignment.

The Location-Based Game was based on Invicta game, which already had some of the features that were needed. After modifications to the tool, it is possible to play any of the games created using the Authoring Tool and also to launch the Programming Mini-Game that runs on the web. This tool took a fairly higher amount of time to modify since it was imported to a much newer version of Unity than the version it was developed in, introducing a lot of bugs and malfunctions.

To integrate all of the components a Back-End Server was created that was capable of hosting most of the content and data the system use, while also working as a bridge.

Overall the system was rather solid. The only component which had some issues was the Authoring Tool, that will be subjected to exhaustive testing and evaluation on the scope of the BEACONING project. With this results improvements will be done.

6.2 Main Challenges

During the course of this Dissertation, there were several challenges that introduced delays and difficulties, the most relevant ones were related to the integration inside the BEACONING project. The Authoring Tool was going to be the main work and some of the collaborator's work was going to be used for the tests. Due to some delays in the project, a back-end for the authoring tool alongside the Back-End Server and the Location-Based Game had to be implemented in the scope of this Dissertation, which increased the amount of work necessary to perform the tests and to get a solution. These problems were overcome and at the end of the Dissertation all of the system is linked and working as expected initially. Also, since the BEACONING Mini-Games don't return the score of the student, they couldn't be used in the tests.

Also, since BEACONING is not yet in a phase where the LMS is required, it is not yet implemented and it is not present in the Dissertation.

6.3 Future Work

The Authoring Tool will undertake improvements along the BEACONING project as feedback is obtained from the small and large pilots. Also, after BEACONING partners end creating mini-games and having a way to return the score of the player, they could be added to the system. Currently, they are displayed in the Authoring Tool, together with the other activities, but they can't be used.

For the Programming Mini-Game, it would be very interesting to have it inside the Mobile game instead of a web page, but this would require a new Scheme auto-corrector since the current one is an executable file.

The two tests that have not yet be done, the Informatics students group and the Informatics teachers group, will be performed and their results will be added to this document for further analyses and conclusions.

As of future work, it will be used in 2017/18 edition of the "Fundamentos da Programação" course at FEUP and evaluate how well the students that use the system perform in compared to the students that followed a traditional learning approach.

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Appendix A

Time traveler (GLP programação)

Time traveler (programação)

Estás no ano de 1958 a beber uma Cuba Libre, quando vês uma luz muito forte a brilhar diante dos teus olhos... Após uma tremenda dor de cabeça perdes os sentidos.

Acabaste de acordar desorientado e perdido. Olhas à tua volta, mas não és capaz de reconhecer nada...

Ficas sentado durante uns instantes enquanto recuperas... Apercebes-te que estás numa espécie de sala e é então que reparas que está tudo desarrumado como se um furacão tivesse por ali passado.

Começas a reparar em vários objetos que nunca antes tinhas visto e que não fazes ideia do que são. É então que alguém abre a porta e olha para ti com um ar surpreso. “Bem vindo, John McCarthy...”, diz a pessoa.

O Dr. Vader, pessoa que te encontrou após a viagem, explicou que ele e mais alguns investigadores abriram um portal temporal que te permitiu viajar até ao futuro, mas que como o portal foi criado no centro da FEUP não te podes afastar muito do local.

O portal tinha como objetivo viajar para o passado, mas aconteceu algum erro. Para conseguires voltar ao teu tempo vais ter que ultrapassar barreiras, tomar decisões e aprender!

O Dr. Vader indicou que enquanto resolves o mistério que te leva de volta ao teu tempo, vais conseguindo conhecer a FEUP e aprender a utilizar a tecnologia recente.

Quando são apresentados vários pontos no mapa, escolhe com cuidado, porque as decisões que tomares vão influenciar o teu futuro!

Dr. Vader - Bem-vindo a 2017, John McCarthy! O portal, tal como praticamente toda a tecnologia utilizada atualmente, foi baseado em Scheme. Scheme é uma linguagem de programação baseada em Lisp, a linguagem que tu criaste. Para que consigas voltar a 1958 terás que corrigir os erros que levaram o portal a abrir no sentido errado.

Dr. Vader – Encontras-te, atualmente, no campus universitário da FEUP. A FEUP tem origem na Academia Politécnica do Porto, fundada em 1837. Em 1915 a Academia passou a ser a Escola de Engenharia e apenas em 1930 é que passou a ser chamada de Faculdade de Engenharia da Universidade do Porto, com os diversos cursos de Engenharia separados. Este campus em que te encontras, foi inaugurado na comemoração dos 100 anos da Academia Politécnica do Porto, em 1937.

Dr. Vader - Para começares a conhecer 2017 e voltares ao teu tempo, vais ter que ir até à Biblioteca, onde podes encontrar todo o tipo de livros que ensinam tudo o que há para aprender do nosso tempo. Lá poderás encontrar alguma informação sobre a linguagem Scheme e pistas sobre o que pode ter corrido mal. Enquanto o fazes, nós vamos, também, procurar o que pode ter falhado e vamos tentar abrir o portal para que possas voltar ao teu tempo.

*Bem-vindo à Biblioteca da FEUP. Este edifício tem 7 andares, cada um deles reservado a várias áreas de estudo. Sente-te a vontade para entrar e explorar o quanto quiseres...*JOGO: Diz em que piso podes encontrar informações sobre Informática. *

Dr. Vader – Vejo que já sabes em que piso se encontra Informática. Vai até lá e procura o livro "*Structure and interpretation of computer programs*" para perceberes como funciona Scheme, já que é ligeiramente diferente de Lisp. Estamos com um erro no código que localiza interferências eletromagnéticas e suspeitamos que essa possa ser a causa da falha. *JOGO: Procura o livro "*Structure and interpretation of computer programs*", vai ao capítulo "*1.1.1 Expressions*" e com base nas informações lá presentes corrige o seguinte código que está a falhar.* JOGO: Indica como se efetua a seguinte conta em Scheme: 1+2+3. 1+2+3, +(1 2 3), (+ 1 2 3), (1 2 3 +)

Dr. Vader – Muito bem! Já conseguimos detetar interferências eletromagnéticas nos geradores que se encontram nas redondezas, mas estas interferências deveriam estar a ser bloqueadas pelos supressores de ruído. Suspeitamos que o portal possa ter aberto do passado para o presente por alguma destas interferências. Em cada um dos locais vais encontrar um painel bloqueado que te permite reprogramar o supressor. Tens que desbloquear os painéis para que os possas reprogramar. Pode ser que consigas corrigir o problema e voltar a 1958.

*3 historias:

Dr. Vader – As indicações para os locais dos geradores podem ser obtidas apartir de um dos meus colegas que te esperam no pátio em frente à biblioteca. Vai ter com um deles e obtém as direções para os geradores! Boa sorte.

*Op1. João - Olá! Estamos com alguma dificuldade em encontrar quais dos geradores possuem falhas. Como vais ter que encontrar vários, gostaríamos de ver até que ponto consegues descobri-los baseado apenas nas indicações que te damos. O primeiro encontra-se no departamento de Mecânica, que se encontra a nossa frente. Vai até lá e quando te aproximares o suficiente o ponto vai aparecer no mapa. Em cada ponto vais encontrar uma pista que te leva ao seguinte.

L Chegaste ao edifício L, este edifício é o departamento de Engenharia Mecânica e de Engenharia e Gestão Industrial. * Nas traseiras do departamento encontra-se uma letra. Este edifício corresponde ao L. Vai agora até ao edifício M, que se encontra atrás do departamento L. Todas as letras dos edifícios estão de ambos os lados dessa rua.

M Chegaste ao edifício M, este edifício pertence ao departamento de Engenharia Mecânica e de Engenharia e Gestão Industrial. É o edifício Norte. Alguns departamentos têm mais do que um edifício e para se aceder a estes edifícios complementares tanto se pode entrar pelas portas ao nível da rua como por pontes de vidro situadas no segundo andar entre o edifício principal do departamento e o edifício complementar. *O próximo ponto está no departamento mais central de entre os 5 departamentos Sul.

G Chegaste ao edifício G, este edifício é o departamento de Engenharia Civil.

Agora desloca-te até ao departamento E, este departamento lida com químicos!

E Chegaste ao edifício E, este edifício é o departamento de Engenharia Química.

A Metalurgia usa química?

F Chegaste ao edifício F, este edifício é o departamento de Engenharia de Minas e de Engenharia Metalúrgica e de Materiais.

O próximo ponto és tu em Inglês.

I Chegaste ao edifício I, este edifício é o departamento de Engenharia Informática e Computação e de Engenharia Eletrotécnica e Computadores. Ao contrário dos restantes departamentos, este tem dois edifícios, juntos por um corredor nos pisos 0 e -1.

A ponte construída no departamento de Civil deve ir dar a algum lado…

H Chegaste ao edifício H, este edifício pertence ao departamento de Engenharia Civil e é o edifício Norte.

Já só falta um… Estiveste atento?

J Chegaste ao edifício J, este edifício pertence ao departamento de Engenharia Informática e Computação e de Engenharia Eletrotécnica e Computadores. É o edifício Norte.

*Op2. Lúcio - Olá! Estávamos a detetar uma certa anomalia no portal que usaste para vir até 2017 e… infelizmente… parece que a tua mulher passou pelo portal! Assim que lhe perguntamos o nome ela respondeu "Vera Watson", pelo que fizemos a associação. Pela tua cara já percebemos e não tens com que te preocupar. Basta fugires dela enquanto ativas os supressores e nos resolvemos o problema, deixando-a ficar aqui presa em 2017 por "engano". Toma decisões para evitares encontrar-te com ela, porque ela anda à tua procura. Para te ajudar vamos dando pistas de onde ela estava e para onde estava a ir a última vez que a vimos! Para já podes começar por ir ate ao edifício H.

H Chegaste ao edifício H, este edifício pertence ao departamento de Engenharia Civil e é o edifício Norte. Alguns departamentos têm mais do que um edifício e para se aceder a estes edifícios complementares tanto se pode entrar pelas portas ao nível da rua como por pontes de vidro situadas no segundo andar entre o edifício principal do departamento e o edifício complementar. Nas traseiras de cada departamento encontra-se uma letra. Este edifício corresponde ao H. Todas as letras dos edifícios estão de ambos os lados da mesma rua.

A última vez que vimos a tua mulher, ela estava no departamento G em direção ao departamento F! Escolhe para onde queres ir! (I|F)

<F> Vera Watson – Então John! Estou tao contente por te ver… Não consegues imaginar. Quando vi aquela luz a aparecer à tua volta e tu desapareceste não sabia que fazer então atirei-me para lá e apareci aqui… Onde estamos? Como vamos voltar? O que estamos aqui a fazer? O que sabes?…

Dr. Vader – Bom dia! Chamo-me Dr. Vader e sou quem os trouxe para aqui. Se quer saber onde é o "aqui" e todas as duvidas que queira esclarecer terei todo o gosto em ajudar, desde que me acompanhe. De momento o seu marido esta a tratar de os conseguir levar de volta para casa.

Dr. Vader – Não te preocupes, nós livramo-nos dela assim que possível e tentamos que ela volte ao vosso tempo…

I Chegaste ao edifício I, este edifício é o departamento de Engenharia Informática e Computação e de Engenharia Eletrotécnica e Computadores. Ao contrário dos restantes departamentos, este tem dois edifícios, juntos por um corredor nos pisos 0 e -1.

Vimos a tua mulher a andar do departamento G para o H! Escolhe onde pretendes ir de seguida. (L|J)

L Chegaste ao edifício L, este edifício é o departamento de Engenharia Mecânica e de Engenharia e Gestão Industrial.

Ela andava a fazer perguntas perto do edifício Norte de Civil! Apressa-te a sair daí! (G|J)

G Chegaste ao edifício G, este edifício é o departamento de Engenharia Civil.

Ela está neste preciso momento a ir para o departamento de Mecânica, esperemos que ninguém tenha visto por onde foste. (E|J)

E Chegaste ao edifício E, este edifício é o departamento de Engenharia Química.

Felizmente a tua mulher foi ter com um dos nossos cientistas para saber se te viu. Parece que está chateada por ter vindo atrás de ti preocupada e agora não te encontra em lado nenhum. Ela diz que parece que estás a fugir dela... Não te preocupes o nosso cientista disse que te viu a ir para o edifício Norte de Informática e Eletrotecnia. (F|M)

F Chegaste ao edifício F, este edifício é o departamento de Engenharia de Minas e de Engenharia Metalúrgica e de Materiais.

Pelo que parece ela foi para o edifício Sul e deve-se ter perdido lá dentro. Só agora saiu e não conseguimos perceber para onde ela estava a ir...(J|M)

J Chegaste ao edifício J, este edifício pertence ao departamento de Engenharia Informática e Computação e de Engenharia Eletrotécnica e Computadores. É o edifício Norte.

Aparentemente ela ainda andava de volta do I para procurar o edifício Norte e reparou em ti! Apressa-te para o edifício de Mecânica Norte! Voltas para o J assim que a tivermos despistado.

M Chegaste ao edifício M, este edifício pertence ao departamento de Engenharia Mecânica e de Engenharia e Gestão Industrial. É o edifício Norte.

Apareceram aqui uns investigadores Americanos com um papel assinado pelo governo a exigir que entregássemos o cidadão Americano que foi transportado pelo portal temporal. Felizmente estava aqui a tua mulher... matamos dois coelhos de uma cajadada só! Embora eles provavelmente a vão mandar de volta a 1958 assim que descobrirem como abrir portais... Entretanto vai ao edifício J colocar o último supressor a funcionar.

J

*Op3. Maria - Olá! O meu nome é Maria Estou aqui para te orientar para os geradores. O primeiro gerador encontra-se no departamento E. Para chegares até lá, desce as escadas e segue o corredor até ao fundo.

E Chegaste ao edifício E, este edifício é o departamento de Engenharia Química. Nas traseiras de cada departamento encontra-se uma letra. Este edifício corresponde ao E. Todas as letras dos edifícios estão de ambos os lados da mesma rua. Desloca-te agora para o edifício ao lado.

F Chegaste ao edifício F, este edifício é o departamento de Engenharia de Minas e de Engenharia Metalúrgica e de Materiais.

Dr. Vader - Parece que ao corrigir duas interferências eletromagnéticas do mesmo lado causaste um desequilíbrio! Apressa-te para o edifício do lado oposto para reequilibrares a interferência, caso contrário o dano pode ser permanente e ficas preso em 2017 para sempre!

M Chegaste ao edifício M, este edifício pertence ao departamento de Engenharia Mecânica e de Engenharia e Gestão Industrial. É o edifício Norte. Alguns departamentos têm mais do que um edifício e para se aceder a estes edifícios complementares tanto se pode entrar pelas portas ao nível da rua como por pontes de vidro situadas no segundo andar entre o edifício principal do departamento e o edifício complementar. Parece que o desequilíbrio já está corrigido e que não houve qualquer tipo de dano permanente. Dirige-te agora para o departamento de Informática, para evitar causar um novo desequilíbrio.

I Chegaste ao edifício I, este edifício é o departamento de Engenharia Informática e Computação e de Engenharia Eletrotécnica e Computadores. Ao contrário dos restantes departamentos, este tem dois edifícios, juntos por um corredor nos pisos 0 e -1.

Ao corrigires o painel este fez uma descarga elétrica e tu ficaste no chão a tremer… Rapidamente vês pessoas a aparecerem mas não consegues perceber o que elas dizem… Começa tudo a ficar desfocado, só consegues pensar no quanto qualquer uma das outras pessoas te teria guiado de maneira diferente e não estarias nesta situação. Tão rápido pensas nisto como de repente… Nada.

E é então que acordas com uma tremenda dor no peito. Toda a gente ao teu redor olha para ti com cara de espanto. “Incrível”, “felizmente” e “graças a Deus!”, ouves tu. Duas pessoas ajudam-te a levantar e fazem-te uma série de perguntas. Rapidamente te apercebes que são paramédicos. Tanto por te terem ajudado, como pelo uniforme que têm vestido.

Dr. Vader – Então John!? Ainda estás connosco? Estiveste morto por momentos! Foste ressuscitado por paramédicos, utilizando um desfibrilador. Por pouco que a tua história ficava por aqui… Felizmente isso não aconteceu e, tanto quanto sei, não ficaste com nenhum dano permanente, apenas tiveste uma paragem cardíaca devido à voltagem do choque que apanhaste. Como já te encontras em bom estado podes continuar o teu percurso. Desloca-te até ao edifício H.

H Chegaste ao edifício H, este edifício pertence ao departamento de Engenharia Civil e é o edifício Norte.

Parece que a consola não está a funcionar… Pelo teste diagnóstico que estamos a correr a partir daqui algum circuito deve estar danificado, vai ao edifício J buscar um novo circuito.

J Chegaste ao edifício J, este edifício pertence ao departamento de Engenharia Informática e Computação e de Engenharia Eletrotécnica e Computadores. É o edifício Norte.

Encontraste o circuito! Aproveita para reprogramar já este supressor. Retorna agora ao edifício H para trocar o circuito e utilizar a consola.

H Parece que a consola já está funcional… Já a podes utilizar. Vai agora até ao departamento de Mecânica.

L Chegaste ao edifício L, este edifício é o departamento de Engenharia Mecânica e de Engenharia e Gestão Industrial.

Já só falta mais um terminal! Vai até ao departamento de Civil e acaba de reprogramar os supressores.

G Chegaste ao edifício G, este edifício é o departamento de Engenharia Civil.

Cada local tem um exercício. Os exercícios são pela ordem seguinte:

1. Como se define uma constante em Scheme? (define altura 5)

(define altura 5)

(define area (* altura altura))

* Existem 5 tipos de dados em Scheme. Quais são? Valores inteiros, racionais, reais, boleanos e strings.

1 1.5 1/2 “string” #t

2. Quais são as operações aritméticas? +,-,*,/, abs, sqrt

Muito bem! O abs dá o valor absoluto de uma expressão, como por exemplo, tanto (abs -5) como (abs 5) dá o valor 5.

O sqrt retorna a raiz quadrada dos valores passados. Como exemplo (sqrt 4) = 2

Calcula a hipotenusa de um triangulo com base nos lados a e b.

```
(define (hipotenusa a b)
  (sqrt
   (+
    (* a a)
    (* b b)
    )
   )
  )
```

* Quotient remainder

Numero é par ou impar ?

(define (pouip n)

(if

(= (remainder n 2) 0)

'par

'impar

)

)

3. Como se define, em Scheme, 3 variáveis numa função anónima, a, b e c? (lamba (a b c) (…), (define (a b c) (…), (let (a b c) (…))

(

(lambda (a b c) (+ a b c))

2 2 6

)

4. Como se dá o nome “soma” a um segmento de código (criar uma função)? (let soma (…)), (define soma (…)), (lamba soma (…))

(define soma

(+ 1 2)

)

5. Como se cria uma função chamada “soma” que leva dois argumentos?

(define soma

(lambda (a b) (+ a b))

)

Ou

(define (soma a b)

(+ a b)

)

6. Como se definem variáveis locais? (let ((a 1)(b 2))

```
(define area
  (let ((altura 5))
    (* altura altura)
    )
  )
```

7. Como se toma uma decisão em código, baseada no valor “a” ser maior que o valor “b”, respondendo a subtração do maior pelo menor? (when (> a b) (- a b) (- b a)), (if (> a b) (- a b) (- b a))

Quais são os outros operadores de condição? =,<,> ,<=,>=

```
(define maior
  (lambda (a b) (if (> a b) a b))
  )
```

8. Vários condições? (cond ((> a b) ‘maior) ((> b a) ‘menor) (else ‘igual))

```
(define (ordem-decrescente a b c d e f g)
  (cond
    ((< a b) #f)
    ((< b c) #f)
    ((< c d) #f)
    ((< d e) #f)
    ((< e f) #f)
    ((< f g) #f)
    (else #t)
    )
  )
```

Dr. Vader – Muito bem, conseguiste ativar todos os supressores. Estamos a reiniciar os serviços para abrir o portal… Tanta deslocação não te deu vontade de um lanchinho? Tens ao teu dispor uma grande

variedade de locais para comer uma refeição dentro do campus da FEUP. Estes locais são a cantina, a cafetaria, o bar da Biblioteca, o Grill e o INEGI. Escolhe um destes locais e desloca-te até ele.

*Bem-vindo à Cafetaria. Aqui as refeições são de boa qualidade a um preço acessível. No preço base apenas o pão, prato e água estão incluídos. À hora de almoço costuma haver uma fila relativamente demorada (15min +/-).

* Bem-vindo ao INEGI. Aqui as refeições são de muito boa qualidade e na quantidade que se quiser pois é buffet. O preço é perto de 10€ por pessoa e inclui entradas, sopa, pratos, sobremesa e bebidas.

* Bem-vindo ao Grill. Aqui as refeições são de boa qualidade e a um preço acessível.

* Bem-vindo à Cantina. Aqui as refeições são de custo baixo a sacrifício da qualidade e quantidade.

* Bem-vindo ao bar da Biblioteca. Aqui as refeições são tipicamente comida leve, como baguetes e pizzas e têm um custo baixo. No entanto à hora de almoço costuma formar-se uma fila bastante grande.

A porta encontra-se trancada e não é possível sair. Para a abrir é necessário reprogramar a porta! Atualmente está a dar o erro seguinte “Idade inválida”.* Editar código para os limites de nascimento corretos:

```
(define data-nascimento 1927)
(define ano-atual 2017)
(define desbloqueia-porta
  (if
   (and
    (> data-nascimento 1937)
    (< data-nascimento (- ano-atual 18)))
   'a-desbloquear
   'desbloqueio-invalido
   )
  )
```

Dr. Vader - Muito bem, conseguiste desbloquear a porta! Ou talvez nós o tenhamos feito por ti… De qualquer modo, uma informação breve sobre os locais de refeição: INEGI é o local mais caro, mas a comida é buffet e inclui bebida, entradas, prato e sobremesas. Um excelente local para comer ocasionalmente. A Cafetaria e o Grill são equivalentes a nível de preço e qualidade, sendo esta última elevada. A Cantina é o que se espera, preço baixo com sacrifício da quantidade e qualidade e por último

o bar da Biblioteca, que vende maioritariamente baguetes, mas também tem outras opções e é barato. Podes consultar a ementa destes locais online no site da FEUP.

Dr. Vader – O portal continua a não funcionar… Um dos cientistas foi até ao Auditório A, passa por lá e descobre o que se passa.

Ao chegares ao local ouves um barulho, que provavelmente vem de uma máquina a trabalhar, mas a porta está trancada…

* A porta encontra-se bloqueada por uma adivinha! Se eu receber 1 cêntimo no primeiro dia de um mês com 30 dias, e a cada dia seguinte receber o dobro do anterior, quantos euros tenho que recebe no final do mês?

```
(define (desbloqueia-porta dias-restantes valor-diario)
  (if
   (<= dias-restantes 1)
   valor-diario
   (+ valor-diario (desbloqueia-porta (- dias-restantes 1) (* 2 valor-diario)))
   )
  )
```

Cientista Maluco – Hahahaha! Chegaste tarde de mais, esta máquina vai fritar todos os dispositivos eletrónicos no raio de 1Km e nunca vais voltar ao teu tempo! Este projeto tem que ser parado!

Sentes um arrepio por todo o teu corpo, os teus pêlos levantam todos e do nada o cientista é atingido por um choque elétrico proveniente da máquina que o deixa inconsciente.

Dr. Vader – Parece que tínhamos um traidor no projeto, provavelmente contratado pelos americanos para que consigam descobrir a viagem temporal primeiro... Ele deve ter sabotado intencionalmente os supressores de ruído para que o projeto nunca funcionasse e como os corrigiste ele tomou outras medidas. A máquina que se encontra à tua frente é um EMP, esta máquina é capaz de enviar um pulso eletromagnético, que queima todos os circuitos elétricos num raio muito grande. Hackeia a máquina para evitares que isto aconteça!

1. * Para parar a máquina é necessário criar um código capaz de somar os 3 numeros que a máquina gera! Mas só se podem somar quando certas condições ocorrem. Dando 3 números, a, b e c, calcula a + b + c no caso de a>b>c ou c>b>a. No caso de nenhuma das 2 condições acontecer, a resposta tem de ser zero.

As operações lógicas são not, or, and.

```
(define (conta a b c)
  (if
```

```
    (or
     (and
      (> a b)
      (> b c))
     (and
      (< a b)
      (< b c)))
    (+ a b c)
    0)
    )
```

Dr. Vader – Muito bem, evitaste que todo o projeto acabasse com essa sabotagem. No entanto parece que ainda há alguma interferência eletromagnética dentro do campus. Talvez te tenha escapado algum supressor… Estamos a correr um teste diagnóstico para identificar o edifício…

Dr Vader – O teste não foi capaz de o localizar. Suspeitamos que exista um edifício dentro do campus que não deveria estar aqui... Temos alguns possíveis locais... Suspeitamos que o local esteja escondido atrás de algo, dai não o termos visto mais cedo. Mas não temos como saber… Encontra-o!

*OPCÕES: 5(+/-) locais no mapa em loop com exercícios. Procurar a Faculdade de Nutrição*Dr. Vader - Talvez seja este o local... Resolve o problema para descodificar o sinal que aqui se encontra! *

```
(define (area-triangulo base altura) (* 1/2 base altura))

(define pi 3.14159265359)

(define (area-circulo raio) (* pi (* raio raio)))

(define (area-retangulo comprimento largura) (* comprimento largura))

(define pi 3.14159265359)

(define (area-elipse raio-horizontal raio-vertical) (* pi (* raio-vertical raio-horizontal)))

(define (area-quadrado lado) (* lado lado))*
```

Dr. Vader – Não era este o local… Mas parece que havia alguma informação no sinal… “o mais N de todos|letra em falta|zona dos departamentos”. Continua a procurar. *

Dr. Vader - Descobriste o local! Este edifício é a Faculdade de Ciências da Nutrição e Alimentação da Universidade do Porto... Não fazemos ideia o que ele faz aqui...

Dr. Vader – A falta de identificação poderia causar anomalias no portal, pelo que foi necessário identificá-lo antes que se tornasse problemático. Desloca-te até ao local assinalado no mapa. Com o portal pronto e todos os erros corrigidos vamos enviar-te de volta para o teu tempo!

* Bem-vindo à zona central do edifício B. Neste decorrem a maior parte das aulas. As 3 salas à tua frente são os anfiteatros B001, B002 e B003. Também são conhecidos como os "queijos". Em todo o campus da FEUP a nomenclatura das salas começa pela letra correspondente ao edifício em que se encontra, de seguida o número correspondente ao andar (-1,0,1,2,3) e os 2 últimos dígitos correspondem ao número da sala. Os números começam a conta do lado oposto à entrada principal e seguem uma ordem ascendente até ao fim do corredor. *Dr. Vader - Vamos abrir o portal onde te encontras. Boa sorte! Espero que tenhas gostado de 2017! Mas antes de ires para abrir o portal é preciso selecionar a chave..."* Como se cria uma lista em Scheme? (1 2 3 4 5), (list 1 2 3 4 5), (list (1 2 3 4 5))

Operações em listas: length, equal?, car, cdr, cons, list, append, null? * Vês uma luz a surgir no teu redor mas tão depressa apareceu como desapareceu…

Dr. Vader - Parece que o portal falhou... Temos informação de 4 possíveis causas do problema... Escolhe um dos locais para testar a solução...

*P1(Eng Civil) – Dr. Vader – Bem-vindo de volta ao departamento de Engenharia Civil. Parece que a interferência magnética não ficou bem bloqueada. Talvez seja preciso ativar um aparelho suplementar capaz de bloquear a interferência! Para isso é preciso ativar a máquina que se encontra à tua frente. Como se comparam duas listas a e b em Scheme? (equal? a b)

```
(define listaA '(1 2 3 4 5 6 7 8 9 0))

(define listaB (list 1 2 3 4 5 6 7 8 9 0))

(define (listas-iguais l)

  (if (equal? listaA listaB)

      (if (equal? listaA l)

          #t

          #f)

      #f)

  )
```

este exercício é complementar e opcional*

Dr. Vader - A interferência parou, mas o portal continua a não funcionar. Talvez um dos outros locais resolva...

P2(CICA) - Dr Vader – Bem-vindo ao CICA. Este local é o Centro de Informática Prof. Correia Araújo. Neste local encontram-se os servidores principais da FEUP. Estamos a detetar uma possível falha num deles que pode ter afetado o portal. Corrige o erro do servidor... (define (pesquisa elemento lista)

(letrec

((aux

(lambda (i lista)

(cond

((null? lista) #f)

((equal? elemento (car lista)) i)

(else

(aux (add1 i) (cdr lista)))))))

(aux 0 lista)))*

Dr. Vader - O servidor está a sobreaquecer! O código devia estar a funcionar mal intencionalmente para evitar a sobrecarga das máquinas... Sai dai o mais rápido que puderes!

*(sala I220) Dr. Vader - Parece que perdemos o servidor juntamente com todos os dados que nos permitiam abrir os portais. Aparentemente vais ficar por aqui durante muito tempo... Talvez decisões diferentes te tivessem levado de volta ao teu tempo.

*P3(INESC) – Dr. Vader – Bem-vindo ao INESC TEC. Este local é um centro de Investigação que emprega mais de 700 investigadores. É com o financiamento deste centro que levamos a cabo a investigação sobre a viagem temporal. Detetamos um erro de autenticação que poderá influenciar o nosso portal por falta de dados. Corrige o problema. * (define (pesquisa elemento lista)

(letrec

((aux

(lambda (i lista)

(cond

((null? lista) #f)

((equal? elemento (car lista)) i)

(else

(aux (add1 i) (cdr lista)))))))

(aux 0 lista)))

Dr. Vader - Parece que o portal está funcional, mas temos um alcance menor do que pensávamos. Vem até a sala I220 para retornares a 1958.

*Dr. Vader - Espero que tenhas gostado de explorar o campus da FEUP. Boa viagem de volta e que tenhas uma vida próspera.

*P4(INEGI) Dr. Vader - O INEGI, Instituto de Ciência e Inovação em Engenharia Mecânica e Engenharia Industrial, criado pelo departamento de Mecânica em 1986, é um centro de investigação e tem mais de 200 colaboradores. Neste local detetamos uma interferência relacionada com a altura do edifício. Tenta redirecionar as antenas para que não bloqueiem o sinal. * (define (pesquisa elemento lista)

```
  (letrec
      ((aux
          (lambda (i lista)
            (cond
              ((null? lista) #f)
              ((equal? elemento (car lista)) i)
              (else
               (aux (add1 i) (cdr lista)))))))
    (aux 0 lista)))
```

Dr. Vader - Parece que conseguiste... Desloca-te até às nossas instalações, na sala I220, para te enviarmos para o teu tempo.

*Dr. Vader -Boa sorte e que sejas feliz até ao último dos teus dias.

Após uma forte luz acordas num ambiente desconhecido e com um aspeto velho. Ficas a pensar que talvez as antenas não tenham ficado corretamente alinhadas... ou talvez devesses ter escolhido explorar outro dos problemas… Ouves um barulho e viras-te para trás... Está um homem a cavalo vestido com uma armadura com uma cruz vermelha a olhar para ti e a gritar "habentis maleficia"... "Feitiçaria".

Appendix B

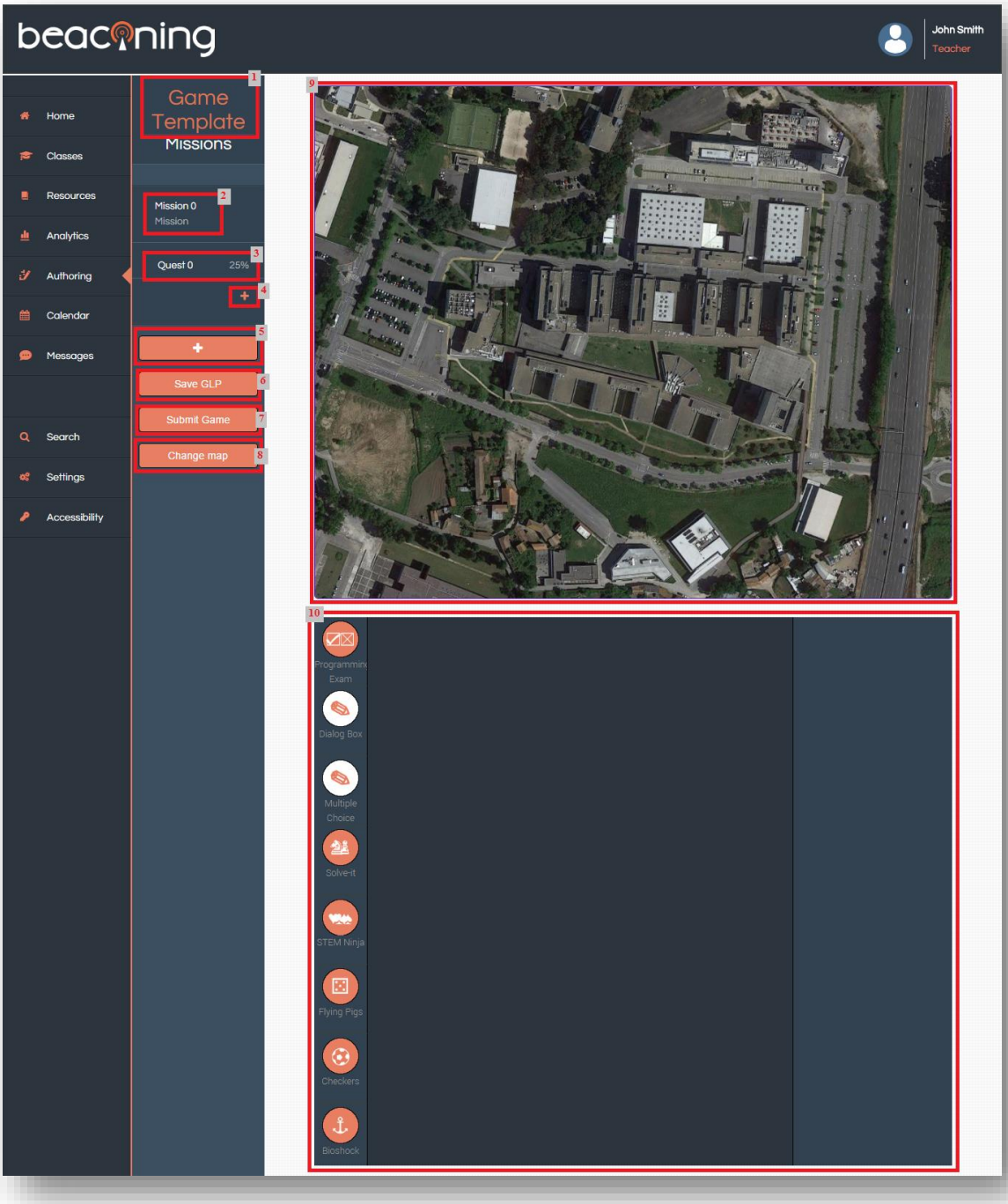
Game Jam Tutorial

Authoring Tool tutorial

Go to http://94.63.116.6:8079/glp/create to create a new game.

Your game ID is already in the URL. Remember it so you can edit later.

Left click the Mission 0 and then the Quest 0. This is the view you should be looking at:



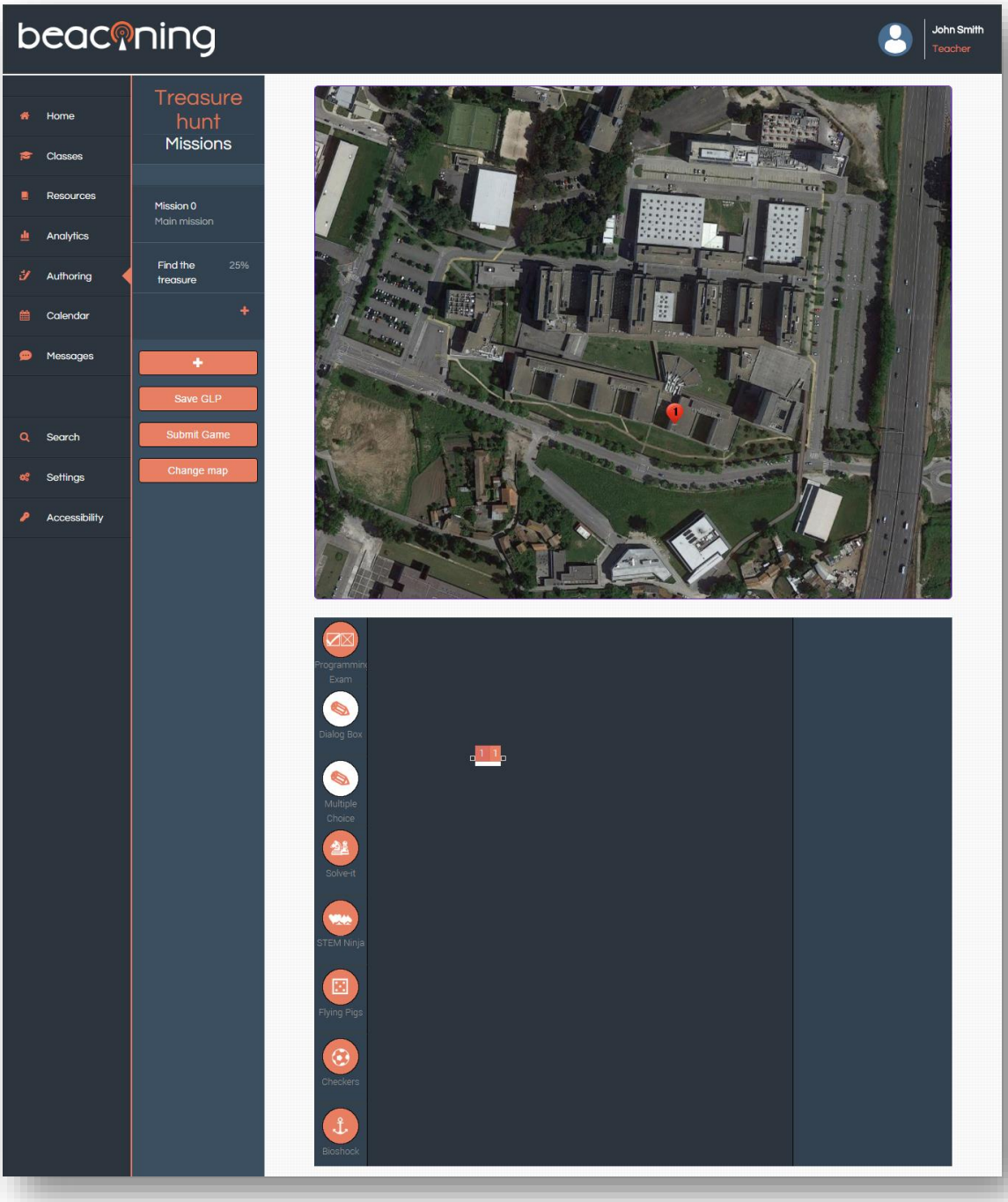
Right click [1] and change the game name to “Treasure hunt”. Notice it is the game name that identifies the game.

Right click [2] and change the mission name to “Main mission”.

Right click [3] and change the quest name to “Find the treasure”.

Now left click on the map (9) to create a pin on the map and a corresponding node on the graph.

This is the view you should be looking at:



Move the pin to the location given in the image.

Now left click the node 1 and change its name to “B107”.

Now drag a *Dialog box* from the left list and drop it on top of node 1.

Left click the dialog box. The details should came up at the right. Copy paste the following text to the dialog box:

“Welcome to the Treasure hunt game! You will have to hunt down the treasure that is hidden by clues. A fellow mate found a lost scroll with some information. Go see him next to Library.”

Now left click in some random place on the map and on the library. Rename node 3 to “Laat” and node 2 to “Fake node”. Also make sure you uncheck the “Execute once” in the *Fake Node*.

Add a dialog box to node 3 and copy paste the following text there:

“Welcome! My name is Laat, I have a scroll but before I give it to you I will need some proof that you are allowed to read it. Answer three questions correctly.”

Add three *Multiple choice* to the node and make the following exercises:

1) What weights more, 1Kg of gold or 1Kg of water?
    a) The gold
    b) The water
    c) They weight the same (correct answer)
2) Two numbers, one one way the double, the other way the same.
    a) 2 3
    b) 4 6
    c) 5 7 (correct answer)
    d) 7 9
3) Thirty white horses on a red hill, first champ, then stamp, and then stand still.
    a) Birds
    b) Teeth (correct answer)
    c) Ants
    d) Larvae

Now create a new node at left of library and name it “Scroll”, also make sure you uncheck “Execute once”. Add a dialog box to the node and copy paste the following text:

“Three of us we are. Inside us a lot fall but many grasp. In the last sunlight, your greed shines.”

Now create a new pin above room B001 and rename the node to *B001* and make it hidden.

Add a dialog box to node 5 and paste there: “At the last sun ray a handle shone, you opened it and inside there is a box that needs a key. Maybe someone have it?”.

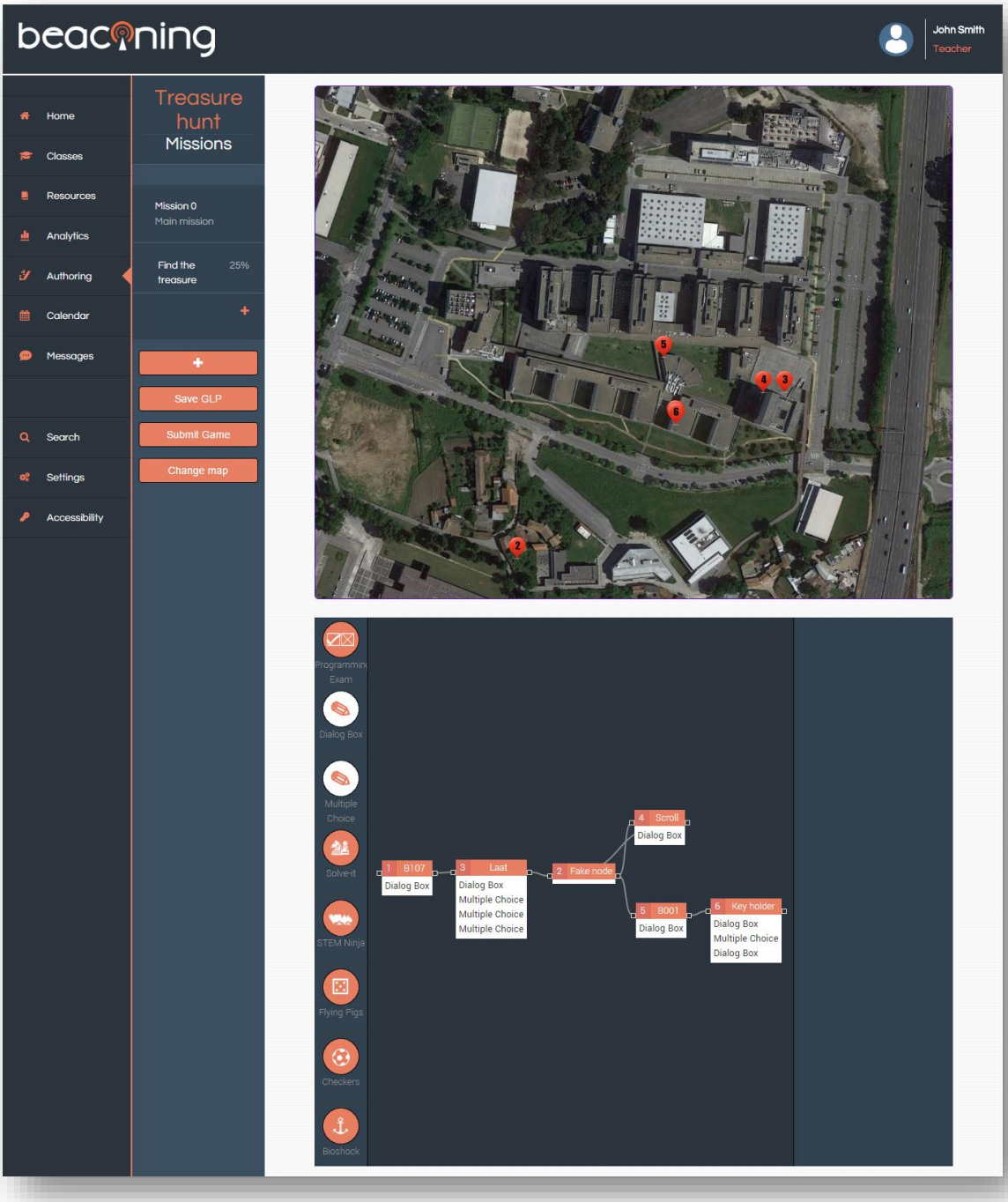
Add now a new pin and move it to top of node 1. Rename the node to *Key holder*.

Add a dialog and paste: “Hello my name is Lucio. I can give you the key to that box you carry there. Mind to solve a riddle for me?”. Now add a *Multiple choice* as follows:

1) Poor man have it, rich men want it.
    a) Gold
    b) Time
    c) Happiness
    d) Nothing (correct answer)

Now add another dialog to the node and paste “Congratulations, you unlocked the box and obtained the treasure.”.

Connect Nodes 1-3-2 and then connect Node 2 to 4 and 5. Connect node 4 back to 2 and 5 to 6. Your game should now look equal to this:



The game flow is explained as follows:

The player has the initial text with the point on room B107. Then he is required to go to Laat where he must solve 3 problems. After that he has the scroll and a hidden pin. The scroll

contains the clue to where is hidden treasure is, since the scroll has execute once = false, it can be read several times. Once the secret pin is found player must return to room B107 and complete a quiz to end the game.

Now go to http://94.63.116.6:8079/getGame on your mobile phone and play the game!

Appendix C

Authoring Tool Documentation

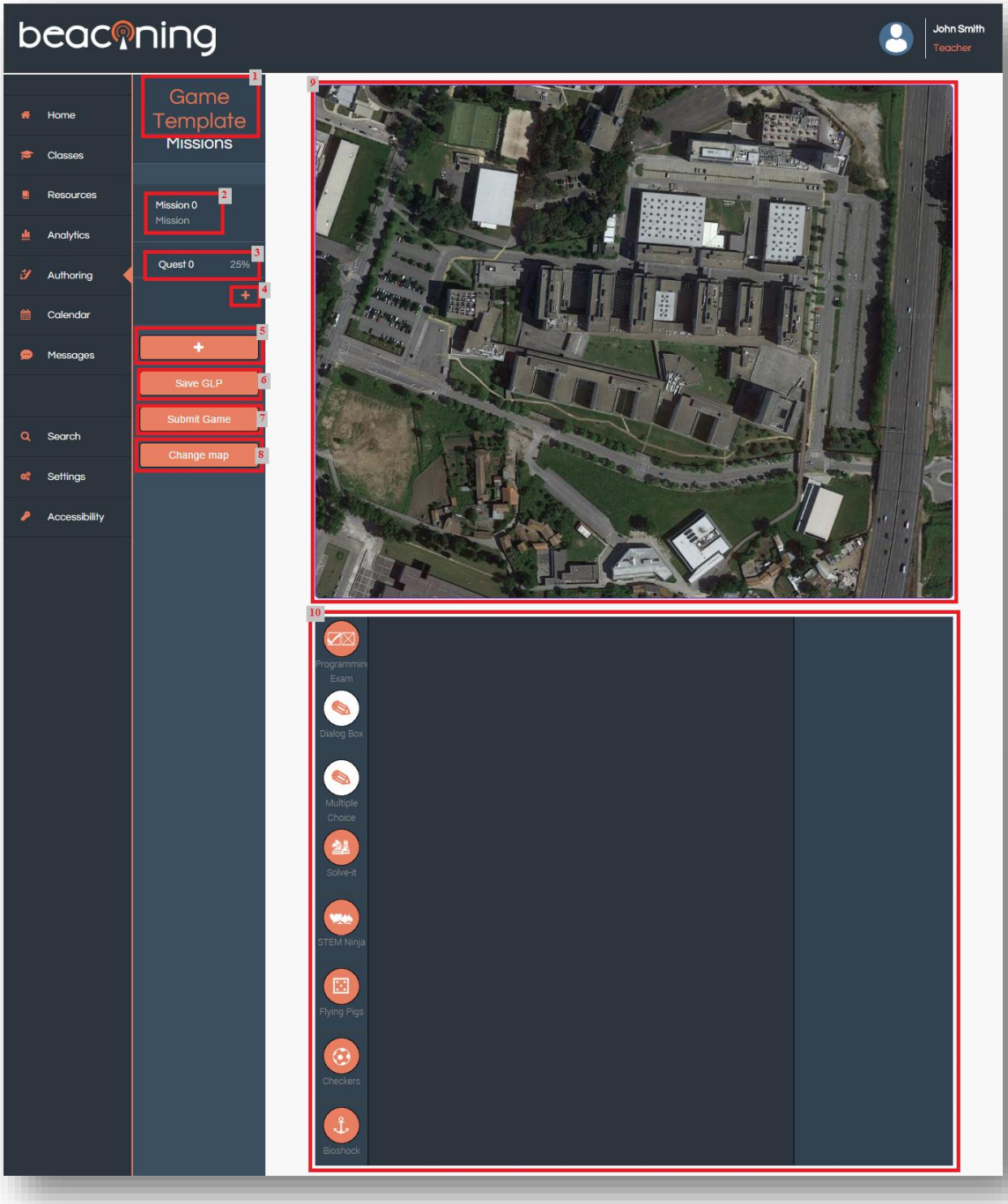
Authoring tool

Documentation

We are considering the URL *seriousgames.fe.up.pt* as being the base url, but this can change by the time you are reading this document.

To create a new Gamified Lesson Plan (glp) one must go to *seriousgames.fe.up.pt/glp/create*. The url of the page will then change to *seriousgames.fe.up.pt/glp/ID* where ID will be the id of the new GLP.

Once inside the AT of the GLP we will have the default game, with one mission, one quest and nothing in the challenges.



It is possible to right click the game name (1), the missions name (2) or the quest name (3) to edit its details.

The small + button (4) adds a new quest to the mission it is insert in. The ID can be ignored.

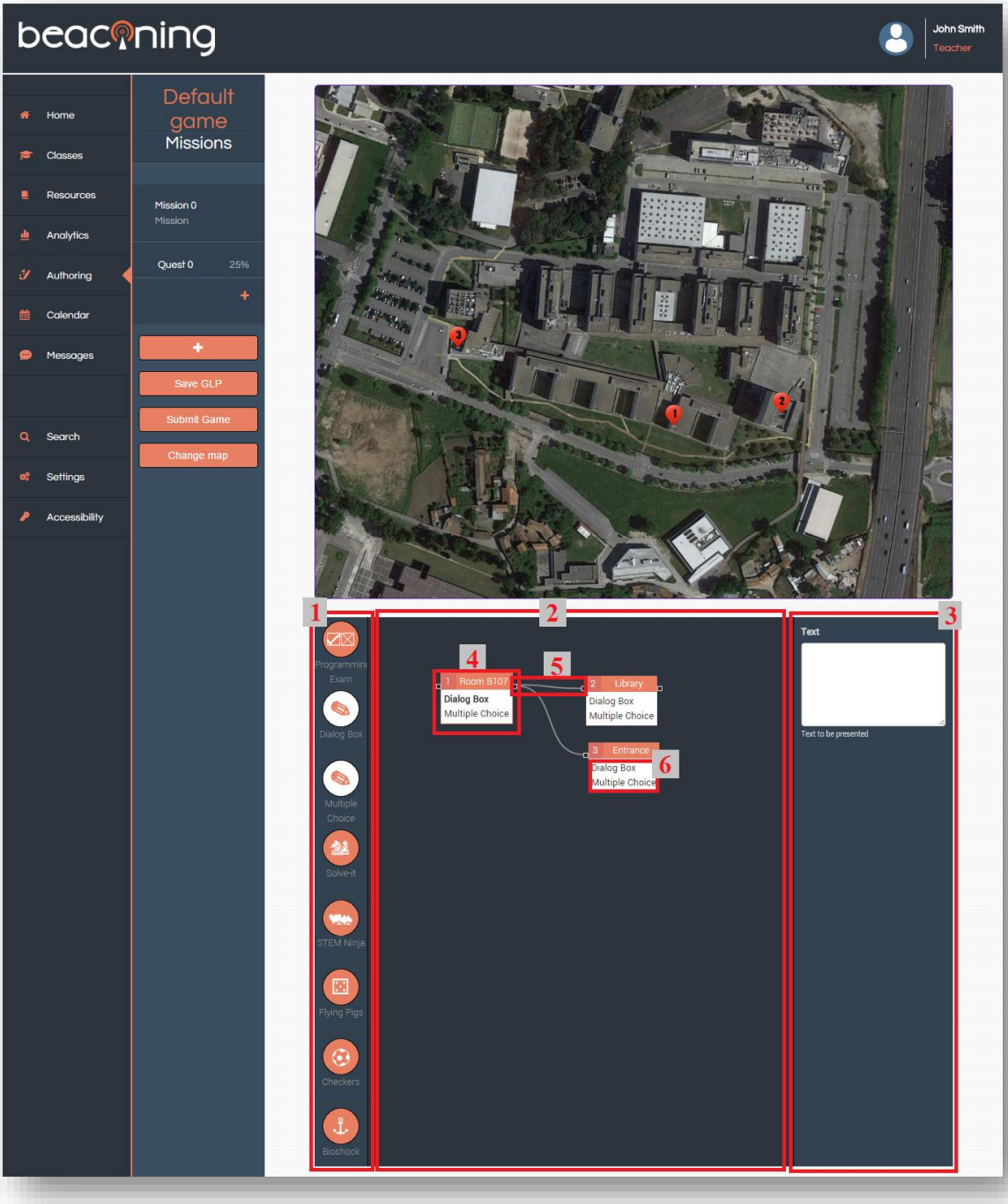
The + button (5) adds a new mission to the game. The ID can be ignored.

The Save GLP button (6) saves the current GLP and any opened challenge and graph (10).

The Submit Game button (7) submits the game to be played on android game and gives the ID for the game. Notice that games have unique Names, so if you change one games name, you will be overriding the existing game with that name, so please avoid using common names.

The Change map button (8) allows the edition of the map (9) to a give URL plus the coordinates of the top left point and the bottom right point.

To create a new node in the graph plus a pin in the map one must left click the map (9). A Pin and a node will be created with a number to identify which pin each node belongs to.



It is possible to move pins around in the map with left click and drag.

To remove a pin and its corresponding node one must right click either in the node (4) or in the pin.

Once a node (4) is create on the graph canvas (2), it is possible to rearrange its position by left click drag.

To add a dialog box or a multiple choice one must drag and drop them from the Minigames list (1) to the node (4). Once dropped a line with its name will be presented in the minigames list (6). If one left click the name, the edit pane (3) will load its current configuration and make it possible to edit. Notice that a node without any content inside will be skipped by the game since it is “complete”, and will be always considered that it was the player that completed them, so the node after that one will always be selected.

To remove one of this minigames from the list just right click it.

Notice the other minigames are not relevant to the actual state of the game since most of them don’t work.

Once several nodes are presented in the graph, they need to be connected to represent the game flow. To do this one must click one of the squares in the nodes and connect it to another node. The left square means input, and the right one means output. Every node that has no input is considered a starting node and every node that has no output is considered an ending node.

To remove a connection one must right click it.

Once several quests / missions are presented in the game, the first quest from the first mission have starting nodes and only the last quest from the last mission will have ending nodes. Every ending node from a quest will be connected to all the starting nodes of the next quest.

It is possible to have several nodes connected to both the input and the output, and the author can have cycles.

Notice that a game without nodes with inputs free or games without nodes with output free is unplayable, since you will either not have nodes to start or not have nodes that end the game. Or both. To avoid this, one can create a “fake” node as a starting point and a “fake” node as an ending point and connect all the starting points to the start node and all the ending points to the end node.

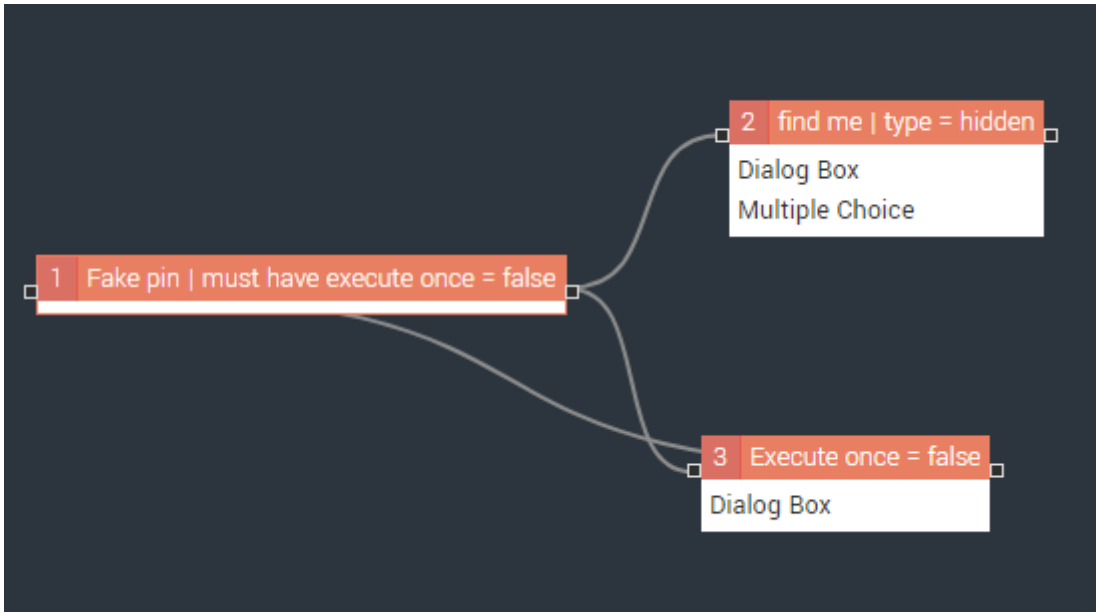
To change the node/pin (4) name one must left click it. The name in the node will be showed both in the graph and inside the game on the pin location. There is also the option to change the pin type, which will affect if the pin is visible once active or only when active and the player is near him, meaning a hidden pin is a pin that only appears on map once you found him. The last option, “execute once”, means a pin will be executed one time and will never be playable again, even if the graph reached the point again. An example of a pin that don’t execute once would be a point in the game where there is someone giving you and information and you need to find a hidden pin, so you want the player to always have that information, otherwise the pin would disappear and the player could forgot the “hint” to find the location.

Examples

One “fake” node that just makes it simpler to connect other nodes in a cycle, this node must have execute once = true, otherwise game breaks.

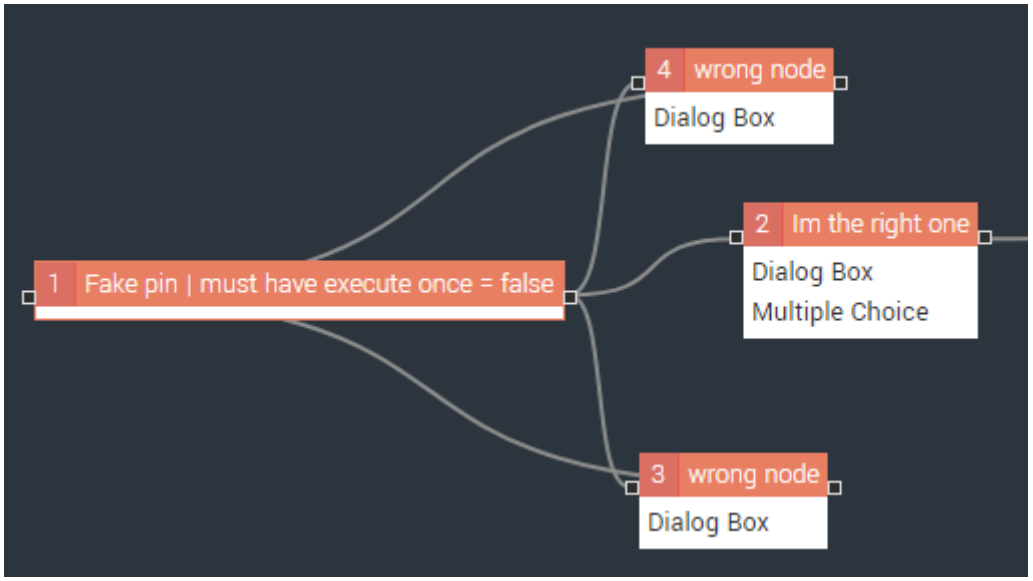
One hidden pin that the player must find.

One pin that will be always present until the player finds the hidden pin.



This is a situation where one would have to find a place and have someone or something that gives a clue, so player can open the clue as many times as he desire.

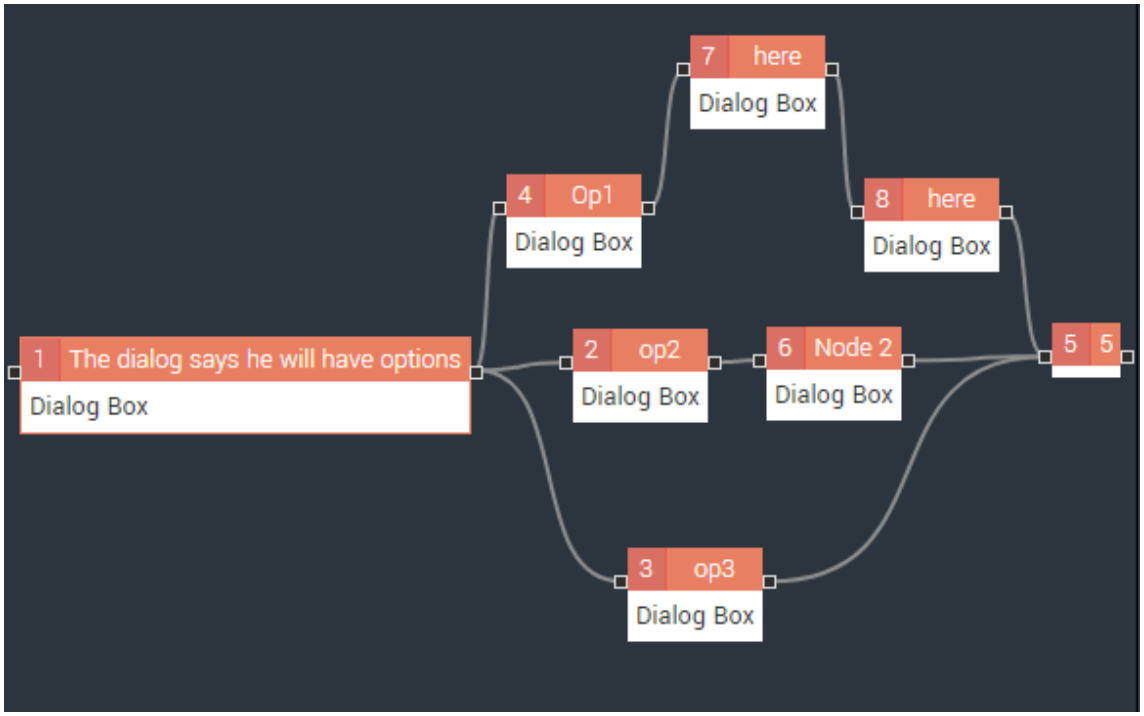
One fake node, two wrong nodes that execute once and one right node that makes the player move forward in the story.



An example of this would be a player that must find a treasure and he have 3 locations, he can go directly to the right one or he can fail and there will one less option left.

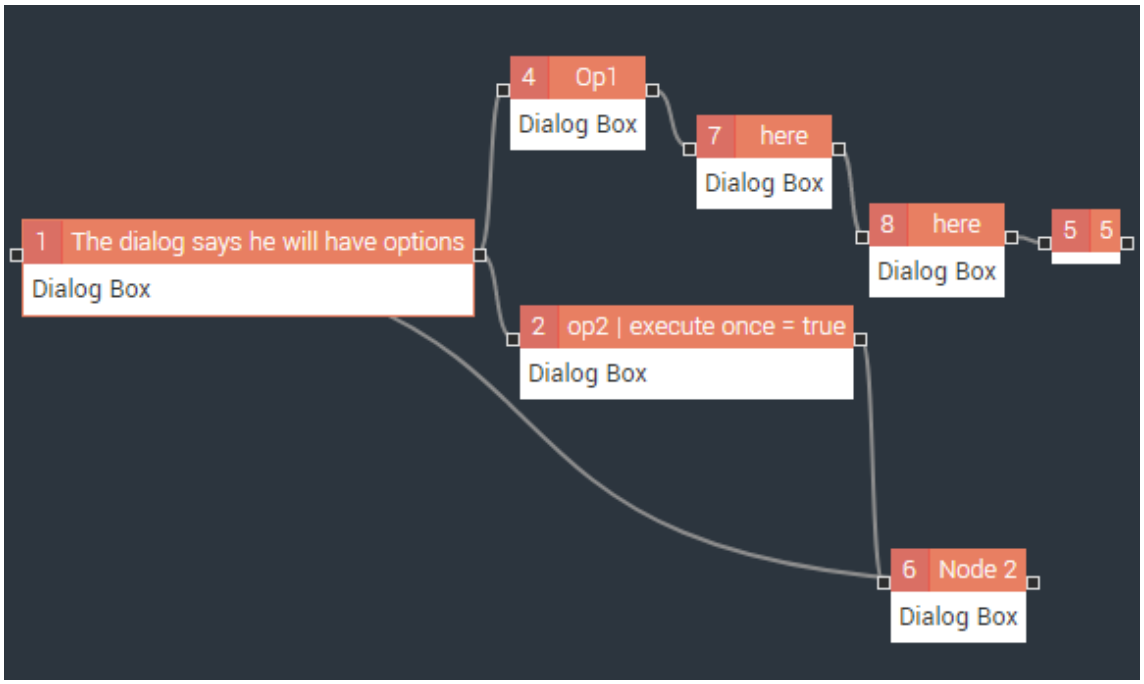
The wrong nodes had clues to which one is the right, they could have execute once = false, so that the player can reach them again to read the clue again.

In this example, there are several nodes, each one leading to a different path.



This is a case where the player must opt for one of the 3 nodes that will be presented and depending on which one he chooses there will be 3 different stories. Option 3 ends in the node he chose, option 2 have another node for him to reach before game ends and option 1 have 2 more points in the map he must reach. This allows side stories, giving each player a different experience when playing the game.

In this next example, there are 2 options after a dialog, which must have execute once = false. After that there is one option that leads to the end and one that leads back to the dialog.



This example is the same as the second but shows a more complex scenario. Because a player here has a dialog before opting, this could be a situation where a player would die for a bridge falling for example and go back to the state before the option just like a “respawn”, while having the bridge still collapsed.

Appendix D

Game Jam Consent Form

DECLARAÇÃO DE CONSENTIMENTO

(Baseada na declaração de Helsínquia)

No âmbito da realização do **Game Jam** intitulado **Location-Based Games for Teaching of STEM**, eu abaixo assinado, _____, declaro que compreendi a explicação que me foi fornecida acerca do estudo que irei participar, nomeadamente o carácter voluntário dessa participação, tendo-me sido dada a oportunidade de fazer as perguntas que julguei necessárias.

Tomei conhecimento de que a informação ou explicação que me foi prestada versou os objetivos, os métodos, o eventual desconforto e a ausência de riscos para a minha saúde, e que será assegurada a máxima confidencialidade dos dados.

Explicaram-me, ainda, que poderei abandonar o estudo em qualquer momento, sem que daí advenham quaisquer desvantagens.

Por isso, consinto participar no estudo e na recolha de imagens necessárias, respondendo a todas as questões propostas.

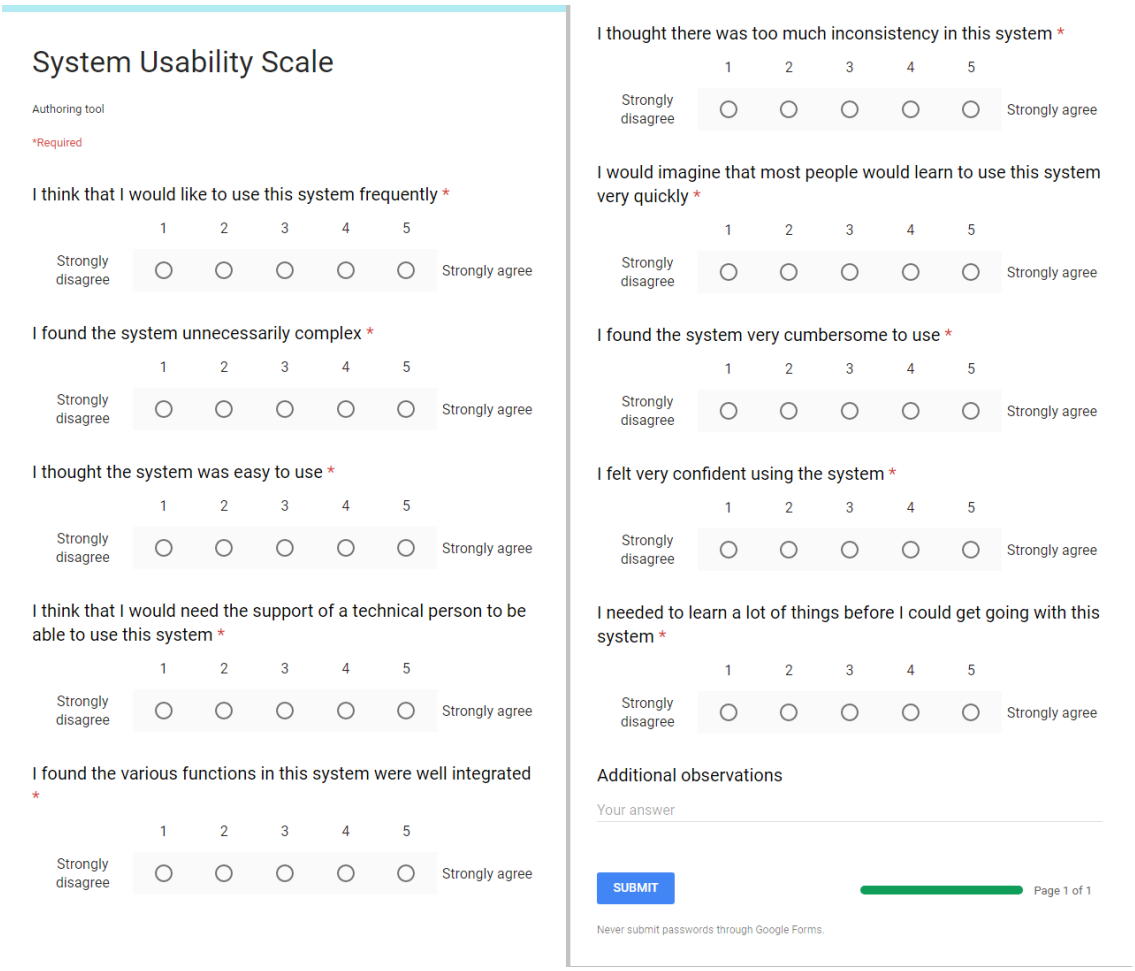
Porto, 12 de Junho de 2017

_____

(Participante ou seu representante)

Appendix E

SUS Form



System Usability Scale

Authoring tool

*Required

I think that I would like to use this system frequently *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I found the system unnecessarily complex *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I thought the system was easy to use *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I think that I would need the support of a technical person to be able to use this system *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I found the various functions in this system were well integrated *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I thought there was too much inconsistency in this system *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I would imagine that most people would learn to use this system very quickly *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I found the system very cumbersome to use *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I felt very confident using the system *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I needed to learn a lot of things before I could get going with this system *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Additional observations

Your answer

SUBMIT

Page 1 of 1

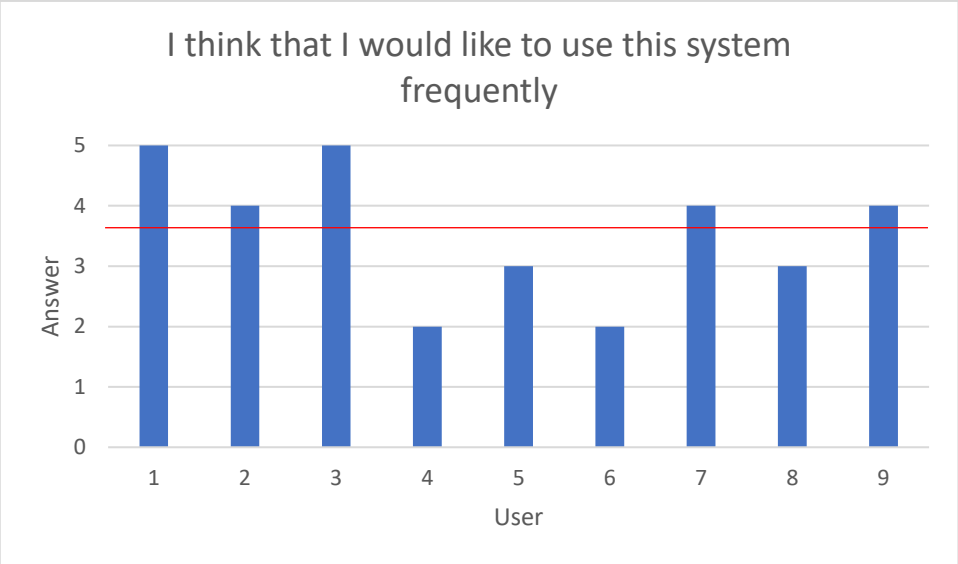
Never submit passwords through Google Forms.

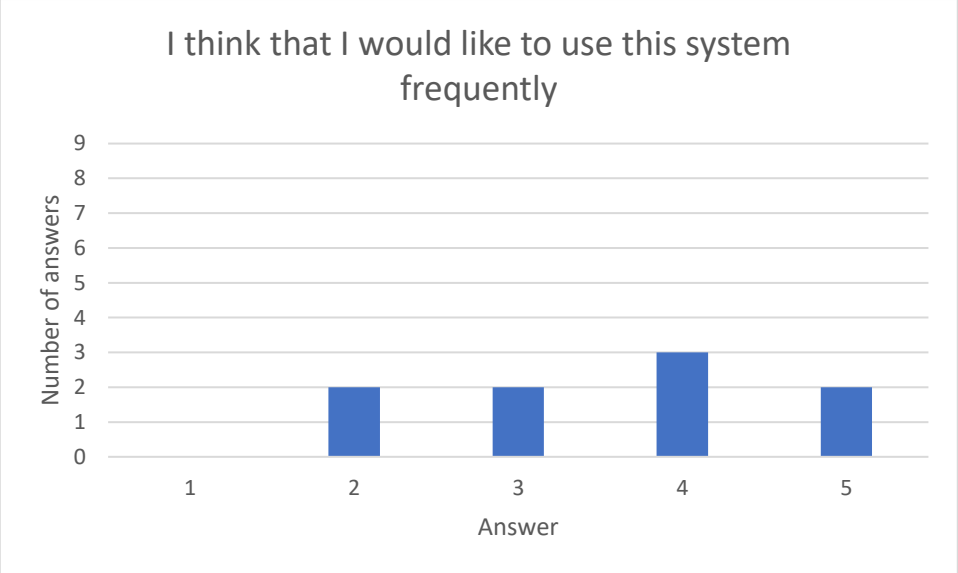
Appendix F

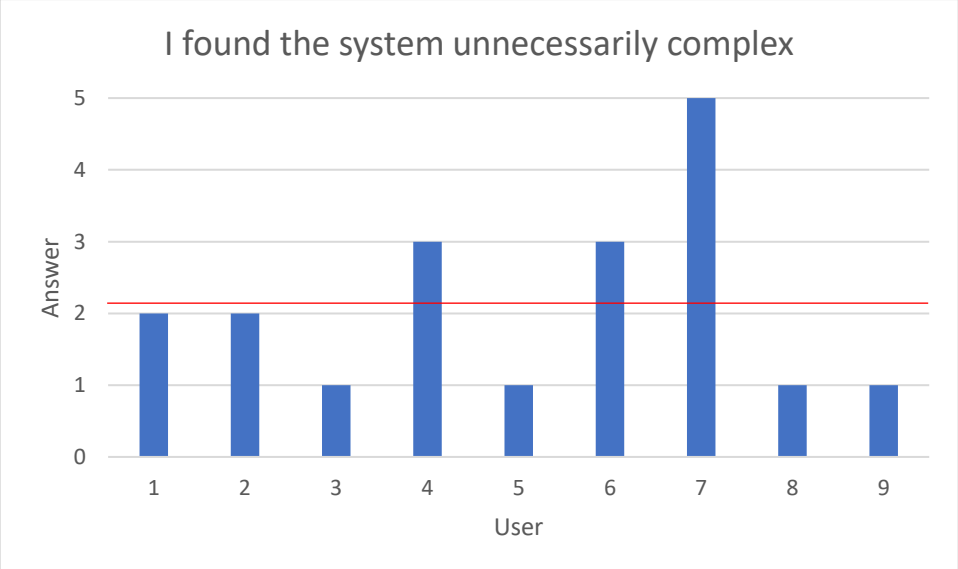
Game Jam Graphs

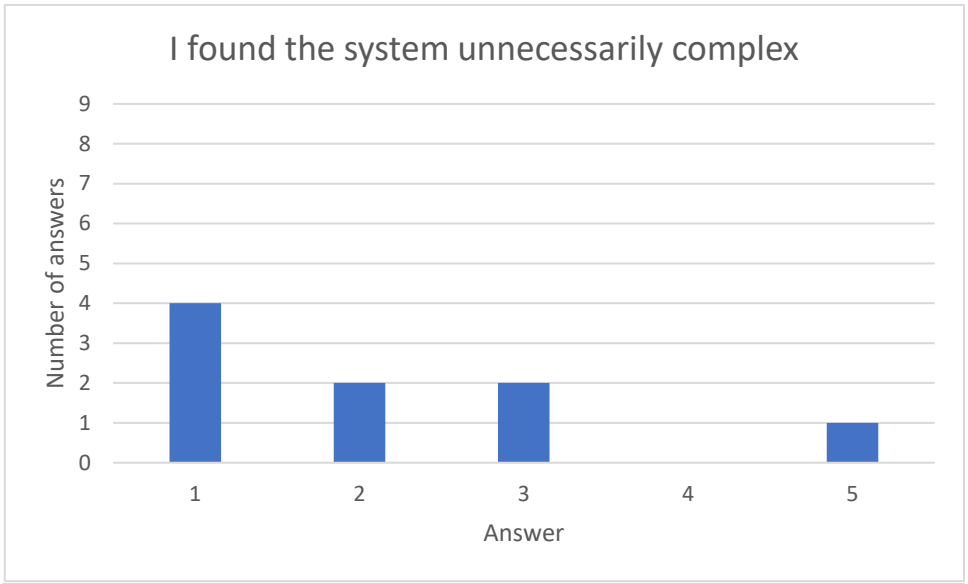
Authoring Tool

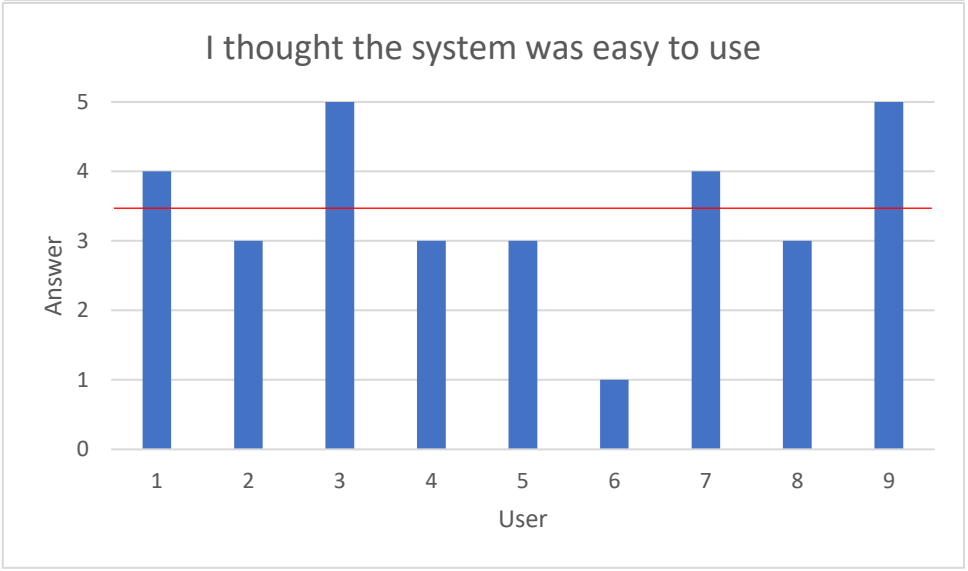
	Question										
Answer	1	2	3	4	5	6	7	8	9	10	SUS Score
1	5	2	4	2	3	2	4	2	4	4	70
2	4	2	3	1	3	3	5	1	5	1	80
3	5	1	5	2	4	3	5	2	4	3	80
4	2	3	3	3	3	3	4	3	2	2	50
5	3	1	3	3	3	3	2	3	3	2	55
6	2	3	1	4	3	3	4	3	1	2	40
7	4	5	4	1	2	1	4	5	4	1	62.5
8	3	1	3	4	3	3	2	3	2	1	52.5
9	4	1	5	2	4	4	5	2	3	1	77.5
Mean	3.56	2.11	3.44	2.44	3.11	2.78	3.89	2.67	3.11	1.89	63.06
Median	4	2	3	2	3	3	4	3	3	2	62.5

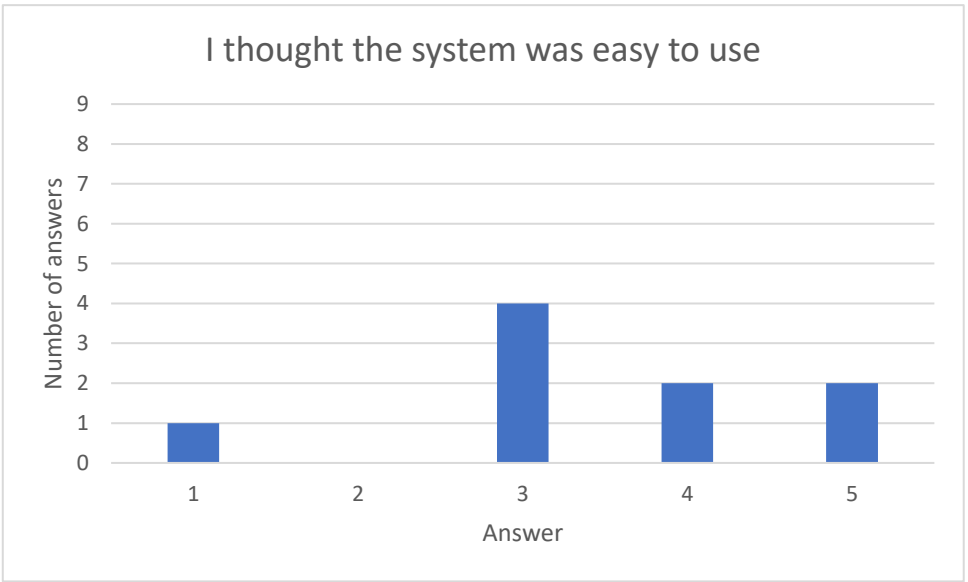

I think that I would like to use this system frequently
Answer
0
1
2
3
4
5
1
2
3
4
5
6
7
8
9
User

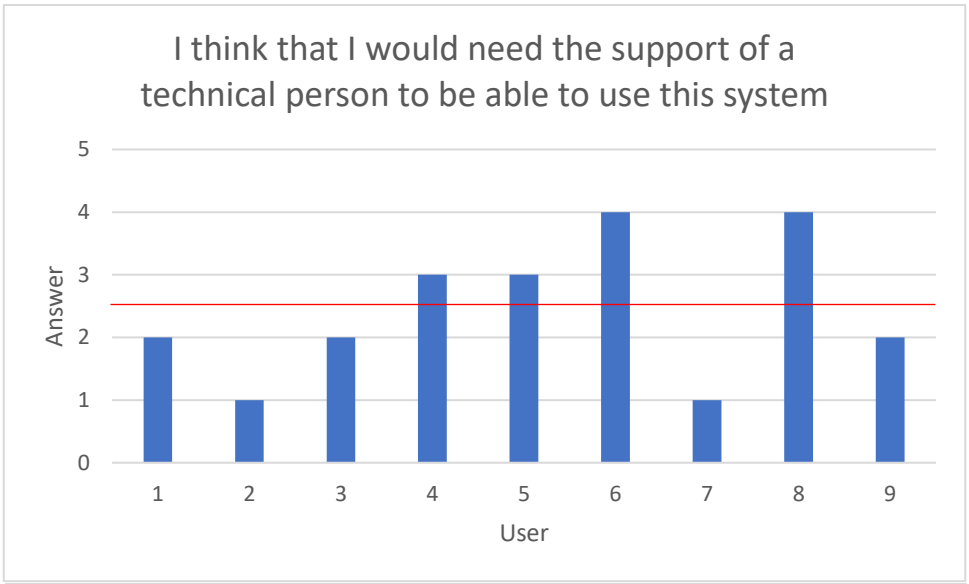

I think that I would like to use this system frequently
Number of answers
0
1
2
3
4
5
6
7
8
9
1
2
3
4
5
Answer

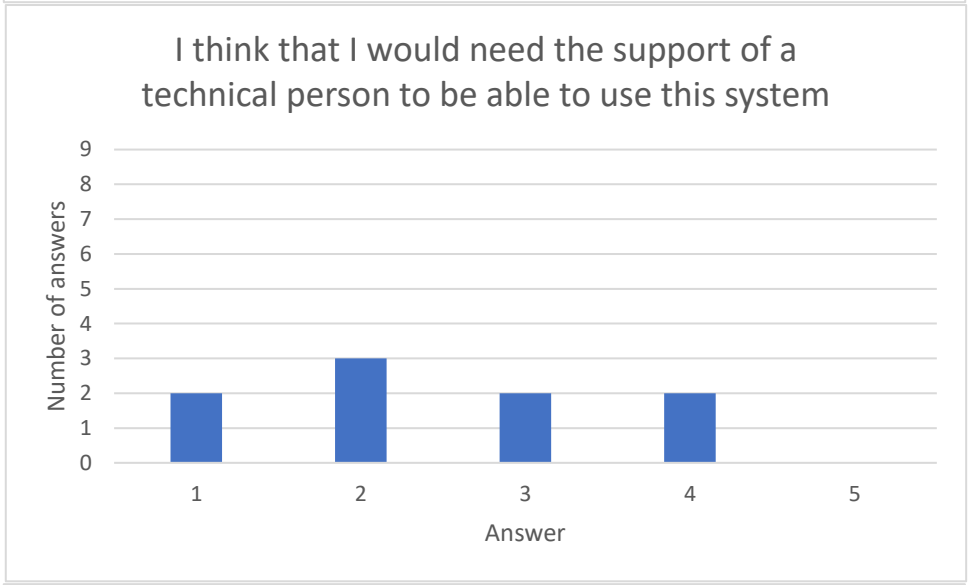

I found the system unnecessarily complex
Answer
0
1
2
3
4
5
1
2
3
4
5
6
7
8
9
User

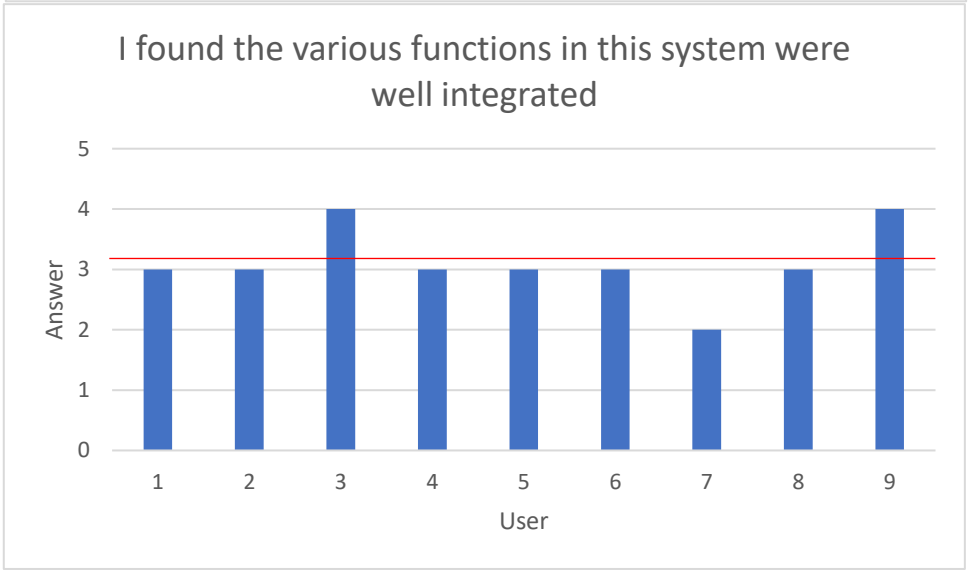

I found the system unnecessarily complex
Number of answers
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
Answer

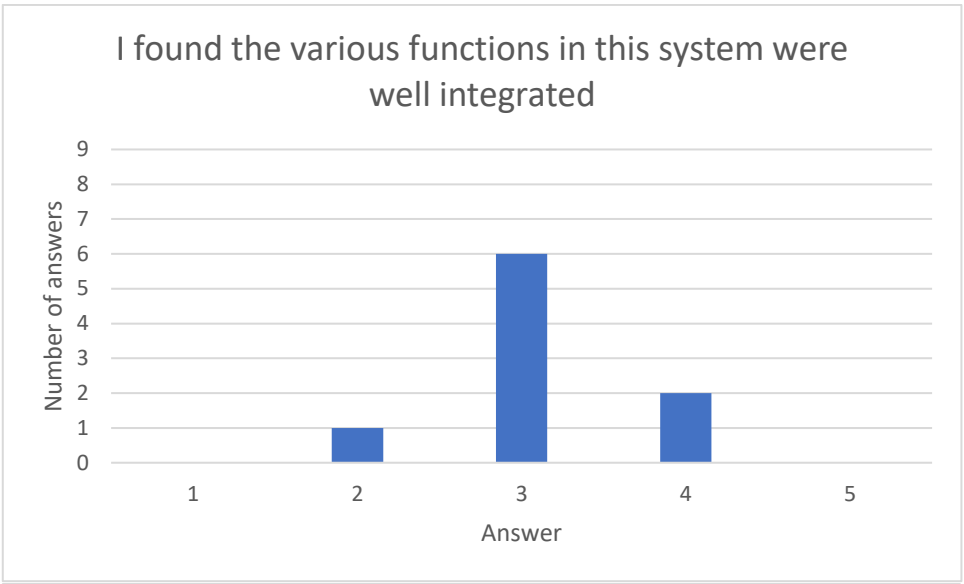

I thought the system was easy to use
Answer
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
User

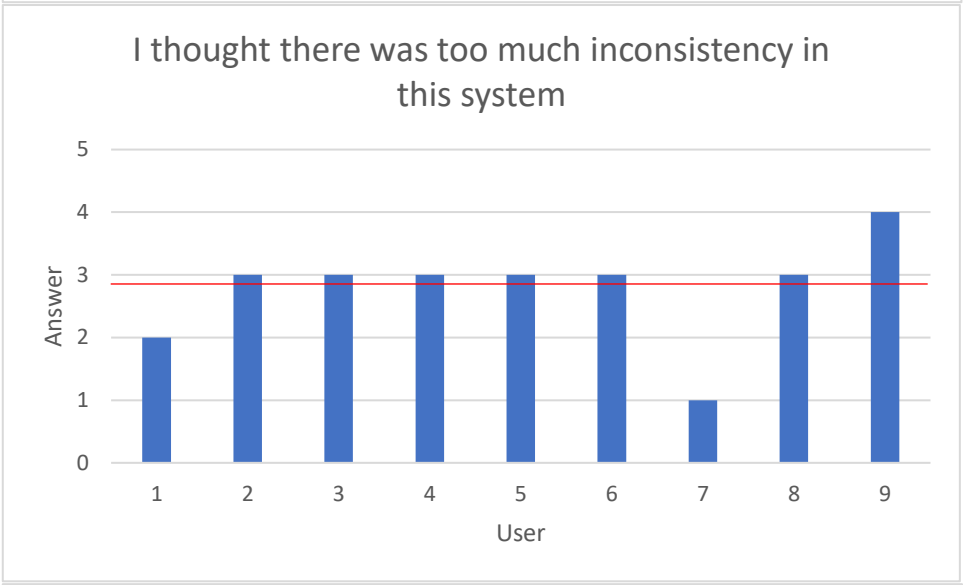

I thought the system was easy to use
Number of answers
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
Answer

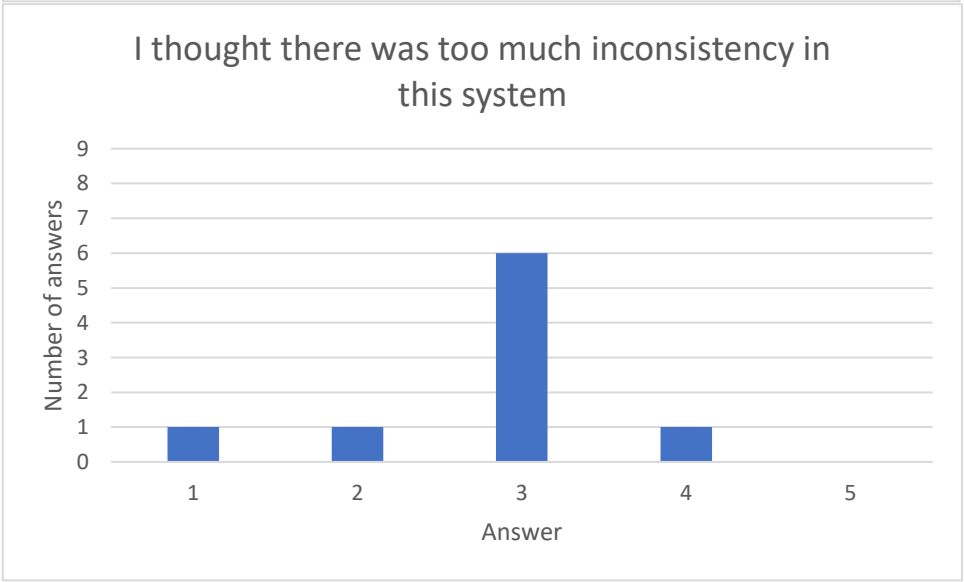

I think that I would need the support of a technical person to be able to use this system
Answer
User
0
1
2
3
4
5
6
7
8
9

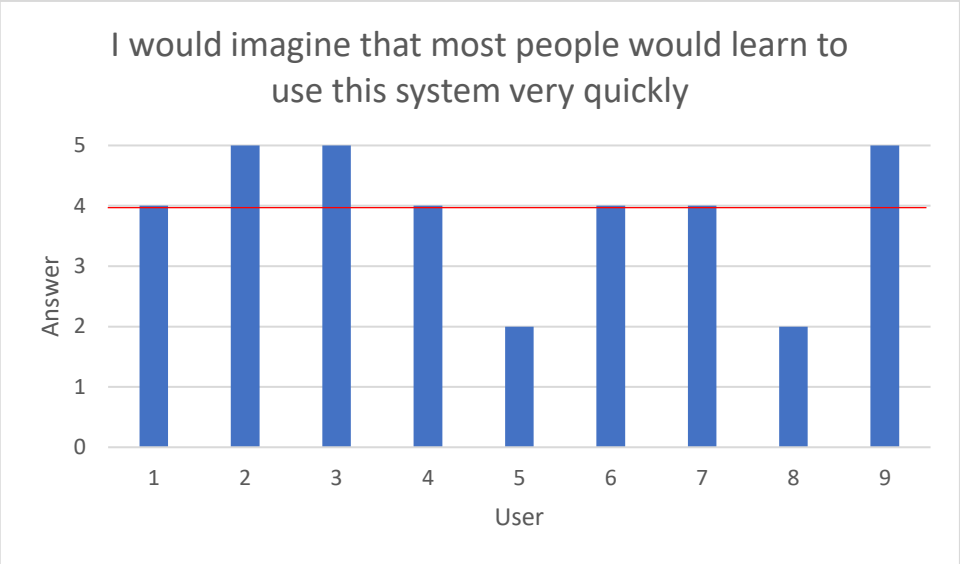

I think that I would need the support of a technical person to be able to use this system
Number of answers
Answer
0
1
2
3
4
5
6
7
8
9

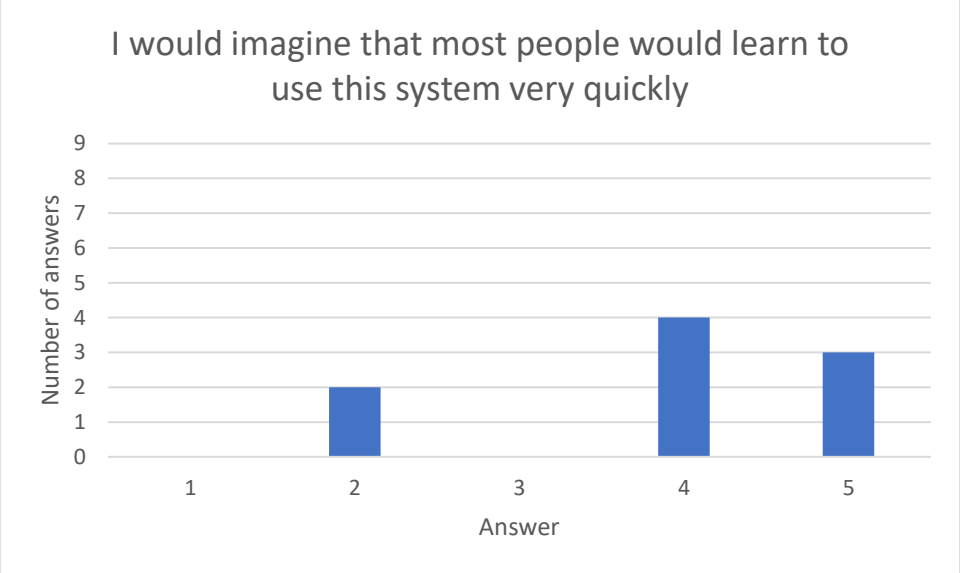

I found the various functions in this system were well integrated
Answer
User
0
1
2
3
4
5
6
7
8
9

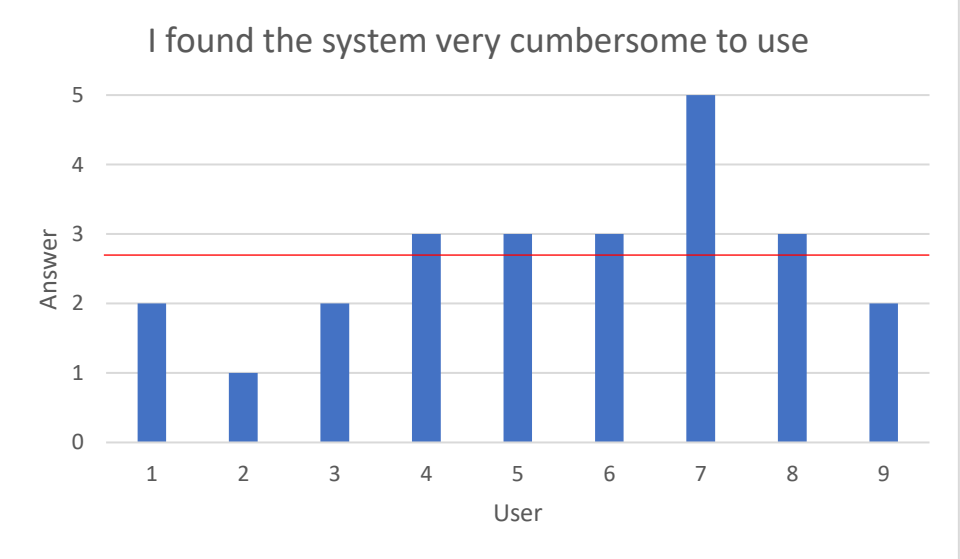

I found the various functions in this system were well integrated
Number of answers
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
Answer

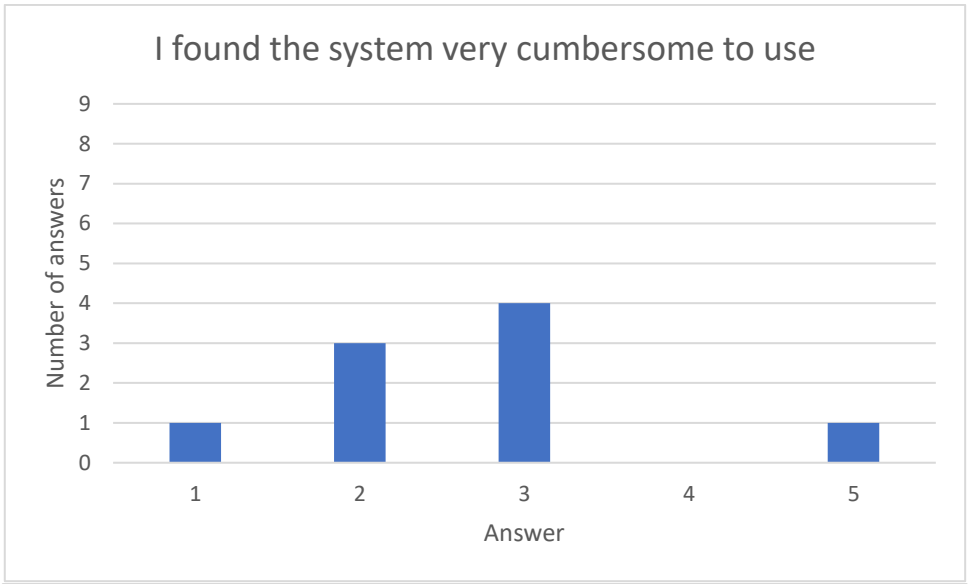

I thought there was too much inconsistency in this system
Answer
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
User

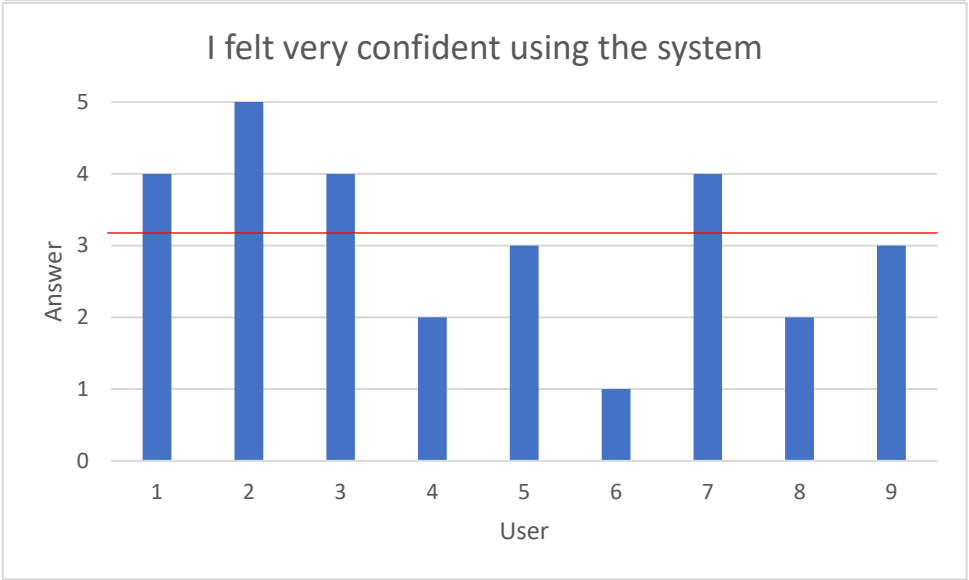

I thought there was too much inconsistency in this system
Number of answers
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
Answer

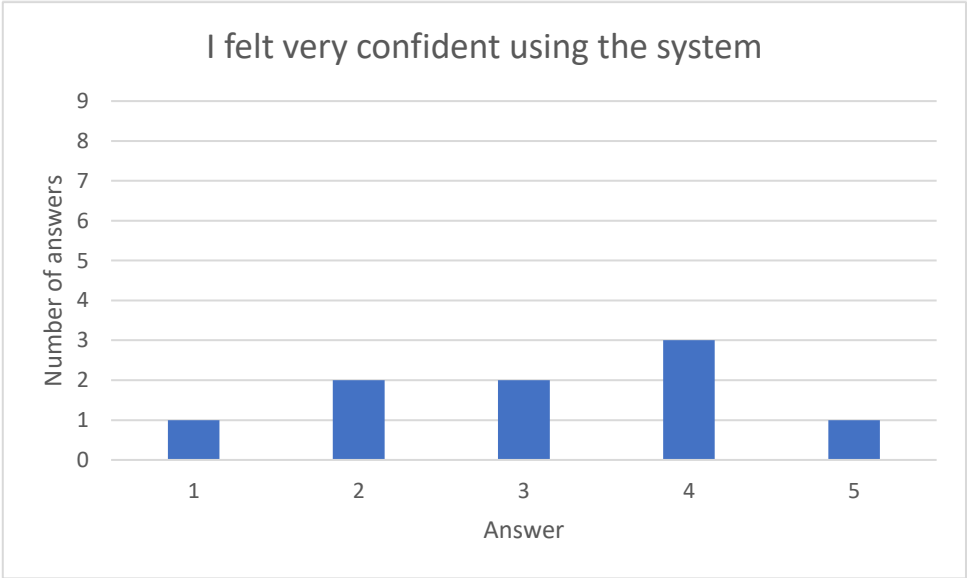

I would imagine that most people would learn to use this system very quickly
Answer
0
1
2
3
4
5
1
2
3
4
5
6
7
8
9
User

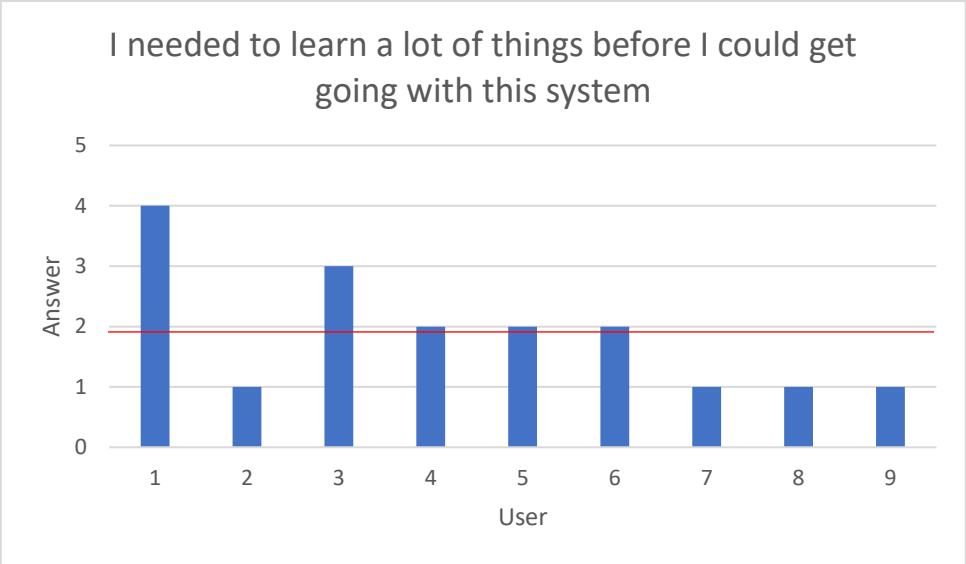

I would imagine that most people would learn to use this system very quickly
Number of answers
0
1
2
3
4
5
6
7
8
9
1
2
3
4
5
Answer

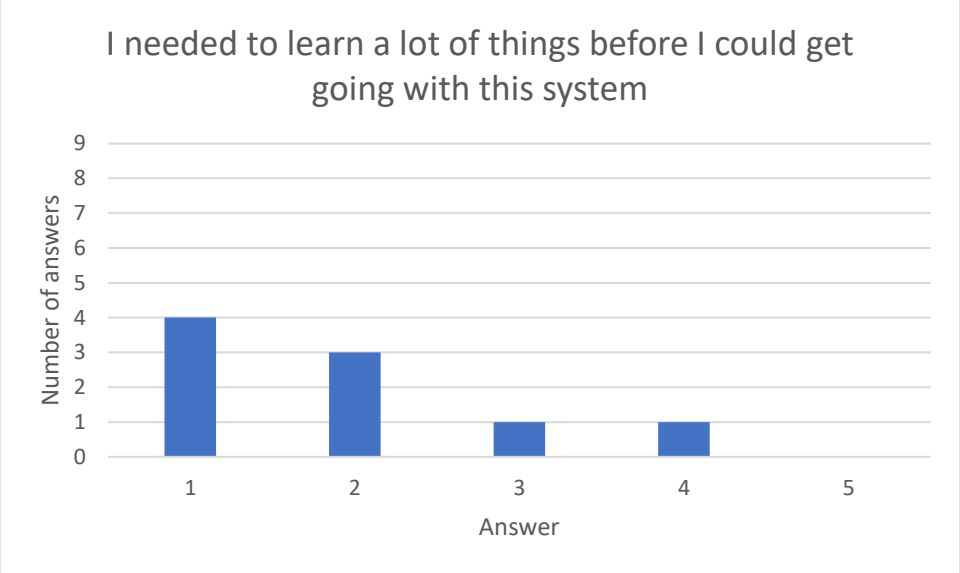

I found the system very cumbersome to use
Answer
0
1
2
3
4
5
1
2
3
4
5
6
7
8
9
User

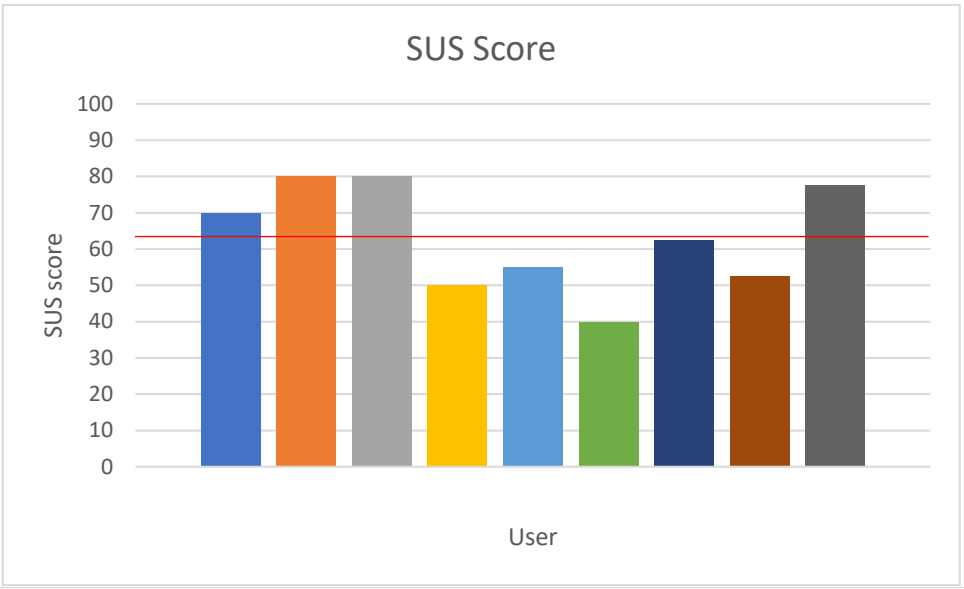

I found the system very cumbersome to use
Number of answers
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
Answer

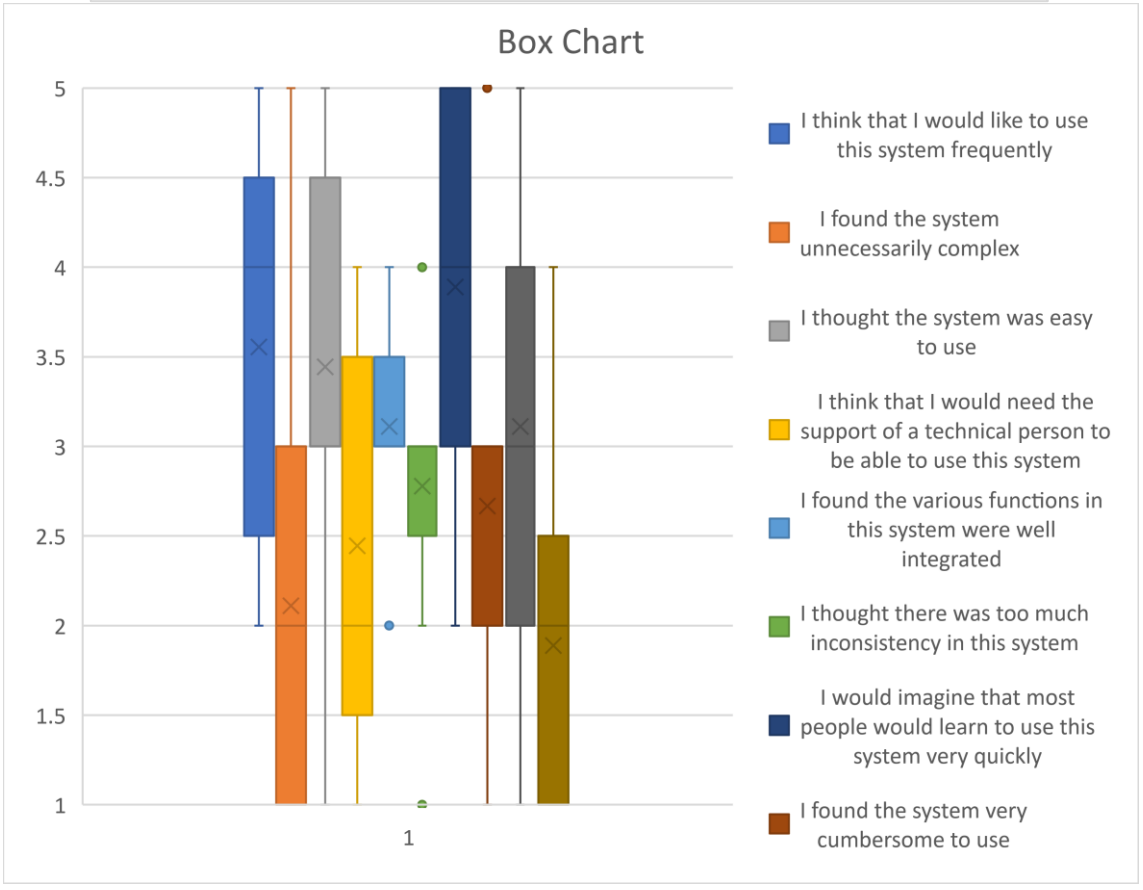

I felt very confident using the system
Answer
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
User


I felt very confident using the system
Number of answers
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
Answer


I needed to learn a lot of things before I could get going with this system
Answer
User
0
1
2
3
4
5
6
7
8
9

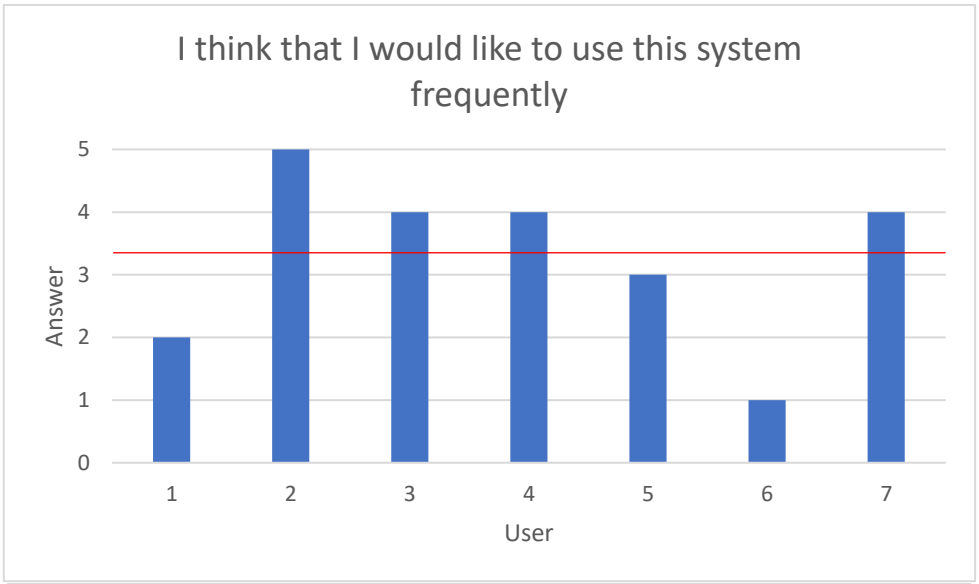

I needed to learn a lot of things before I could get going with this system
Number of answers
Answer
0
1
2
3
4
5
6
7
8
9

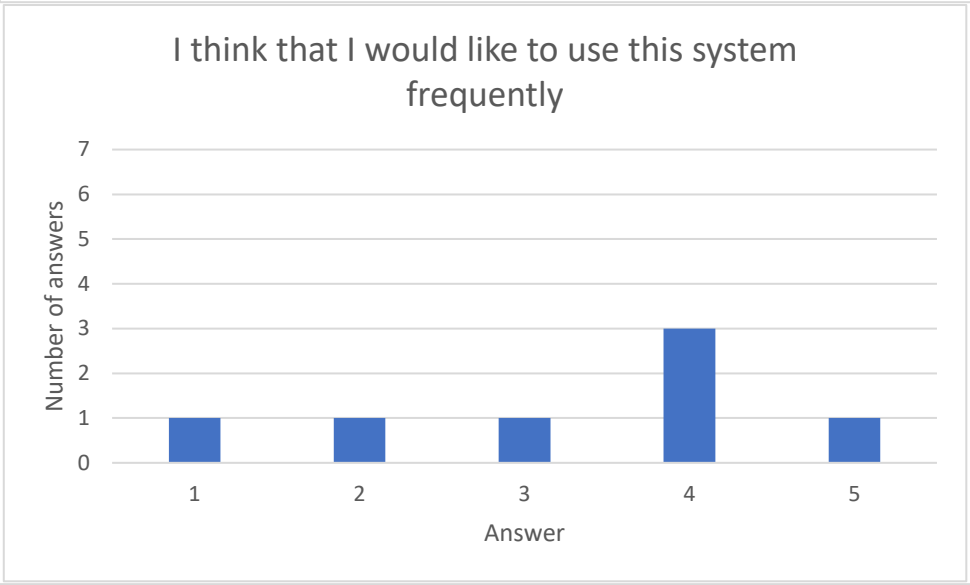

SUS Score
100
90
80
70
60
50
40
30
20
10
0
SUS score
User

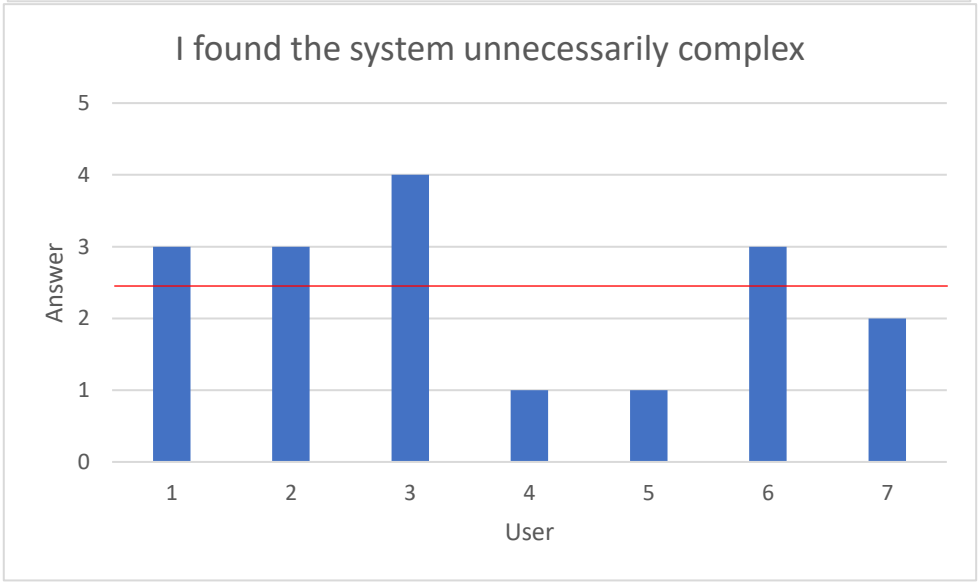

Box Chart
5
4.5
4
3.5
3
2.5
2
1.5
1
1
I think that I would like to use this system frequently
I found the system unnecessarily complex
I thought the system was easy to use
I think that I would need the support of a technical person to be able to use this system
I found the various functions in this system were well integrated
I thought there was too much inconsistency in this system
I would imagine that most people would learn to use this system very quickly
I found the system very cumbersome to use

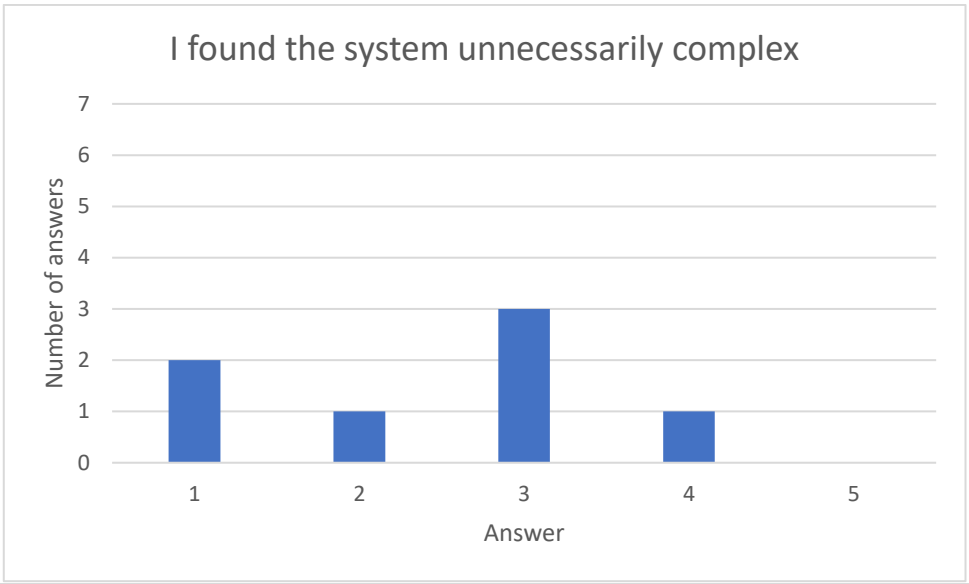
Location-Based Game

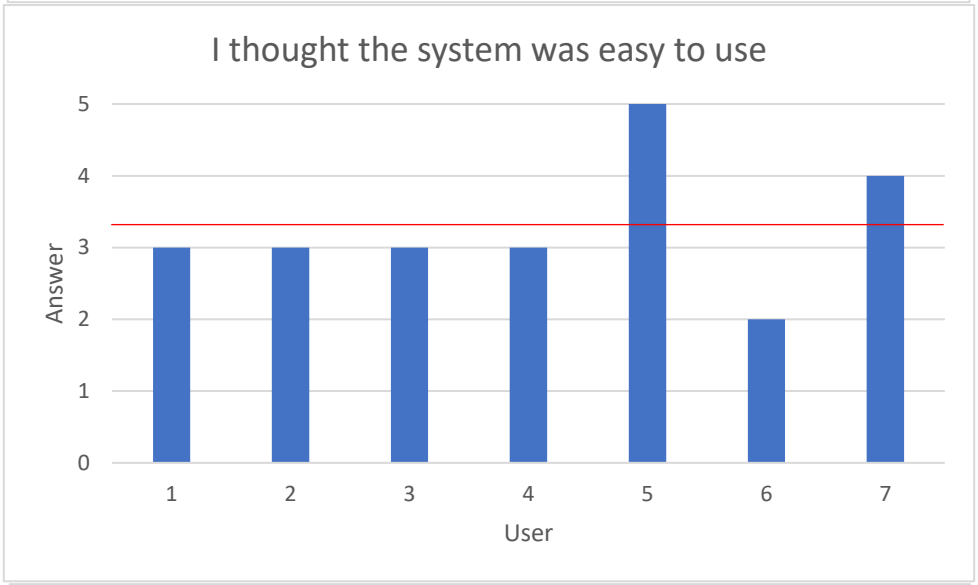
	Question										
Answer	1	2	3	4	5	6	7	8	9	10	SUS Score
1	2	3	3	3	3	3	3	4	3	2	47.5
2	5	3	3	4	4	3	5	3	4	3	62.5
3	4	4	3	3	3	2	4	3	3	2	57.5
4	4	1	3	3	3	2	3	4	3	2	60
5	3	1	5	2	3	3	4	3	4	1	72.5
6	1	3	2	3	2	3	2	3	1	3	32.5
7	4	2	4	2	4	3	4	2	4	2	72.5
Mean	3.29	2.43	3.29	2.86	3.14	2.71	3.57	3.14	3.14	2.14	57.86
Median	4	3	3	3	3	3	4	3	3	2	60

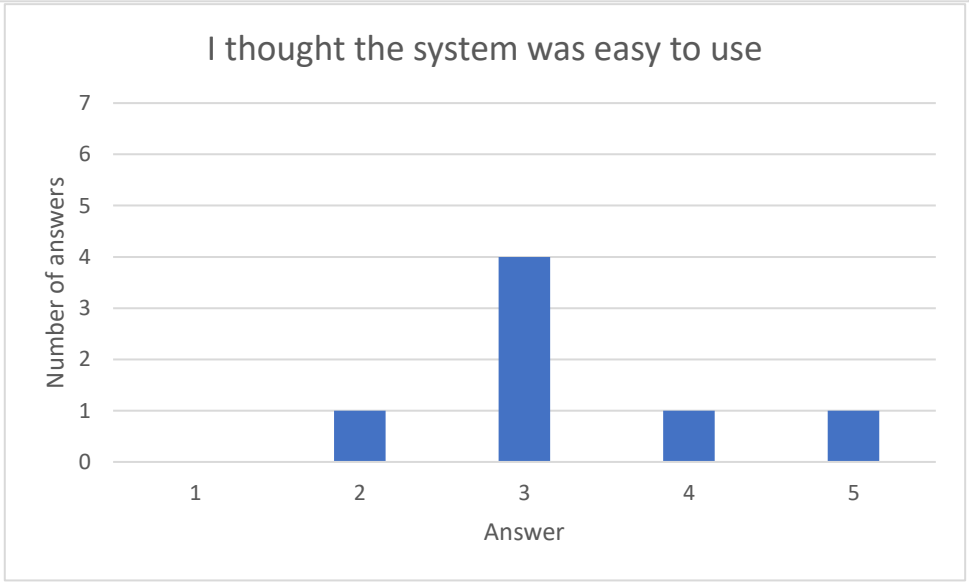

I think that I would like to use this system frequently
Answer
User
0
1
2
3
4
5
6
7

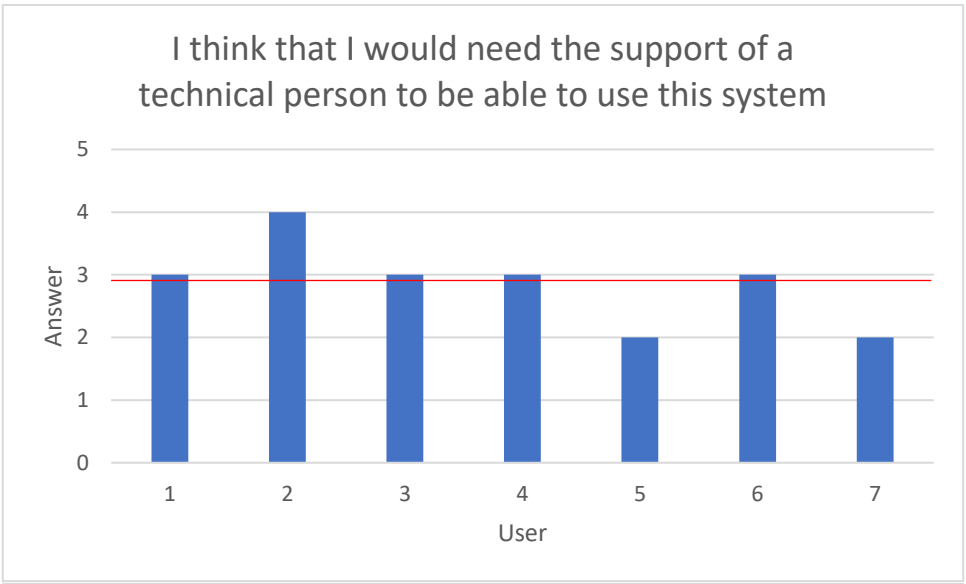

I think that I would like to use this system frequently
Number of answers
Answer
0
1
2
3
4
5
6
7

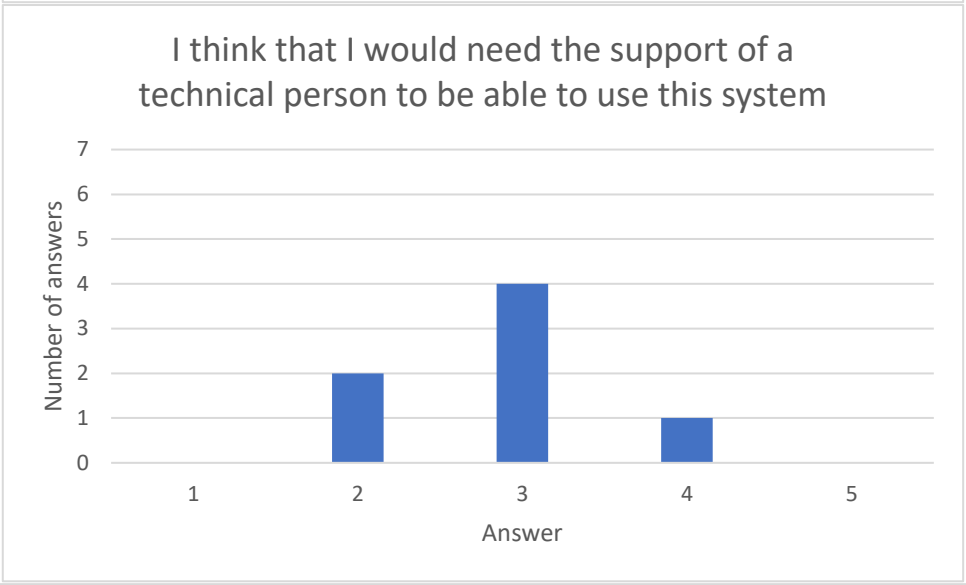

I found the system unnecessarily complex
Answer
User
0
1
2
3
4
5
6
7

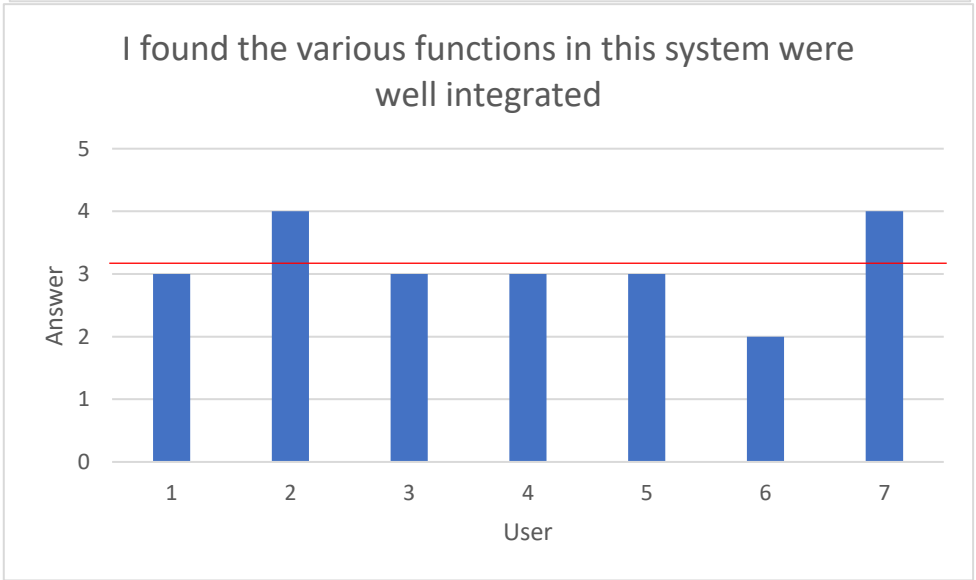

I found the system unnecessarily complex
Number of answers
0
1
2
3
4
5
6
7
1
2
3
4
5
Answer

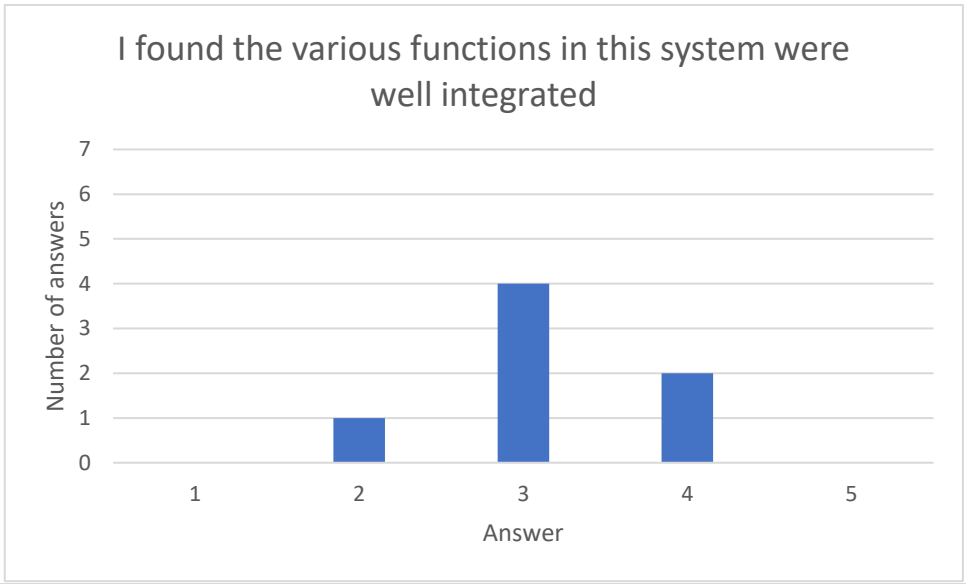

I thought the system was easy to use
Answer
0
1
2
3
4
5
1
2
3
4
5
6
7
User

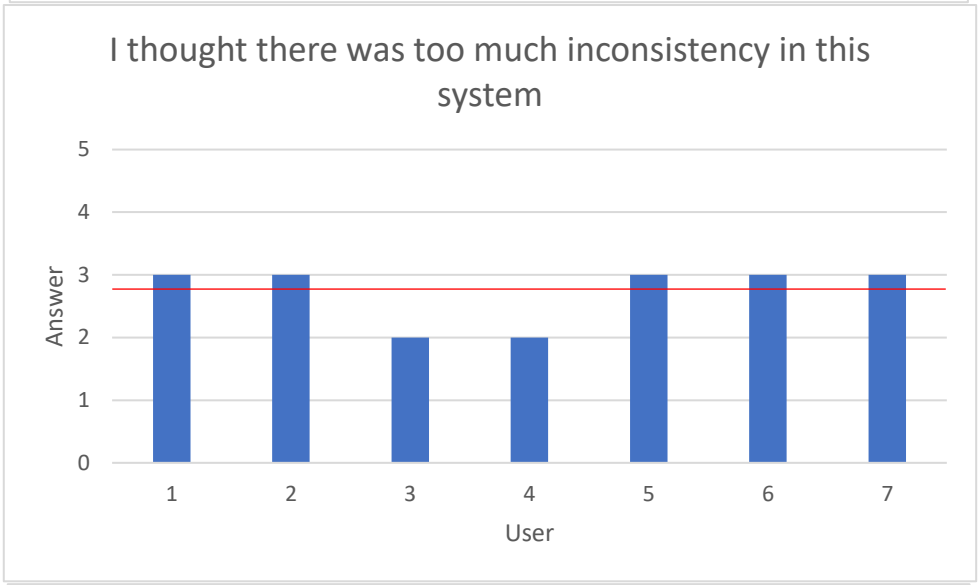

I thought the system was easy to use
Number of answers
0
1
2
3
4
5
6
7
1
2
3
4
5
Answer

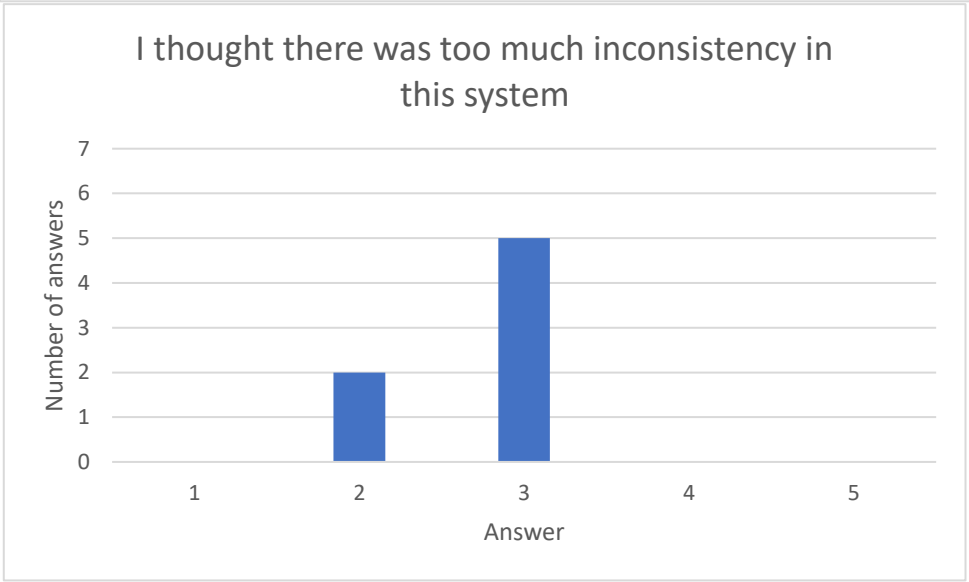

I think that I would need the support of a technical person to be able to use this system
Answer
User
0
1
2
3
4
5
6
7

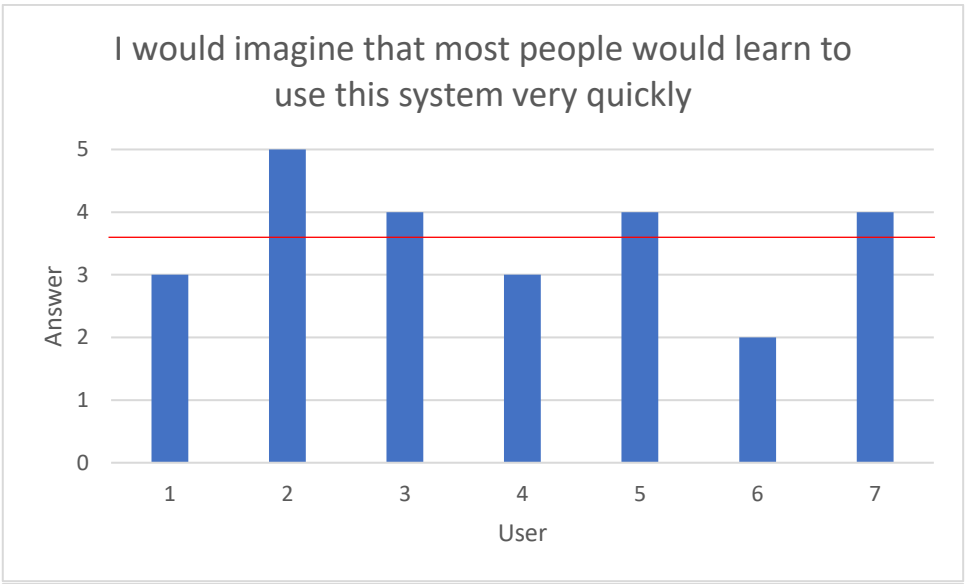

I think that I would need the support of a technical person to be able to use this system
Number of answers
Answer
0
1
2
3
4
5
6
7

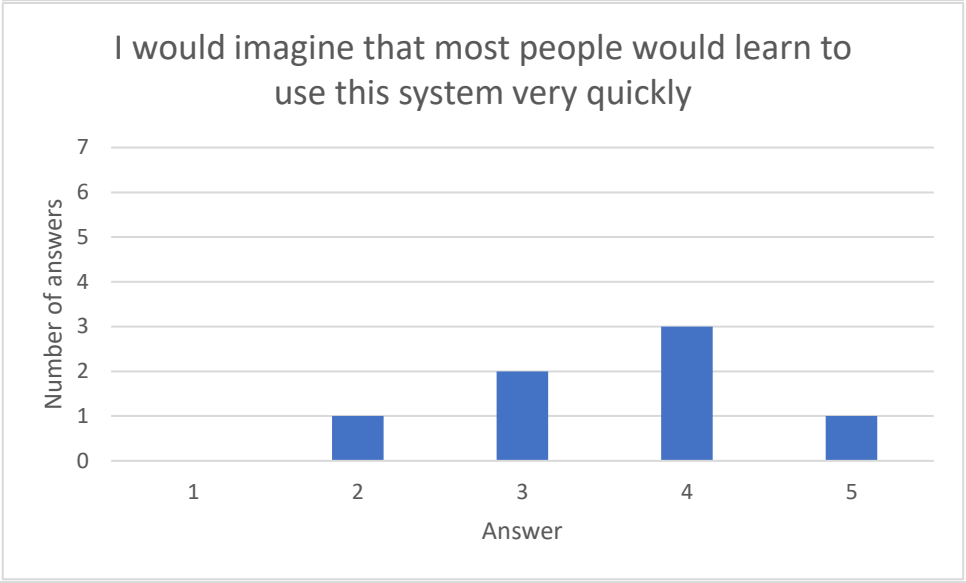

I found the various functions in this system were well integrated
Answer
User
0
1
2
3
4
5
6
7

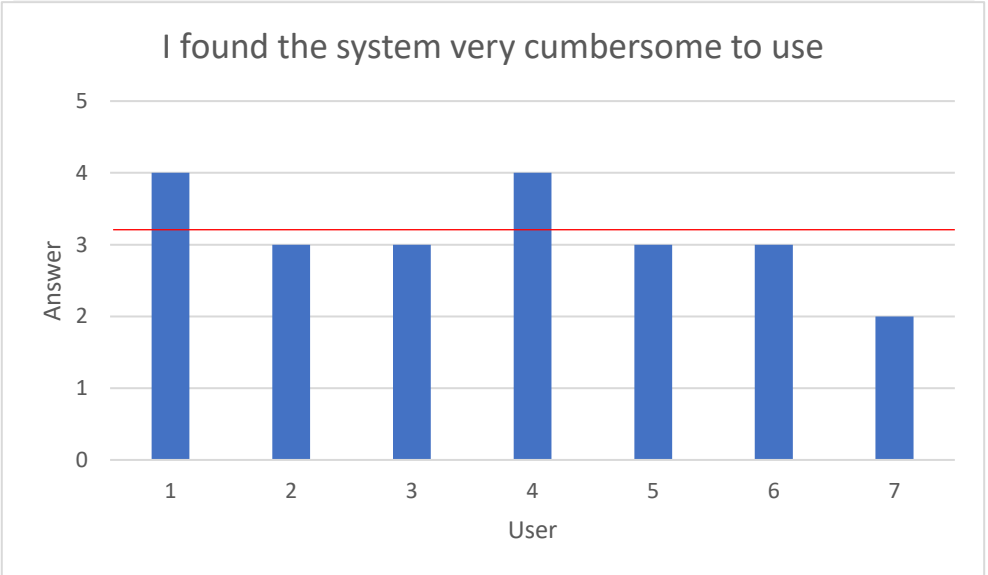

I found the various functions in this system were well integrated
Number of answers
0
1
2
3
4
5
6
7
1
2
3
4
5
Answer

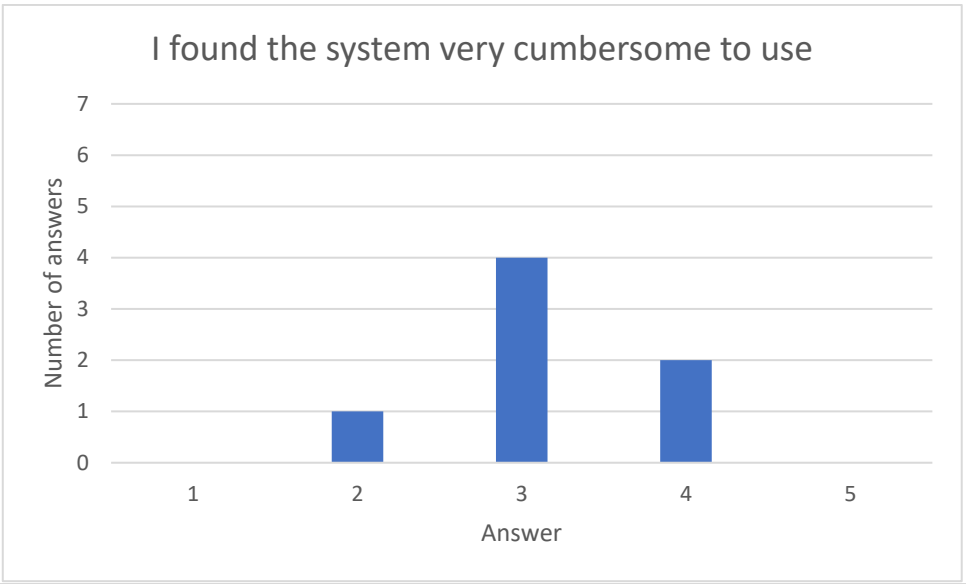

I thought there was too much inconsistency in this system
Answer
0
1
2
3
4
5
1
2
3
4
5
6
7
User

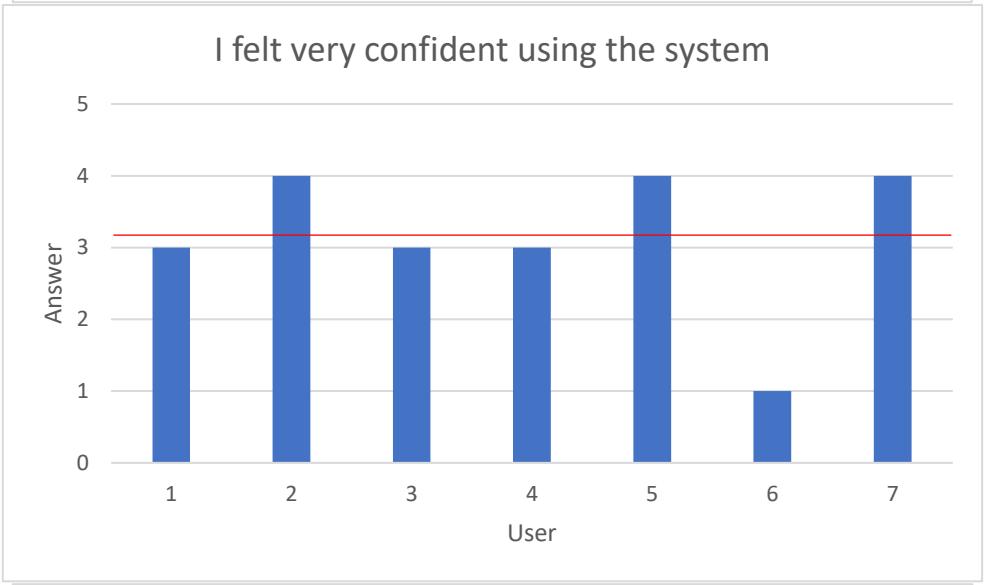

I thought there was too much inconsistency in this system
Number of answers
0
1
2
3
4
5
6
7
1
2
3
4
5
Answer

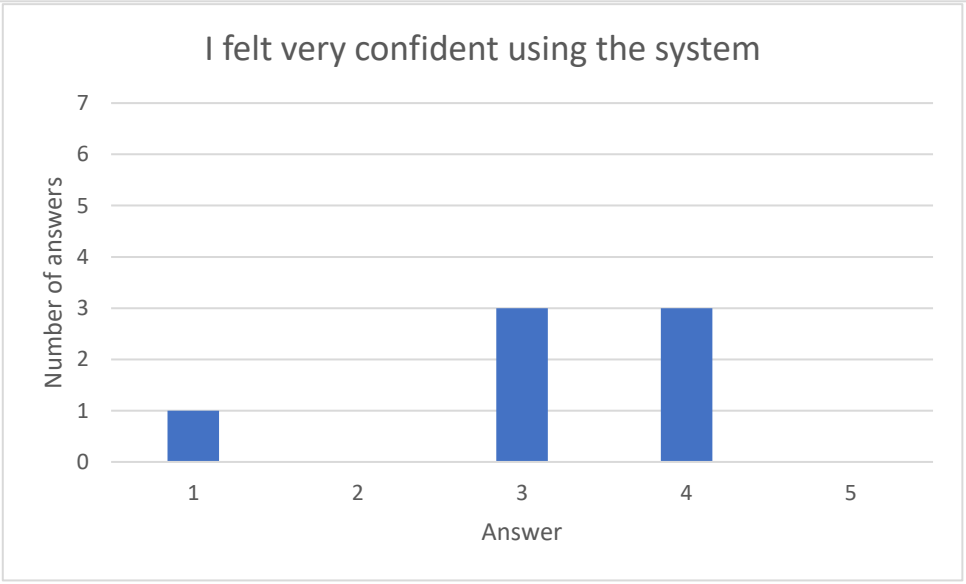

I would imagine that most people would learn to use this system very quickly
Answer
User
0
1
2
3
4
5
6
7

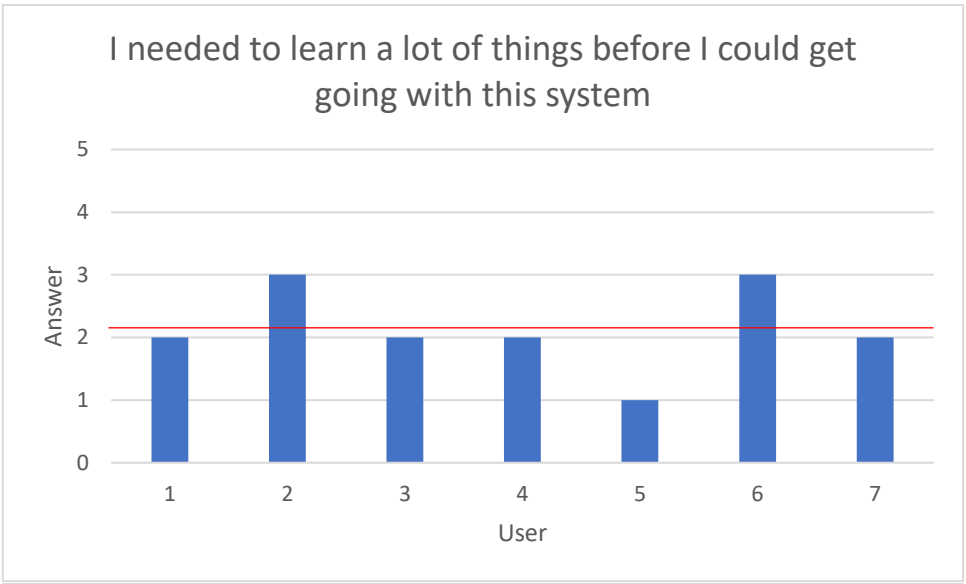

I would imagine that most people would learn to use this system very quickly
Number of answers
Answer
0
1
2
3
4
5
6
7

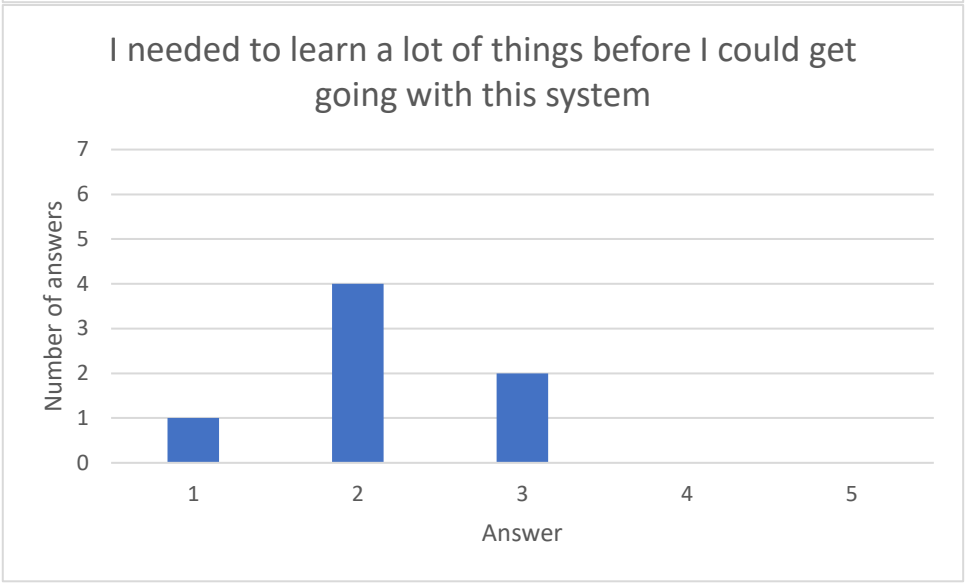

I found the system very cumbersome to use
Answer
User
0
1
2
3
4
5
6
7

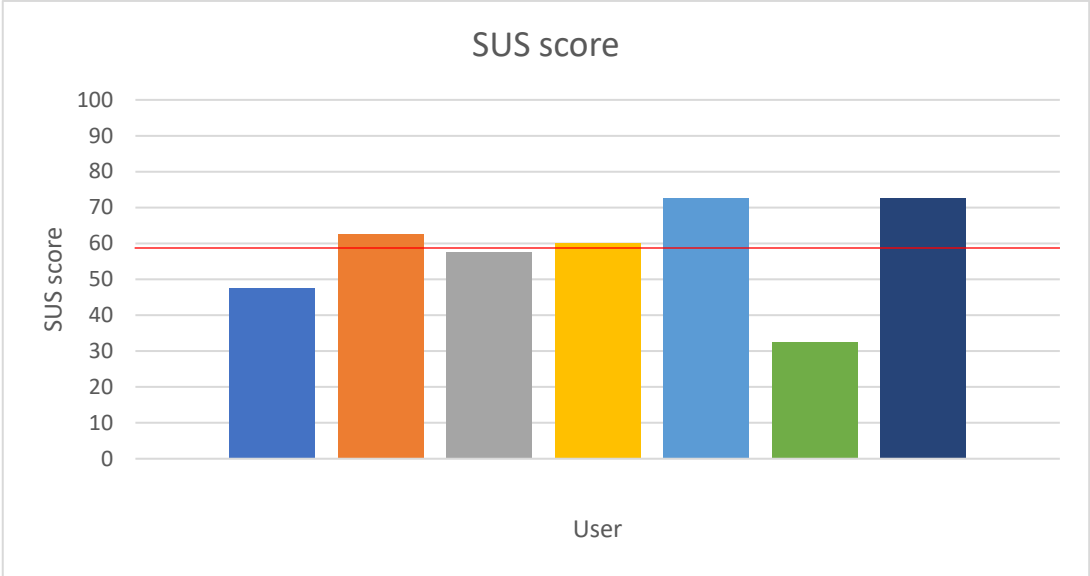

I found the system very cumbersome to use
Number of answers
0
1
2
3
4
5
6
7
1
2
3
4
5
Answer

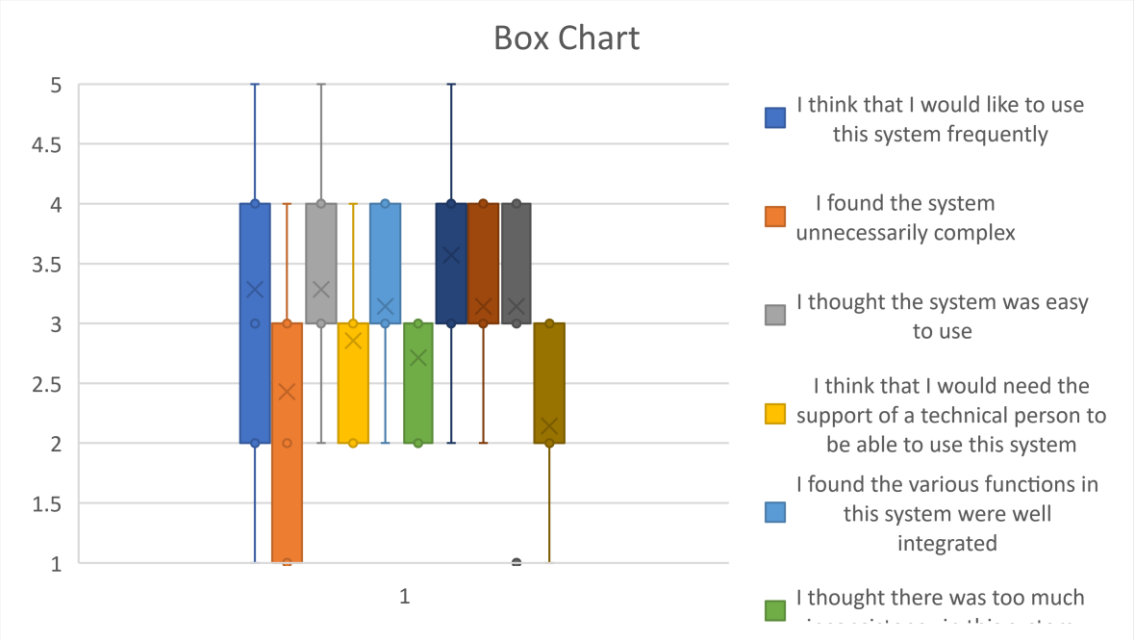

I felt very confident using the system
Answer
0
1
2
3
4
5
1
2
3
4
5
6
7
User


I felt very confident using the system
Number of answers
0
1
2
3
4
5
6
7
1
2
3
4
5
Answer


I needed to learn a lot of things before I could get going with this system
5
4
3
2
1
0
Answer
1
2
3
4
5
6
7
User


I needed to learn a lot of things before I could get going with this system
7
6
5
4
3
2
1
0
Number of answers
1
2
3
4
5
Answer


SUS score
100
90
80
70
60
50
40
30
20
10
0
SUS score
User


Box Chart
5
4.5
4
3.5
3
2.5
2
1.5
1
1
I think that I would like to use this system frequently
I found the system unnecessarily complex
I thought the system was easy to use
I think that I would need the support of a technical person to be able to use this system
I found the various functions in this system were well integrated
I thought there was too much

Appendix G

Game Jam Sample Files

GLP JSON File


```
{
   "id": "9",
   "name": "Super Tolkien Extraordinary Map - STEM",
   "mapSrc": "http://i.imgur.com/mxw0Bg1.jpg",
   "mapTop": "0",
   "mapLeft": "0",
   "mapBottom": "0",
   "mapRight": "0",
   "missions": [
      {
         "id": "The Lord of the Rings",
         "name": "The Fellowship",
         "description": "",
         "skills": "English",
         "quests": [
            {
               "id": "1",
               "name": "The Hobbit's Journey",
               "graph": "graph-km1zfje6eo.json"
            }
         ]
      }
   ]
}
```

Graph JSON file


```
{
   "quest": {
      "challenges": [
         {
            "id": "0",
            "name": "The Shire",
            "x": "25",
            "y": "38",
            "lat": "-8.598619611566065",
            "lon": "41.17873813595241",
            "type": "normal",
            "executeonce": "true",
            "pinid": "1",
            "activities": [
               {
                  "name": "Dialog Box",
                  "configuration": "/samples/configurationy855b6ouz.json",
                  "schema": "/samples/invicta-dialog.json",
                  "resources": "",
                  "minigame": "true"
               },
               {
                  "name": "Multiple Choice",
                  "configuration": "/samples/configuration8ltbdp72r.json",
                  "schema": "/samples/invicta-options.json",
                  "resources": "",
                  "minigame": "true"
               }

            ]},
         {
            "id": "1",
            "name": "Bree",
            "x": "296",
            "y": "109",
            "lat": "-8.597943410036699",
            "lon": "41.17869315995061",
            "type": "normal",
            "executeonce": "true",
            "pinid": "2",
            "activities": [
               {
                  "name": "Dialog Box",
                  "configuration": "/samples/configurationopeb0i98i.json",
                  "schema": "/samples/invicta-dialog.json",
                  "resources": "",
                  "minigame": "true"
               },
               {
                  "name": "Multiple Choice",
                  "configuration": "/samples/configurationdmk92pfns.json",
                  "schema": "/samples/invicta-options.json",
                  "resources": "",
                  "minigame": "true"
               }

            ]},
         {
            "id": "2",
            "name": "Rivendell",
            "x": "450",
            "y": "190",
            "lat": "-8.597169534953089",
```

```
            "lon": "41.178698781950835",
            "type": "normal",
            "executeonce": "true",
            "pinid": "3",
            "activities": [
               {
                  "name": "Dialog Box",
                  "configuration": "",
                  "schema": "/samples/invicta-dialog.json",
                  "resources": "",
                  "minigame": "true"
               },
               {
                  "name": "Multiple Choice",
                  "configuration": "",
                  "schema": "/samples/invicta-options.json",
                  "resources": "",
                  "minigame": "true"
               }

            ]},
         {
            "id": "3",
            "name": "Ringwraiths",
            "x": "153",
            "y": "89",
            "lat": "-8.598296537502033",
            "lon": "41.178715647951506",
            "type": "hidden",
            "executeonce": "true",
            "pinid": "4",
            "activities": [
               {
                  "name": "Dialog Box",
                  "configuration": "/samples/configuration64ehhjqe6.json",
                  "schema": "/samples/invicta-dialog.json",
                  "resources": "",
                  "minigame": "true"
               },
               {
                  "name": "Multiple Choice",
                  "configuration": "/samples/configurationwl97631c8.json",
                  "schema": "/samples/invicta-options.json",
                  "resources": "",
                  "minigame": "true"
               }

            ]},
         {
            "id": "4",
            "name": "The Mines of Moria",
            "x": "62",
            "y": "323",
            "lat": "-8.597237155106026",
            "lon": "41.17820404593108",
            "type": "normal",
            "executeonce": "true",
            "pinid": "5",
            "activities": []
         },
         {
            "id": "5",
            "name": "Lorien",
            "x": "225",
            "y": "402",
            "lat": "-8.596951647793626",
            "lon": "41.178069117925695",
            "type": "normal",
```

```
            "executeonce": "true",
            "pinid": "6",
            "activities": []
         },
         {
            "id": "6",
            "name": "Down the river",
            "x": "442",
            "y": "403",
            "lat": "-8.596688680532205",
            "lon": "41.1777936399147",
            "type": "normal",
            "executeonce": "true",
            "pinid": "7",
            "activities": []
         },
         {
            "id": "7",
            "name": "Attack at Redhorn pass",
            "x": "234",
            "y": "271",
            "lat": "-8.597131968201458",
            "lon": "41.178434547940284",
            "type": "hidden",
            "executeonce": "true",
            "pinid": "8",
            "activities": []
         }
      ],
      "connections": [
         {
            "source": "1",
            "target": "2"
         },
         {
            "source": "0",
            "target": "3"
         },
         {
            "source": "3",
            "target": "1"
         },
         {
            "source": "2",
            "target": "7"
         },
         {
            "source": "7",
            "target": "4"
         },
         {
            "source": "4",
            "target": "5"
         },
         {
            "source": "5",
            "target": "6"
         }
      ]
   }
}
```

Game XML

```
<invicta map="http://i.imgur.com/mxw0Bg1.jpg" top="0" left="0" bottom="0"
right="0">
    <game>
        <checkpoints>
            <checkpoint pointId="1" lon="41.17873813595241" lat="-
8.598619611566065" image="Rose" name="The Shire" type="normal"
executeOnce="true">
                <challenges>
                    <challenge type="narrative">
                        <narrative value="Welcome, young halfling! I am very
pleased you have chosen to embark on this amazing " />
                    </challenge>
                    <challenge type="question">
                        <question value="Hobbiton has 11 other halflings. Your
adventure needs 1/4 of the population to be successful. How many friends
should you bring?" url="http://56b2304c.eu.ngrok.io/api/saveResult">
                            <answer value="4" isCorrect="false" />
                            <answer value="8" isCorrect="false" />
                            <answer value="2" isCorrect="false" />
                            <answer value="3" isCorrect="true" />
                        </question>
                    </challenge>
                </challenges>
            </checkpoint>
            <checkpoint pointId="2" lon="41.17869315995061" lat="-
8.597943410036699" image="Rose" name="Bree" type="normal" executeOnce="true">
                <challenges>
                    <challenge type="narrative">
                        <narrative value="You have arrived to Bree, and can
finally enjoy some rest and comfort. Or can you?!?" />
                    </challenge>
                    <challenge type="question">
                        <question value="1+1?"
url="http://56b2304c.eu.ngrok.io/api/saveResult">
                            <answer value="1" isCorrect="false" />
                            <answer value="2" isCorrect="true" />
                        </question>
                    </challenge>
                </challenges>
            </checkpoint>
            <checkpoint pointId="3" lon="41.178698781950835" lat="-
8.597169534953089" image="Rose" name="Rivendell" type="normal"
executeOnce="true">
                <challenges>
                    <challenge type="narrative" />
                    <challenge type="question" />
                </challenges>
            </checkpoint>
            <checkpoint pointId="4" lon="41.178715647951506" lat="-
8.598296537502033" image="Rose" name="Ringwraiths" type="hidden"
executeOnce="true">
                <challenges>
                    <challenge type="narrative">
                        <narrative value="You have been waylaid by RingWraiths
on horses, you must hide to avoid them. " />
                    </challenge>
                    <challenge type="question">
                        <question value="The Wraiths ambushing you. If their
horses run at 9km/h and you run at 3km/h, and you start with 6km of advance,
how many minutes would they need to catch up to you?"
url="http://56b2304c.eu.ngrok.io/api/saveResult">
                            <answer value="30 minutes" isCorrect="false" />
                            <answer value="2 hours" isCorrect="false" />
```

```
                            <answer value="1 hour" isCorrect="true" />
                        </question>
                    </challenge>
                </challenges>
            </checkpoint>
        </checkpoints>
        <connections>
            <connection source="2" target="3" />
            <connection source="1" target="4" />
            <connection source="4" target="2" />
        </connections>
    </game>
</invicta>
```

Appendix H

Authoring Tool Sample Schemes

Gamified Lesson Plan schema


```
{
  "$schema": "http://json-schema.org/draft-04/schema#",
  "type": "object",
  "properties": {
    "id": {
      "type": "string",
      "form_input_type": "TEXT_INPUT",
      "form_label": "GLP ID",
      "form_description": "ID of the Gamified Lesson Plan",
      "mandatory": true
    },
    "name": {
      "type": "string",
      "form_input_type": "TEXT_INPUT",
      "form_label": "GLP Name",
      "form_description": "Name of the Gamified Lesson Plan",
      "max_length": 50
    },
    "missions": {
      "type": "array",
      "items": {
        "type": "object",
        "properties": {
          "id": {
            "type": "string",
            "form_input_type": "TEXT_INPUT",
            "form_label": "Mission ID",
            "form_description": "ID of the Mission",
            "mandatory": true
          },
          "name": {
            "type": "string",
            "form_input_type": "TEXT_INPUT",
            "form_label": "Mission Name",
            "form_description": "Name of the Mission",
            "max_length": 50
          },
          "description": {
            "type": "string",
            "form_input_type": "TEXT_AREA",
            "form_label": "Description",
            "form_description": "Description of the Mission"
          },
          "skills": {
            "type": "string",
            "form_input_type": "TEXT_INPUT",
            "form_label": "Skills",
            "form_description": "Skills contained in Mission",
            "max_length": 50
          },
          "quests": {
            "type": "array",
            "items": {
              "type": "object",
              "properties": {
                "id": {
                  "type": "string",
                  "form_input_type": "TEXT_INPUT",
                  "form_label": "Quest ID",
                  "form_description": "ID of the Quest",
                  "mandatory": true
                },
                "name": {
```

```
                    "type": "string",
                    "form_input_type": "TEXT_INPUT",
                    "form_label": "Quest Name",
                    "form_description": "Name of the Quest",
                    "max_length": 50
                  },
                  "graph": {
                    "type": "string",
                    "form_input_type": "TEXT_INPUT",
                    "form_label": "JSON name",
                    "form_description": "Name of the JSON file containing the
Quest graph"
                  }
                }
              }
            }
          }
        }
      }
    }
  }
}
```

Sample schema from a BEACONING partner for a mini-game


```
{
    "$schema": "http://json-schema.org/draft-04/schema#",
    "type": "object",
    "properties": {
        "session_id": {
            "type": "integer",
            "hidden": true,
            "mandatory": true
        },
        "repository_game_name": {
            "type": "string",
            "lookup": "@repository_game_name",
            "mandatory": true
        },
        "displayed_game_name": {
            "type": "string",
            "lookup": "@displayed_game_name",
            "mandatory": true
        },
        "lang": {
            "type": "string",
            "hidden": true,
            "mandatory": true
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        "game_description": {
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            "lookup": "@game_description",
            "mandatory": false
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        "lesson_plan_id": {
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        "user_token": {
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            "hidden": true,
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            "mandatory": true
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                                "lookup": "@available_game_layouts",
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                    "item_selection_limit": {
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answers",
                        "mandatory": false
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                        "form_description": "Question skippable",
                        "mandatory": false
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                        "form_description": "text template for this question",
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                            "form_label": "cluster label",
                            "form_description": "the label of the cluster in
the game",
                            "mandatory": false
                        }
                    },
                    "answers": {
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                        "max_length": 20,
                        "items": {
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                            "properties": {
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                                    "hidden": true,
                                    "mandatory": true
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                                    "type": "string",
                                    "form_input_type": "TEXT_INPUT",
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                                    "form_description": "this is the text for
the question",
                                    "mandatory": false
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                                    "form_label": "Answer correct",
                                    "form_description": "Set true if this
answer is correct",
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            "form_description": "tells if the game is pausable",
            "mandatory": false
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            "form_description": "Accessibility of the game",
            "lookup": "@isAccessible",
            "readonly": true
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                    "form_description": "track the total elapsed time for
quiz?"
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                "skipped_answers": {
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        }
    }
}
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