Final Report

'Means, Modes, and Medians': Teaching fundamental statistics using serious games.

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Acknowledgements

I would like to thank my supervisor Dr Daniel J. Finnegan for supporting me throughout this project as well as offering guidance and constructive feedback where needed. He was especially very supportive and kept in touch during the very uncertain time of the Coronavirus pandemic and offered help where needed which helped me to keep the project on track and be able to deliver you this report.

CM3203: One Semester Individual Project – 40 Credits

Abstract

In this report I will share how I went about developing my own serious game around the subject of basic statistics. I will talk you through the design and implementation of the game, about some of the initial background research I did into the area of serious games, and what work can be done in future iterations of the system. I will also share some of the results that I gathered from the Case Study performed with the final version of the game. This is where we gathered a test group of primary school students to not only play and test the game but also, through a number of questionnaires, to see if there was any significant improvement in their knowledge about the subject in hand after playing the game, and whether such learning processes could be set for wide scale adoption in traditional educational environments. In this report I will also draw conclusions based on my results from the study and the overall status of serious games right now in 2020 and whether they should replace or support the current traditional learning methods performed in class to help make the processes of learning more efficient and interactive.

Table of Contents

CM3203: One Semester Individual Project – 40 Credits

Introduction

Serious games are growing rapidly as a gaming industry as well as a field of academic research. Researchers predict that technology-enhanced learning will increase with educational computer games [1] with serious games in particular playing an important role and leading the way. The debate has moved from should students play digital games to how to gain the most benefit from this gameplay. Many of these serious games showcase a number of features to try and keep the player engaged as much as possible, from in game rewards to time pressured environments. These features I believe is what has helped the category to grow the way that it has. In this report I will be developing such game myself and testing it among its target audience by carrying out a small but useful Case Study. I am aiming to be able to draw conclusions on whether such games are ready to be used as the basis of learning in educational environments and whether there is any noticeable positive effect of using them. I have therefore broken up this introduction into further sections to be as clear as possible in explaining where exactly I am going with this project and how I will be approaching it.

Project Aims

I want to study how serous gaming impacts the learning of students who use such games as their main learning process, more specifically when applied to mathematical concepts such as Mean, Median, and Mode which I have picked as the basis for this project [2]. Traditional methods of teaching being when a teacher is often directing students to learn through memorization and recitation techniques have been around for decades. Such methods do not focus on the development of students critical thinking, problem solving, motivation and decision-making skills in quite the same way as a serious games can. Although things have moved forward in this area with more and more techniques such as Project-Based Learning and Real-World Learning being adopted [18], I believe a lot more can be done especially with the help of serious games.

This proposal will involve the conception, design, development, and evaluation of a serious game that will teach primary school students basic statistics, more specifically Mean, Median, and Mode. The design principles which will be used during the development are: Employing familiar game mechanics from popular video games, Providing constructive trial and error gameplay to help make learning a more effective experience, and Engaging the students through a competitive and rewarding experience.

Project Objectives

The project objectives are: To be aware of the current space of serious games in 2020 (identifying market leaders and evaluating their process), at the same time gathering more detailed user requirements alongside core functionality that the game must have, then designing Game UI and its functionality, at the same time also identifying core functionalities of the system, evaluating the developed game through a Case Study that looks to see the impact that a serious game has on one's learning, and finally evaluating on the progress of the project itself at the end planning to draw conclusions as well based on the results gathered.

Alongside the project objectives I would also like to highlight some personal ones as well. At the beginning of this project I would only consider myself to be a beginner Java Programmer and therefore wanted to use this opportunity to learn and understand Java programming in much more depth, making sure I knew of its flaws and opportunities. I planned to do this by first completing "*The Complete Java Certification Course*" on Udemy, which I did. Receiving my completion certificate successfully at the end, which can be seen in [Appendix A]. I also look forward to developing my problem-solving skills as well as my project management skills which are both necessary for any project to be successful.

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Project Scope

The main aim of this project was to design and implement a serious game aimed at primary school students based around the subject of basic statistics. This core aspect of the project did not change and remained the main focus throughout. The final game itself was designed to contain 3 mini games each representing a part of the chosen concepts Mean, Median, and Mode which were used as the titles of the games. The development of a new serious game was then to be turned into a Case Study where to evaluate its performance in the real world an experiment would be conducted with participants of the required age group to see if their knowledge of the concepts would improve after playing the game. As part of the project conclusions would be drawn based on the results gathered to see if serious games do indeed have a positive impact on one's learning process.

Project Approach

The start of this project is mainly focused on researching the field of serious games to gather as much knowledge as possible on current most popular serious games as well as what features have been proven to be successful in engaging the students. I also wanted to see the overall acceptance of such games within the education system in its current state. Based on this research I was able to draw up acceptable requirements for the design and development of my own game for this project. Once the design was in place, implementation then began with the focus on implementing the core functionality of the system first, then followed by the Improvements in the User Interface and other additional content to improve the look and feel of the application.

In this project I used Java based programming, because it supports features like multithreading and sockets which make it easier to ensure that the game has low system requirements, considering that most schools operate on older systems. While at the same time keeping in mind the huge number of resources and support material Java brings with it. Its wide adoption in many projects has generated a very helpful and powerful tool to be able to overcome any challenges that the project might bring. In this project, I am hoping to be able to improve and learn new skills in Java as well as project management and problem-solving. I believe these skills are well valued within the industry and are very important to have going forward.

Finally, the game was then to be put to the test in a small case study scenario supported by the University's Saturdays Computer Club group. Nine participants were able to test the game in a real word situation and answer questions on the mathematical concepts presented to them. This enabled me to generate the results that I did which I will go through in more detail in the Case Study section of this report.

Background Research

Serious games are growing rapidly as a gaming industry as well as a field of academic research. The term 'serious games' has developed because people wanted to make a clear distinction between games for entertainment, fun and enjoyment and games that have a serious outcome such as a specific learning message. For example, one of the most successful serious learning games is the Microsoft Flight Simulator [3]. When designing a serious game around mathematics there are a number of key principles, I believe one should follow:

1. Employ familiar game mechanics from popular video games, as talked about by Rieber in Seriously Considering Play (1996) [21]: where he mentions that for knowledge to be useful and meaningful to an individual it must be relevant to that individual.
2. Provide constructive trial and error gameplay for learning, as talked about by Gee in his chapter on Deep Learning Properties of Good Digital Games [22]. Where he talks about how people learn best from their experiences when they get immediate feedback during those said experiences.
3. And I would also go one step further to suggest that, engaging the students through a competitive and rewarding experience should also be included as one of the principals. I say this because games that have a competitive nature often imply training, discipline, and other positive characteristics and are often promoted among the community. Reward systems provide things that are easily compared amongst players, thus encouraging one to keep going and learning.

There is compelling evidence for the effectiveness of serious games as teaching resources [4], and it can be said that the majority of teachers are on board in trying some form of Game-Based Learning in their classrooms [19]. However not all are on board: it very much depends on the subject area itself and current learning methods already in place. The majority of the studies about teachers' attitudes regarding serious games as educational tools find that teachers are often sceptical of certain aspects of Game-Based Learning [19][4]. A lot of articles which highlight the pros and cons of Game-Based Learning do well in picking up on those aspects [20]. Things like the addictive nature of games, the cost associated in the development and for some a potential decrease in the student's attention span are all contributing factors towards a cautious feeling towards serious games. A potential feature that could help ease these aspects is one of being able to track in-game progress. Such a feature was also highlighted in the '*Meta-Analysis of Use of Serious Games in Education*' Article [4]. Success in tracking learning progress could obtain immediate feedback for teachers to moderate teaching material and objectives. Therefore, as I will be mentioning later in the core requirements table I will be including some sort of a reporting tool feature within the application that will help teachers evaluate the effectiveness of the games the students are playing. It will help teachers see all the users and their scores to see if there are any improvement trends among students and to also help out the students who seem to be struggling.

As mentioned above one of the most popular and effective serious games is the Microsoft Flight Simulator [3], which has seen a number of iterations over the years to become one of the best simulation games out there if not the number one of all time [5]. This led me down the path of researching more thoroughly into my own area of serious games, which are around basic mathematical and statistical concepts and to see if some of these have already been adopted in education more specifically primary school education. This research then led me to the discovery of already adopted examples such as Times Table Rockstars [TTRockstars]: a screenshot of the game can be seen in [Figure 1].

Figure 1

TTRockstars has been very successful in taking a basic mathematical concept such as times tables and implementing it in a user friendly and engaging way that resonates with young learners. It has been widely adopted by primary schools not only in this country but across the world [7]. It has successfully been able to implement many of the features talked about at the beginning and in the Introduction like: In game rewards, progression through trial and error, and time limited questions giving it that competitive advantage and feeling. You can see the full feature list on their website [8]. Games where you can collect and use coins or in-game items have proven to be very popular among the young students and combining that with the aspect of speed is what really gives them that competitive feeling and is something I will look to implement in my own game with the goal of making it more engaging.

Nowadays formal education systems are under increasing pressure to respond and adapt to rapid technological innovations. As well as accommodation of technology in its ever-diversifying nature, there is a fundamental need to enhance learning processes through evolution in pedagogical approaches, so as to make learning in formal education more engaging and, it is hoped, more effective [6]. The adoption of technology within these environments can help schools to operate even during such events as school closures, which have a great impact on learning currently. As an example of such event the 2020 global coronavirus pandemic forced millions into lockdown and schools had to be closed nationwide to prevent further spread of the virus [23]. This made schools rush to find ways of operating digitally and with the same learning outcome that one would see if attending a school as normal. This certainly encouraged further adoption of online learning for students staying at home through current serious games such as TTRockstars and perhaps gave schools the opportunity to invest and trial other games as well. This opportunity given to schools to research more into this topic should help prepare them for future such event and perhaps can help serious games as well on their road to widescale adoption.

In this last section of my research I would like to focus more on why I decided to go with the tools I used and what benefits they bring in a scenario like this. Once the decision had been made to create a stand-alone desktop app, the next step was to decide on a programming language. First of all, as the project required the storage of user data the obvious choice of using the Computer Science School MySQL servers as the backend was made. It would allow me to conduct the case study on as many machines as I wanted as long as they were connected to the University's network. Alongside that, the idea of using Java based programming made the integration between these two languages a very simple and easy process as I was able to draw upon my previous knowledge from past years projects to execute the solution.

The decision to use Java came from a number of advantages offered by the language. First of all being able to export the game files as a playable JAR file made things especially helpful during the Case Study which included nine participants all with their own machines. As long as the machines had a version of Java installed and were connected to the University's wireless network, I was able to simply drag and drop the game file onto their desktop. Java provides a rich set of libraries to create Graphical User Interfaces in a platform independent way. One such library that I planned to utilise was the Java Swing library which I will talk more about in the design and implementation section. Doing this project in Java would also help me tremendously develop my own skills in the language as it is a very sought-after skill within the IT industry.

Due to this project handling user data and participants being under the age of 18 years, it was vital to seek Ethical Approval from Cardiff University to make sure all the guidelines were followed, and consent was granted to carry out the research I needed. For this it was also important that I completed the University Research Integrity training [Appendix B]. This helped me in understanding the responsibilities of working with children under the age of 18, the storing of user data and the different privacy guidelines that come into effect when doing so.

Specification and Design

To make things easier to follow I have broken down the specification and design of this project into the following key sections:
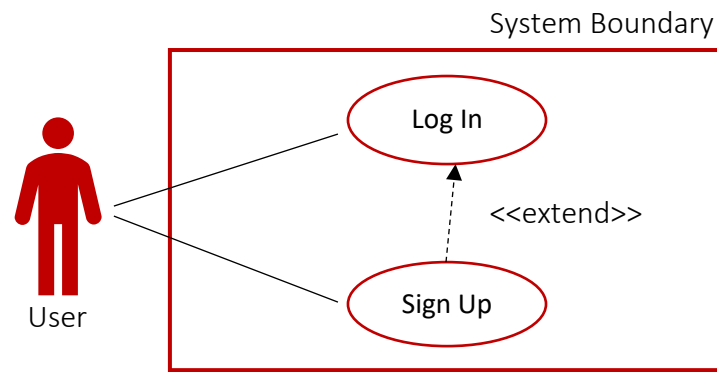
- The Use Cases which will help describe the type of interaction a user might have with the system in order to achieve their goals.
- The Login System, which must allow access to both teachers and students and must allow to both sign-up and login with correct credentials.
- Game Mechanics where I will go through in detail about how exactly the games will work and what in game rewards will be on offer for players.
- 3 Mini games each covering a part of the statistical and mathematical concepts chosen (Mean, Mode, and Median in this case).
- Core Requirements which will outline all the requirements the game should achieve by the end of the project.
- User Interface Designs where I will conceptualise how the game will look and talk through some of the key features it will have.
- Risk Assessment being the final section where I will conduct a thorough risk analysis to minimise and mitigate some of the most likely things to go wrong.

Use Cases

The following Use Cases are what I believe to be some of the main types of activity a typical user that will be using the system will make. It should help show and describe possible interactions between a user and the system. The Use Cases will be aimed both at Teachers and Students who are the target users as mentioned earlier in the report. Each Use Case will follow with a Use Case diagram to aid with understanding the situation.
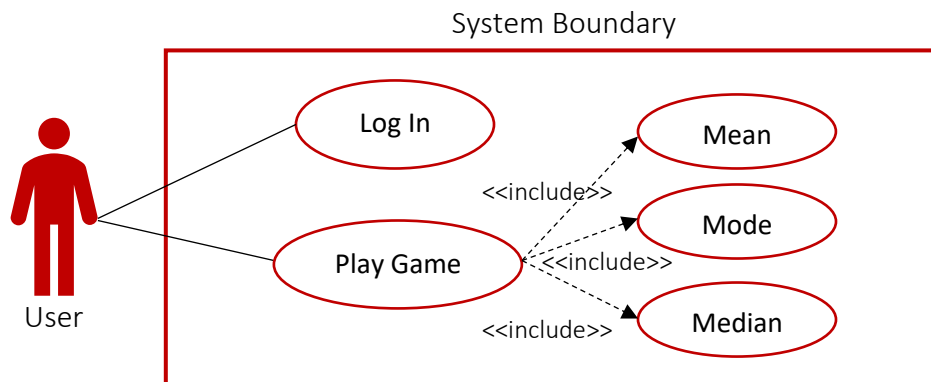
Logging In Use Case

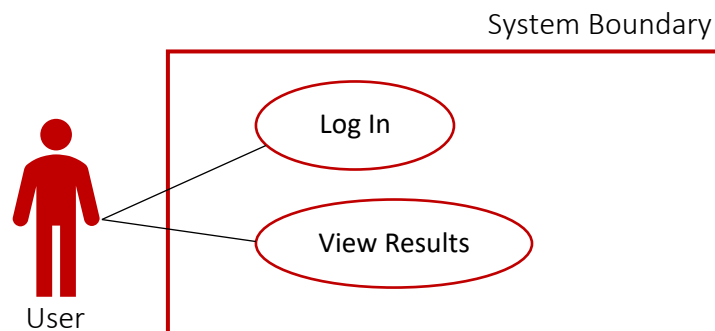| Use Case Name	Logging In
User Type	Student
Description	The User will be able to log into the system using her made up username, and password of their choosing. If not, user will also be able to sign up and try again.
Pre-conditions	User has the system downloaded on their machine. User is connected to University's network. User has Java supported on their machine.
Post-conditions	User is inside the system and is able to choose a game and processed with their interaction.
Basic Flow	1. User opens the system on their machine. 2. User enters all the required information into the field text boxes. 3. User clicks 'Log In'' button.
Alternative Flow	1. User opens the system on their machine. 2. User enters all the required information into the field text boxes. 3. System rejects username as it does not exist. 4. User clicks on the signup button which will take you to the signup screen. 5. User enters all the required information into the field text boxes and clicks 'Sign Up' button. 6. System accepts and takes the user back to the Log In screen. 7. User enters all the required information into the field text boxes again. 8. User clicks 'Log In'' button.

System Boundary

Playing A Game Use Case

Use Case Name	Playing A Game
User Type	Student
Description	The user will be able to pick a game of his or her choosing and be able to progress through it. A total number of 3 games will be available to play Mean, Median, and Mode. Each game will have an information page to inform the user of how to play the game before proceeding to play.
Pre-conditions	User has the system downloaded on their machine. User is signed up to play. User is connected to University's network. User has java supported on their machine.
Post-conditions	Users score is recorded on the database in term of number of questions the user got right and wrong. The Users total points have also been added up and are assigned to his surname.
Basic Flow	1. User opens the system on their machine. 2. User successfully logs in. 3. User selects to play Mean and proceeds to the Instruction screen. 4. User proceeds to play the game. 5. Database accurately logs user scores and points. 6. User is given the option to play again or return to main menu.
Alternative Flow	1. User opens the system on their machine. 2. User successfully logs in. 3. User selects to play Mode/Median and proceeds to the Instruction screen. 4. User proceeds to play the game. 5. Database accurately logs user scores and points. 6. User is given the option to play again or return to main menu.

System Boundary

Teacher Checking Progress Use Case

Use Case Name	Teacher Checking Progress
User Type	Teacher
Description	The teacher will be able to log in into the teacher's portal and be able to view all the scores from all the games from all the users.
Pre-conditions	Teacher has the system downloaded on their machine. Teacher is successfully signed up. Teacher is connected to University's network. Teacher has Java supported on their machine.
Post-conditions	Teacher can see a table of scores from all the users and what games they played over time.
Basic Flow	1. Teacher opens the system on their machine. 2. Teacher enters all the required information into the field text boxes. 3. Teacher ticks the radio button for Teacher Log In. 4. Successfully logs in. 5. Selects to view Student Results. 6. Backend system successfully pulls all the results into one table accurately.
Alternative Flow	1. Teacher opens the system on their machine. 2. Teacher enters all the required information into the field text boxes. 3. Teacher ticks the radio button for Teacher Log In. 4. System rejects username as it does not exist. 5. Teacher requests an account to be made for them from the admin. 6. Teacher enters all the new account information into the field text boxes. 7. Teacher Ticks the radio button for Teacher Log In. 8. Successfully logs in. 9. Selects to view Student Results. 10. Backend system successfully pulls all the results into one table accurately.

Using Earned Rewards Use Case

Use Case Name	Using Earned Rewards
User Type	Student
Description	User is able to successfully purchase in game features through the "Game Shop" with their points accumulated by playing the mini games. The features should be accessed through a special area inside the main menu user interface and the accumulated number of points should be displayed to the user on the main menu screen and with in the shop itself.
Pre-conditions	User has the system downloaded on their machine. User is signed up to play. User is connected to University's network. User has Java supported on their machine.
Post-conditions	User has purchased one of the in-game features and the new feature is now displayed to the user.
Basic Flow	1. User opens the system on their machine. 2. User successfully logs in. 3. User selects to open the in-game shop. 4. Database accurately displays available to purchase features and the Users total number of points. 5. User Clicks to purchase. 6. Purchase Successful.
Alternative Flow	1. User opens the system on their machine. 2. User successfully logs in. 3. User selects to open the in-game shop. 4. Database accurately displays available to purchase features and the Users total number of points. 5. User Clicks to purchase. 6. Purchase Failed, Not enough points. 7. User return to Main Menu and processed to keep playing the game to earn more points. 8. User return to the in-game shop and tries again. 9. Purchase Successful.

System Boundary

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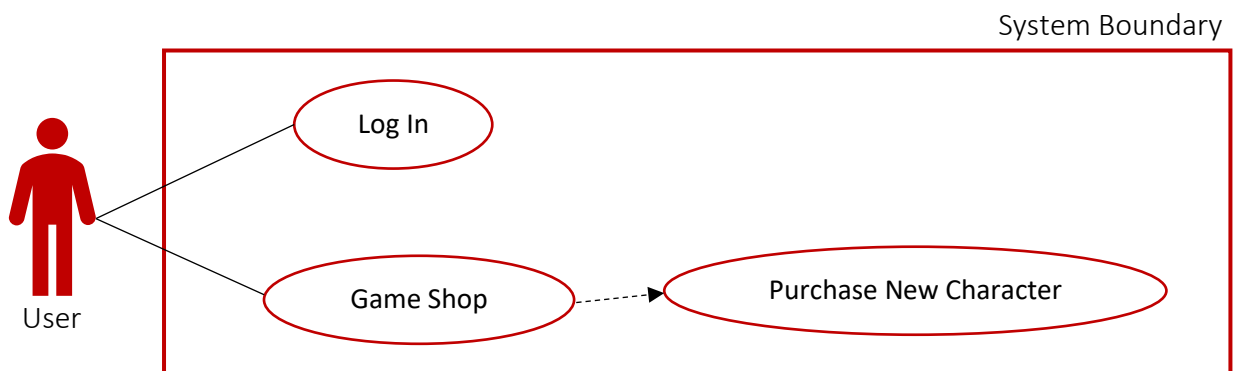
The Login System

The login system is the first thing that will greet the new users to the system. Therefore, it had to remain simple and easy to use so as not to discourage potential users with a long sign-up process, while at the same time secure enough to comply with GDPR. From the user's perspective the first page they would see would be the Log In page with an option to sign up below. This would allow the user to register an account, taking only the necessary information from them. These would be the users name, username, and password. After the successful registration, the user would only require username and password to login into the system and proceed with their intentions. After successfully logging in, the user would be taken to the main page, where he or she can proceed to play the mini games available, view their previous result and attempts, and access the in-game shop as mentioned in the last Use Case.

The plan was to store the user's credentials in an SQL table along with the rest of the data on the same database. In fact, one table would be for Student credentials and one for Teacher credentials. To be able to distinguish between the users, a teacher login would be accompanied by a click on the Teacher Log In option below the required text field boxes given on the Login screen. Due to security reasons Teachers would have to request the admin to make them an account as to prevent students having the same access. In any case if the credentials were incorrect a message would appear to say that the login was unsuccessful, and the user would be able to try again.

Game Mechanics

One of the biggest challenges of developing a serious game is harmonizing how fun the game is with how educational you want it to be. After taking some inspiration from how TTRockstars and other serious mathematical games operate I decided to go with a time limited format. A format where the player is given a limited time to answer as many questions as possible. Where each game round would last 1 minute and allow the player to answer as many questions as possible, allowing the game to continue even if the answer was incorrect.

For each correct answer, the player will be awarded 100 points which will then be totalled up at the end of the game and added to the players running points count. The points will then be available to use in the Game Shop. For this game I have chosen to give the player the ability to upgrade their in-game character. A total of 7 different characters will be available to the player to purchase using their points. In order to maintain the motivation to collect points, different characters within the shop will cost different amounts of points, with some being as high as 10,000 points for example. These points will be acting as in-game rewards and are intended to give players a sense of achievement for accomplishing the task in hand, giving them the motivation to try and answer as many questions correctly as possible. The running total number of points for each user will be displayed in the Main Menu area and inside the Game Shop at all time to inform the user of how many points they have accumulated thus far and how much they can spend or how much more they need to save up.

The Game scoring will be very simple and will only be based on the number of questions answered correctly or incorrectly. Scoring is a crucial part of any game: a good scoring algorithm helps to hook players to the game experience [17] and combined with a balanced rewards system should help to retain players for as long as possible. During the 1-minute game rounds to provide a constructive trial and error gameplay experience it wouldn't matter if the player answered the question correctly or incorrectly the game will still move on to the next question and at the end of each game a tally will be shown as feedback to the user. The tally will show the number of correctly and incorrectly answered questions alongside the total number of points gained from that round, which would be number of correctly answered questions times by 100.

Mini Game Design

Mean	Median	Mode

The mathematical concepts I have chosen as mentioned earlier in this report are Mean, Median, and Mode. Each one will be presented in the Main Menu as a mini game as shown above. The feel and look of the games will be identical for simplicity of the development and for the benefit of the user. The similarity of the games should help the user understand and get his or her head around how the system works much quicker, so they focus on the learning outcome sooner. The user will be free to choose whichever game they like at the start and be able to switch to a different game at the end of each game round. As mentioned in the Game Mechanics section the player will have 1 minute for each round of the game to answer as many questions as possible. With this time limit I am intending to provide an interactive learning experience that helps to keep the user engaged and their interest high while giving them a sense of urgency. Getting the balance right is definitely one of the main challenges for serious game development [10].

Each game round question will consist of 5 randomly generated numbers which the players will have to use to correctly calculate the chosen concept for that game. The numbers will be represented like below, making sure that they are clearly visible and are easy to read for the player:

1	2	3	4	5

With colours matching that of the games theme, which for this game I have chosen to be Red for Mean, Green for Median, and Purple for Mode. It is well known that colour has a profound impact on one's ability to learn and stay focused [9]. Colours unavoidably affect our attention and motivation to work due to their impact on our emotions. With the colour red being linked to drawing one's attention to detail thus help improve and stimulate the brain. By setting different colours for different games I will be trying to stimulate the brain and help students benefit from learning more effectively. Giving each topic a colour is intended to help separate the knowledge gained from each concept while at the same time helping to improve the retention rate of said knowledge as well. There will of course be a certain percentage of the users who may be colour blind and may not fully benefit from this particular design feature, but they should still be able to fully benefit from the game itself by reading about the concepts and taking part in the gameplay.

Core Game Requirements

| Requirement	Reasoning
The game must keep a total score during the game.	In order to sustain motivation, feedback needs to be aligned with reward mechanisms in games. Moreover, having the right reward is key to making sure players feel there is value to their actions. There are different ways of rewarding players, such as increasing a score, collecting tokens in exchange for things, or changes in the avatar or virtual world in response to actions. [11]
The game must have a Teacher reporting feature.	The teachers can also get some feedback on the progress of their students. Once data is collected as part of the game statistics, it is easy to make reports of them for the teacher to outline the strengths and weaknesses of each student.
The game should have some kind of bonus material.	In order to maintain the motivation to collect points or tokens, they can be associated with bonus material. For instance, the player can have access to tools that assist them in their goals, collector items for their avatar, ability to unlock games, or upgrades to the graphics.
The game should have a break timer.	Apart from the score, the system should indicate if the player has played too long and encourage them to take a break for their own wellbeing. One way to do this for example is for the character to have an energy meter or have rounds with time limits after which the player will have to pause playing.
The game must have an effective user experience.	In order for the game to be engaging it should of course have a user interface in order to provide some sort of visual feedback during the game. This could feature a number of different locations in order to keep the player motivated to keep playing and exploring. These locations can also be unlocked throughout the game by completing different levels.
The game should feature a Competition/ Challenge aspect.	All games involve an element of challenge. At its simplest form, the player's main challenge is to beat their high score. Keeping also in mind the target audience, a natural competition between the pupils is bound to occur as to who can get the highest score possible.

User Interface Designs

Login/Sign Up Screen Designs
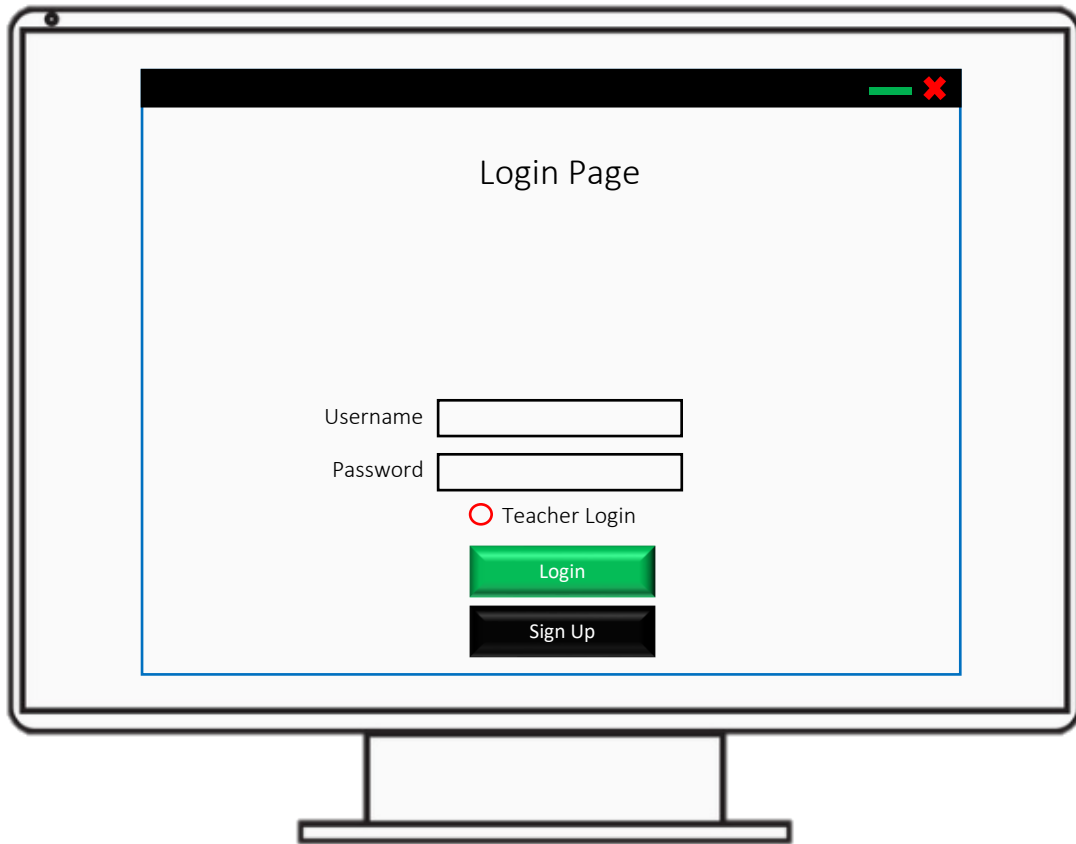
<u>Notable Features</u>

Feature	Description and Justification
Login Button	The Login button will be used as a trigger for the system to validate the information entered in the text fields to check for user's existence on the database. If anything is missing or the information is incorrect an appropriate error message will be displayed to the user.
Sign Up Button	The Sign-Up button is there for new users to be able to sign up and will take you to the sign-up screen (shown below) where you will be asked to make a new account using your name, new username, and a memorable password.
Teacher radio button	As mentioned earlier teachers will have their own area to check upon the progress of students. Because I plan to store teacher logins in a different table for security reasons, by activating this radio button it will tell me to use that table instead of the normal user table.
Text Fields	Text fields will be given for users to enter in their details before logging in order to validate their account.
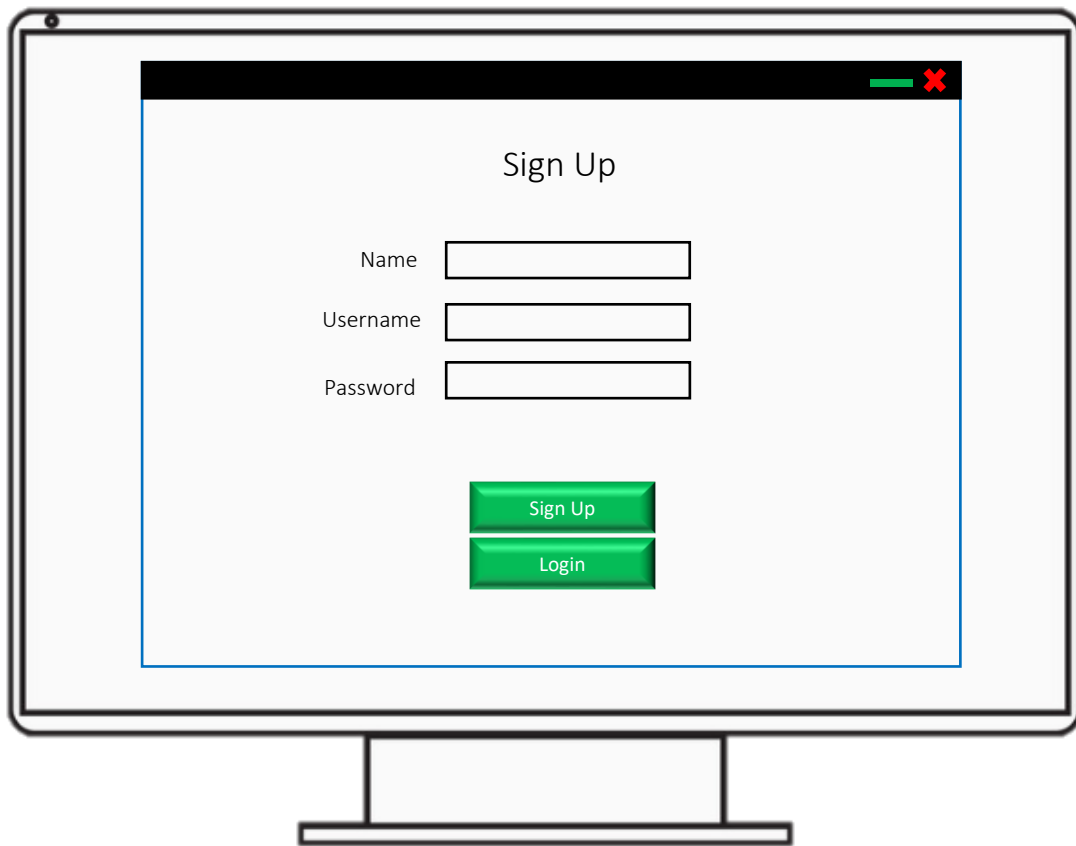
Notable Features

Feature	Description and Justification
Sign Up Button	Once the new user has entered all their information, he will then proceed to click the Sign-Up button which will trigger the application to register the new account on the applications database. A helpful user message will also be displayed to confirm a successful sign-up.
Login Button	After a user has signed up he can then click on the Login button and proceed to the login screen once again.
Text Fields	Text fields will be given for users to enter in their details in order to sign up for a new account.

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Main Menu Screen Design

Notable Features

| Feature	Description and Justification
Results Button	This will take the user to the results table where they will be able to see all their attempts and all the games played over time. For each attempt it will show them the number of correct and incorrect questions for that round along with the number of points they got. Alongside the game name, it will also show their name and the associated ids.
Game Shop Button	This will navigate to the Game Shop where the player will be able to spend their points on in-game items such as purchasing a new character. For more detail on this please refer to the *Game Shop Screen Design*.
Mean Game	This will navigate into the Mean mini game. Where the first thing the user will see is an Information screen which will explain the concept of Mean by giving user examples of how to calculate it. It will also give some idea of how the rounds will work.
Median Game	This will navigate into the Median mini game. Where the first thing the user will see is an Information screen which will explain the concept of Median by giving user examples of how to calculate it. It will also give some idea of how the rounds will work.
Mode Game	This will navigate into the Mode mini game. Where the first thing the user will see is an Information screen which will explain the concept of Mode by giving user examples of how to calculate it. It will also give some idea of how the rounds will work.
Quit	This will give the user the option to quit the application if they have had enough of playing.
Total Points	As mentioned previously the number of total points associated to that player will be visible throughout the game to make sure the player knows how much they have accumulated over time.

Game Shop Screen Design
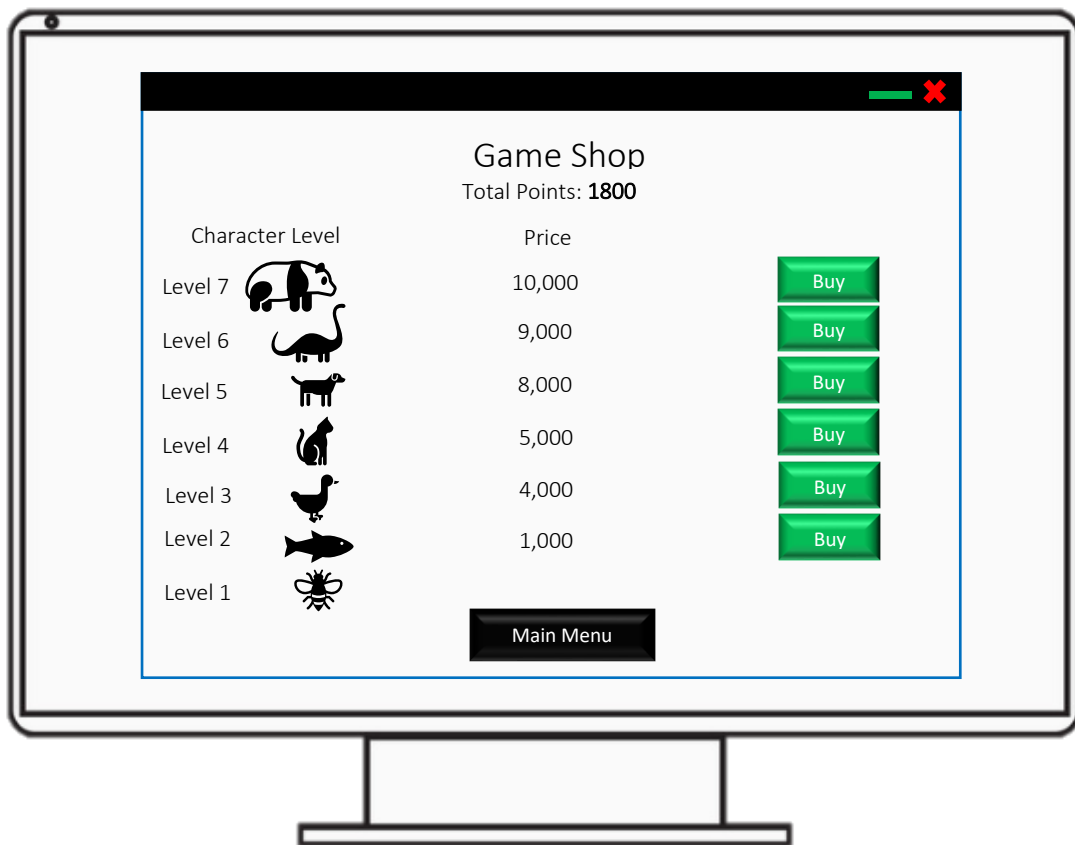
Notable Features

| Feature	Description and Justification
Character Levels	Characters will be ranked from levels 1 to 7 to help reinforce the feeling of progression for the user as they try to get to the next level. The character levels unfortunately will not affect the game play directly. However, this can potentially be implemented in future iterations of the game.
Price	The price will reflect the character level with higher levels costing significantly more than the previous, with the highest cost being 10,000 in order to make the player work for it. It will be interesting to see whether I was able to strike the right balance.
Buy button	The Buy button will help the user execute the purchase. When clicked the total number of points will be checked to ensure that there are sufficient funds in the users account. Whether the purchase has been successful or not due to the lack of points an appropriate message will be displayed to the user.
Total Points	As mentioned previously the number of total points associated to that player will also be visible in the Game Shop. This will allow the player to see exactly how much they have accumulated from playing, helping them see how much they have to spend or how much more they need to earn.

Game Information Screen Design
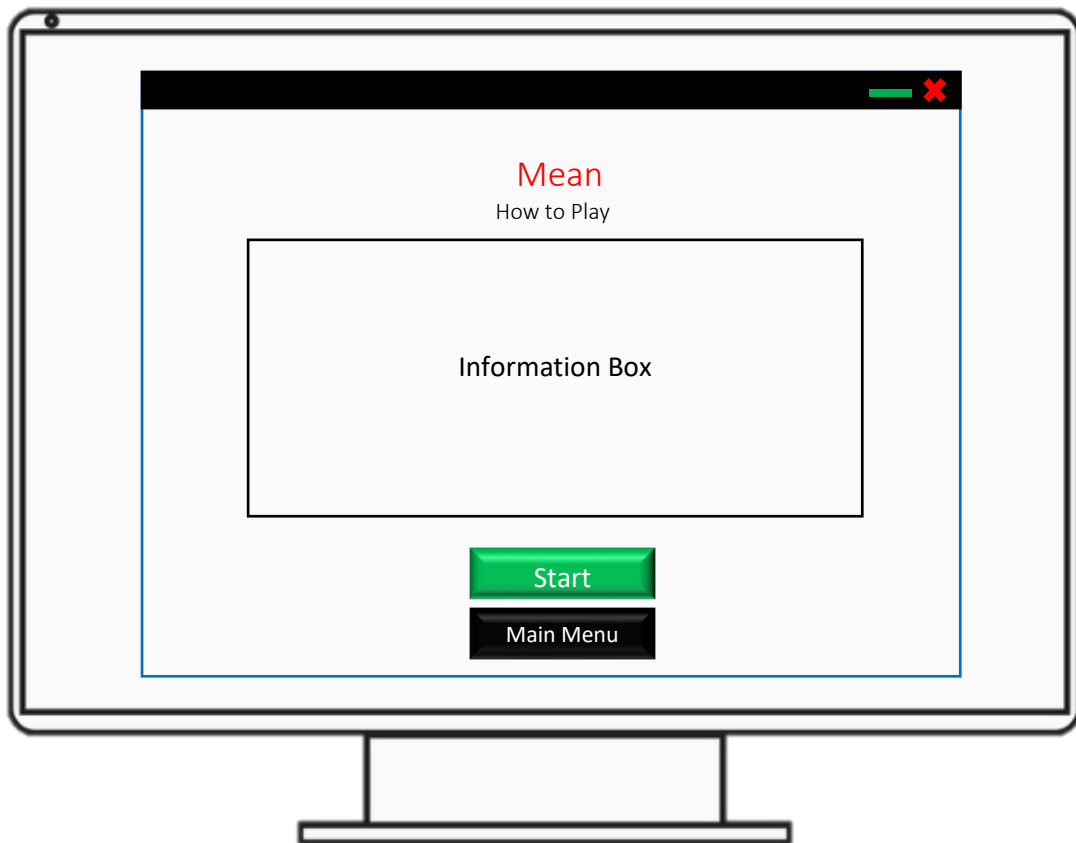
Notable Features

The Game Information Screen Design will remain the same for all 3 mini games with only the information box being changed to reflect the chosen mathematical concept. As an example, I have chosen the Mean mini game above.

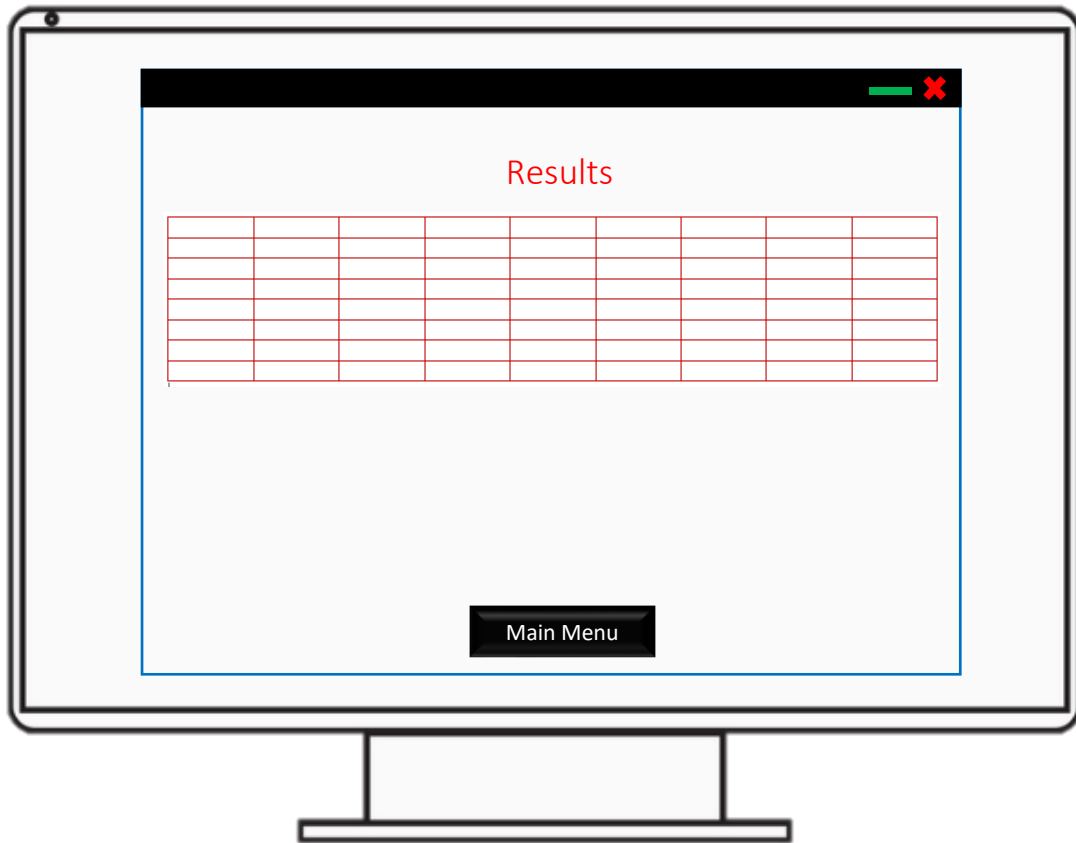| Feature	Description and Justification
Information Box	The Information box will aim to explain the concept of the game to the user. It will provide an example of a typical question that will be asked and will walk them through the solution. The information will of course vary depending on what game the user has chosen.
Start Button	This will navigate the user straight into a game round where they will have 1 minute to answer as many questions as possible.
Main Menu Button	This will navigate the user back to the Main Menu if they wish to choose a different game or if they clicked this one by accident.

Mini Game Screen Design
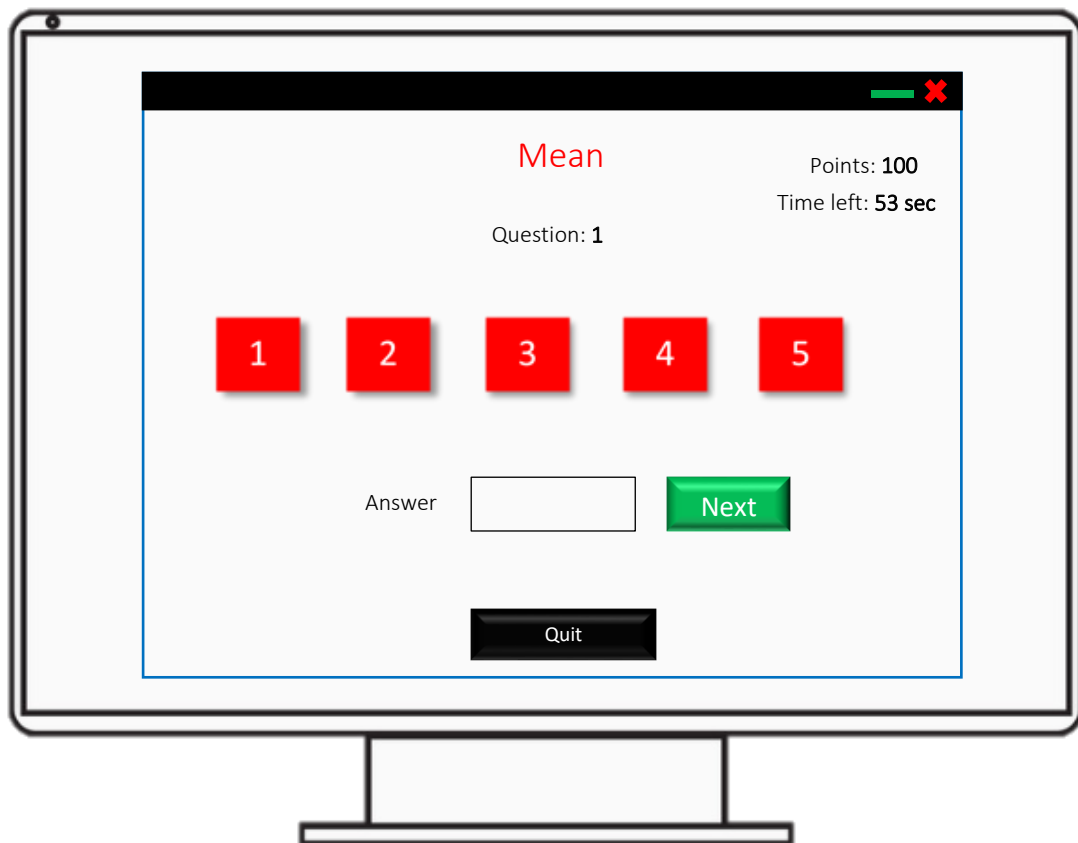
Notable Features

The Mini game design will be the same for all games as mentioned before. The screen design itself will not change visually but will be different on the backend side as the answer validation will have to be different depending on what mini game the user has chosen to play. As an example, I have chosen the Mean mini game.

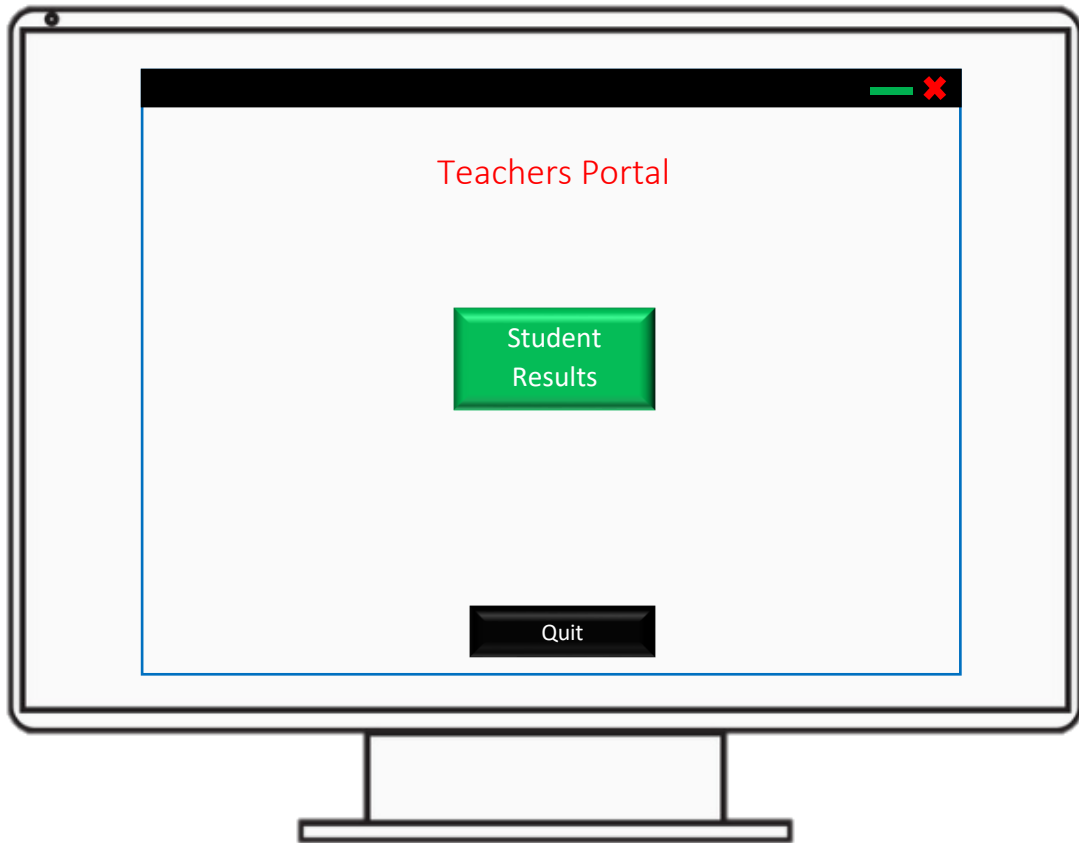| Feature	Description and Justification
5 numbers	These number are at the center of the way the game will work, therefore they will be at the center of the screen hopefully making them easier to see and understand. Each number will be randomly generated from 0 to 10 for each question.
Answer Box	The answer box provides the user with a way to input their answer. It will be a simple text field box.
Next Button	When clicked the Next button will validate the users answer to be correct or incorrect, either way the game will move on to the next question. If the answer is correct, then 100 points will be added to the users point score, which will be visible in the top right corner. For both outcomes, the system will keep track of how many questions the user has answered correctly or incorrectly and will display the totals at the end of the game.
Time Left	The countdown will be in seconds starting form 60 and going to 0. It will inform the user of how long they have left in this round to answer the questions.

Results Screen Design

Notable Features

Feature	Description and Justification
Results Table	The results table will show every game the user has attempted, the number of correct questions, the number of incorrect questions, how many points they achieved on a specific game, and the appropriate ids for the game and the user.
Main Menu Button	The Main Menu button will take the user back to the Main Menu screen where they can continue playing the mini games.

Teachers Portal Screen Design

Notable Features

Feature	Description and Justification
Student Results Button	After a teacher has successfully logged in, they will be presented with a Teacher Portal screen where they can access all the student results. When clicked, the Student Result button will take the teacher to a similar screen described in the *Results Screen Design* but in this case, it will have the scores of all the students signed up to the game. The intention by providing this feature is that the Teachers will be able to track and monitor student progress and be able to attend to students who might be struggling to understand the concepts chosen for the game.
Quit Button	Just like the students the Teacher will also have a Quit button in order to exit the application once they are done using it.

CM3203: One Semester Individual Project – 40 Credits

Risk Assessment

In any software project such as this, there is always an element of risk associated. By completing a risk assessment prior to implementation, this will most certainly help to minimise any potential risks with the project and help me achieve the project aims to the best of my ability. Below is a table of potential risks I believe could occur during the project along with their likelihood of occurrence and how I plan to avoid each one.

Risk	Risk Severity	Risk Likelihood	How to avoid it.
1. Actual loss of development progress	High	Low	Ensure that backups of all data are taken regularly and stored in a different location.
2. illness	Medium	Low	Ensure sufficient time is allowed for setbacks and illnesses within the work plan.
3. Scope Change	High	Low	Make sure to keep work plan up to date and be able to reallocate time as soon as any change is introduced.
4. Learning Curve Delays	Medium	High	Start learning Java as soon as possible within the project to give a better understanding of all the flaws and possibilities that it offers.
5. Delays in Schedule	Medium	Medium	Ensure all tasks are started as soon as possible. If ahead of schedule start early on the next task.
6. Integration Risk	High	Medium	Activities involving integration of technology or different parts of the project can often cause setbacks. In order to smooth out the process early research should be done on the compatibility of each part.
7. Design Change Risk	Medium	Low	The potential that my design can fail to meet core requirements agreed upon. I will make sure to conduct regular supervisor meetings in order to make sure I am on track.

Below I have also put these risks into a Risk Matrix, hopefully giving you a better understanding of how they might impact the project.

Risk Matrix

| Severity	Likelihood of Occurrence		
	Low	Medium	High
Low			
Medium	(2) (7)	(5)	(4)
High	(1) (3)	(6)	

Implementation

Throughout the implementation of this system I have tried my best to use the best coding practices to help ensure my code is easily understandable and readable for anyone new to the project. These practices included:

- Commenting my code where possible and giving a brief description of what's going on and where.
- Reducing code duplication where possible by reusing bits of code around different parts of the system where I can.
- Giving appropriate names to variables used that help describe their purpose in the system.

To make things easier to follow I will go through each section of the implementation in the same order as discussed in the Specification and Design. For each section I will talk you through how I went about implementing the designs and the functionality behind them. I will include screenshots where possible of the final design as well as screenshots of the source code behind that design.

As mentioned previously I will be using the programming language Java to implement the system. More specifically, as this project requires the use of a GUI, I will be using Java Swing. Java Swing is part of Java and provides the ability to create graphical user interface components, such as buttons, scroll bars, check boxes etc. [12] It's easy-to-use nature will help me to deliver the project on time and to achieve all the requirements set out at the beginning of this project. As I am working with Java, I will be using the Eclipse IDE as my code editor due to its Java friendly environment.

Software Architecture diagram
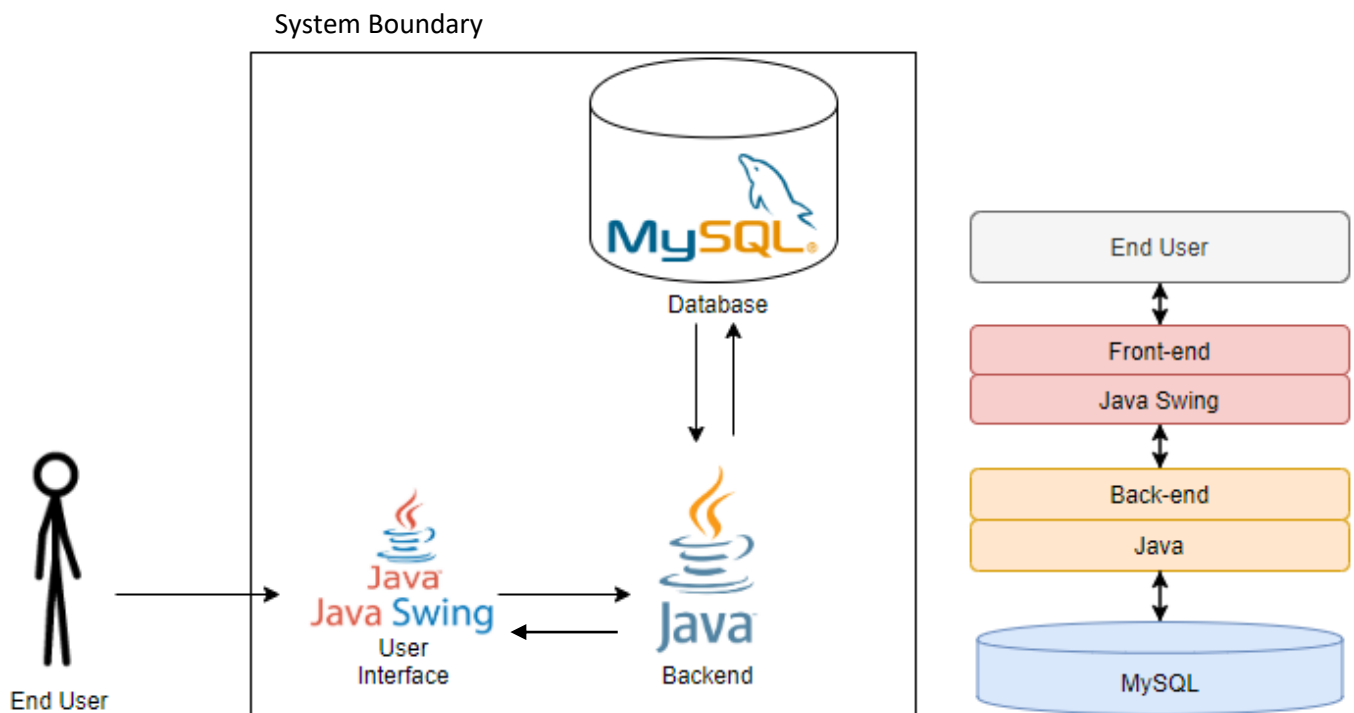
The software architecture diagram above shows the technology used for each part of the system. The user will interact with the application first using the User Interface which will be built using Java Swing. Java will act as the backend of the system in this case and will process all the information given to it from the user interface inputs. For the purpose of logging in and storing users results the application will communicate with a MySQL database which will be hosted on Cardiff University's schools' network for the purpose of this project.

Database Connection

In order to achieve some of the core requirements set out in the beginning like having a teacher portal, allowing players to purchase in-game items, and recording player scores, the application needs to be connected to a database where I can store all this necessary information. To accomplish this, I have chosen to use my *MySQL* university account as mentioned already. Although to access it you need to be connected to the University wireless network, as the Case Study will be carried out within the University's premises it will be more than sufficient for the development of this project.

Once I have created the necessary tables like *Users*, *Teachers*, and *Results* I needed to establish connection between MySQL and the application, this was achieved with the following code.

```java
dbconnection(){
    try
    {
        String s = "jdbc:mysql://csmysql.cs.cf.ac.uk:3306/c1618004?serverTimezone=UTC";
        con=DriverManager.getConnection(s,"          ","          ");
        stmt = con.createStatement();
    }
    catch(Exception e)
    {
        System.out.println(e);
    }

}
```

For security reasons I have covered up my username and password. In case the connection fails I have used a *try-catch* block to let me know of the issue that caused it to fail. Within the database connection file, I have also defined all the situations where I will need to either retrieve the data or write new data to the database. These include *Logging in for Students, Logging in for Teachers, Signing Up, Inserting new Results, updating player points, updating user character after purchase, getting player results, getting results for teacher*, and *getting player points*. As an example [Figure 2] shows the *Logging in* procedure: where I pass in the user input for username and password and then check their existence in the table with an if statement. *String s* reads in all the existing users' and if the users input match up then I retrieve their points and other relevant information and let them proceed to the main menu where some of this information will then be displayed on the screen such as the user total points.

```java
boolean  Login(String username,String pass){
    try
    {
        boolean flag=false;
        String s=("select * from users");
        ResultSet rs=stmt.executeQuery(s);
        while(rs.next())
        {
            if(username.equals(rs.getString(3)) && pass.equals(rs.getString(4)) ){
                flag=true;
                Login.name=rs.getString(2);
                Login.points=rs.getString(5);
                Login.charid=rs.getString(6);
                Login.userid=rs.getString(1);
            }
        }
        return flag;
    }
    catch(Exception e)
    {
        System.out.println(e);
        return false;
    }
}
```

Figure 2

Login In Screen

The Login screen was fairly simple to implement and needed to include the required validation checks mentioned earlier, as well as the ability to switch to a Teacher login as required to access the teacher's portal area.

Below are the source code screenshots of the User interface implementation for the Login page [Figure 3][Figure 4]. In the screenshots given you can clearly see me declaring the Java Swing elements such as *JButton* and *JLabel* representing the features on the page such as username and password fields required during the login process. The elements require you not only to set the position on the screen but also all the other properties such as the font and colour which you can also see down below. In [Figure 4] you can see how I implemented the Teacher login validation. In order to switch to Teacher login, I included a radio button which the Teacher would have to activate to access the teacher's portal. By checking the status of this radio button, I can then check which table I need to look in, as I will have a separate table to store login details for teachers. I also proceeded to add a static background to the screen so as to visually please the user. This can also be seen at the end of [Figure 4]

```java
JButton btnNewButton = new JButton("Login");
btnNewButton.setFont(new Font("Tahoma", Font.BOLD, 12));
btnNewButton.setBounds(294, 361, 109, 29);
contentPane.add(btnNewButton);

JLabel lblNewLabel_1 = new JLabel("LOGIN");
lblNewLabel_1.setHorizontalAlignment(SwingConstants.CENTER);
lblNewLabel_1.setForeground(Color.BLACK);
lblNewLabel_1.setFont(new Font("Tahoma", Font.BOLD, 30));
lblNewLabel_1.setBounds(279, 11, 124, 52);
contentPane.add(lblNewLabel_1);

JLabel lblUserName = new JLabel("User Name");
lblUserName.setForeground(Color.BLACK);
lblUserName.setFont(new Font("Tahoma", Font.BOLD, 12));
lblUserName.setBounds(294, 246, 73, 14);
contentPane.add(lblUserName);

JLabel lblPassword = new JLabel("Password");
lblPassword.setForeground(Color.BLACK);
lblPassword.setFont(new Font("Tahoma", Font.BOLD, 12));
lblPassword.setBounds(294, 289, 73, 14);
contentPane.add(lblPassword);

JButton btnSignup = new JButton("SignUp");
btnSignup.addActionListener(new ActionListener() {
    public void actionPerformed(ActionEvent e) {
        new signup().setVisible(true);
        Login.this.dispose();
    }
});
btnSignup.setFont(new Font("Tahoma", Font.BOLD, 12));
btnSignup.setBounds(294, 392, 109, 31);
contentPane.add(btnSignup);
```

Figure 3

```java
JRadioButton rdbtnTeacherLogin = new JRadioButton("Teacher Login");
rdbtnTeacherLogin.setBounds(294, 331, 109, 23);
contentPane.add(rdbtnTeacherLogin);

passwordField = new JPasswordField();
passwordField.setBounds(294, 304, 109, 20);
contentPane.add(passwordField);

JLabel fieldsalert = new JLabel("");
fieldsalert.setForeground(Color.RED);
fieldsalert.setBounds(20, 200, 145, 14);
contentPane.add(fieldsalert);

JLabel lblNewLabel = new JLabel("");
lblNewLabel.setIcon(new ImageIcon(Login.class.getResource("/images/mainLogin.jpg")));
lblNewLabel.setHorizontalAlignment(SwingConstants.LEFT);
lblNewLabel.setBounds(0, 0, 673, 447);
contentPane.add(lblNewLabel);

this.setLocationRelativeTo(null);
```

Figure 4

In [Figure 5] you can see how exactly the functionality of the page was implemented. As well as how appropriate error messages are used like, *"Both Username and Password are Required!"* and *"Wrong login Details"*, in case the user entered wrong information or does not fully fill in the information required to log in. Log in checks are carried out by first declaring a new database connection at the beginning of the file with the following statement.

```java
public static dbconnection db=new dbconnection();
```

then passing in the entered username and password where appropriate to check their existence in the appropriate table as mentioned in the Database Connection section. The first if statement in [Figure 4] demonstrates the Teacher check mentioned earlier. If the radio button is selected, then I can call the appropriate method from the database connection file and pass in the details entered. If login details are

correct the relevant page will be loaded and Log in page will be disposed of. [Figure 6] shows the final product when the source code is compiled.

```java
btnNewButton.addActionListener(new ActionListener() {
    public void actionPerformed(ActionEvent e) {

        if(rdbtnTeacherLogin.isSelected()) {
            String username=textField.getText();
            String password=passwordField.getText();
            if(username.equals("") || password.equals("")) {
                fieldsalert.setText("Both Username and Password are Required!");
                return;
            }
            fieldsalert.setText("");
            Logincheck=db.TeacherLogin(username, password);
            System.out.println(Logincheck);
            if(Logincheck) {
                new TeacherPanel().setVisible(Logincheck);
                Login.this.dispose();
            }else {
                ImageIcon icon = new ImageIcon(signup.class.getResource("/images/cross.png"));
                JOptionPane.showMessageDialog(null,"Wrong login Details!","Failure", JOptionPane.PLAIN_MESSAGE,icon);
            }
        }else {
            String username=textField.getText();
            String password=passwordField.getText();
            if(username.equals("") || password.equals("")) {
                fieldsalert.setText("Both Username and Password are Required!");
                return;
            }
            fieldsalert.setText("");
            Logincheck=db.Login(username, password);
            System.out.println(Logincheck);
            if(Logincheck) {
                new games().setVisible(Logincheck);
                Login.this.dispose();
            }else {
                ImageIcon icon = new ImageIcon(signup.class.getResource("/images/cross.png"));
                JOptionPane.showMessageDialog(null,"Wrong login Details!","Failure", JOptionPane.PLAIN_MESSAGE,icon);
            }
        }

    }
});
```

Figure 5

Figure 6

Teachers Portal

Teachers portal was designed to be as simple as possible. However, in future iterations this can be expanded to include more features such as using graphs and providing further assistance for Teachers to be able to assist students. Once a teacher successfully logs in, they will be presented with a screen which will have just one button for now. The button to *"View Student Results"* will trigger the application to open the results table for all students. In the source code in [Figure 7], you can see that I use an *ActionListener* to check whether the teacher has requested to view results, if *true* then load the results table [Figure 9]. Such as *ActionListener* is used on most of the buttons. The final results of how the page looks when the code is compiled can be seen in [Figure 8]

```java
JButton btnViewResults = new JButton("View Student Results");
btnViewResults.addActionListener(new ActionListener() {
    public void actionPerformed(ActionEvent e) {
        try {
            new TeacherResult().setVisible(true);
        } catch (SQLException e1) {
            // TODO Auto-generated catch block
            e1.printStackTrace();
        }
        TeacherPanel.this.dispose();
    }
});
```

Figure 7
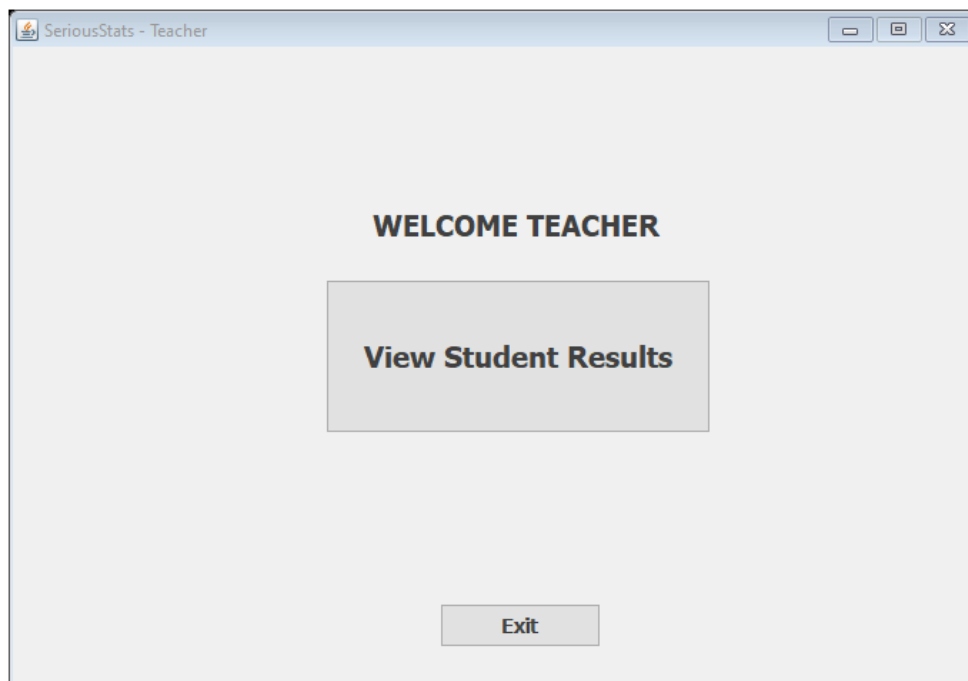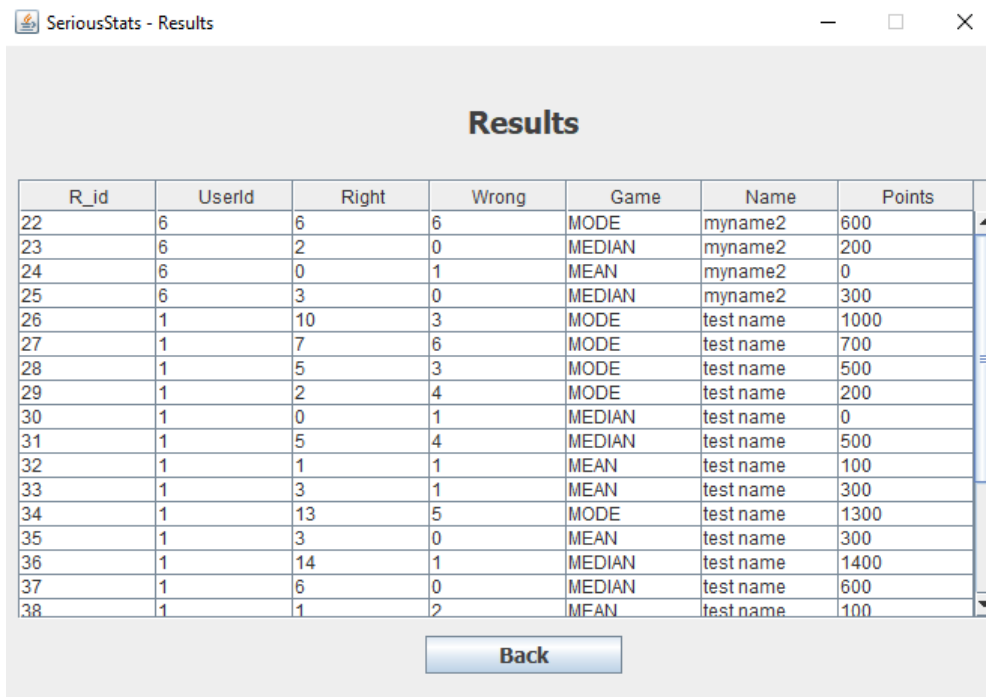
Figure 8
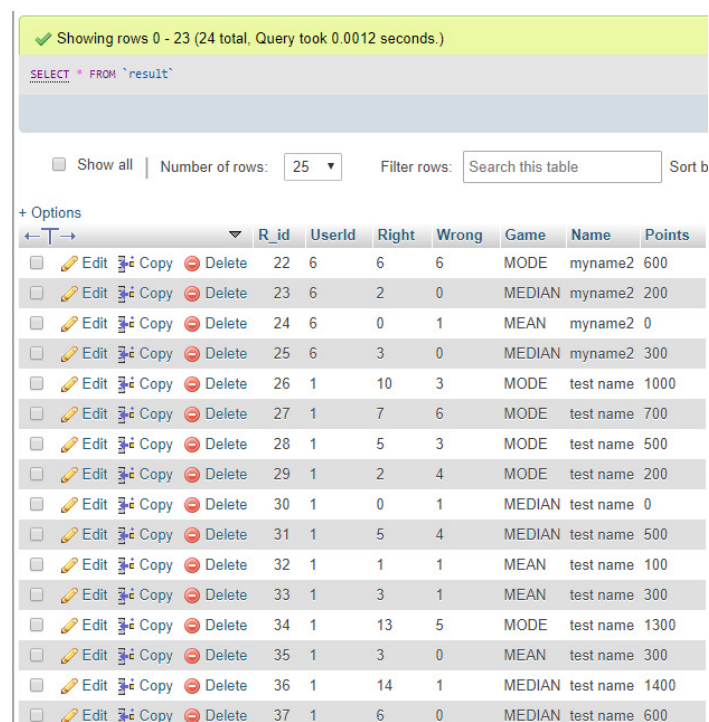
To demonstrate the results table, I have generated some test results which you can see below in [Figure 9]. As mentioned before, the database connection file will have all the methods for retrieving the data from the database. Therefore, by simply calling the appropriate method from that file I will be able to populate the table like so.

Figure 9

In the table above a teacher will be able to check how each individual student is doing and their results over time. They will be able to see what games they played and their scores on those games. For example, in the table you can see users *test name* and *myname2* and their scores for each attempt on all the games, along with their user ids. I will also include a screenshot of how the database table itself looks like in [Figure 10]. Upon request the teacher will also be able to receive an excel spreadsheet with all the results from the admin so as to help them further analyse the numbers.

Figure 10

Main Menu Area

The Main Menu will be the homepage of the application from where the users will be able to navigate to all the available features such as viewing results, accessing all the minigames and accessing the Game Shop. It will also display total number of points accumulated by each user along with their current in-game character, which will of course be updated if they purchase a new one from the Game Shop later on.

The game Main Menu area will be made up of similar Java Swing elements as discussed in the Login screen part of the implementation such as *JLabel* and *JButton*. The Results button seen in the top right corner of the final product of the page [Figure 12] acts in a similar manner as in the teacher's portal. It just simply calls the appropriate method from the database connection file and displays the results for that specific user by using their user id to search the database as can be seen in [Figure 11]. The end result will be the same as seen in [Figure 9] in Teacher Portal section. The user will be able to see all of their game attempts and what scores they were able to achieve for each game round, including the number of correct and incorrect questions. Unlike the Teacher's portal however they do not see other users results.

```
String s=("select * from result where userid='"+userid+"'");
ResultSet rs=stmt.executeQuery(s);
return rs;
```
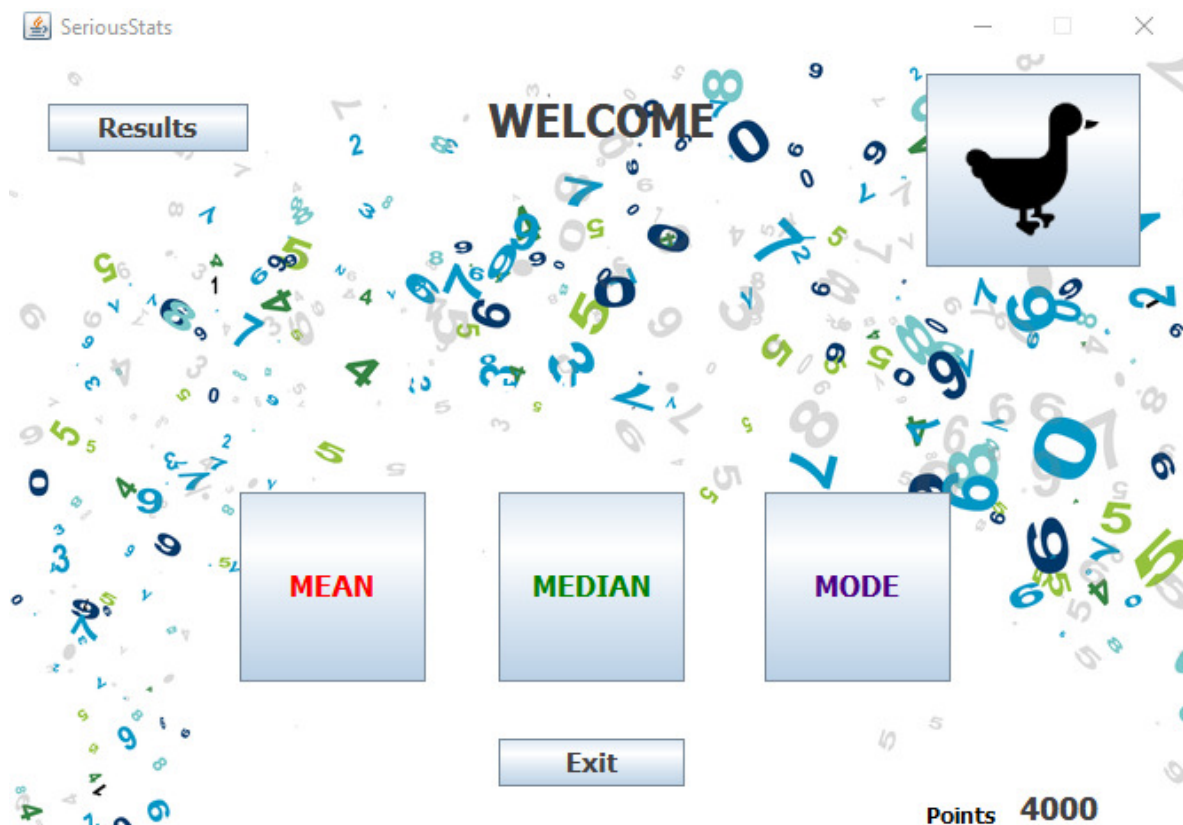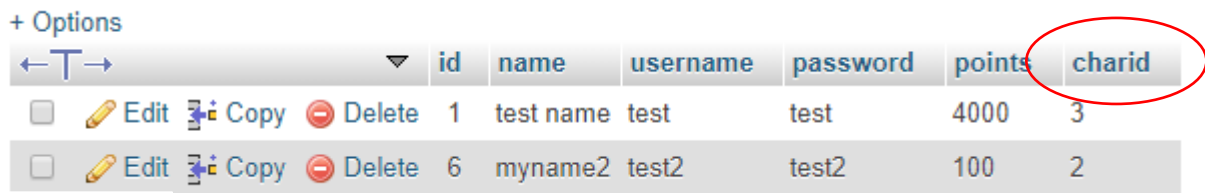
Figure 11

Figure 12

The top right corner of the screen will be used to show the user's in game character as can be seen in [Figure 12]. The information of which character the user has at any specific time will be stored alongside the user as a *charid* in the User table as seen in the database screenshot in [Figure 13].

Figure 13

This will be updated using the appropriate method in the database connection file if the user decided to purchase a new character in the Game Shop.

[Figure 12] also shows the total number of points in the button right corner which will update after every game round depending on how many questions the user gets right that round. This will be another method in the database connection file. By storing all these methods within the database connection file, I am able to call them multiple times and therefore reuse my code as best I can so as to follow the best code practice mentioned at the beginning of this section.

The mini games will be at the center of the screen where the user will be able to choose between playing the Mean, Median, or Mode games [Figure 12]. For more information about how exactly the games work please refer to the Mini Games part of the implementation section. But as far as the Main Menu screen goes the games will be triggered using a button which will open the game information screen and allow the user to proceed to learn the concept and play the game itself. For example, the piece of code seen in [Figure 14] shows how the Mean button would work. This would be the same for the other mini games as well. The functionality of the button is also very much similar to how I have implemented other buttons in the game, it simply loads the appropriate screen in this case being *mean()* and closes the current one.

```java
JButton btnNewButton = new JButton("MEAN");
btnNewButton.addActionListener(new ActionListener() {
    public void actionPerformed(ActionEvent e) {
        new mean().setVisible(true);
        games.this.dispose();
    }
});
```

Figure 14

Game Shop

The Game Shop is where the users will be able to purchase other in game characters as discussed before. They will be able to do this by using the points they have accumulated by playing the different mini games available. As discussed earlier by having these in-game rewards I am hoping to encourage and motivate the user to keep playing the games in order to be able to buy that next level of a character, thereby giving the user a concrete sense of achievement.

The Game Shop will be accessible through the Main Menu icon as shown in the Main Menu implementation. Once in the shop the player will still be able to see their accumulated points total in order to let them know what they can and can't afford to purchase. [Figure 15] shows the final implementation of the Game Shop screen where you can see the total points at the top.
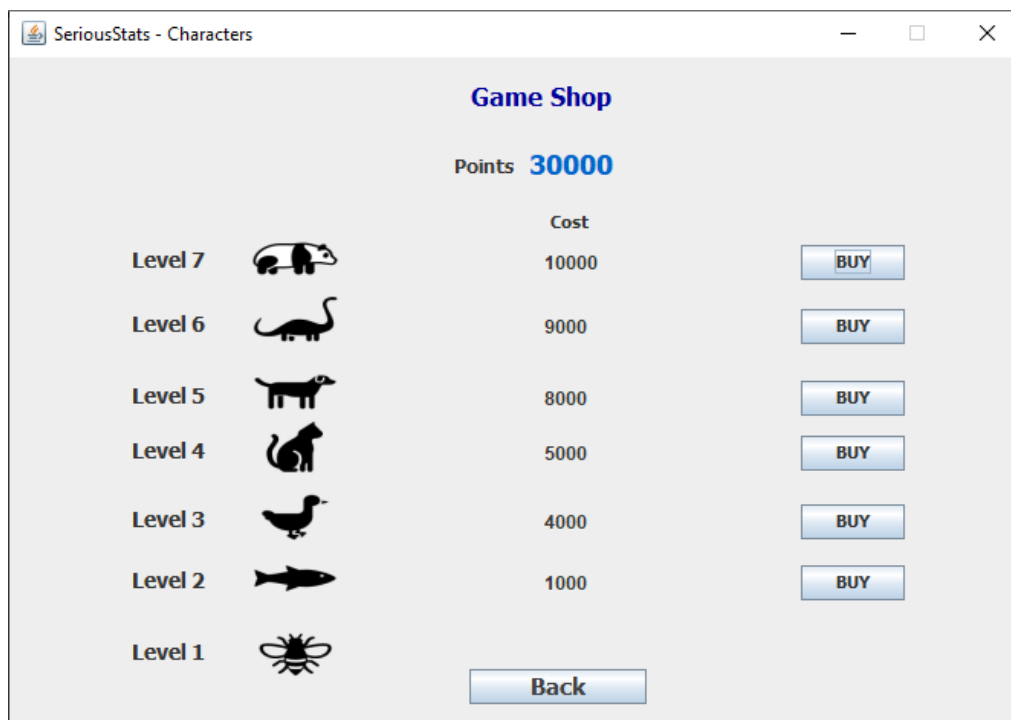

Figure 15

You can also see the different characters available and their price. Each *Buy* button will need to check whether the user has the right amount of points and will also need to update the users *charid* value which will reflect the user's current character which is stored alongside each user in the *user* table.

```
JButton btnNewButton = new JButton("BUY");
btnNewButton.addActionListener(new ActionListener() {
    public void actionPerformed(ActionEvent e) {
        if(Integer.valueOf(Login.points)>=10000) {
            Login.points=String.valueOf(Integer.valueOf(Login.points)-10000);
            Login.charid="7";
            Login.db.updatePoints(Login.points, Login.userid);
            Login.db.updateChar(Login.charid, Login.userid);
            ImageIcon icon = new ImageIcon(characters.class.getResource("/images/tick.png"));
            JOptionPane.showMessageDialog(null,"Purchase Success!","Success", JOptionPane.PLAIN_MESSAGE,icon);
            label_12.setText(Login.points);


        }else {
            ImageIcon icon = new ImageIcon(characters.class.getResource("/images/cross.png"));
            JOptionPane.showMessageDialog(null,"Not Enough Points, Go play and Earn More!","Failure", JOptionPane.PLAIN_MESSAGE,icon);
        }
    }
});
```

Figure 16

35

The source code in [Figure 16] shows exactly how each *Buy* button works. The first *if* statement will check first of all whether the user has the right amount of points, for example in this case the number of points required is 10,000. If not, an appropriate error message will be displayed such as *"Not Enough Points, Go play and earn More!"*. If, however, the user has enough points I will proceed to subtract that amount from their total and update the required fields in the database table. While giving the user feedback of a successful purchase with an appropriate message such as *"Purchase Successful"*.

In [Figure 15] you can also see *Back* button which the user will be able to use to return to the Main Menu screen once they are done upgrading their character or wish to continue playing in order to earn more points to afford to buy a new character.

Mini Games

As mentioned previously in this report I plan to make the games very similar to each other. This will simplify some of the development I have to do and make sure I reach the project aims and fulfil the set-out requirements successfully. This will also help new users to learn the system much quicker and hopefully allow them to benefit from it sooner rather than later. Therefore, as an example I will discuss the Mean mini game in this part of the implementation.

Once the user has chosen which game they would like to play they will be directed to the game information screen as seen in [Figure 17]. The purpose of the information screen is to let the users familiarise themselves with the concept at hand and be able to start the game once they are ready. The Information screen will also help explain a little bit on how the game will work and how long they will have for each game round.
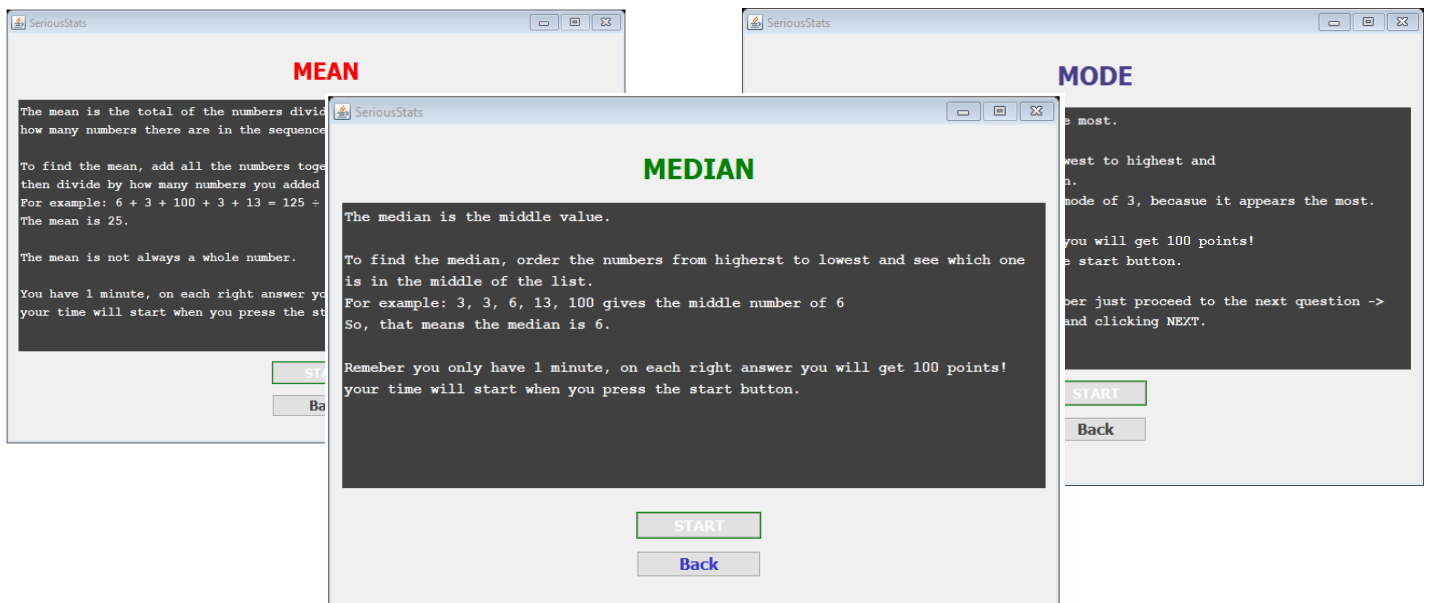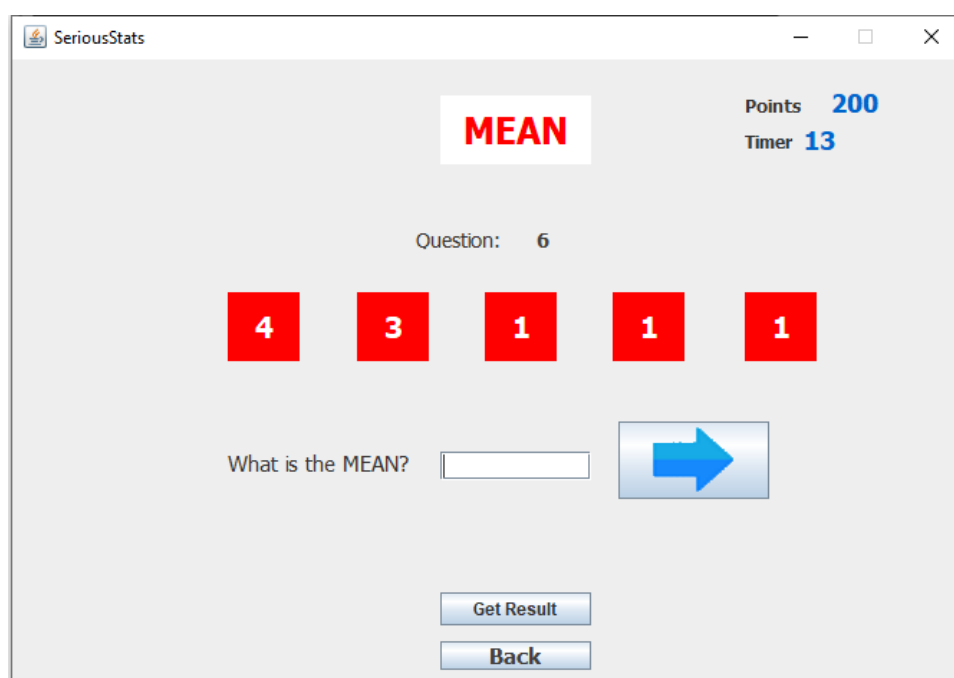

Figure 17

Figure 18

Once the user presses the start button they will jump straight in into a timed round. [Figure 18] shows a typical round, where the user will be presented with 5 randomly generated numbers and then asked to work out the appropriate statistical concept, which in this case will be mean. Throughout the round *JLabels* will be used to inform the user of how long they have left in that round, and their current points earned from the round in the top right corner, as can be seen in [Figure 18].

The function for the text field provided for the answer will require to perform validation in real time and be able to record number of correct and incorrect questions at same time as giving the user 100 points if the question is answered correctly. [Figure 19] shows the source code for this type of functionality. Where you can see how I address the said points. First of all, the answer to the question is worked out after each set of numbers is generated and is stored in a variable like so:

$$answer=(number1+number2+number3+number4+number5)/5.0;$$

I can then call upon this variable in the *if* statement when the user has entered their answer and check its validity. If the answer checks out I will procced to add 100 points to the users score and increment the appropriate variable which will store the number of correct or incorrect questions, as can be seen in the code in [Figure 19] to be *rightAns* and *wrongAns*.

```
String inputans=textField.getText();
if(!inputans.equals("")) {
    double inputanss=Double.valueOf(inputans);
    if(answer==inputanss) {
        games.Gamepoints=games.Gamepoints+100;
        label_1.setText(String.valueOf(games.Gamepoints));
        games.rightAns++;
    }else {
        games.wrongAns++;
    }
}
questioncounter++;
label_7.setText(String.valueOf(questioncounter));
generateNumbers();
textField.setText("");
```

Figure 19

At the end of each round the user will be presented with their score, as well as the number of correctly and the number of incorrectly answered questions. [Figure 20] shows the final implementation of the end of round results screen; from where the user will be able to navigate to the Main Menu to have another go or choose another game.

At the end of each round I will also have a function that will be responsible for carrying out the necessary updates to the user and results tables stored in the database. The following code:

```
db.InsertResult(Login.userid, String.valueOf(games.rightAns),
String.valueOf(games.wrongAns),games.gameName,Login.name,String.valueOf(games.Gamepoints));
int updatedpoints=games.Gamepoints+Integer.valueOf(Login.points);
db.updatePoints(String.valueOf(updatedpoints), Login.userid);
```

will update the database to contain the latest results from that user and will also update the total number of points the user has accumulated over the round. The methods *InsertResult* and *updatePoints* are contained within the database connection file with the other SQL methods for accessing the database as shown and discussed previously.
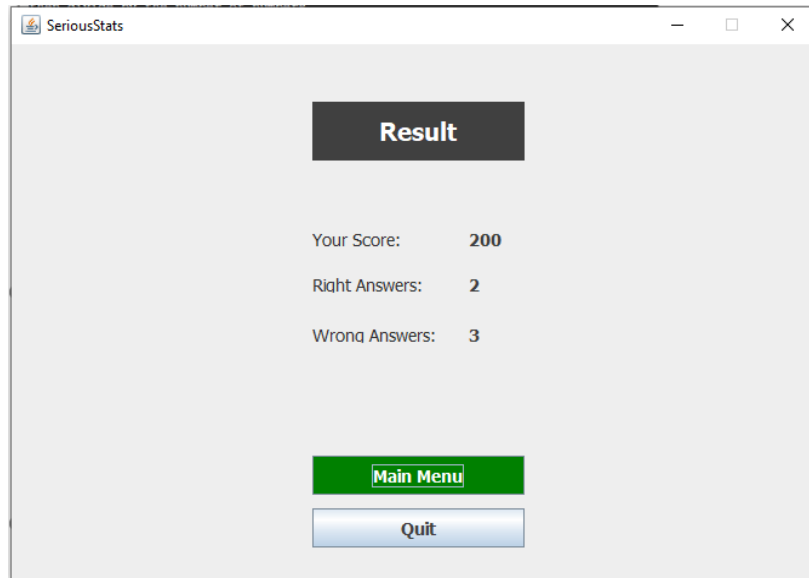
Figure 20

CM3203: One Semester Individual Project – 40 Credits

Case Study

With the implementation of the game now finished it is now important to analyse it and study it to understand how well it has met the requirements set out at the beginning of this report. Another important question that I asked myself at the beginning was that of whether serious games were effective enough in their current state to be used as a primary educational source in primary schools.

Before we jump into my results and findings maybe it is important we revisit the purposes behind the study. For a long time, educators tended to ignore computer games as a potential source of education. Nowadays, however, the role of games in education is increasing [13]. A possible reason why serious games are now being considered to be beneficial in education, is that students are often motivated to play games in the first place. A paper by Marilla D. Svinicki [14] on serious games talked about how traditional schooling methods do not tend to motivate students and how by adding these types of games we have the potential to try and improve that. Certain factors such as class and curriculum structure, teacher behaviour and personality, and existing teaching methods all seem to affect one's motivation [25]. It is also therefore generally assumed that well-motivated students learn better anyway. Therefore, the initial idea of building this game was followed by the need to put it to the test among its primary audience group in order to access its effectiveness in the real world. The mathematical concepts chosen were specifically targeted at older primary school children as it was their first time learning these concepts.

Experiment Set-Up

In order to investigate the effectiveness of using serious games in the classroom, I ran an experiment in which, with the support of the Cardiff University Computer Club, we let a group of primary school aged students play the game. I asked them to complete a short survey beforehand, to judge their understanding of the concepts up until now, and a second questionnaire after the gameplay of my game to see if it had improved their understanding of said concepts.

In this experiment a total of 9 primary school students took part. 4 participants were male, and 5 participants were female. Unfortunately, the average age of participants was not recorded and the possible implications of this I will discuss in the discussion section of this Case Study, but they were all of a primary school age. The experiment as mentioned earlier took place alongside Cardiff University Computer Club where each student was provided with their own machine. The classroom divided students by desk space with up to 4 students sitting together as friends. After introducing the research that we were going to carry out as well as the overall process of the experiment to the participants, I then proceeded to make my way around the room. The game itself was stored on my memory stick and since the machines already had Java pre-installed and were connected to the Universities Wi-Fi network, I was able to simply drag and drop the game file on their desktop in order for them to play. Prior to playing the game the students were given a questionnaire which tried to explain each individual concept of Mean, Median, and Mode [Appendix C]. Following this a number of simple example questions were then asked and the answers were recorded for each of the concepts. Since the seating plan was compact we politely asked participants not to communicate to one another during the experiment. This was done in order to achieve the best results for the study by attempting to test their own individual knowledge instead of a collaborative one.

After the students finished playing the game where they were asked to attempt each Mini Game at least once, I then proceeded to hand out another questionnaire in order to test and see whether there were any changes or improvement in their knowledge of the concepts. The post questionnaire was in the same format as the one done prior to the experiment but this time it did not include any instructions or example questions on the subject [Appendix D]. All of the student results were stored in the MySQL database created for the game: for more information please refer to the Design and the Implementation sections of this

report. I will now proceed to analyse the results gathered which can be found in [Appendix E] and also draw my conclusions on the subject.

Discussion

The general opinion and feeling of the game itself from my own observations was very much positive and many students expressed their enjoyment in participation. In particular the character feature added to the game helped it gain that competitive feeling as initially envisioned which was great to see. Some of the participants even attempted to play second rounds in order to achieve the points required to unlock the next character. Alongside this it was also good to see that all of the core requirements set out at the beginning of this project were successfully met. Things like Teachers Portal, Bonus material, and a scoring system were successfully implemented and worked as intended during the experiment itself.

However, this experiment was not without its setbacks. Before I get too much into the results I would first like to point out some of the issues that occurred prior to the testing taking place which might have impacted the outcome achieved. One of the main issues being the fact that the experiment date and time was forced to be moved two weeks earlier than initially planned due to the coronavirus pandemic happening at the time. This was a good decision however as the prediction of the closure of primary schools nationwide was correct and would have resulted in the experiment not being able to take place at all. However, this change did push me to rush the final implementation of the game as well as making me think quickly on the experimental setup without perhaps fully checking it in order to see whether it had the basis to provide good and accurate results for the study's intent. For example, elements such as:

- The limited number and uniform nature of questions presented to students in the questionnaire.
- The lack of further questions such as age of the participants.
- Also, further questions to find out what each participant was like and what they enjoyed and were motivated by.

I believe all played a part in the lack of clarity we can now see from the gathered results. Failing to consider adequately the likely size of the test group as well as the time given with them, which was limited to a few hours, further prevented me from gathering not only more results but also more clarity from the experiment itself. Having said all this however, it is very easy now to look back and see what could have been done better. As mentioned earlier, if it was not for those actions to move the date forward in the first place I would not even have any results to talk about now. So, let's go ahead and discuss those.

On first analysis my results show what I believe to be inconclusive data from which it is hard to give a verdict on and say whether my serious game has proven effective as an educational tool. I shall first pursue this initial analysis to its conclusion, but then I'll follow this with a second analysis of the results, where I propose to omit one clear outlier. As you will see, this second analysis can lead to a more focused conclusion.

First Analysis:

As noted previously the study was made up of 4 male students and 5 female students, therefore let's take a look first at whether there was a gender gap in these results. Below is a summary of the total number of questions that were answered correctly and incorrectly in all Questionnaires and Game rounds split by gender.

		Correct	Incorrect
Questionnaire 1	Male	30	6
	Female	43	2
Game Round	Male	114	38
	Female	139	11
Questionnaire 1	Male	29	7
	Female	43	2

From this table you can clearly see that females have performed better overall on the questions given to them. You can back this up by conducting a T-Test [24] of the data using the number of correctly answered questions for males vs females. The resulting T-score value ends up being 4.51, which means that statistically the two groups tested are indeed quite different from one another in terms of their results, since the larger the T-score, the more difference there is between groups. Even when taking into account the fact that there were more females then males which will result in higher number of questions attempted, the percentage difference between correctly and incorrectly answered questions still concluded that females answered questions more accurately. For example, just by looking at Questionnaire 1 you can see that males answered 6 questions incorrectly compared to only 2 answered incorrectly by females. This falls in line with the general idea that females perform better in education then males [15], but contradicts a similar study done on serious game *'Serious Games in Education'* [1] where they found that males performed better using serious games than females. This was then associated to the fact that males were more motivated to play games in general, and so with much more game experience were able to outperform females. However, it is important to say that different serious games will produce different results depending on their overall purpose and design, thus making them difficult to compare. It could have also depended on the average age of the females vs males, but since this metric was not recorded it is hard to say for certain. Even a year or two in age difference (within this primary school age group) would greatly impact once ability and speed to understand such concepts for the first time. The older you are the more experience you would have had in school in dealing with numbers and more advanced mathematical concepts giving you a potential advantage in this situation.

Looking at a more general picture of the experiment however is where things become a little harder to conclude and where a lot of the issues mentioned earlier might have played a part in giving this lack of clarity. Below is a table which shows the total number of questions answered correctly and incorrectly for all the Questionnaires as well as the Game Round itself.

	Correct	Incorrect
Questionnaire 1	73	8
Game Round	253	49
Questionnaire 2	72	9

You can see that the 2nd questionnaire which took place after the Game Round in fact showed a decrease in the number of correctly answered questions by 1 point. As this is such a low number which could have been caused by a huge range of variables present at the time, including potential questionnaire design flaws, it would not therefore be correct to conclude that serious games don't help improve a student's performance in an educational scenario. The game round itself showed a high percentage of questions answered correctly demonstrating the students' understanding in the theory behind the game and the concepts themselves and suggesting that in fact it was very unlikely that the game was the cause for the drop.

Second Analysis:

Importantly, if in the second analysis we were to exclude the the outlier of the study, such as participant number 8 (P8), we would in fact see a totally different picture. As can be seen in the results, participant number 8 (P8) managed (for whatever reason) to get most of his second questionnaire questions wrong. This is after getting them all right on the first questionnaire and performing exceptionally well during the Game Round itself. Such a swings had a great impact on the final results of the study and so, if we were to exclude the scores of this outlier participant from both the questionnaires and game round, we would see in fact that the second questionnaire results performed much better and showed a clear improvement in the scores.

The scores would total to be:

	Correct	Incorrect
Questionnaire 1	64	8
Game Round	216	47
Questionnaire 2	69	3

Which would show a clear increase in the correctly answered questions between the two questionnaires and at the same time a clear decrease in the incorrectly answered questions. These results would in fact do well in supporting the hypothesis that this serious game does have a positive impact on one's educational learning.

We can also go ahead and take a look at each individual game's performance, concept, and perhaps the difficulty of each one which might have contributed to the results we have gathered for each. Most would agree that the concept of finding the Mode of a sequence of numbers is easier and required less steps than perhaps working out the Mean of the same sequence of numbers. By taking a look at the Mean first we can see where that extra incorrect question happened from the table above. There were certainly more students who struggled in the second questionnaire for whatever reason, but there were also some that

improved in particular participant number 9 (P9). Once again though due to the limited number of questions asked it is hard to draw any firm conclusions upon these results. Taking a look now at Mode we see much less inaccuracy among participants perhaps reinforcing my statement earlier to suggest that working out the Mode is much more straight forward. Finally, working out the Median is where we saw the most improvement among students, with most students achieving the same number or higher of correct answers. For example, participants number 2 and 6 (P2, P6) managed to improve their results in the second questionnaire.

Future Work

Whilst this project has created a usable system and all of the core requirements were met, there are still many possibilities for the system to be expanded further. There are a lot of features that could be improved and worked on in order to improve this project and explore further ideas presented throughout the report. In this section I will attempt to cover some of the unrealised ideas and will point to a possible starting point for any further development.

Before I dive into any potential improvements, I would first like to say that first order of business would be to carry out a more thorough experiment on the existing system as it is. As mentioned in the Case Study there were a number of issues that may have reduced the clarity in the results gathered. With a further study lessons could be learned, and better results could be gathered, which could give an improved picture of the effectiveness of the system in an educational learning environment. A further study can include many more user-based questions such as their age, their background, what motivates them, what type of learner they are etc. As well as more thorough knowledge tests before and after the Game Rounds. A further study can also be better controlled with, for example, a stricter criteria for entry to ensure that the participants are all of the same age and are at a similar stage in their education.

Once a more conclusive study has been carried out, the project itself may need further work before being released into the real world. During the implementation phase of the project no method of handling network errors apart from a user error message *"Failed to Login"* was put in place. Assumptions were made that these network errors would not happen as the game was hosted on an internal University network, however this would not be the case in real world. These errors are often out of a user's hands and so should be handled within the application itself. A further experiment hosting the system on a wider network could be carried out in order to understand any potential issues that may arise. Apart from that the system itself did not present any major bugs that affected its usability, and this was very positive.

While implementing the system, I structured everything to be as simple as possible. The result of this is easy to understand code and a design that is modular enough to provide a great foundation for the opportunity of adding new features. While developing the system I also came up with some of my own additional features which would greatly improve the gameplay and usability of the application. One of these features would be to make the randomly generated number squares easy to move around the screen by dragging and dropping. This would open up a huge door for possibilities to make the gameplay a lot more engaging for the students. From being able to order numbers by dragging and dropping when playing the Median game to being able to drag and drop the answer into the answer box while playing the Mode game. I believe this would greatly improve the enjoyment factor and would motivate the players even more to keep playing. Another feature which I have already mentioned in this report is being able to increase the difficulty of the game step by step: i.e. the potential for relating the character levels to game levels, thereby letting the player progress at their own pace by evolving their character. There can also be made a potential improvement with regards to the information screens of each game, which are currently just text. Diagrams and perhaps further screens which the user can navigate by pressing 'next' can be added in order to facilitate the explaining of the example questions in a much more interactive way.

Further improvements to the Teachers Portal could also be made to include some sort of a visual representation of student results. A graph feature that would help teachers understand a lot better the strengths and weaknesses of students based on their results. Whether that be a line graph to show percentage number of questions answered correctly by the user over time or a bar chart to help better visualise the results, it would tremendously improve the ability for any teacher to make better decisions and improve their understanding of the results. As discussed earlier in this report a good game should always have some sort of a competitive feeling and features to help motivate users to keep playing and keep learning to improve their scores. Although the current state of the game allows users to view past results which they can go ahead and compare with their friends, a further addition of a system wide leader board can be easily made. This could serve as another incentive for users to keep playing in order to try and beat their classmates. The leader board could display all the players in a table with a rank based on their progress. The rank could be determined using the number of games a player has played, number of correct answers, their total number of points and many more parameters. The implementation of such feature would not take long as all the results are already stored in a database table and are readily accessible. A simple manipulation of result numbers and an extra screen with an ordered table is all that it would take.

From a usability perspective the addition of sounds to the game could also help in the improvement of the learning process. A paper about sounds in serious games *"Serious Games: Customizing the Audio-Visual Interface"* [16] has suggested that there is a potentially strong effect of sounds on the participants performance. Therefore, the addition of game sound effects as simple as ones for correct and incorrect attempts could help reinforce learning. I believe it would help immerse the user into the game environment even more and help them to better focus on the task in hand. If such an addition was to be made, a further study would help in finding out the exact impact that sounds could make on participants learning. The experiment itself could involve the two versions of the game being run in parallel with one having the sounds effects and the other without any. Finally, to help new users understand how the game works an embedded video could be implemented within or after the signup screen. This video could involve an interactive walkthrough of the Mini Games, Game Shop, and other game features to help new users familiarise themselves with the system and be ready to play.

In this section I have outlined numerous changes and improvements that could be made to the current system. Some of which I believe could be projects and studies within themselves for example the addition of sounds as mentioned earlier. Any developer that wished to continue this project would have access to the source code and would be able to go ahead and conduct the necessary research, whether that be further study on the current system or the implementation of the said additional features.

Reflection and Learning

Upon the completion of such a project it is important to look back at its time in development and be able to draw valuable lessons from its mistakes and failures, but at the same time be able to celebrate its successes as well. During this project I developed a far broader and better understanding of how bigger developments take place and all the stages that go into them, most of which are invisible to the end user. The most important thing I probably learned during this project is that sometimes the experimental procedure such as the Case Study carried out, can be as important as the actual coding phase of a project. A carefully designed experiment will help greatly to investigate any hypotheses or theories put forward, thus helping you reach a conclusive outcome faster. Although in my case the experiment was moved forward by two weeks, which might have impacted its execution, it is important to be ready for any changes in the plan and highlights the need for good project management from the start.

Undertaking such a large project has helped me to appreciate the need for good project management skills and the importance of them in any project. In fact, improving such skills was one of the aims for me at the beginning along with the improvement of other skills such as Java programming, which was the programming language used. The learning process has helped me massively to be able to leverage online resources effectively and be able to resolve any issues, whether they be code related or overall project related much faster.

My initial choice to use Java as the primary programming language was, I believe, a good one. Not only did it help me to improve my own skills in the language, which was one of my personal aims of the project as mentioned, but it also helped the project to be completed on time. Due to the fact that the language is widely adopted and used in many different ways already, I was able to find the support and the resources I needed when I needed it. However, looking at the overall implementation of the idea, perhaps an even better choice would have been to make it a web-based project utilising language such as JavaScript and HTML instead of Java. Such fundamental change could not have been made halfway through the project and is something that needs to be considered right at the beginning. Being able to look back at the project now helps me see some of the advantages such a change would bring. The need for any system to support Java applications prior to the game being installed can be seen as a bottle neck going forward and thus by just simply being able to access such a game through your browser would make things much simpler. This idea is also kind of supported by the existing serious game, TTRockstars [7] which is already a web-based platform.

Looking at a wider view of the project the regular supervisor meetings helped me greatly to stay on track and were also a great experience, helping me to improve both my communication skills as well as my organisational skills. Going forward now into the IT industry this project will be held by me as a benchmark for future projects I undertake. I will be able to draw upon the experiences and the skills gained from this project to help me reason more effectively about the work I am doing, as well as help me be more independent and proactive.

Overall, the project has been very successful in my opinion. Not only in its resulting game, but also in the experience it has provided for me and all the lessons it has taught me along the way, which will no doubt be very useful going forward.

Conclusion

The main aspirations of this project were to create and investigate how a serious game might be an effective tool in a real educational environment and to see if in fact they were a better tool to use then traditional education methods. As mentioned at the beginning serious games are growing rapidly as a gaming industry as well as a field of academic research. Researchers predict that technology-enhanced learning will increase with educational computer games [1] with serious games playing an important role in that. By revisiting the project aims you can see that I wanted to study how serious gaming impacts the learning curve of students compared with traditional methods of teaching, which I did to some effect by conducting my Case Study on my own serious game. Although my results showed what I believe to be inconclusive data from which it was hard to give a verdict on the question whether my serious game was an effective educational tool, the results of a similar but much more expanded study could provide a much more conclusive outcome. Having mentioned some of the reasons that affected the outcome in the discussion section, I believe if those were to be addressed in the expanded study the results would prove to be a more solid piece of evidence for the question whether serious games can be an effective educational tool. In fact, during my second analysis of the results I highlighted that if it was not for the outlier participant of the study my results could very well be considered to support such hypothesis.

As to where serious games are at the moment as an industry I would like to say the following. As mentioned in the background section, formal education systems are under increasing pressure to respond and adapt to rapid technological innovations, with some having already done so successfully. There are currently a huge variety of serious games available and room for many more to follow in these footsteps. I believe many schools should already be trialling such methods of teaching to further understand how it can benefit teachers and their students. I strongly agree with the fact that there is fundamental need to do our best in enhancing the learning processes of any educational establishment, so as to make learning a more engaging and therefore a more effective exercise. Having said this, the wide adoption of such learning processes is still some years away and I believe that we will first see such processes being used to support learning rather than to substitute it.

All of this came under more and more attention especially during the global coronavirus pandemic of 2020. The drastic actions taken by the government in order to stop the spread of the virus saw millions being forced into lockdown and schools being closed nationwide. This made schools attempt to improvise new ways of operating digitally and with the intention of hopefully a similar outcome in learning levels that one would see if attending school as normal. I believe this was a great opportunity to adopt a much more digital way of learning that many serious games offer. By doing so on such a scale it will no doubt help us understand much more about how such learning resources can be used within our schools and whether they are an effective learning tool. At the same time, It will also greatly help schools in preparing for such an event if it was to happen again.

No doubt serious games will be an important part of learning in the future, but there is still much work to be done.

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Appendices
Appendix A

Certificate of Completion

This is to certify that **Artem Protasavytsky** successfully completed 17.5 total hours of **The Complete Java Certification Course** online course on March 14, 2020

Imtiaz Ahmad
Imtiaz Ahmad, Instructor

&

𝘶 **Udemy**

Certificate no: **UC-62b7bb2e-3226-4fa3-8419-62e7ec8fe646**
Certificate url: ude.my/UC-62b7bb2e-3226-4fa3-8419-62e7ec8fe646

#BeAble

Appendix B

Research and Innovation Services

This is to certify that

Artem Protasavytsky

has successfully completed

19/20 Research Integrity Training (Student)

on

10 February 2020

Welcome

Are you ready to do some serious stats…?
Today we will learn how to calculate the Mean, Median, and the Mode of 5 numbers!

First Let's do the Mean!
The Mean = the total of the numbers divided by how many numbers there are.
To find the mean, add all the numbers together then divide by the number of numbers.
For example, let's take the numbers: 6, 3, 100, 3, 13
First, we add them all up: 6 + 3 + 100 + 3 + 13 = 125
Then we divide by 5 (because there are 5 numbers): 125 ÷ 5 = 25
The mean is 25!

The mean doesn't have to be a whole number.
See if you can do the same for these numbers

2	3	1	1	3	What is the Mean of these number?	Answer

3	2	1	4	10	What is the Mean of these number?	Answer

10	3	2	5	10	What is the Mean of these number?	Answer

Now Let's do the Median!

The Median is the middle value.

To find the median, order the numbers and see which one is in the middle of the list.

For example, let's take the numbers: 6, 3, 3, 100, 13

First, we need to order them from smallest to largest: 3, 3, 6, 13, 100

The median of these numbers is 6!

Because when you order them the number in the middle is 6.

See if you can do the same for these numbers

Answer

| 2 | 3 | 4 | 8 | 1 | What is the Median of these number? |

Answer

| 3 | 2 | 1 | 4 | 10 | What is the Median of these number? |

Answer

| 10 | 3 | 2 | 5 | 10 | What is the Median of these number? |

Now Let's do the Mode!
The Mode is the number that appears the most.
To find the mode, order the numbers lowest to highest and see which number appears the most often.
For example, let's take the numbers: 6, 3, 3, 100, 13
First, we need to order them from smallest to largest: 3, 3, 6, 13, 100
The mode of these numbers is 3!
Because it appears the greatest number of times.

See if you can do the same for these numbers

Answer

| 2 | 3 | 2 | 8 | 1 | What is the Mode of these number?

Answer

| 1 | 2 | 1 | 4 | 10 | What is the Mode of these number?

Answer

| 10 | 3 | 2 | 5 | 10 | What is the Mode of these number?

Thank you!

Cool, thanks for taking part in our experiment!
Let's see if you have learned anything.

Let's calculate the Mean!

⬇ **See if you can do the same for these numbers** ⬇

| 2 | 2 | 2 | 2 | 2 | What is the Mean of these number? | Answer |

| 5 | 2 | 3 | 5 | 10 | What is the Mean of these number? | Answer |

| 10 | 5 | 5 | 5 | 10 | What is the Mean of these number? | Answer |

Now Let's do the Median!

↓ **See if you can do the same for these numbers** ↓

| 3 | 3 | 4 | 8 | 1 | What is the Median of these number? |

Answer

| 7 | 2 | 8 | 4 | 10 | What is the Median of these number? |

Answer

| 15 | 3 | 5 | 5 | 10 | What is the Median of these number? |

Answer

Now Let's do the Mode!

See if you can do the same for these numbers

3	3	2	8	1	What is the Mode of these number?	Answer

4	2	1	4	10	What is the Mode of these number?	Answer

11	5	2	5	10	What is the Mode of these number?	Answer

Here follow the results achieved from the first questionnaire where each participant is referred to as P#:

Score for the Mean questions

Participant	Answered Correctly	Wrong Answers
P1	3	0
P2	2	1
P3	3	0
P4	3	0
P5	3	0
P6	3	0
P7	3	0
P8	3	0
P9	2	1

Score for the Median questions

Participant	Answered Correctly	Wrong Answers
P1	3	0
P2	0	3
P3	3	0
P4	3	0
P5	3	0
P6	1	2
P7	3	0
P8	3	0
P9	2	1

Score for the Mode questions

Participant	Answered Correctly	Wrong Answers
P1	3	0
P2	3	0
P3	3	0
P4	3	0
P5	3	0
P6	3	0
P7	3	0
P8	3	0
P9	3	0

CM3203: One Semester Individual Project – 40 Credits

Here follow the results achieved from the game rounds where each participant is referred to as P#:

Score for the Mean round

Participant	Answered Correctly	Wrong Answers
P1	11	1
P2	12	2
P3	12	1
P4	22	0
P5	8	0
P6	5	0
P7	7	0
P8	15	1
P9	5	1

Score for the Median round

Participant	Answered Correctly	Wrong Answers
P1	12	24
P2	6	2
P3	6	2
P4	13	0
P5	10	0
P6	7	0
P7	4	0
P8	10	1
P9	4	1

Score for the Mode round

Participant	Answered Correctly	Wrong Answers
P1	16	1
P2	7	3
P3	9	4
P4	13	2
P5	11	0
P6	5	1
P7	7	1
P8	12	0
P9	4	1

Here follow the results achieved from the second questionnaire where each participant is referred to as P#:

Score for the Mean questions

Participant	Answered Correctly	Wrong Answers
P1	2	1
P2	3	0
P3	2	1
P4	2	1
P5	3	0
P6	3	0
P7	3	0
P8	3	0
P9	3	0

Score for the Median questions

Participant	Answered Correctly	Wrong Answers
P1	3	0
P2	3	0
P3	3	0
P4	3	0
P5	3	0
P6	3	0
P7	3	0
P8	0	3
P9	3	0

Score for the Mode questions

Participant	Answered Correctly	Wrong Answers
P1	3	0
P2	3	0
P3	3	0
P4	3	0
P5	3	0
P6	3	0
P7	3	0
P8	0	3
P9	3	0