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Game for Teaching and Learning Programming

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Abstract

This project creates a game that will teach programming and programming concepts to beginners. The design of the game will take an approach that has been used on previous work to teach programming with games.

1. Introduction

Computer programming involves problem solving skills and is considered as an essential skill for today's digital world [1]. Game based learning has been considered as an effective way for helping others to construct knowledge by playing games. By taking this approach learners are more engaged in their learning and have high learning motivation which they can use to apply their gained knowledge to real-life situations [1].

Sometimes it is hard to keep individuals interested or motivated when it comes to learning and teaching technology related courses. Many people might find it dry and boring which lowers their motivation and interest in learning the concepts of programming [2]. Over the years an increasing number of teachers have endeavoured to integrate educational computer games into training and teaching as it has been recognised that well-designed game-based learning is an effective means to help individuals construct knowledge and skill [3].

1.1. Overview of Project

This project will involve designing a game to teach programming concepts and implementing the game. The game will be created and developed based on past research and work that have been already implemented. Some user testing will take place within fellow students to gain feedback on the design and implementation. This project will be a simple browser-based game that will teach the basic concepts of the programming language Java.

Work done in trimester 1 included, exploring the past work that has been done to teach programming with games and evaluating the design approaches that were taken to accomplish developing these games. As well as developing a partially working level 1 with a design approach that was researched about. trimester 2 will focus on implementing another level as well as conducting some user tests.

Project Objective:

- Research about previous work done and the effects it has on users
- Create a design for a game to teach programming and programming concepts
- Implement a game for teaching programming concepts to beginners
- User testing to test the functionality of the game

2. Background

Some people may find the process of learning programming unpleasant and difficult [2]. There are many theories on why programming education can be difficult, such as the traits of the individuals for example, lack of motivation or becoming impatient with the lack of immediate results. Individuals may not understand how their program relates to the underlying system and are not able to create a clear model of the program. Programming does not only require one skill it is a complex cognitive activity where individuals must simultaneously build and apply their skills [4]. This section will discuss what game-based learning is and discuss some approaches that are taken to design a game to teach programming.

2.1. Game-Based Learning

Game-based learning (GBL) describes an environment where game content and game play enhance knowledge and skills. These games involve problem solving spaces and challenges that provide players and learners with a sense of achievement. GBL maintains motivation and user engagement in

2.2. Authoring-Based Approach

2.1.1. Scratch

3

2.1.2. Alice

Alice is an open education resource made available to the teaching community to make it easy for non-programmers to use an interesting 3D environment to develop interactive games. Alice uses this environment to create computer animations using 3D models and uses animations, storytelling, and game construction to introduce object-based concepts to the users [4]. Similarly to Scratch, Alice uses a drag and drop environment that consists of statements and expressions. Users are able to see immediately how the program runs which can lead them to understanding the actual program functions and different programming language constructs [9]. This also helps to sustain the user's interest and involvement. The target audience for Alice is non-programmers to use a 3D environment to develop a game. It has been stated in previous research that Alice can be a useful tool for supporting users and obtaining skill in problem solving and arithmetic thinking as the user needs to build animations with Alice to solve a set of problems [9]. Figure 2 shows a similar interface like scratch, there are predefined blocks that help to develop a game.

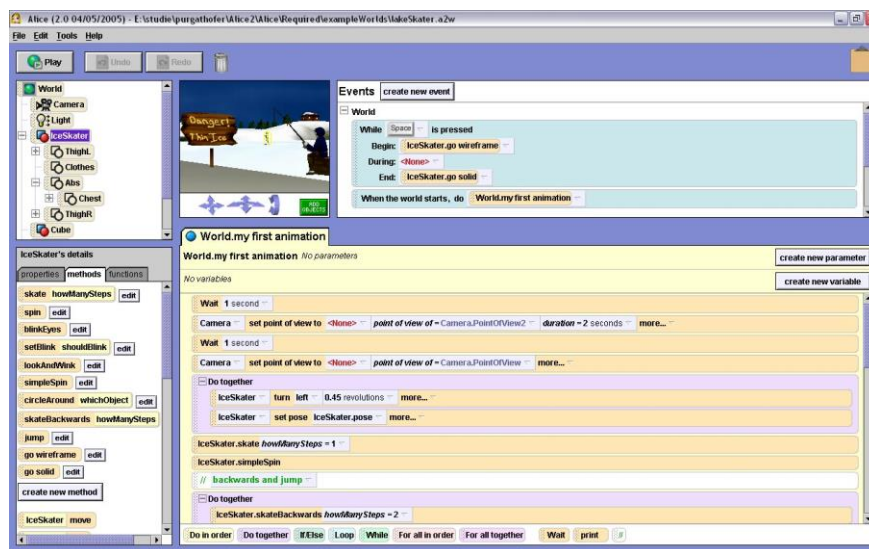
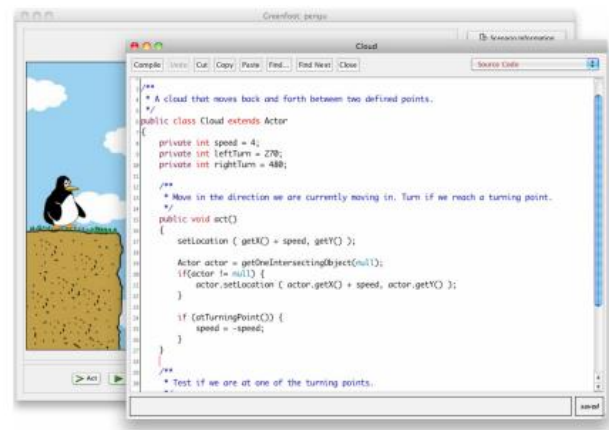


Figure 2: Alice Interface

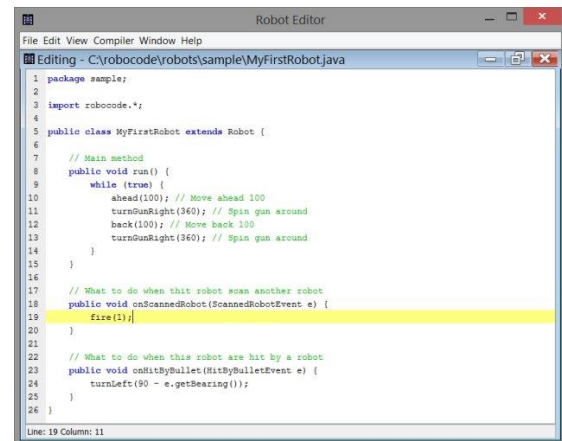
2.1.3. Greenfoot

Greenfoot is an educational integrated development environment aimed for learning and teaching programming [10]. Greenfoot combines interactive graphical output with the programming language Java. The target audience are students around the age of 14 years old however, this tool is also suitable for students in college and university education. One of the goals of Greenfoot is a design that explicitly visualises important concepts of object-orientated programming [10]. Unlike Scratch and Alice Greenfoot does not use drag and drop elements. It has source code that has some base code already provided to allow the users to build off and program. Figure 3 and 4 shows us the interface of Greenfoot which is slightly different to Scratch and Alice. Figure 3 shows the main window which is the Greenfoot world and where the program executes. This window holds the project scenario, and the classes for the project and their inference relations. When double clicking the class the Greenfoot editor opens which is shown in Figure 4. The editor has predefined functions which are in Java that need to be modified by the user. Once some code has been written the project can be executed and the user can see immediate results, which again just like Alice can help sustain users' interest and involvement.



2.1.4. Robocode

Robocode is similar to Greenfoot as it involves user to insert code in an editor in order to progress with the game. Robocode is an easy-to-use robotics battle simulator that operates across various types of computer platforms supporting Java [11]. The goal of the game is to develop a robot battle tank to battle against other tanks in Java or .NET [12]. The player must write code for the AI robot telling it how to behave and react to events occurring in the battle arena. The battle occurring in the game is at real-time and on-screen, which makes the activity more dynamic and keeps users motivated and more engaged just like in Alice and Greenfoot [12]. This program allows students to define strategies and implement them according to the multiple programming procedures available. The editor involves predefined functions in Java that need to be completed or modified just like Greenfoot. Figure 5 shows the battle arena that shows all the tanks and Figure 6 shows the editor that appears and needs to be completed to progress in the game.



2.3. Play-Based Approach

Play-based approach is when there are a series of missions and tasks which is related to a concept. From this approach the user is able to gain knowledge from the concepts by developing programming skills to complete the tasks and missions provided by the game [4]. Even though this technique may require users to develop code for the system as their solution, this differs from authoring-based

approach as there is a smaller emphasis on coding. The code given is usually restricted to completing a function or completing a certain task. Systems that use this approach also tries to target a specific programming concept unlike most authoring systems that try to cover a full language or concept. Keeping it concise this way helps users to focus on smaller areas of the language instead of overwhelming them with too much information. There has been some previous work done with this approach in place.

2.2.1. Saving Sera

The game Saving Sera is a 2D game where the user must save princess Sera who has been abducted. The users must complete a number of tasks in order to progress in the plot of the game [13]. These tasks involve the user to complete lines of code that will result to an executable program, or they have to map existing lines of code to their proper position or order [13]. This game introduces concepts such as, simple and nested loops, recursion and control structures all in the process of trying to complete tasks. Figure 7 shows one of the screens from the game Saving Sera, we can see a task given to the user as well as a dialog screen that lets the user enter a bit of code to complete the task.

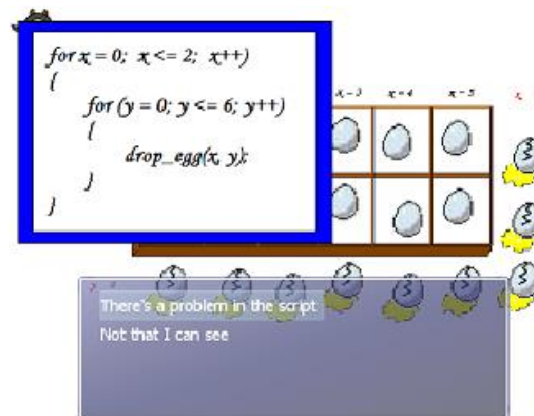


Figure 7: Egg Quest screen

2.2.2. Light-Bot

Light-Bot is a puzzle game where the objective is to program a small robot to light up all the blue blocks on a grid-based board [14]. The objective is completed by giving the robot a set of instructions from a limited set of commands, with a finite instruction space [14]. As the levels progress the board becomes more increasingly complicated, and the user is required to create a combination of commands that are more simplified to achieve the task. Figure 8 shows the game on level 1.

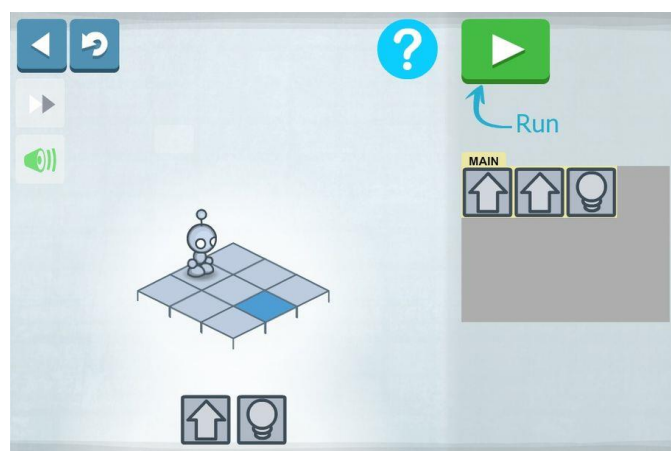


Figure 8: Light-Bot level 1

The program gives the user predefined command tiles as we can see in Figure 8, and the main can only hold a certain number of commands. This will push the user to use additional functions for repetitive actions or to develop a recursive solution [4].

2.4. Summary

Table 1 summarizes the key differences between the two approaches. Both approaches have some drawback and some benefits. Authoring approach allows users that are at a beginner level to understand concepts and gives them a base and structure to start with, however play-based approach doesn't require as much coding, so they tend to not produce as much structure as authoring provides. However, this is a drawback to play-based as users that are at beginner level can get confused while using the game.

Play-based provides a scenario where tasks need to be complete to progress through the game, however authoring does not provide a story or plot to develop and usually doesn't provide tasks. This has its pros and cons, letting users have the freedom to construct and develop what they want gives them the exposure to a number of things however confining users to a task or mission helps them to focus on the concepts or language you want.

For authoring users are usually provided a program that is a game themed assignment along side a set of development libraries and partial implementation which can cause users to be less involved and interested, however for the play-based approach the program is set out as a game and requires very little amount of coding. It usually is a program that needs functions completed or to specify commands such as Light-Bot for example.

Both approaches focus on programming however, play-based tends to focus on a specific language or concept where in most cases authoring tends to be quite broad with what they try to cover. Keeping it concise will help the user to focus on specific things and have a deeper understanding of it instead of having a shallow understanding of a broader concept.

| Authoring Approach | Play-Based Approach |
|--|---|
| Provides base code that user can construct, complete, or modify. | Given scenarios where users have to complete tasks by implementing code. |
| Allows users to construct and modify the given code or structure as much as they like. | Approach provides code that restricts users to completing a function or completing a certain task. |
| Focus on larger concepts and how programming works instead of a single language. | Focus on one specific language or concept |
| Requires some sort of code or works with drag and drop functionalities. | Doesn't require as much code to complete tasks. |
| Let's user see their progress immediately which sustains their interest and involvement. | The design makes it feel like users are playing a game and not implementing code or learning which keeps them interested. |

Table 1: Comparison between the approaches

2.4.1. Approach Chosen

Based on the findings and the research, the most appropriate approach for this project would be play-based approach. As this project will be targeted towards beginner level the approach play-based requires very little coding and is focused more on problem solving and programming concepts which

will allow beginners to create a better foundation when it comes to programming. Setting tasks and missions for users will guide the users of what's required instead of confusing them or overwhelm them with information. As there is very little emphasis on coding in this approach the user will be more interested and motivated to use the program as it will feel like a game and not a game themed assignment.

3. Work Done

3.1. Research

Most of this trimester has gone into the researching to construct a design for the project. The first step taken to implement a game to teach programming was to investigate previous work that has been done and the different kinds of benefits produced by the project for the users. There were many systems that had been created already that introduced games for learning programming such as Scratch, Alice, Greenfoot, Saving Sera, Light-Bot and Robocode. Once inspiration was gained from the previous work done the design approaches that were found through research needed to be used to start the implementation of the project.

3.2. Design

After the research had taken place there were two kinds of design approaches found that can be taken to implement some systems, authoring and play-based approach. After weighing out the advantages and disadvantages of both approaches, play-based was the design approach that was decided on. Play-based allows users to focus on one concept or language rather than making the programming concept being taught too broad. Taking this approach for this project, our teaching focus for the game will be on introducing Java like concepts such as statements and expressions.

Play-based approach provides a plot or scenario as a part of their game which helps create tasks and missions surrounding a scenario. Following that approach, the project scenario will be a dog trying to collect all its bones and food before reaching its home. A lot of the past work had a character or an animal as their main object that completes task such as, in Light-Bot the main character that moves around is a robot. Therefore, for this project the main character will be a dog that will be moved around to complete tasks.

The dog will move around a board which will be a 5x5 grid with commands. The reason to have a grid like this is to simplify the movement for the user. When the user will be moving the dog around the board it will be easier for them to navigate through the board and know the actual coordinates that the dog needs to be at instead of guessing or being confused. However, the size of the board might need to be reevaluated after some user tests have been conducted. The current size of the board might not be too small to introduce more complicated layouts for the game which could be a bit too easy for the users. The commands to move the dog would be buttons that would start off simple such as `moveLeft`, `moveRight` etc. and as the game progresses the game would introduce statements, expressions and obstacles that would challenge the user a bit more.

In the proposal the rough idea was to allow the users to input code in an editor, however, after researching, the initial idea changed and instead of an editor the user will control the dog with button commands that will be predefined for them. The reasons for changing from an editor to button controls was while researching and trying to find JavaScript libraries that allow users to add their code and execute it, there weren't many that were found. And due to this being a browser-based game, the buttons restrict the actions that the user can make so they essentially don't break or infect the program, which would take care of some of the security concerns that would be difficult to prevent when using an editor.

For the project a rough blueprint was created to understand the design of the system. A Class Diagram was created to describe the attributes and operations involved in a class and to model the system. Figure 9 shows the base classes that will need to be created as well as the necessary methods and constructors.

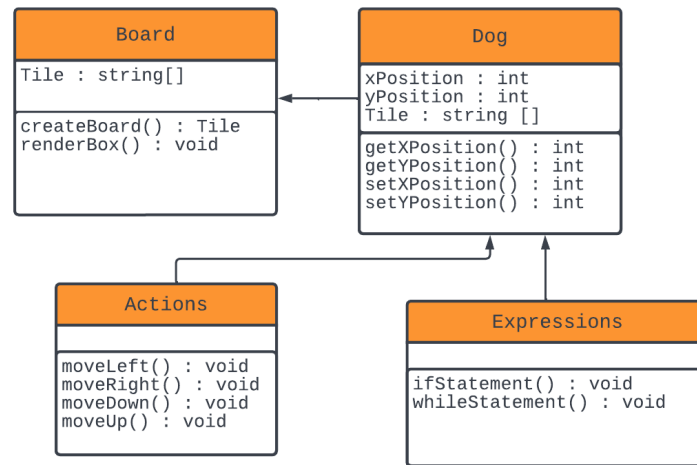


Figure 9: Class Diagram

The actions and expressions class are created to work with the logic to move the dog object that is represented by the dog class shown in Figure 9. The board class creates the board and uses the dog object which will move using the logic being passed through from the action and expressions class.

To understand the system requirements a Use Case Diagram was designed. A Use Case Diagram is used in system analysis to identify, clarify, and organize system requirements. This diagram lays out the possible sequences of interaction between systems and users. As we can see in Figure 10 a use case is created for a user and the sequence of interaction they can have with the system and what the possible outcome could be.

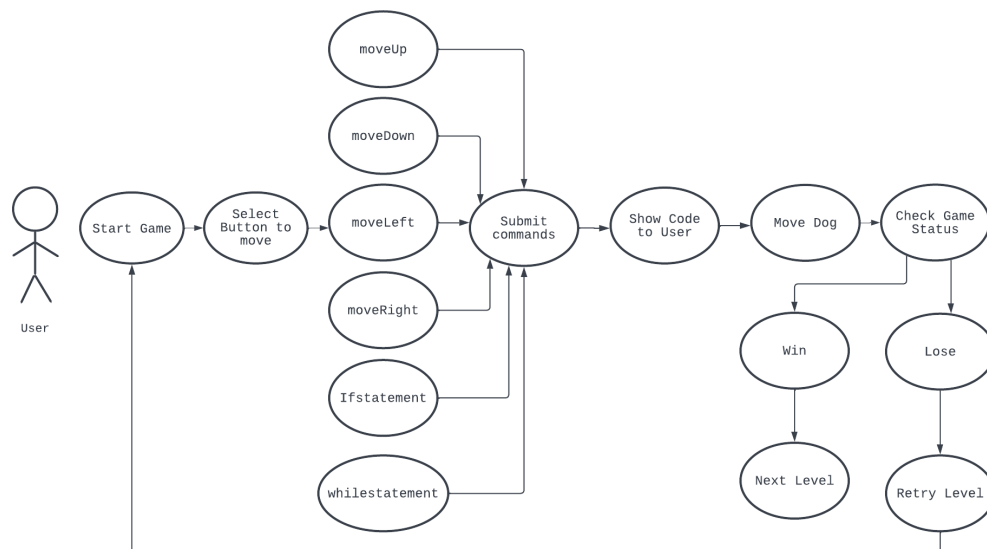


Figure 10: Use Case Diagram

3.3. Implementation

The framework chosen for the game will be React using the programming language JavaScript. React is an open-source JavaScript library that is used for building user interfaces and is a preferred framework due to React components. Another option to use other than React was HTML5. HTML5 is a markup language for structuring and presenting content on websites. The difference between the two is that for HTML5 there are three components that need to be handled, HTML, CSS, and JavaScript, on the other hand React is a JavaScript library that assists developers to create many components and parts on a website which makes using React more efficient, simpler, and faster. In comparison to HTML5, React often is seen as being faster as it allows you to create smaller, more efficient code files which can lead to a more faster and responsive user interface.

The project will be browser based instead of mobile based due to it being more convenient to user test this project. If the project is implemented on the browser, it will not require a setup and we will not need to worry about device compatibility. For example, if this was a mobile based game and the project was implemented on an iPhone, then the project would not run on for android devices which would limit the compatibility. If mobile based was taken as an approach, there would be a setup required to run the game. The phone being used would need an application installed to allow the phone and computer to connect and run the game which would be a lengthy process.

This trimester the base implementation has been completed. Figure 11 shows the 5x5 board that is created with a dog object that is placed in the centre. The dog is able to move with the four button commands that are present on the bottom right side of the screen and the submit button will be pressed once the user is happy with the sequence of commands. The white panel will show the code sequence as the buttons are being pressed.

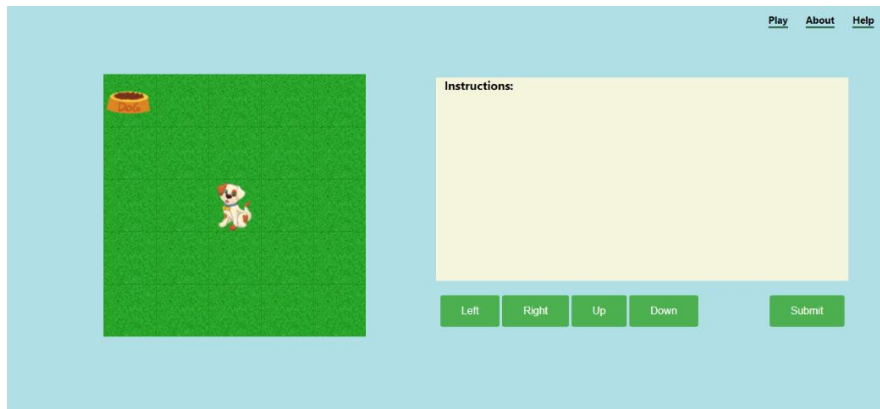


Figure 11: Screenshot of the game implementation currently

The next part is to show the code as the user clicks the button commands as well as moving the dog after the instructions are complete. For this finite state machines seem to be the most appropriate technique to store the users' instructions and execute the instructions once they are done. Finite state machines will reduce the need for long if else conditions and will help keep the implementation cleaner and simpler. These states will handling multiple different scenarios once the user has submitted their instructions and from there these states will execute the game logic based on those scenarios. If this was done with if else statements, it could lead to repetitive code as well as errors to occur.

3.3.1 Implementation Issues

An issue I had while implementing is choosing the library for the base board. Originally, I was creating the board with `<td>` and `<tr>` tags which created a grid. However, this made it hard to use the board later on for the logic. On searching more, I was able to find some React libraries that helped

create a grid board however the libraries restricted me from working with the dog object within the cells of the grid. Therefore, finally I created an array which I iterated through, and I was able to add the board logic in easier. These iterations for the board did delay the progress I was able to make with the implementation.

4. Future Plan

4.1. Progress Compared to Original Plan

According to the original plan laid out in the project proposal it was expected to have a prototype with level 1 completed for the game by the week 11. However, a prototype has not been able to be created and the current version only has level 1 partially implemented for the game.

4.2. Revisions to Project Timeline

Weeks 11 and 12 will be quite busy with a lot of deadlines and assessments coming up. Due to not being able to be complete level 1 implementation by week 11 there is a little work needed to be done to complete that which should be completed by week 14. Once that is completed, we will be able to test the prototype just before the mid trimester break however if there are no students that are able to test the prototype the user testing will need to occur first week back in trimester 2.

The research and implementation of the 2nd level which would introduce more to the project will take place during the break and in the first few weeks of trimester 2. After that is complete and implemented around week 26 another user testing should take place to test level 2. After the refining of both level 1 and 2 most of the work should be complete by week 27, allowing time to write the Final Report and start preparations for the presentation. Initially in the project proposal there was about 3 to 4 levels mentioned however due to a tighter timeline and higher coursework it would add a lot of stress to add more levels.

| Task | Trimester 1 | | | | BREAK | Trimester 2 | | | |
|------------------------------|-------------|-------|-------|-------|-------|-------------|----|-------|-------|
| Preliminary Report | 11 | | | | | | | | |
| Implement finite state | | 11-12 | | | | | | | |
| Complete level 1 | | | 13-14 | | | | | | |
| User Testing | | | | 15 | | | | | |
| Research for another Level | | | | 16-17 | | | | | |
| Start Implementation | | | | | 18-19 | | | | |
| Complete level 2 | | | | | | 20-23 | | | |
| User Testing | | | | | | | 26 | | |
| Draft Final Report | | | | | | | | 27 | |
| Implement Changes to Level 2 | | | | | | | | 27-28 | |
| SnapShots | | | | | | | | | 29 |
| Presentation Slides | | | | | | | | 27-29 | |
| Final Report | | | | | | | | | 25-30 |
| Presentation | | | | | | | | | 32 |

Figure 12: Updated Preposed timeline for Project

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6. Appendix

Abstract

It has been suggested by researchers and educators learning occurs naturally while playing games. Although generally what first attract people to games is the fun and entertainment, the engaging learning experience of game playing is contributed to by the effective principles or approaches embedded in game designs to facilitate positive learning outcomes [1]. This proposal will cover an overview of the project “Game for teaching and learning programming.”

1. Introduction

Computer programming involves problem solving skills and is considered as an essential skill for today's digital world [2]. Games based learning has been considered as an effective way for helping others to construct knowledge by playing games, by taking this approach learners are more engaged in their learning and have high learning motivation which they can use to apply their gained knowledge to real-life situations [2].

This project will involve designing a game to teach programming concepts and implementing the game. This project will be conducted using Agile methodology. Agile is an iterative approach to project management and software development that helps to deliver the product effectively and efficiently [3]. Some user testing will take place within fellow students to gain feedback on the design and implementation.

2. Problem

Sometimes it is hard to keep individuals interested or motivated when it comes to learning and teaching technology related courses. Many people might find it dry and boring which lowers their motivation and interest in learning the concepts of programming [4]. Over the years an increasing number of teachers have endeavoured to integrate educational computer games into training and teaching as it has been recognised that well-designed games-based learning is an effective means to help individuals construct knowledge and skill [5].

3. Proposed Solution

The project aim is to implement a game that efficiently teaches beginners to learn the basic concepts of programming. This project will be a simple game that will teach the basics of the programming language Java.

The initial steps I will take for this project is to research. Starting off with research is crucial as it will help to understand the effects of game-based learning as well as gaining knowledge on the various ways to it can be implemented into a game to teach programming concepts.

An initial game idea is that the player will help a dog find all its bones which will be spread across the board, and once the bones are all picked up the game will go to the next level. The player is required to write Java code in the editor which would be next to the board, and this code will help the dog move around the board. When the player has successfully written code that helps the dog pick up all the

bones the game goes up a level, each level will introduce new concepts such as if statements, for loops, while loops etc.

This game idea will help build a more secure foundation for the basics for the programming language Java which will help people easily grasp more in depth understanding of programming. Having each level introduce new concepts will help the player build their understanding of the programming language as the game progresses.

3.1. Initial Findings

For this project I have chosen to use the Framework React using the programming language JavaScript. This game will be hosted on Heroku so it can be accessed through the web browser.

I have chosen to make this game browser based as this will make user testing an easier experience in comparison to a mobile application which would require a lot of preparation in order to test the functionalities. Web browser will help cater the project to many people where a mobile application will cater for only Apple or only Android which is a big disadvantage of making the game mobile based.

I have chosen the framework React as I have had previous experience with this framework for both web development and mobile development which will be beneficial for me during the development process as I will know the basics to get me started on the game implementation. Having past experience with React will speed up the learning time that would potentially come with learning a new framework or platform. As well as past experience React is a very popular framework currently and there is a lot of research and support online that will be able to guide me during the project.

4. Proposed Method

The method Agile will be used to achieve the final product for this project. Agile method is an iterative process that requires flexibility to jump between different stages of the development process. Agile would be the most effective methodology because it will allow you to work more flexibly with the project process which would include constant testing, feedback and refinement.

To design a game there would be a lot of researching involved as research would help to understand the benefits of game-based learning and help learn the many ways it can be incorporated into a game to teach concepts and critical thinking.

For this project we will be carrying out user testing as it will be the best way to test the game and obtain feedback. User testing is the process through which the interface of a website, app etc. are tested by real users who perform specific task in realistic conditions [6]. The purpose for user testing is to evaluate the usability of the product. User testing will be done by fellow 300-400 level students from Victoria University.

4.1. Gantt Chart

Below in Figure 1 there is a proposed timeline. This timeline is very flexible and can be altered according to

situations. As I am following an Agile Methodology this Gantt Chart involves a lot of steps that occur multiple times this is because in Agile it is a constant iteration between planning, implementing, testing and back to implanting.

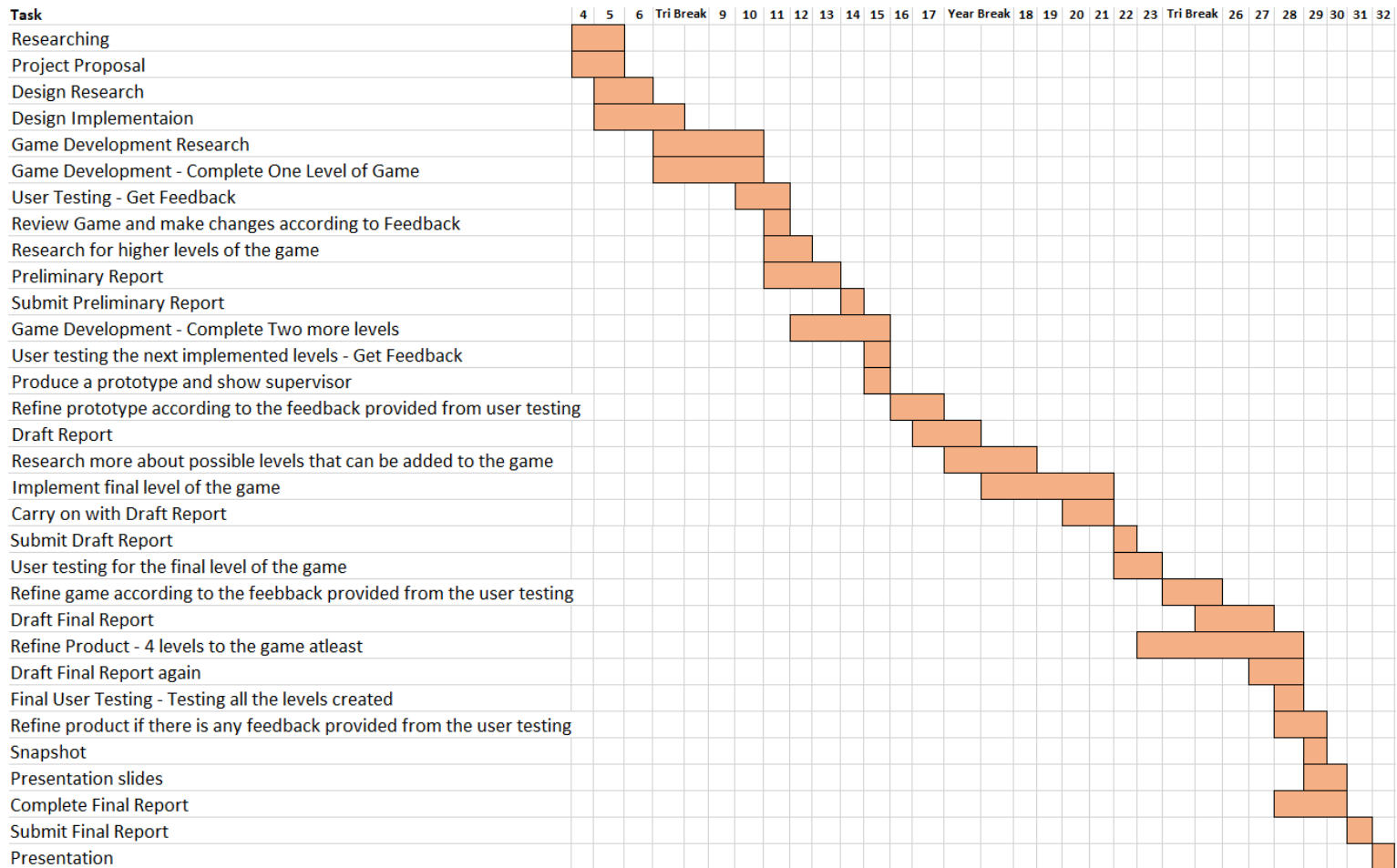


Figure 1: Proposed Timeline

5. Ethics and Resourcing

5.1. Ethics

The ethics considerations around this project are that the project is open source so after completing the development of the game, the code can still be accessible to the supervisor and others. According to the IP agreement 300-400 level students are able to use the product for testing purposes, this is covered by the ethics application (application id: 0000029386). This is agreement is beneficial for the project as it is based on teaching programming concepts and having students that have had prior experience with the language can help give feedback to improve the developed game or to find the bugs within the implementation.

5.2. Budget

There is not budget for this project as there is no need for a budget. However, resources are needed for the project for example, the Victoria University Library. The books and articles that are necessary for researching more about game-based learning for the project are best found in the Campus library. Another resource needed for the project is having accessibility to the ECS Lab computers to test the game on. Testing the game on multiple devices will help understand the speed and capabilities of the game.

6. Risks and Hazards

According to the current circumstances Covid is a pretty big risk, seeing as it is a software project not much will change apart from changing it to keeping it all virtual. If the primary supervisor is unavailable to some reasons, for example, not feeling well due to covid I am expected to reach out to my secondary supervisor Simon McCallum. Table 1 below is outlining some of the risks and hazards.

| Risk | Likelihood | Severity | Mitigation |
|--|-------------------|---|---|
| COVID Lockdown/Isolation | Moderate | Low (The severity is low as this will not impact my project as much as I will still be in contact with my supervisor virtually and will be able to carry out the project at home. | Have weekly video call meetings with supervisor and email updates and questions regularly. |
| Supervisor is ill/ Access to supervisor is limited | Moderate | Moderate | Reach out to secondary supervisor and communicate with them until primary supervisor is not well. |
| Losing code | Low | High | Be sure to keep copies of the developed code and be sure to always commit the code to GitLab repository to avoid losing code. |
| Underestimation of project life cycle | Moderate | High | Need to break down tasks into reasonable blocks and be sure to create and complete those tasks in a estimated timeframe. |

| | | | |
|---|----------|--------|--|
| Hardware failure | Moderate | High | If the device I am working on crashes or breaks down have the code on the cloud such as GitLab, so you are able to access the code from a different device such as the University lab computers. |
| RSI or other strain injury from equipment overuse | Moderate | Medium | Ensure that breaks are taken often. Maintaining good posture and ensure seat, keyboard and screen are positioned as such to minimize strain. |

Table 1: Risks and Hazards

7. Reference

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