The Use of Gamification with Dynamic Difficulty Adjustment for Learning Applications

Carlos Galea

Supervisor: Mr Franco Farrugia

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Authorship Statement

This dissertation is based on the results of research carried out by myself, is my own composition, and has not been previously presented for any other certified or uncertified qualification.

The research was carried out under the supervision of Mr Franco Farrugia.

Carlos Galea

June 6, 2020

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Carlos Galea

Tal-Mirakli,
Tal-Giebja, Limiti ta' Birzebbuga
Birzebbuga BBG 1410

June 6, 2020

Dedication

I would like to dedicate this study to my family and to my companion Vi for providing me with unconditional love and emotional support. A special thanks goes to my parents Mario and Marian Galea who have always supported and encouraged me throughout my studies. Their teachings have thought me to never give up and to always focus on the end result, as all bad moments will eventually come to pass.

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Abstract

This research investigates the effectiveness of educational games, featuring different game elements and Dynamic Difficulty Adjustment (DDA) on the players' performance. Methods proven throughout previous studies, in relevance to gamification and the use of dynamic difficulty adjustment in games, were adopted to achieve the objectives of this study. Such methods include the use of player modelling and dynamic scripting to implement DDA, heuristic evaluation to evaluate an application and the CEGE framework to calculate user experience. This study makes use of quantitative methods to collect data. Data gathering was split into two different stages. In the first stage, a questionnaire collected sufficient demographic information on the people interested in this study, while heuristic evaluation was conducted by a group of 5 evaluators to assess the design of the first implementations of the prototypes. According to the results gathered from the evaluation of the prototypes, specific elements were adapted to eliminate bugs and other features affecting the player's gameplay and enjoyment. Throughout the second phase of data collection, two different game implementations featuring DDA were tested by two groups of 15 participants. Each game consisted of two versions, one featuring adaptive difficulty and the other non-adaptive difficulty. The endless runner game made use of dynamic scripting to dynamically adjust the game's difficulty in real-time, while the level-based game made use of player modelling to adjust the game's difficulty according to previous player achievements. The participants progress while playing, were monitored and recorded onto an online database. After playing one version of a game, the participants answered a post-questionnaire in order to calculate their experience. An analysis of the data obtained from each version of the prototypes and post questionnaires was done to find the different effects on the participant's progress and experience. The analysis shows that both games featuring adaptive difficulty scored significantly better results than the non-adaptive versions. Another evaluation was carried out between the adaptive versions of both games. Although there was no significant difference between the scores of both adaptive games, the endless runner game scored an overall better score. The final objective of the study was to identify the difference in player experience from the different game implementations and versions. The analyzed results obtained from the prototypes and questionnaires stated that most participants were in favour of the adaptive versions of the games. This research concluded that adaptive difficulty in games, making use of DDA, was more effective and engaging than non-adaptive games.

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Abbreviations

ADC	Duo-chromosome Controller
A.I	Artificial Intelligence
AUC	Uni-chromosome Controller
CEGE	Core Elements of the Gaming Experience
DDA	Dynamic Difficulty Adjustment
IT	Information and Technology
MDA	Mechanics, Dynamic and Aesthetics
NPC	Non-Player Characters

Chapter 1

Introduction

The main area of this study is the use of gamification with dynamic difficulty adjustment (DDA) in learning applications. The use of gamification assist to deliver material in a more enjoyable and interactive mean. This study also investigates the use of DDA to regulate a game's difficulty and core functionality according to the players' skill. This research aims to provide insight into how the use of gamification with dynamic difficulty can be implemented into learning applications to tailor the requirements of people with different learning curves.

1.1 Hypothesis and Research Questions

The hypothesis of this study is; The use of Educational Games featuring different game elements and dynamic difficulty adjustment, had a positive effect on the player's performance and ability to learn. This study also aims to answer the following questions:

- Is there a difference between two different implementations of DDA: Level Based and Endless Runner?

- Does the use of DDA to adjust the game's difficulty yields better results than with static difficulty?
- Does the use of DDA increases the player's immersion and interest in the game?

1.2 Motivation for Choice

A personal motivation for this choice of research was the increasing number of reports regarding students dropping out of school. In an article (Jacob Doll, Eslami and Walters, 2013), some ex-students reported that they had dropped out because of the amount of discouraging and un-motivational material being covered at school. Others also stated that due to not fully understanding specific topics because the level of difficulty, they were not doing well in their studies. In the book "Creativity: Flow and the Psychology of Discovery and Invention" (Csikszentmihalyi, 1996), it was stated that there are two kinds of activities, autotelic and exoteric. Learning is considered to be an exoteric activity since people do not do it for fun, but for the outcome of knowledge that they obtain. On the other hand, autotelic activities happen when people do them on their initiative and satisfaction, such as playing video games. By making use of gamification, this study aims to combine both activities to provide an alternative means of learning through the use of an educational game. Also, by investigating the use of DDA in games to adjust a game's difficulty, the effectiveness of the educational game's ability to adapt to the player's skill is calculated.

1.3 Dissertation Outline

In the literature review, other studies relevant to this study are evaluated. Studies on the use of gamification and different implementations of dynamic difficulty adjustment are summarized and critically evaluated for their strengths and weaknesses. In the methodology, methods that were proven from previous studies are adopted to achieve the objective of this study. The methodology also discusses the means used to collect and analyze the data. Tools and other materials used to conduct the research are also discussed. In the results chapter, the main findings that were acquired from the research are observed by making use of visual elements, such as graphs and tables. The findings that relate to the research questions or the hypothesis are shown. The results are then interpreted in detail throughout the discussion section. A detailed evaluation between results is carried out to distinguish the effects of different implementations used during data collection. Results are also discussed to identify whether the data supports the hypothesis and to evaluate their significance. In the concluding chapter, the answers to the research questions and the hypothesis are clearly stated. A summary of the study's approach and results is also carried out. Furthermore, limitations that were encountered throughout the study and future recommendations are also mentioned.

Chapter 2

Literature Review

2.1 Positive and Negative Aspects of Video Games

From the perspective of different people, many were troubled by the violent nature that certain games tend to offer, while others were concerned with the intensity of involvement that youth tend to spend so much time engaging with games. Despite this, many people would say otherwise. video games are used by people of all ages, genders, and backgrounds. A study carried out by Lenhart and et al. in 2008 states that a total of 97% of teens between the ages of 12 and 17 play computer, web, or console games. Furthermore, the majority of the teens also stated that the last time that they played a video game was "yesterday."

One of the concerns regarding video games is the amount of time that people tend to spend in front of a screen, which may be bad for children's eyesight. However, in a study carried out by Bavelier in 2012, she stated that people who play video games tend to have better than normal vision. These people were able to resolve fine detail and capable of distinguishing different levels of the same colour. In another study (Green et al., 2012), one can also see how gaming increases the ability to multitask between different tasks running at the same time.

This ability is essential in our current daily lives since technology is integrated into most of our tasks. Gamers are also better at solving tasks that require attention and tasks involving tracking objects (Bavelier, 2012).

Despite the benefits of video games, there are many concerns regarding the aggressive behaviours found in some games. One study found that the amount of time children spent playing violent games took part in the child's negative behaviour in the following four months, even while controlling for initial levels of aggressive behaviour (Anderson et al., 2008). In another study (Rachel and Lydia, 2013), the American Academy of Pediatrics recommended that young children should be limited by the amount of media per day and that they should spend time doing physical activities to stay healthy and also to interact with other peers.

2.2 The Effectiveness of Gamification in Education

While learning is considered to be an exoteric activity, because students do not do it since they enjoy it, but they do it for the information that they obtain, video games are considered to be an autotelic activity since people play them on their initiative and because they enjoy the experience (Csikszentmihalyi, 1996). From this statement, we can establish how educational games can be considered both as an exoteric and autotelic activity since people making use of the game are still obtaining information that they need while having a more enjoyable experience that games tend to leave on people. As stated by R. Garris and et al. in the study "Games, Motivation and Learning. A research and practice model", published in 2002, educational games have the potential to keep players playing through successful gameplay rather than having to go through a tedious amount of papers and notes.

Games can cover a wide range of preferences, themes, and contents. On the other hand, Educational Games can also be developed to meet different learning curves and to suit people with special needs.

Gamification aims to harness the effects that video games tend to leave on people, which makes them want to play more and implement the game elements to everyday situations. Many believe that introducing gamification to classrooms is an innovative concept since people voluntarily spend countless amount of their time playing games.

A study which was published in 2004 by Squire et al., stated that a group of students who played a game called Supercharged and received a series of interactive lectures obtained better results on the conceptual exams than the students that only attended the usual lectures.

Educators should harness the capability for motivational and enjoyable experience obtained from games to introduce new material that is being covered at school. In the study "Gamification in Education - Learning Theories," published in 2016, L. David stated that gamification is under the assumption of delivering the same type of engagement that gamers experience with games while supporting various educational contexts.

2.3 Evaluation Methods of an Application's Design

In the study "Pragmatic Evaluation: Lessons from Usability," C. N. Quinn stated, that, there is a pressure to minimize the amount of resources used to evaluate applications since it is considered less important than the development stages.

In his study, he also mentioned the following evaluation methods, including:

- **Automated Testing:** This form of testing makes use of a computer program to evaluate the interface of an application;
- **Formal Modelling:** This makes use of mathematical analysis of usability. This form of evaluation does not work well with complex interfaces;
- **Empirical Testing:** This method might result to be expensive to carry out since it requires multiple individuals to inspect the interface for a set period of time;
- **Usability Inspection:** This method is an alternative to other evaluation methods as it is resource-efficient;

From the mentioned methods, most Usability Inspection methods can be easily applied to evaluate an application's interface by regular developers. Also, it requires a low cost of resources to perform. On the other hand, better results can be obtained by usability specialists (Quinn, 1996).

2.3.1 Usability Inspection Methods

In the book "Usability Inspection Methods," published in 1994, Mack and Nielsen write how "Usability inspection is the generic name for a set of methods that are all based on having evaluators inspect the interface."

The book also mentioned various inspection methods. These included:

- **Heuristic Evaluation:** Usability principles are set and used by specialists to compare the software's design and establish how the product does not abide by those principles;
- **Cognitive Walkthroughs:** This evaluation technique makes use of one or more evaluators to proceed through a set of tasks. A series of questions are asked from the user's viewpoint to efficiently simulate the user's problem-solving process while making use of the software;
- **Formal Usability Inspections:** This makes use of a detailed six-step procedure to combine both Heuristic Evaluation, to find usability defects, and Cognitive Walkthroughs to uncover the goals and purpose of the user's mind while making use of the application;
- **Pluralistic Walkthroughs:** Meetings consisting of a group of representative users, product developers, and professional inspectors are set. The attendees are tasked to go through a procedure of dialogue elements while assuming the role of a typical user making use of the application. After each scenario is evaluated, users are given a brief questionnaire to analyze the usability of the interface.

- **Feature Inspection:** Feature checklists are used to assess a proposed feature set of an application. This technique involves the comparison of the software with the pre-defined checklist. The effectiveness of feature inspection depends on the amount of detail that the checklist is built on, which incorporates the knowledge of the user's point of view and requirements.

While Heuristic Evaluation, Cognitive Walkthrough and Feature Inspection requires one evaluator at a time to inspect the interface, Pluralistic Walkthrough Inspections require a group of individuals to carry out the inspections. On the other hand, Formal Usability Inspections make use of a combination of both individual and group inspections.

Since Heuristic Evaluation is among the easiest and most efficient methods to be carried out, it was used to carry out the interface's evaluation of this study's prototypes.

2.3.2 Selection of different Heuristic Evaluation Principles

As mentioned earlier, this method makes use of evaluators to conduct independent inspections were an application's interface elements are compared to a list of usability principles referred to as heuristics.

In this study, two different sets of heuristics are used to identify problems that should be corrected before publishing the final implementations of the prototypes. This process will increase the credibility of results gathered from the prototypes.

Nielsen's ten interface heuristic principles were used to evaluate the interface design of the prototype (Mack and Nielsen, 1994). Quinn's educational heuristics were also applied to evaluate the educational features of the application's design (Quinn, 1996).

An analysis of both heuristics is shown in **Figure 2.1** and **Figure 2.2**. Some changes to the wording of principles were made to avoid the use of technological terminology.

The application offers constant visibility of the system's status	The application must consistently keep the user updated with what is going on-screen through feedback.
System concepts must match those of the real world	Information is displayed in the correct format and the application makes use of the user's language, rather than system terminology.
User is in control while navigating through the application.	Users always have control to enter and exit different states of the application without having t wait for an event to end.
Consistency of terms and standards	The software makes use of careful implementation, which prevents errors from occurring while the user is playing.
Prevention of run-time errors	Information is visible and accessible when needed without having to rely on memory.
Information Accessibility	Users can adjust settings to their liking.
Application's flexibility to different users	The application follows a consistent design and dialogues do not contain irrelevant information.
Application makes use of an atheistic and minimalist design	Error messages are displayed in a user-friendly format and should also suggest helpful solutions.
Error Exceptions	Error messages are displayed in a user-friendly format and should also suggest helpful solutions.
Help and Documentation	The software provides accessible help, which provides information on player controls and the game's objective.

Figure 2.1: *Nielsen's 10 Interface Design Heuristics*

Clear goals and objectives.	The application makes it clear of what is to be accomplished.
Context meaningful to domain and learner.	The activities throughout the application are situated in practice and also engaging to the learner.
Content is well represented and navigable.	The application supports different access pathways and content is clearly shown.
Activities are scaffolded.	User's activities are structured while delivering meaningful chunks of knowledge.
Elicit learner understandings.	Learners need to articulate their conceptual understandings as the basis for feedback.
Formative evaluation.	The application provides feedback to the player's achievements.
Performance should be 'criteria - referenced.'	The outcomes should be clear and measurable.
Support for transference and acquiring of 'self-learning' skills.	The application supports the transference of skills beyond the learning environment.

Figure 2.2: *Quinn's 8 Educational Design Heuristics*

2.4 Game Interaction

Games are developed to simulate unique experiences for players, compelling them to keep playing by interacting with the game's internal systems. Video games can become tedious when they are too easy or repetitive, but frustrating when in-game simulations becomes too complicated. With the use of adaptive Artificial Intelligence (A.I.) games have the potential to adapt the difficulty, story, and functionality through the player's in-game actions.

Varying forms of player interaction with games can affect how adaptive A.I. can be deployed. In the study published by Salen and Zimmerman in 2004, four different types of interactivity in video games are listed.

These included:

- **Cognitive Interaction:** This is the emotional and intellectual interaction between the player and the game;
- **Functional Interaction:** This highlights the interaction between the player and the user interface of the game;
- **Explicit Interaction:** This consists of the interaction between the player and the core mechanics of the game, for example: shooting, jumping and re-spawning.
- **Cultural Interaction:** Takes the form of fan sites, blogs and the use of cheats.

In the study by Cowley et al. (2008), it was mentioned that while going through the game, players gather information to understand the complexity of the game environment through emotional and intellectual interaction.

The complexity of the game is measured by its narrative story, objectives and opponents, while cognitive complexity refers to the player being able to observe and react accordingly.

If the game overwhelms the player with much information at once, the player would not be able to react in an ideal way. On the other hand, if the game is not challenging enough, the player will lose motivation. Therefore, a balance between game complexity and cognitive interaction is required.

There are two different types of games: Single Player and Multiplayer.

In multiplayer games, adaptive algorithms can be applied for multiple reasons, such as having different weather conditions.

The challenge of these games mainly comes from the actions of other players that are connected to the same network.

On the other hand, the use of non-player characters (NPC) in single-player games have the most significant effect on the player's experience. Adaptation in the NPC's behaviour or in-game parameter manipulation is essential for the player's experience and gameplay design.

Players increase their effectiveness in competitive play by learning the NPC's behaviour, which, unlike real players, tends to be linear and predictable. This behaviour from NPCs causes players to develop strategies more quickly to complete the game.

One of the reasons why people enjoy playing against others is the unpredictability in their gameplay. Players will feel more satisfied in their accomplishments rather than playing against NPCs, which follow a linear path.

2.5 Dynamic Difficulty Adjustment in Games

A simplified approach to adaptive artificial intelligence includes dynamic difficulty adjustments (DDA). User models are designed by monitoring the player's psychology while interacting with the game. In-game parameters are adjusted accordingly to the designed user model to implement DDA. This method is applied by changing the NPCs effectiveness or by reducing the in-game currency yield to purchase more items (Cowley and Charles, 2016).

An example of current DDA implementations include games like Max Payne, Homeworld 2 and Madden NFL 09. The games' difficulty were adjusted according to the player's progress.

However, DDA is capable of doing more than just adjusting in-game difficulties.

Crash Bandicoot 2 used DDA to adjust difficulty elements where players repeatedly fail by adding more checkpoints and reducing the speed of obstacles.

In the game Left 4 Dead, the publishing company, Valve had created a new type of A.I. called "Director." The A.I. offered the functionality to change the layout of the level and also added additional challenges. In Half-Life 2, the ratio of health or ammo spawn rates was also linked to the player's progress (Baranowski, 2018).

2.5.1 How Dynamic Difficulty Adjustment (DDA) works

Before the implementation of dynamic difficulty adjustment (DDA), an understanding of the term "difficulty" is required. Difficulty can be measured through multiple different factors such as characteristics of game design, provided resources, percentage of past victories and number of defeats.

The study "Dynamic Difficulty Adjustment (DDA) in Computer Games: A Review," published by Zohaib M. in 2018, reviews different implementations of DDA that were carried out by various research studies published after the year 2009. By observing **Figure 2.3**, it is noticeable how there has been an increase of research regarding dynamic difficulty adjustment over the past years through journals, conference papers, and theses. The years 2012 and 2017 had the highest amount of research regarding this topic.

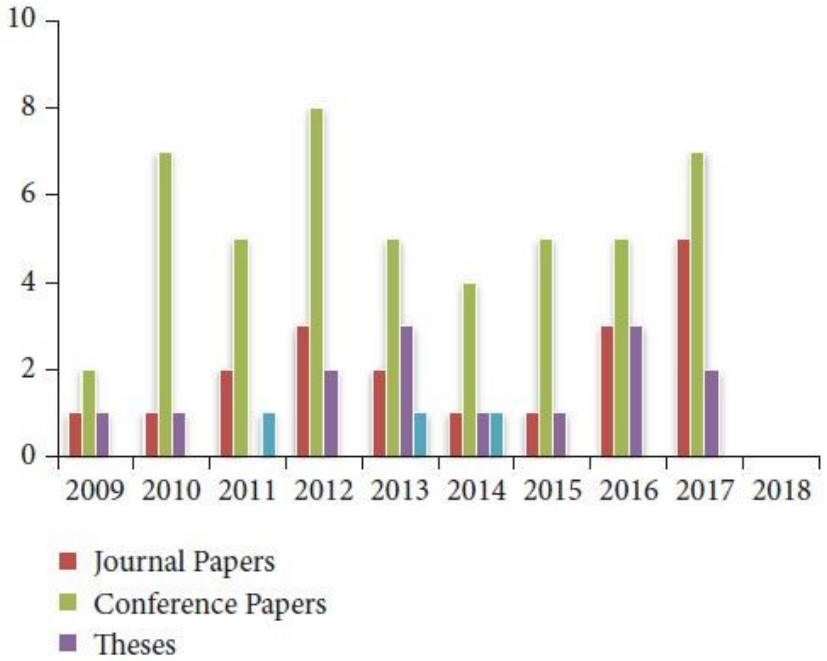

Figure 2.3: *Number of studies on Dynamic Difficulty Adjustment between the years 2009 and 2017*

Different approaches for implementing or improving DDA include Probabilistic Methods, Dynamic Scripting, Hamlet System, and Reinforcement Learning.

One common feature which was noticeable throughout all different implementations of DDA was the requirement to measure the level of difficulty in a game at any given time (Zohaib, 2018). Heuristic functions were also used to calculate and provide an estimate of the game's difficulty.

Probabilistic Methods: In the study "Dynamic Difficulty Adjustment for Maximized Engagement in Digital Games," published in 2017, Xue et al. proposed a new DDA system that maximized player engagement by recording the player's in-game progression in a probabilistic graph. The same study made use of a level-based game where players can unlock and advance to higher levels by completing levels. The writers defined the different states of a level-based game and designed the model, as shown in **Figure 2.4**.

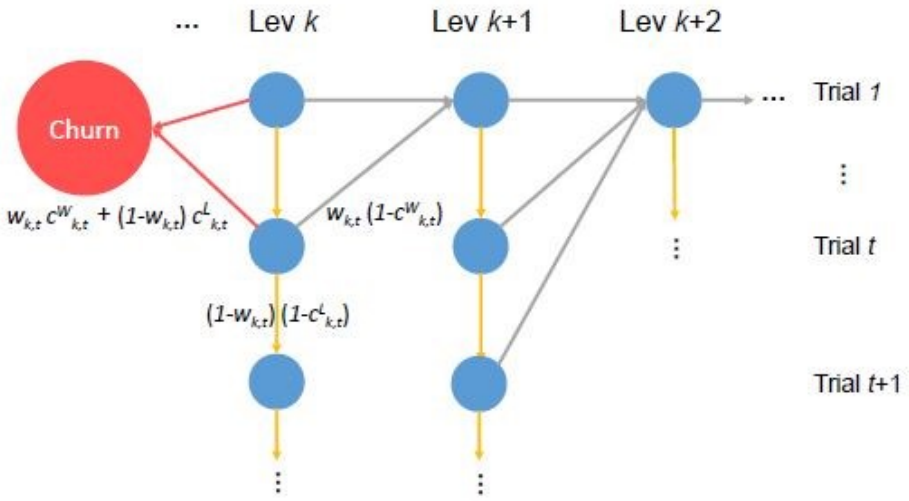

Figure 2.4: *A typical progression model of a level-based game*

With the use of **Figure 2.4**, three different transitions between player states were recorded and different probability formulas were formulated.

1. The Level-up Transition happened only if the player won the level and did not churn. This function for the level-up transition can be seen in **Figure 2.5**.

$$\Pr(s_{k+1,1}|s_{k,t}) = w_{k,t}(1 - c^W_{k,t})$$

Figure 2.5: *Level-up Transition*

2. The Retry Transition happened when the player retried the same level after losing and did not churn. The retry transition can be seen in **Figure 2.6**.

$$\Pr(s_{k,t+1}|s_{k,t}) = (1 - w_{k,t})(1 - c^L_{k,t})$$

Figure 2.6: *Retry Transition*

3. The Churn Transition happened when the player either completed all levels or stopped playing the game. **Figure 2.7** shows the function for the churn transition.

$$\Pr(churn|s_{k,t}) = w_{k,t}c^W_{k,t} + (1 - w_{k,t})c^L_{k,t}$$

Figure 2.7: *Churn Transition*

This probabilistic graph was the foundation for the optimization framework carried out in the study (Xue et al., 2017). The study concluded that the proposed system was successful since there was a 9% improvement in player engagement.

Dynamic Scripting: Dynamic Scripting makes use of various sets of rules and conditions for every type of in-game parameters which affects game objects such as obstacles, enemies and player resources. When a game object is added into a game, the values affecting its functionalities are set from a pre-defined rulebase. A new script is generated and assigned to the newly created game object, as shown in **Figure 2.8**.

The rulebase values are adjusted accordingly to the player's progress. When the player is successful in an encounter, the rule weights are increased, leading to a higher difficulty. On the other hand, when the player is defeated, weights are decreased while adjusting the game to an easier difficulty. This approach is used to generate new dynamic opponent tactics while optimizing the difficulty of the game's A.I. to match the player's difficulty.

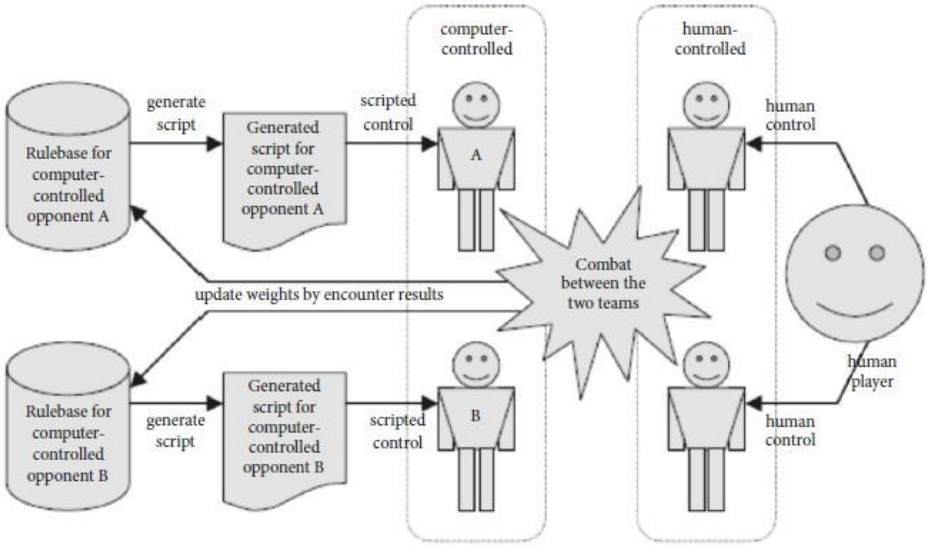

Figure 2.8: *This figure displays the process of Dynamic Scripting*

Hamlet System: The Hamlet System looks to manipulate the resource's supply and demand of a player's inventory to adjust the game's difficulty dynamically. This DDA system makes use of methods taken from the "Inventory Management and Operations" study (Hunicke and Chapman, 2004). The Hamlet System manages game statistics according to statistical metrics from the player's progress. As the player advances in-game, the system decides and implements new tasks/rules which tweaks data and system settings as required. It also anticipates when a player is having a difficult time completing a level.

Reinforcement Learning: This method of dynamic difficulty adjustment makes use of adaptive A.I. to adjust its script parameters and game behaviour in real-time according to the player's skill. Since this technique of DDA makes changes in real-time, the A.I. must be adept enough to make rational judgments and also be able to gather information on the player at the beginning of the game.

The study "Dynamic game difficulty scaling using adaptive behaviour-based A.I.," introduced two adaptive algorithms that made use of evolutionary computation and reinforcement learning (Tan, Tan and Tay, 2011). The two adaptive algorithms are the unichromosome controller (AUC) and the duochromosome controller (ADC). The AUC algorithm stored a single chromosome which mapped up to seven numbers. Each number indicated the probability of initiating a change in the game whenever a checkpoint was reached. When a checkpoint was reached, the chromosome was updated to adapt to a player's skill-set. Although both algorithms are similar to each other, the ADC algorithm maintained two sets of chromosomes instead of one.

2.5.2 Two effective frameworks for the implementation of DDA

2.5.2.1 Mechanics, Dynamics and Aesthetics (MDA) Framework

In game development, balance and feedback are essential characteristics when it comes to player experience. If a game's functionalities are not balanced, such as a new type of ability which is much better than other abilities, entire player communities would quickly get upset.

Furthermore, if the game does not provide consistent feedback, players might exploit unintended game functionalities which automatically affect the game's economy (Adams, 2002).

The Mechanics, Dynamics and Aesthetics framework (MDA), assist us to understand how to build successful dynamic difficulty adjustment implementations which maintains both balance and feedback characteristics in a game (Hunicke, 2005). DDA systems must accommodate both the player's experience and the game's fundamental design.

In the paper "MDA: A Formal Approach to Game Design and Game Research," published in 2014, the authors investigated how the MDA framework breaks games into three different components, which are; rules, systems and enjoyment. It is also essential to recognize their design counterparts: **mechanics**, **dynamics** and **aesthetics** (Hunicke et al., 2014).

Game mechanics include player actions, progress, and control mechanisms. In-game mechanics supports the overall gameplay dynamics.

Figure 2.9 shows an example of in-game mechanics in a First-Person Shooter game (Hunicke, 2005). It showed a continuous process of conditions and loops, where the player started by spawning into the game and continued by engaging with obstacles, items and enemies.

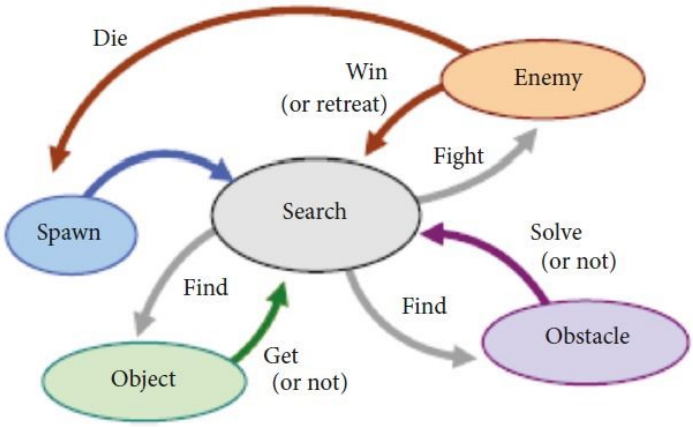

Figure 2.9: *A state transition diagram for player activity in a First-Person Shooter game*

Game dynamics are functionalities that encourage emotions and desires to resonate within people.

The emotions are the compelling motivational triggers that entice players to enjoy the game. Dynamics include the run time behaviour of different mechanics acting upon the player's inputs. Game dynamics also include the increasing variability and difficulty of obstacles as the player progresses through the game. Rewards may also become more challenging to achieve while encouraging players to work harder to gain better equipment.

Aesthetics experiences include the emotional feedback experienced while playing example the use of a timer or making use of more challenging opponents.

The emotions are characterized by the following taxonomies:

- **Sensation:** The pleasure experienced while playing;
- **Fantasy:** The make-believe content such as magic and mythical creatures;
- **Narrative:** The story of the game;
- **Challenge:** The difficulty level of the obstacles faced through progression, such as enemies;
- **Fellowship:** The social framework with other people through means of chat boxes, microphones, or formed parties;
- **Discovery:** The exploration of new territory.

On a final note, the MDA framework helped to explain the different parts of a game needed for the user to have an engaging experience and also provided an understanding of the experience outcome.

2.5.2.2 Charles's and Black's Framework

In the paper "Dynamic Player Modelling: A Framework for player-centred Digital Games " (Charles and Black, 2004), a model was introduced for the implementation of adaptive games based on player modelling.

In their study, they mention that there are two sources of information that are used to set up a basic adaptive game system.

The **first source** included the information that a player provides at the start of a game, such as, gender, skill level and age.

The **second source** of information is the monitoring of a player's progress and gameplay habits while playing. This process can also be referred to as player modelling.

There are two main reasons for player modelling in games. Player modelling can either be used to:

- capture human-like qualities to implement them into a non-player character or;
- recognize pre-defined player types from player monitoring to adapt the game according to the player's frustration level or progress.

Figure 2.10 outlines the functionality of the framework developed in the study (Charles and Black, 2004).

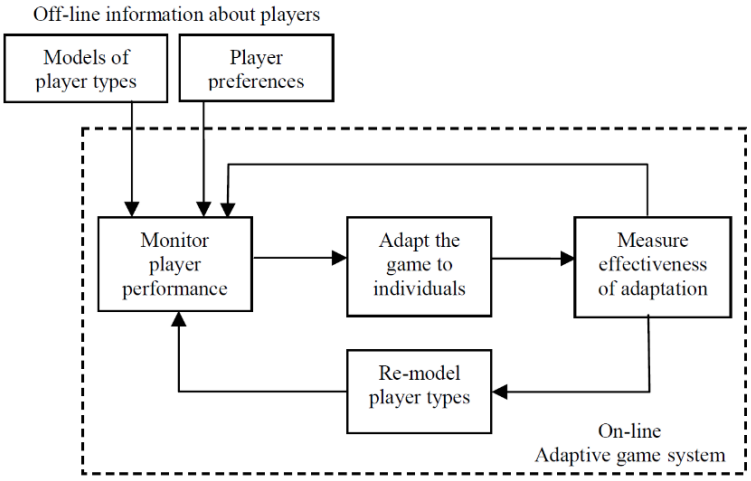

Figure 2.10: *Charles's and Black's adaptive game system model using player modelling.*

The model **(Figure 2.10)** is composed of four main aspects:

- Player modelling is set by pre-defined data entry from the information acquired at the start of a game, hence the requirement for off-line learning;
- In-game player progress is monitored;
- The difficulty of the game is adapted accordingly;
- The effectiveness of the adaptation is measured.

The study (Charles and Black, 2004), measured the effectiveness of adaptation by calculating the reduction of the player's frustration and in-game progress.

If the last adaptation did not improve the player's frustration level or the player's performance, it meant that the player had either been classified incorrectly or that the initially designed model, was no longer applicable. In such a scenario, the player's model was remodelled accordingly to the player's skill level.

2.5.3 Evaluation of parameter manipulation in DDA using Dynamic Scripting

The study "Dynamic Difficulty Adjustment through parameter manipulation for Space Shooter game" (Segundo, Calixto and Gusmao, 2015), discussed the use of data manipulation to adjust the difficulty of the game dynamically. This game was developed using the Unity game engine. In the space shooter game, the player started with full health (100 hit points) and 50 ammunition.

Throughout the game, the player had to face off different types of enemies and obstacles while also collecting in-game points. Furthermore, items that offered more health and bullets were accessible by interacting with a specific game object.

The study made use of parameter manipulation of both offer and demand parameters to dynamically adjust the game's functionality while the player was playing. Offer parameters are the resources that were assigned to the player, while demand parameters affected the enemy's behaviour. Offer parameters included the health and ammunition available to the player, while demand parameters included the opponent's strength, behaviour and endurance (Segundo, Calixto, and Gusmao, 2016).

The following function, shown in **Figure 2.11**, was used to determine the player's skill level in-game while varying accordingly to the damage suffered at a given time.

$$\sum_{i=1}^{n} d(i)$$

Figure 2.11: *The heuristic function used to determine the player's skill*

Figure 2.12 was used in the study "Evaluating dynamic difficulty adaptivity in shoot'em up games" (Araujo and Feijo, 2013) to depict the flow channel and proportionality of a player's skill and challenge while going through a game.

Two different control zones: comfort and discomfort areas, were used to calculate the flow of difficulty to the player's skill and apply control policies accordingly. The comfort zone happened when the flow of the game was easy and required no effort to complete the game, which resulted in a lack of interest to continue playing. On the other hand, the discomfort zone happened when the game exceeded the player's ability to complete the game.

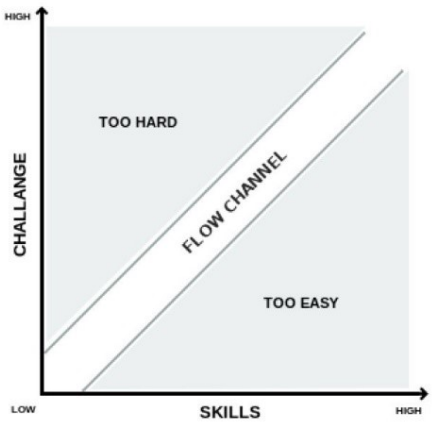

Figure 2.12: *Shows the difficulty flow channel in proportion to the player's skill*

In the study (Segundo, Calixto and Gusmao, 2015), it was concluded that the player must continuously remain in the flow channel were the game's challenges are consistent with the player's skill. The player must also be able to continue engaging with the game and enjoy the experience while successfully progressing at a steady pace.

When the players were in the comfort zone, enemies spawned at a higher rate and dealt more damage.

However, while the players were in the discomfort zone, players had more resources (ammunition and health) while enemies spawned at a slower rate and also dealt less damage.

Policies were used to manipulate the game parameters to keep the player in the flow channel. When a player was classified in a region, values were applied accordingly to increase or decrease the game's difficulty. The difficulty was adapted by varying the variable's weights accordingly to the player's skill. This form of DDA is known as Dynamic Scripting.

Finally, in this study (Segundo, Calixto and Gusmao, 2015), a questionnaire was used to gather data regarding the respondent's perception of game difficulty. This study also made use of three different difficulties: easy, hard and dynamic. From the 30 participants, 18 people (60%) chose dynamic difficulty to be the best version of the game, while 9 people (30%) chose hard difficulty and the remaining 3 (10%) participants chose easy difficulty. (Segundo, Calixto and Gusmao, 2015).

Chapter 3

Methodology

This chapter outlined the process taken to answer the research questions that were proposed in the Introduction chapter.

The objective of this study was to provide a better understanding of the effectiveness of educational games in modern education and featuring dynamic difficulty adjustments to adapt to the player's performance.

This study aimed to analyze and discuss the difference in player performance when engaging with the same game but different difficulty levels. The objective was to observe and gather data from various participants while engaging with the developed prototypes. Data gathered from static difficulty were compared to that of dynamic difficulty, which measured the difference in the players' performance.

This study also calculated the increase of participants' immersion and interest towards a particular type of difficulty, either static or dynamic, while playing the game. A framework proposed in a different study was used to evaluate the participants experience while interacting with the prototypes. When comparing results, an evaluation between the immersion rates of both types of difficulties was done.

For the purpose of this research study, two different types of games were developed, one featured a level-based game, while the other featured an endless runner game. Each game also consisted of two different difficulty versions, either non-adaptive (static) or adaptive (dynamic).

The reason for developing these implementations was to continuously monitor and gather data from each version of both games while the participants were playing. The data gathered from the prototypes were then compared and analyzed, proofing if there was a difference between the participants' results who played the different games.

3.1 Data Collection Methods

Quantitative research methods were chosen to gather and analyze the data needed to answer the objectives of this study. This type of research method provided the ability to study a larger sample size, thus increased the credibility of data. Questionnaires and experiments were carried out to gather data quickly and provide immediate answers. Furthermore, data was presented in the form of numbers, statistics and various charts, including Pie Charts and Bar Charts, which were easily constructed in an attempt to explain what was observed from the data.

For the purpose of this study, data collection and analysis of data were split into two different phases. Data gathered during the first phase was used to increase the effectiveness of the prototype's implementation, together with the credibility of data gathered obtained in the second phase of data collection.

Google Forms was utilized to design and share the questionnaires. This application was selected because it is an open-source and online application that allowed for a more accessible collection of data. Another reason for using Google Forms is that the collected data was automatically generated into a variety of graphs.

3.2 First Phase of Data Collection

Two questionnaires were designed to increase the accuracy of the results gathered during the second phase of data collection.

- The **first questionnaire** served as a screening process for potential participants during prototype testing in the second phase of data collection;
- The **second questionnaire** was used to carry out an evaluation of the first implementation of both prototypes. Heuristic evaluation was chosen to be the most effective way to carry out this process. The results assisted to detect and fix any issues affecting the participants' gameplay and enjoyment level, which will help to obtain more definitive results during the second phase of data collection.

3.2.1 Initial Questionnaire: Screening Process

By utilizing this questionnaire, basic demographic and experience questions were asked. The results allowed the establishment of a set of criteria on who is interested in this type of research.

This questionnaire gathered data about the most popular age group of people that are interested in this study. The age group of the participants who will be taking part in the second phase of data collection was decided according to the obtained results.

Other questions such as the preferred device to play games on, difficulty levels and game types were also asked to gather data. The results gathered from these questions were used to help develop the prototypes (Refer to Appendix A.1.1 for the design of the initial questionnaire).

3.2.2 Heuristic Evaluation

This evaluation was carried out after the first implementation of the prototypes. Five people from the IT sector, with expertise in user interface design and educational design, were chosen to carry out Heuristic Evaluation. Since they have high experience in this field of study, they had a better insight on the user interface, therefore, being able to carry out a more effective evaluation.

As one of the objectives of this study was to calculate the participant's experience throughout the adaptive and non-adaptive versions of the prototypes, it was vital to eliminate other in-game elements that were affecting the players' experience. This evaluation helped to detect and fix any issues affecting the participants' gameplay and enjoyment level.

Two different heuristics were used to evaluate the interface's and educational features' design of the first implementation of the prototypes. From the study (Mack and Nielsen, 1994), Nielsen's 10 heuristic principles were used to evaluate the interface design of the prototypes. On the other hand, Quinn's educational heuristics were utilized to evaluate the educational features' design (Quinn, 1996).

Scales from 1 to 5, 1 = Poor Implementation, and 5 = Excellent Implementation, were used to calculate the severity rating of each usability problem according to how the heuristic principle was implemented in the first implementations of the prototypes. One questionnaire was sufficient enough to carry out the evaluation of both prototypes since the interface's and educational design of both games was consistent (Refer to Appendix A.2.1 for the full design of the heuristic evaluation questionnaire).

After gathering all the necessary data, the severity ratings for each principle were created. The required resources were all allocated to fix the most severe issues with the prototypes. Other factors were also taken into consideration when calculating the severity rating of each heuristic.

These include:

- the frequency rate of which the problem had occurred and;
- the type of impact level of a problem, whether it was easy or difficult to overcome by the evaluator.

3.3 Second Phase of Data Collection

During the second phase, two different games were implemented and used to monitor data while the participants were playing. Each game consisted of two different versions.

Participants were asked to answer a post-game questionnaire after they had completed a version of the game, to measure their experience during the process.

3.3.1 Prototypes

For this study, two prototypes were developed using the Unity game engine.

Throughout this process, C# was used as the programming language since it is the most popular tool when developing games with this game engine.

Unity supports cross-platform development, were it quickly allows developers to build games on different devices, such as smartphones and desktop computers. This game engine is continuously updated and also consists of a large community with helpful forums.

In both prototypes, the player was required to control a spaceship in order to answer either addition or multiplication questions correctly by continuously colliding with the asteroid that contained the valid answer. Every time players incorrectly guessed an answer, they would lose a set amount of health assigned at the start of the game. When the players' health reached 0, they had the option to either return to the main menu, retry to achieve a better result or exit the game.

Two different game implementations were developed:

- An endless runner game which used dynamic scripting (Zohaib, 2018);
- A level-based game which featured an adaptation to Charles's and Black's framework of player modelling.

The MDA (Mechanics, Dynamic and Aesthetics) framework was used in both games to maintain the balance and feedback characteristics (Hunicke, 2005).

Figure 3.1: *Typical in-game gameplay*

The objective of the endless runner game was for the player to play the game for multiple times while trying to beat the highest score that they had previously achieved. This type of game did not have a pre-defined amount of questions or an ending.

The level-based game featured 15 different levels, each incrementing level being more complicated than the last. Each level had a pre-defined amount of questions and lives for the player.

Two versions of each game were developed. First was the non-adaptive version, featuring constant difficulty throughout the game, and secondly an adaptive version which made use of dynamic difficulty adjustment.

3.3.1.1 Adaptive algorithm: Endless Runner game using Dynamic Scripting

Before the start of a new game session, the endless runner game allowed players to choose 1 out of 3 different difficulties (Easy, Hard and Dynamic). According to the chosen difficulty, at the start of a match, different entry data was assigned to the behaviour variables.

For Easy and Hard difficulties, the entry data assigned to the variables remained the same for the rest of the match.

For the Dynamic difficulty, the entry data that was assigned to the variables, at the start of a match, varied by decreasing their values when the player incorrectly guessed answers or by increasing them when there is a continuous progression of the player's score.

At the start of a new match, variables were reverted to their original values. A set (V) of different behaviour variables are taken into account to control and adjust in-game's functionalities that affected the different difficulties of the game (Refer to Appendix A.3.1 for a more detailed look at the mentioned parameters).

V = { minWeight_Add, maxWeight_Add, minWeight_Multi, maxWeight_Multi, damageValue, obstacleSpeed }

"minWeight_Add" and "maxWeight_Add" affected the minimum and maximum range of randomly generated numbers used for addition questions while "minWeight_Multi" and "maxWeight_Multi" had the same functionality for multiplication questions. The lower the values, the easier the questions were to answer, while the higher the values, the harder it was for players to answer the questions correctly.

"damageValue" affected the amount of health points that the players took after incorrectly guessing a question.

"obstacleSpeed" affected the speed that the asteroids moved at. The lower the value of the obstacle's speed, the more time the player had to figure out the correct answer. When the obstacles started moving at higher speeds, the player had less time to think.

Figure 3.2 refers to a flowchart of the implemented system in the endless runner game, based on Charle's and Black's framework, together with, the MDA framework showing the different stages of the game. After the player had selected one of the difficulties, the game starts by randomly generating a question, while making use of the pre-defined weights according to the player's difficulty preference. Once the player had collided with an obstacle, the game checks whether the difficulty is adaptive (dynamic) or non-adaptive (static). If it was non-adaptive, another question is generated without monitoring the player's performance, while on the other hand, if the difficulty version was adaptive, the player's performance is monitored. The behaviour variables are adapted to the player's progress accordingly depending on the type of difficulty.

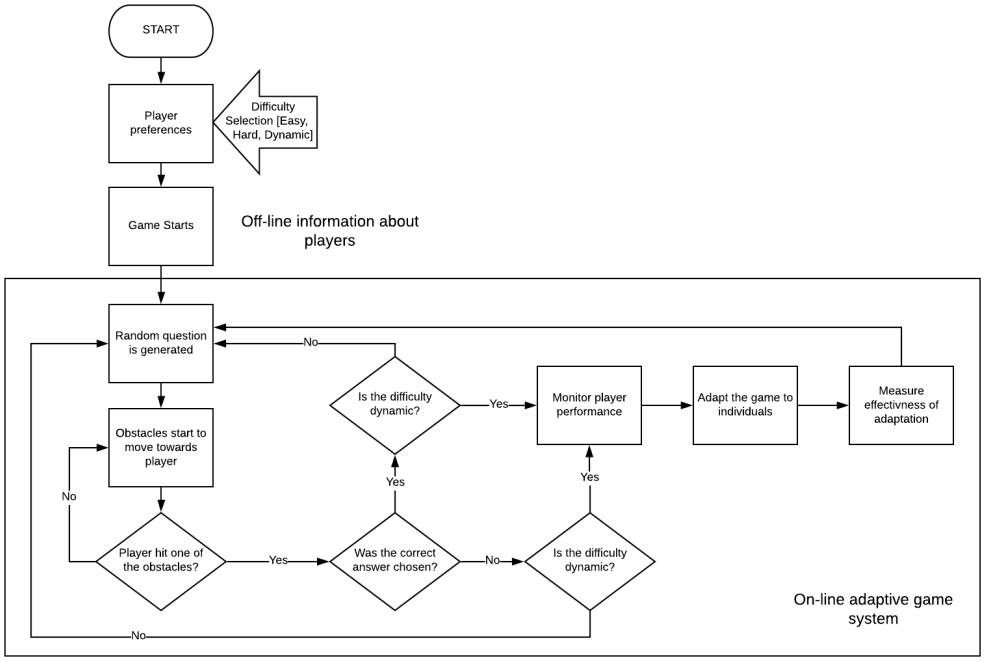

Figure 3.2: *The algorithm of the dynamic difficulty adaptive system used in the Endless Runner game, making use of Charle's and Black's and MDA frameworks*

3.3.1.2 Adaptive algorithm: Level Based game using player modelling

Similar to the implementation of the endless runner game, a set of behaviour variables were used to adapt the difficulty of different levels according to the player's performance. Minimum and maximum weights were used to vary the difficulty of the generated questions, along with other variables to vary the speed of obstacles, particles, and background (Refer to Appendix A.3.2 for a detailed look at the parameters used in the level based game).

As previously mentioned, the level-based game consisted of 15 different levels, each increasing level adjusting the variables to increase the difficulty from the previous level.

When a level is completed by correctly answering a set amount of questions, the next level is unlocked. If players failed to complete a level, after losing all of their lives, they can retry the same level or even play other previously unlocked levels.

In **Figure 3.3**, an adaptation to the Charle's and Black's framework used in the level-based game is shown. At the end of each level, the player's performance was monitored. The game was adapted by increasing or decreasing the number of times the player had completed a level. The higher the number is, the player model is adapted to provide harder levels than usual by increasing the minimum and maximum weights of questions, speed of obstacles, amount of lives (that players start with) and the number of questions needed to complete the level. If the number of wins decreases, the behaviour variables are decreased to make levels easier to complete. Behaviour variables are set at the start of a match according to the selected game level and the player model.

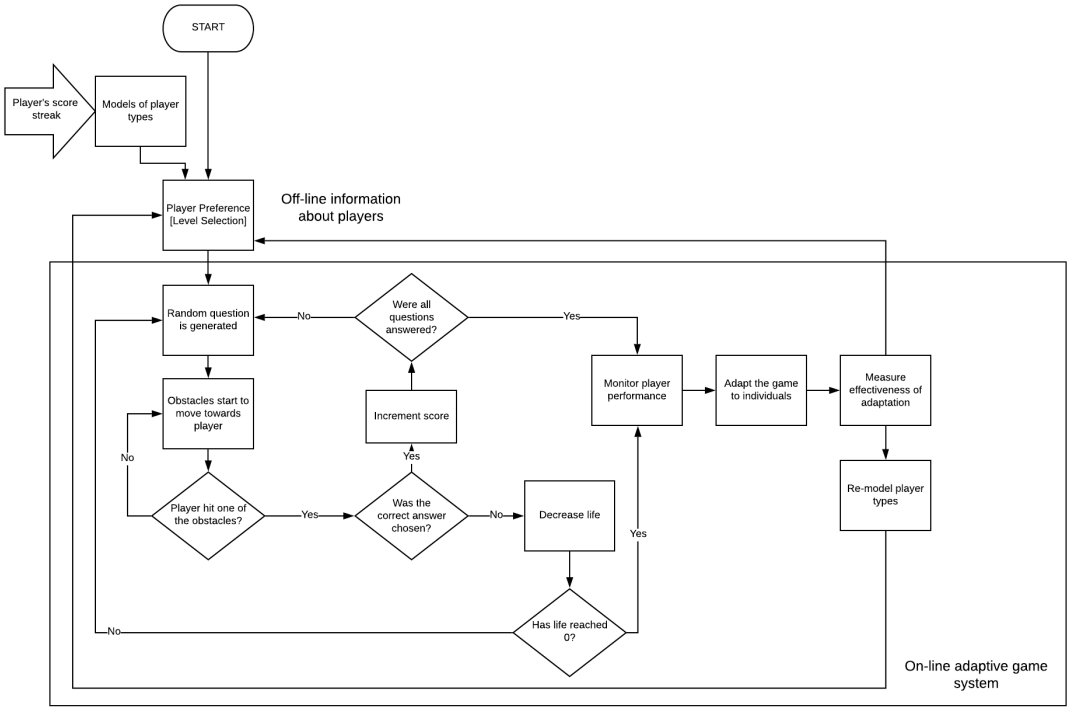

Figure 3.3: *The algorithm used in the level Based game, making use of Charle's and Black's and MDA frameworks*

3.3.2 Post-Questionnaire: CEGE Framework

In this study, the CEGE framework has been used to evaluate the player experience through the use of a post-game questionnaire (Eduardo et al., 2010).

The CEGE theory was identified to be the best method to measure players' experience for the following reasons:

- Due to unforeseen events, it was restricted to gather participants in sessions and be able to monitor their expressions while playing the prototypes;
- It was impossible to obtain sensors to measure the participants' peripheral physiological activity, similar to the method used in the study by Bétrancourt (2011), to calculate the difference in heart rates and temperature.

This theory was also proven successful to measure the players' experience in other studies, including the study by Eduardo et al. (2010) and the study by Araujo and Feijo (2013).

By using the CEGE framework, it was possible to pursue a statistically significant comparison between the level of enjoyment and frustration in each version of the prototypes (Refer to Appendix A.4.1 and Appendix A.4.2 for the full designs of the post-questionnaires).

As this framework makes use of a hierarchical approach while using various scales to collect data, it can identify specific features that were either enjoyable or frustrating by the player.

The 7-point Likert scale was used to rate the observable elements of gaming experience and also evaluate which version the players enjoyed playing the most.

The CEGE framework consists of 2 core elements, video-game and puppetry, which are the interaction between the player and the game.

The relation between these two guiding elements are structured as:

- Puppetry and video-game are the two core elements that define the player's experience, enjoyment or frustration;
- Constructor elements allow for a better insight into the observable elements;
- Observable elements are measurable in-game variables which are categorized under different constructor elements.

Figure 3.4 and **Figure 3.5** show the hierarchical structure of the constructor elements and their respective observable variables.

Observable elements are the measurable in-game variables such as time, player controls and score. Constructor elements are used to calculate the enjoyment and frustration levels of the player's experience.

PUPPETRY			← (Core Elements)
Control	**Ownership**	**Facilitators**	← (Constructor Elements)
Small Actions	Big Actions	Time	
Controllers	Personal Goal	Aesthetic Value	
Memory	You-but-not-you	Previous Experiences	← (Observable Elements)
Point-of-view	Rewards	-	
Goal	-	-	
Something-to-do	-	-	

Figure 3.4: *Hierarchical structure of the Puppetry core element, making up the CEGE framework*

Video-Game		← (Core Elements)
Game-play	**Environment**	← (Constructor Elements)
Rules	Environment	
Scenario	Graphics	
-	Sound	← (Observable Elements)
-	-	
-	-	
-	-	

Figure 3.5: *Hierarchical structure of the Video-Game core element making up the CEGE framework*

3.4 Evaluation Plan

In the first stage of data collection, the initial questionnaire was posted online to gather different demographic data on the respondents.

Once data was collected, it was evaluated and the first implementations of the prototypes were developed.

After gathering data, Heuristic evaluation was then carried out on the first implementation of the prototypes to find any issues affecting the monitoring of results and the player's enjoyment/frustration levels. Results were then evaluated and the severity rating of each heuristic was calculated. The prototypes were then amended accordingly to the severity ratings.

In the second phase of data collection, 30 participants were selected to play the prototypes. The age group of participants was decided according to the results obtained in the initial questionnaire. The participants were divided into two separate groups consisting of 15 individuals per group. One group was instructed to play the endless runner game while the other played the level-based game. The groups had to play two different versions of the same game, one being adaptive and the other non-adaptive. Participants were not informed of which version they were playing, so there would not be any bias in the results and to test whether the participants would be able to differentiate between one version to another.

The experiment was conducted in two steps:

- **In the first step**, the participants were first instructed to play one version of the game and to answer a post-questionnaire after they had completed the version;

- **In the second step**, participants were instructed to play the other version of the game and to answer the same post questionnaire relative to that version of the prototype.

Players were not instructed on the number of times they required to play the game in order to measure the participant's interest in replayability throughout the different versions of the games. Furthermore, it was planned that each step of the experiment would be completed within one day.

Firebase Realtime Database was used for the collection of data from the players' progress each time they finished a match. Such data included the player's score, time played, date, and name, as shown in **Figure 3.6**.

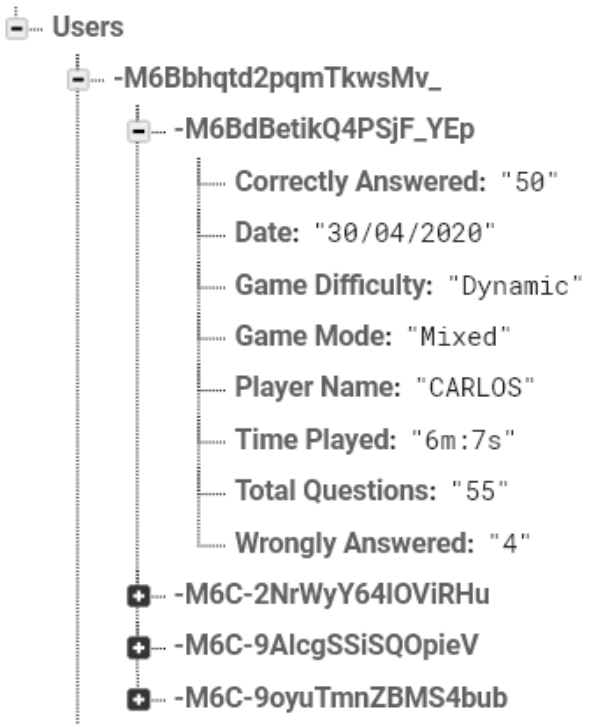

Figure 3.6: *Typical player data entry on Firebase Realtime Database*

In the post questionnaire, which made use of the CEGE framework (Eduardo et al., 2010), observable variables were measured to evaluate the players' experience. A total of 38 questions were categorized under 10 different scales. The scales were divided into two different sets. Set 1 contained the core elements (puppetry and video-game), while set 2 referred to the respective constructor variables from the core elements. **Figure 3.7** shows the relationship between each question from the questionnaire and the different sets of scales.

Question/s	Set 1	Set 2
1, 4, 5	Enjoyment	-
2, 3	Frustration	-
6-38	CEGE	-
6-12, 38	Puppetry	Control
13-18	Puppetry	Facilitators
19-24	Puppetry	Ownership
25	Puppetry	Control/Ownership
26-31	Video-game	Environment
32-37	Video-game	Game-play

Figure 3.7: *Relationship between questionnaire questions and different sets of scales*

Set 1: **Enjoyment:** The pleasure while playing; **Frustration:** The negative experience while playing; **CEGE:** Refers to both Puppetry and Video-Game; **Puppetry:** The interaction and sense of control while playing the game; **Video-Game:** Playability and environment of the game, such as graphics.

In this set, both puppetry and video-game are linked to enjoyment. If CEGE is present, frustration should be low and uncorrelated.

Set 2: **Control:** The player's ability to control the game; **Facilitators:** Any previous experiences in similar games; **Ownership:** The results of the player's actions over the game; **Environment:** Refers to the graphics and audio effects in the game; **Gameplay:** Correlates to the game's objectives.

Chapter 4

Results and Discussion

In this chapter, the results gathered from the methods described in the methodology chapter, are presented and discussed with reference to the main objective of this study, which was to determine the use of gamification in learning applications featuring dynamic difficulty adjustment.

The results and discussion will be split into two different phases.

The **first phase** will analyze the data gathered from the initial questionnaire and the data obtained from the heuristic evaluation that was carried out on the first implementations of the prototypes.

During the **second phase**, the data recorded while the participants interacted with the prototypes will be discussed and compared to distinguish the results obtained from different game versions and difficulties. Data gathered from the post questionnaire will also be analyzed to measure the difference in the player's experience throughout the second phase of data collection.

4.1 First Phase

This phase will analyze and discuss the results obtained throughout the initial questionnaire and heuristic evaluation to ultimately increase the validity and reliability of methods used to gather data throughout the second phase of data collection.

4.1.1 Initial Questionnaire

This questionnaire acted as a screening process with the aim to gather information regarding the people interested in this type of study (Refer to Appendix A.1.2 to see the additional data that was collected from the initial questionnaire).

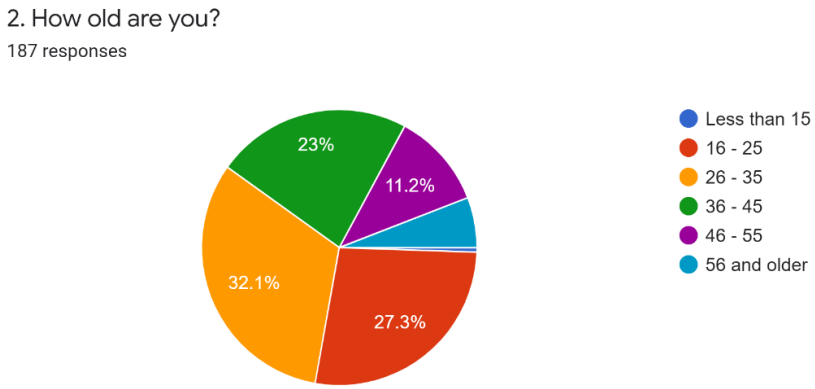

Figure 4.1: *Presentation of the respondents' age*

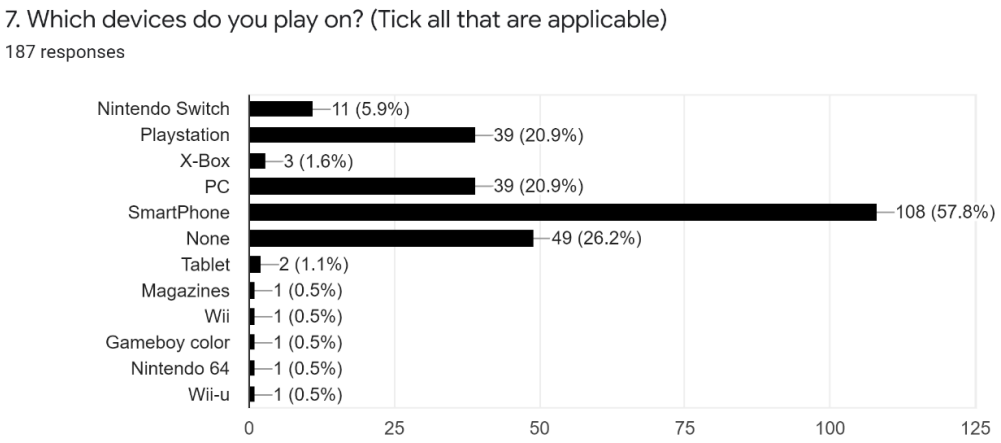

Figure 4.2: *Representation of the devices used by respondents to play games on*

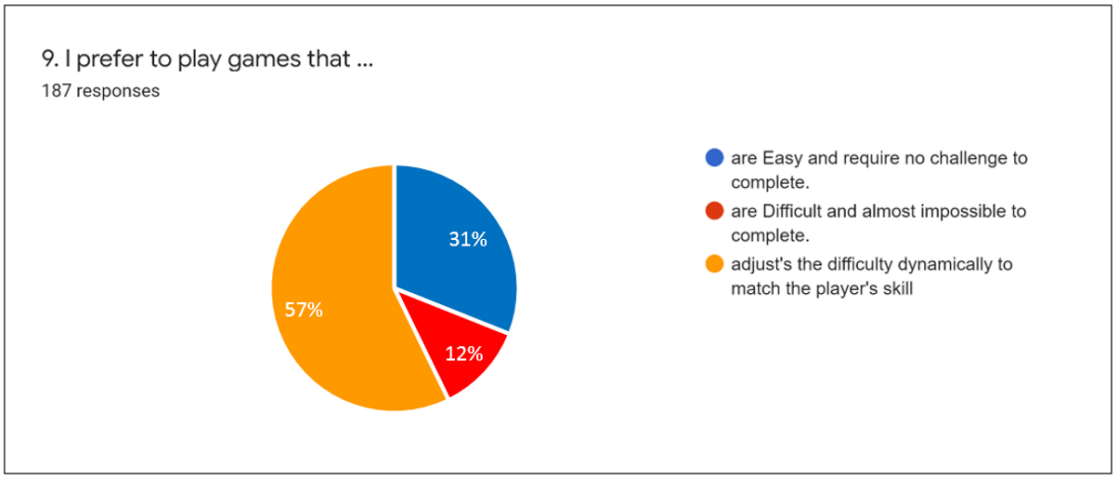

Figure 4.3: *Respondents' preferred game difficulty*

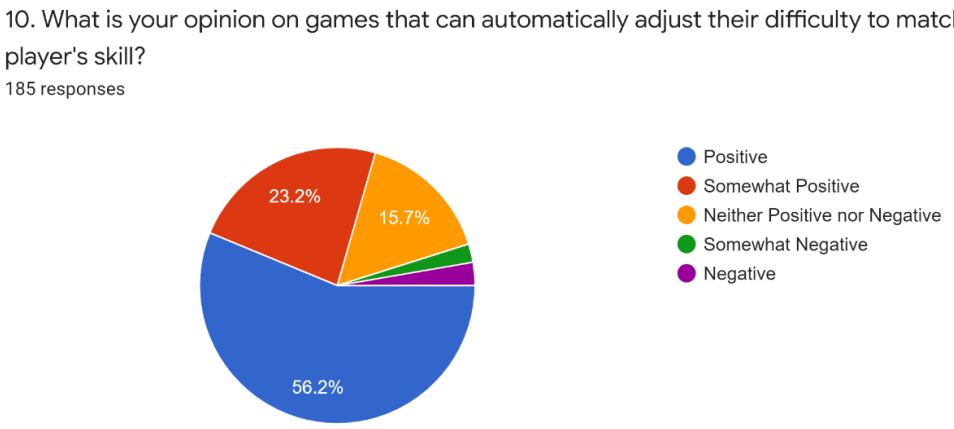

Figure 4.4: *Respondents' opinion on DDA*

From **Figure 4.1**, a clear representation of the respondents' age groups was shown. 32.1% of the respondents that took part in this questionnaire claimed to be 26 to 35 years old, while 27.3% claimed to be between the ages 16 to 25 years old. 0.5% of the respondents said to be less than 15 years old, while the other 40.1% of the respondents declared to be older than 35 years old. The majority of respondents were between the ages of 16 to 35 years old. It was decided that the selected age group of participants to take part in the second phase of data collection will be between the ages of 20 to 30 years old.

In **Figure 4.2**, respondents were asked which devices they mostly use while playing games. From the responses, 20.9% declared that they use PlayStation and PC to play games on. On the other hand, 26.2% of the responses state that respondents use none of the mentioned devices. It was concluded that the final implementation of the prototypes would be published onto smartphones since the majority of the responses (57.8%) stated that smartphones are the most popular device used to play games.

Figure 4.3, shows the results obtained from the respondents as regarding the preference for in-game's difficulty. By analyzing the data, it showed that 57% of the respondents prefer to play games that adapt to their skill. On the other hand, 31% of the respondents prefer games that are easy and provide no challenge to complete while the remaining 12% prefer games that are almost impossible to complete. From the results obtained, it was concluded that the respondents are more interested in playing games featuring a form of dynamic difficulty adjustment rather than easy or hard difficulties.

Figure 4.4 represents the gathered data regarding the respondents' opinions on the use of dynamic difficulty adjustment (DDA) in games. The data obtained from this question showed that a similar percentage of respondences was obtained to that of the previous figure (**Figure 4.3**). This data relates to the respondents' previous experience with games featuring DDA. After analyzing the data, 56.2% of the respondents had a favourable opinion on the use of adaptive difficulty in games, while 23.2% of the respondents claimed that they have a somewhat positive opinion. On the other hand, 15.7% of the respondents stated that they have neither positive or negative opinions. Therefore, it was concluded that 2.2% of the respondents have a somewhat negative opinion, while the remaining 2.7% of the respondents have a negative opinion on the idea of using DDA in games.

4.1.2 Heuristic Evaluation

The time taken by the evaluators to assess the first implementations of the prototypes varied between a few days to a couple of weeks. Apart from the data obtained from the questionnaires, constructive suggestions were offered from the evaluators (Appendix A.2.3). The 5 point scale was used to calculate the severity of each heuristic throughout the questionnaire. The 5 point scaled varied from 1 – Very Poor, 2 – Below Average, 3 – Average, 4 – Above Average to 5 – Excellent.

4.1.2.1 Nielsen's Interface Heuristics

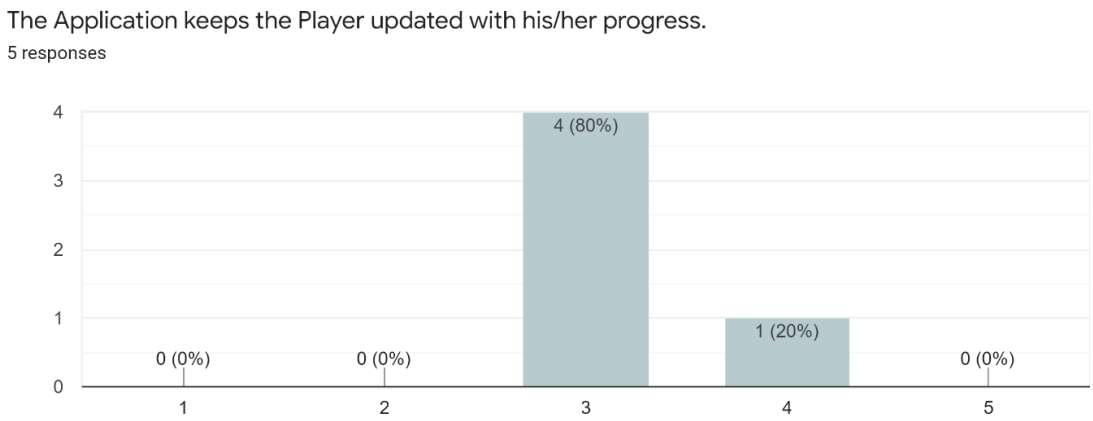

Figure 4.5: *Graph representation of how the application keeps the players updated with their progress*

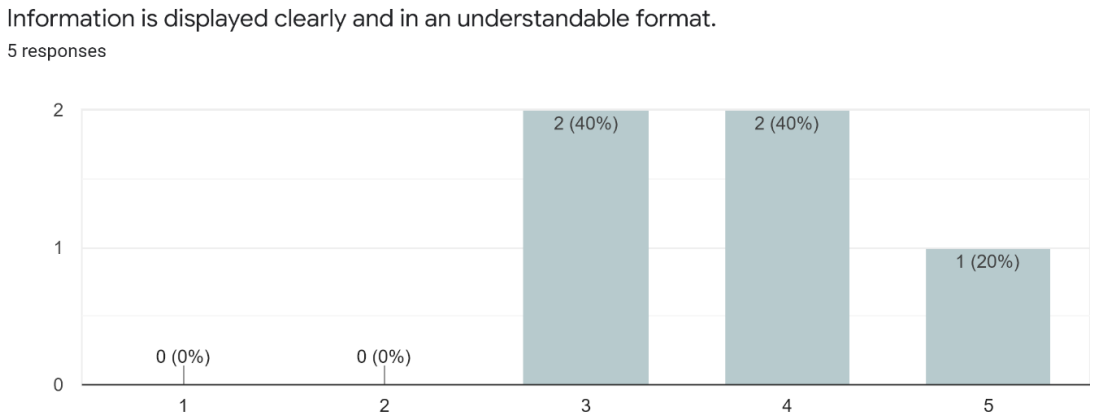

Figure 4.6: *Graph representation of how data is displayed clearly and in an understandable format throughout the prototypes*

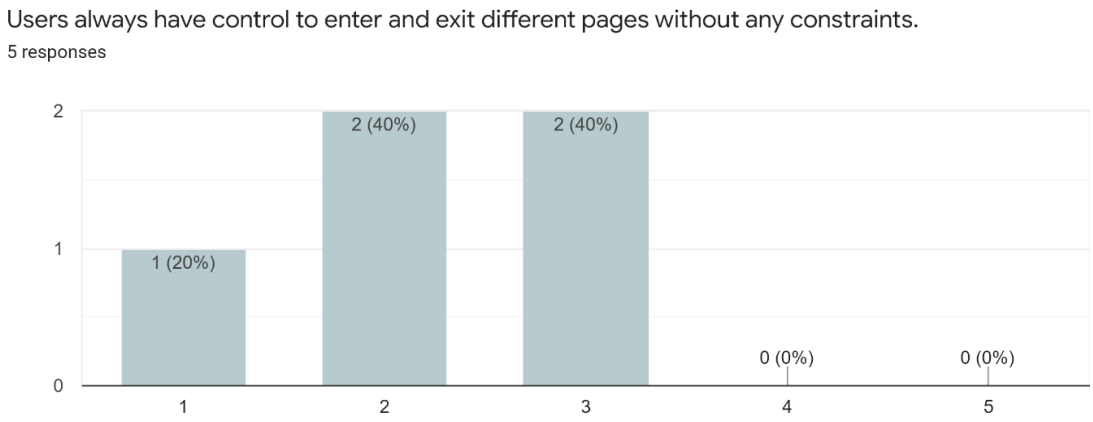

Figure 4.7: *Graph representation of the player's navigational control in the game*

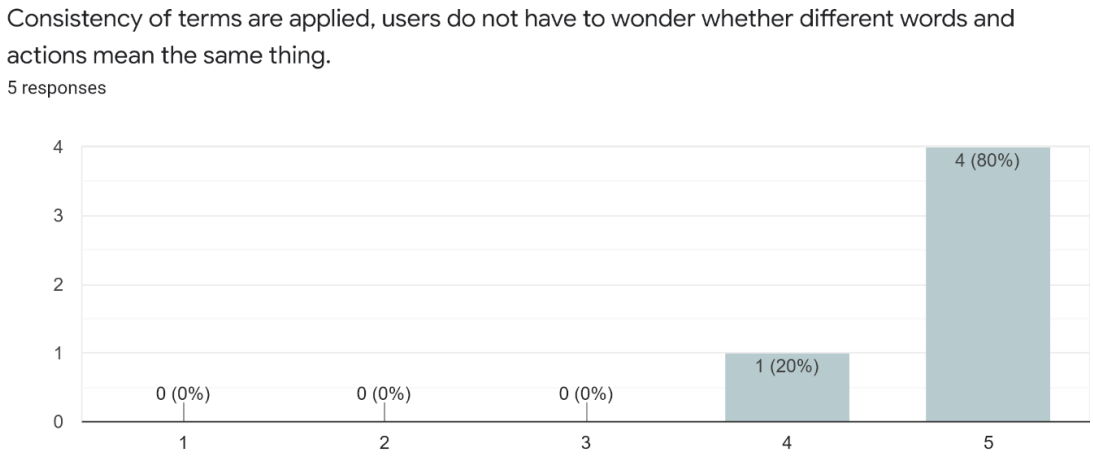

Figure 4.8: *Graph representation of the consistency of terms used throughout the prototypes*

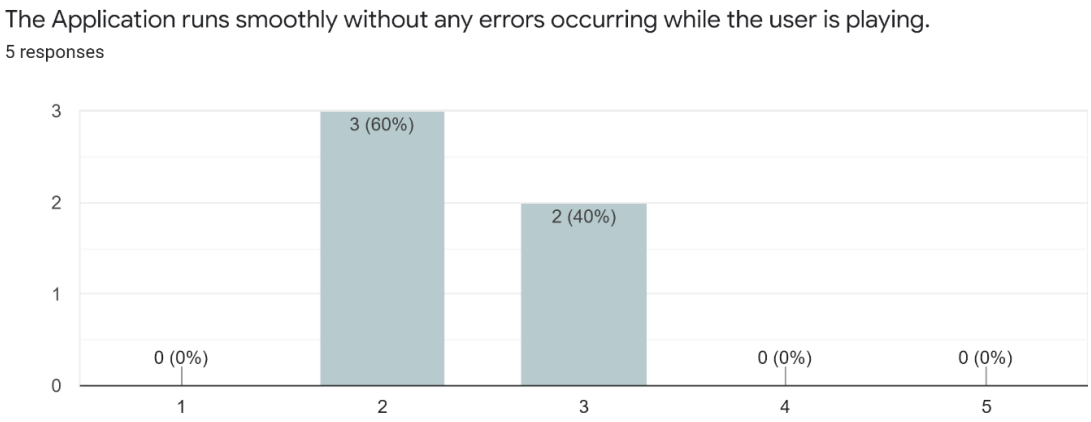

Figure 4.9: *Graph representation of any occurring errors while the game is running*

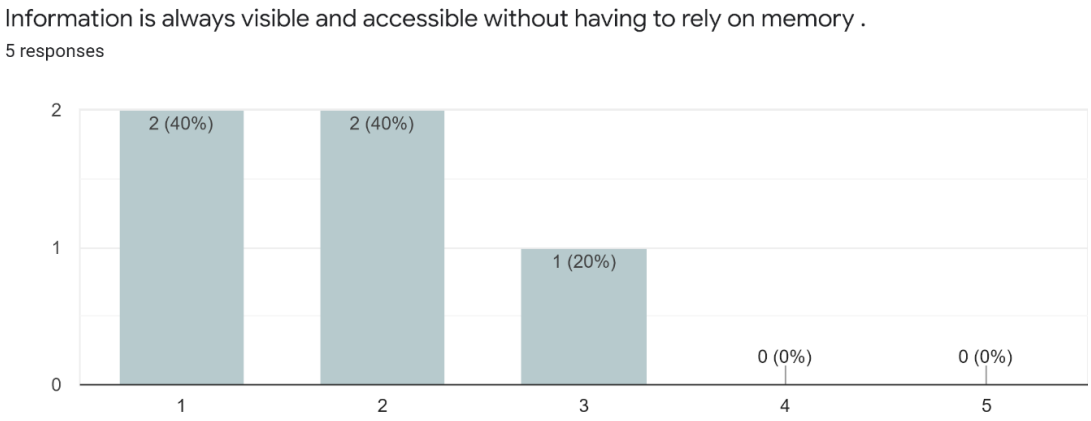

Figure 4.10: *Graph representation of the accessibility to information by the players*

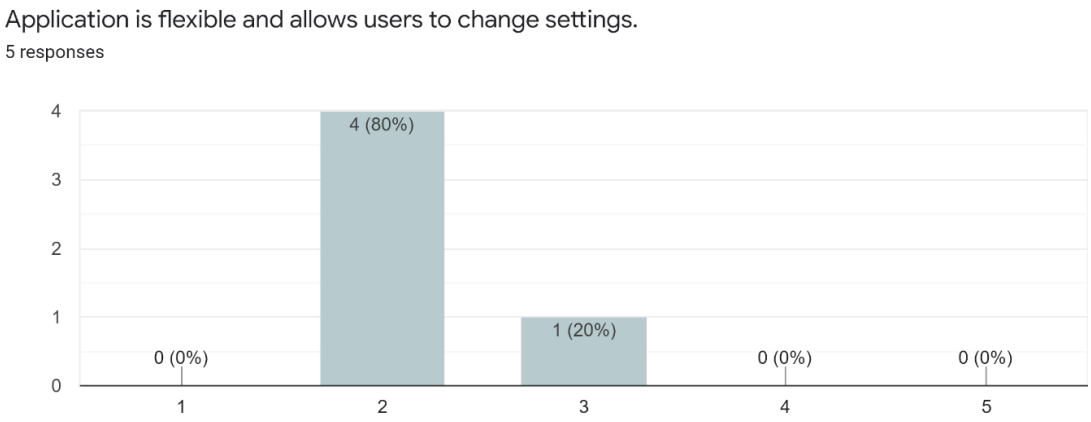

Figure 4.11: *Graph representation of the player's ability to change in-game's settings*

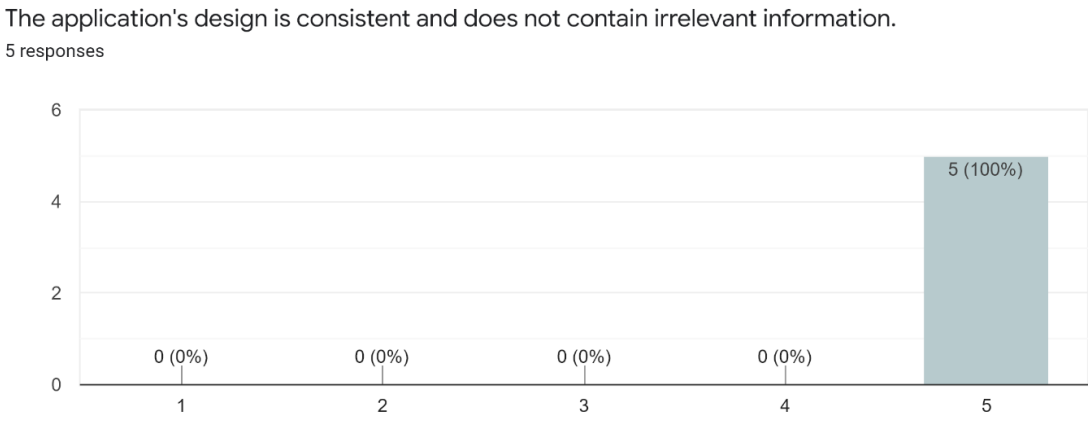

Figure 4.12: *Graph representation of the implemented design in the prototypes*

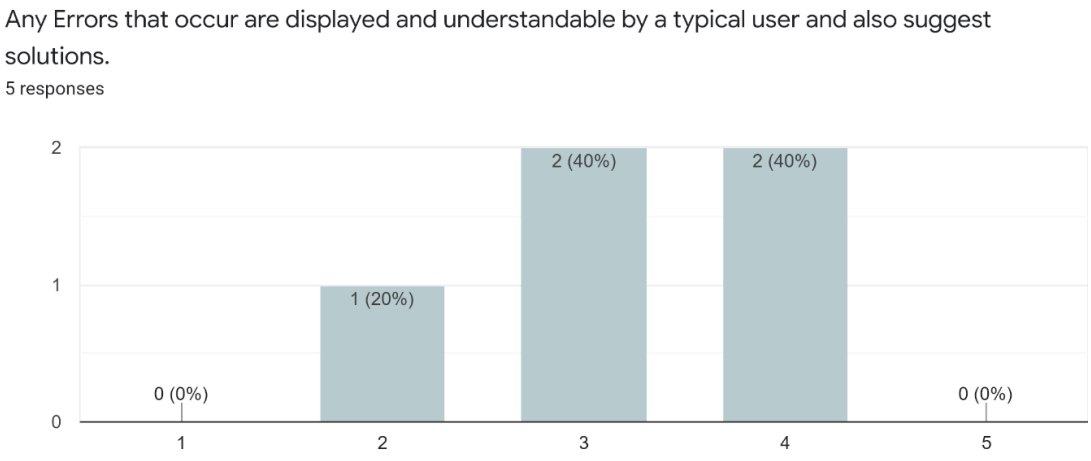

Figure 4.13: *Graph representation of error reporting used in the games*

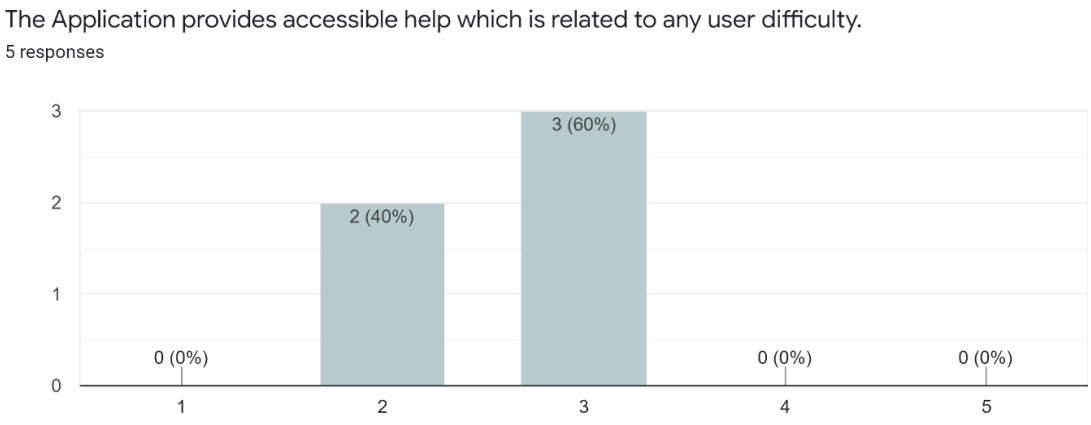

Figure 4.14: *Graph representation of the user's ability to get help*

According to **Figure 4.5**, the majority of the evaluators ranked this heuristic to be of average rating. Furthermore, additional comments were received stating that players had to switch onto a different menu to view score while the game was still running, which was hindering their game-play. The severity rating of this heuristic was considered to be important since a positive player experience was a vital contribution to the objective of this study. A side menu was added into the game to replace the previous menu so players will be able to continuously keep track of their scores, lives, and time while playing without having to sacrifice game-play.

In **Figure 4.6**, the majority of the evaluators stated that the display of information in the game was average (40%) and also above average (40%), while the other 20% of the respondents stated that it was excellent. As no additional suggestions were given and the majority of the results were positive, no improvements were made regarding this heuristic.

In **Figure 4.7**, the evaluators stated that the navigational control in the game was below average (40%) and average (40%). On the other hand, the remaining 20% of the responses stated that the navigational control was poor. Furthermore, one of the evaluators commented that although the player had full navigation throughout the application, there was no way to exit or stop a match mid-way while playing. The evaluator also stated that the lack of control to exit games was effecting the immersion and interest while playing. Therefore, a button was added to the side menu of the game to allow players to exit matches and to be able to return to the main menu.

In **Figure 4.8**, the majority of the respondents (80%) stated that this heuristic was implemented excellently while the other 20% stated that it was above average. No additional comments were received and therefore, no improvements were implemented on the prototypes regarding this heuristic.

In **Figure 4.9**, from the majority of the response received, 60% of the results showed that the heuristic was implemented below average while the other 40% of the results stated that it was average. Multiple constructive comments were received regarding this heuristic. One of the comments received, stated that, after playing on Hard difficulty, the other difficulty levels were not functioning correctly. It was also mentioned how, in some cases, when playing the game on dynamic difficulty, some questions had negative values which in the scenario of the game seemed odd. Furthermore, one of the respondents had interacted with an in-game bug were on certain screen resolutions the player was able to exit the screen, which would cause the game to stop generating new questions. It was concluded that the severity rating of this heuristic was severe. Apart from the negative effect on the game-play functionality of the game, the error was also hindering the validity of the data that was being monitored while players were playing the game. After evaluating all the data received, all errors were fixed by allocating new values at the start of a new match between different difficulties. Furthermore, conditions were implemented to restrict negative values from being generated and in-game boundaries were also added to restrict the player from exiting the screen.

In **Figure 4.10**, it was shown that most evaluators had ranked the visibility and accessibility of player data as poor (40%) and below-average (40%). The remaining 20% of the respondents ranked the heuristic as average. Some of the evaluators suggested to add a high score feature were players can keep a record of previous scores achieved while playing.

This feature will increase the interest of participants playing the games since they can view their progress and try to achieve better scores. A high score feature was implemented on both prototypes. In the endless runner game the top 5 scores from each difficulty are displayed in the score page, while in the level-based game the match history of the last few games played are visible.

In **Figure 4.11**, 80% of the respondents stated that the severity of the heuristic was below average, while 20% of the responses were average. One of the comments received was that the game was causing the device's temperature to rise and the game would also slow down during the process. Another respondent stated that when the particles reached a certain speed, it was becoming harder to solve questions since the particles were becoming too distracting. After measuring the severity rating of the received comments, it was decided to add a new feature that allows players to disable particle effects that were used throughout the game. This feature was added since it was affecting the playability of the game while also negatively affecting the results monitored while the player was playing the game.

In **Figure 4.12**, all respondents stated that the heuristic regarding the design's consistency and relevance of the information used throughout the prototypes was excellent. All evaluators ranked this heuristic to have been efficiently implemented and no additional comments were given.

Figure 4.13, shows that 40% of the data received suggests that the heuristic was ranked on average and above average (40%). The other 20% ranked it to be below average. The evaluators mentioned that although they encountered no form of error reporting, the errors that they had encountered do not directly affect the integrity of the game. After analyzing the situation, it was concluded that since error reporting does not affect the results being logged, there was no need to implement this feature for the time being.

In **Figure 4.14**, the majority of the evaluators (60%) ranked this heuristic at average while the remaining 40% ranked it below average. One of the comments received was that there was no feature present which explained the player's controls and the goal of the game. As this feature was easy to implement into the prototypes, a help page was added to both games.

4.1.3 Quinn's Educational Heuristics

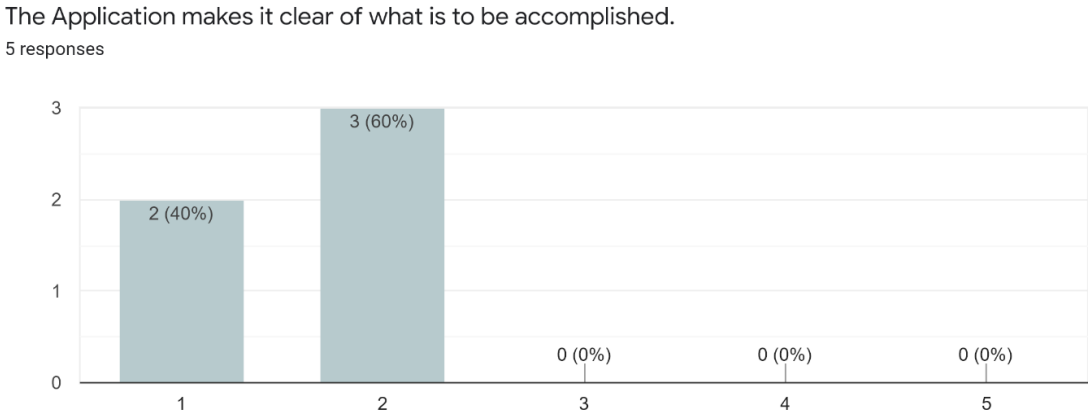

Figure 4.15: *Graph representation of the game's ability to explain the goals of the game*

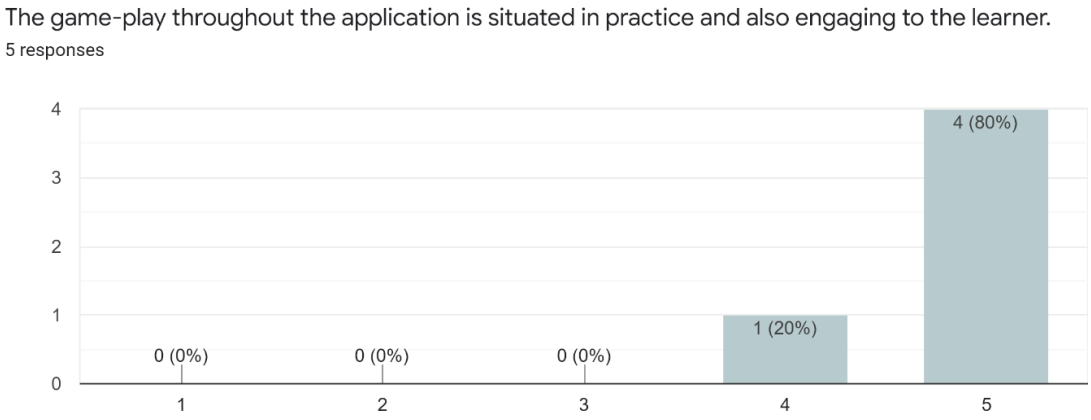

Figure 4.16: *Graph representation of the player's engagement with the game*

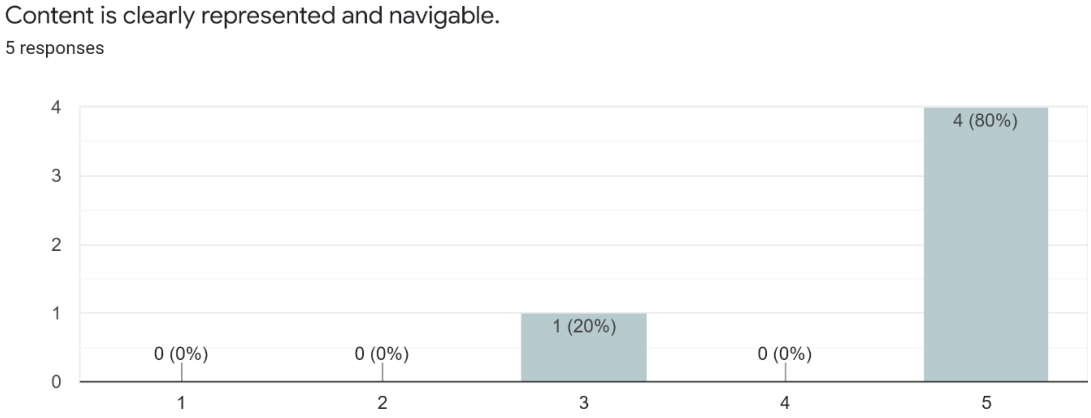

Figure 4.17: *Graph representation of the presentation and navigation between content*

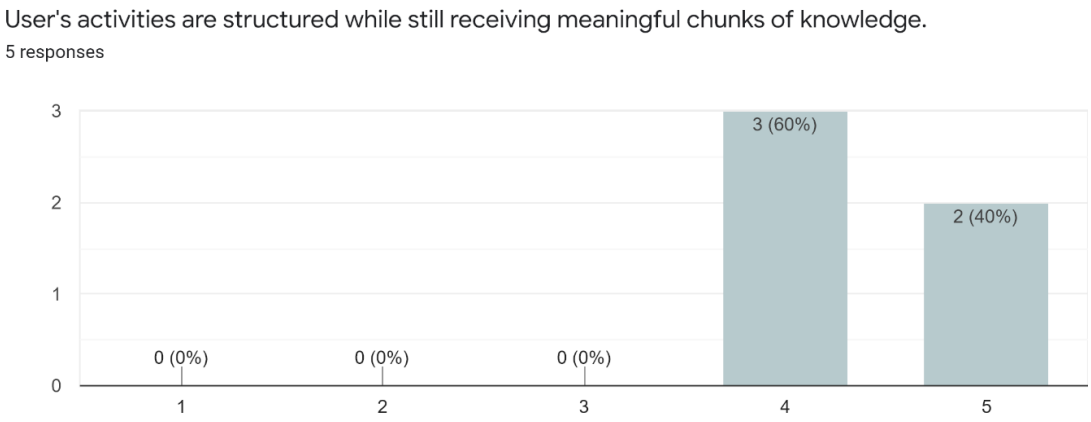

Figure 4.18: *Graph representation of the game's activities structure*

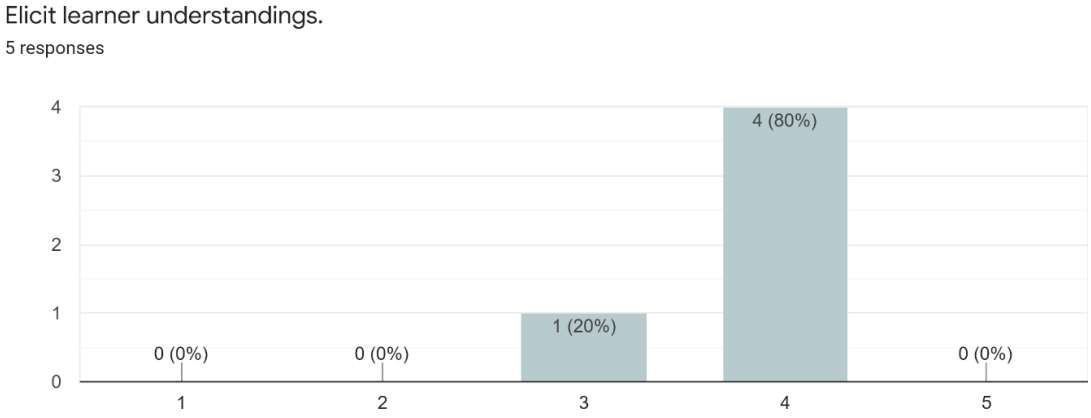

Figure 4.19: *Graph representation on elicit learner understandings*

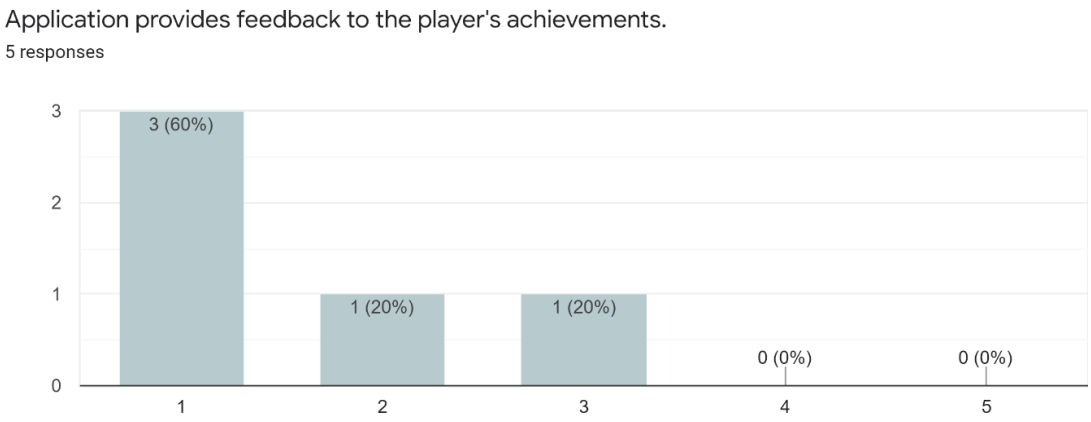

Figure 4.20: *Graph representation of feedback regarding a player's achievements*

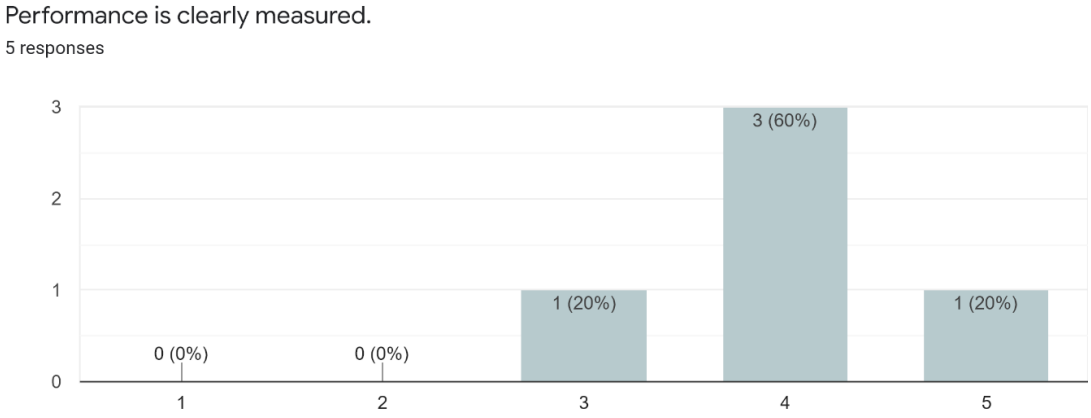

Figure 4.21: *Graph representation regarding the measure of a player's performance*

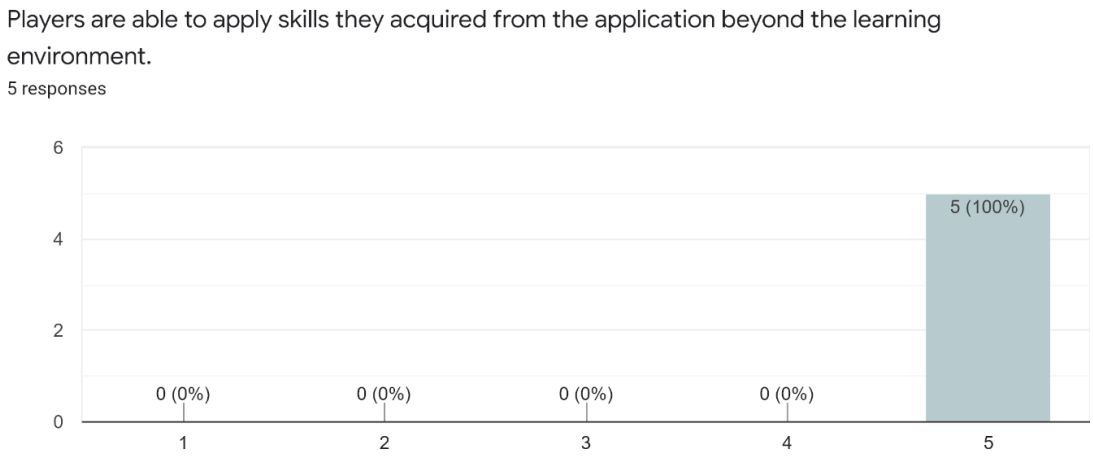

Figure 4.22: *Graph representation on the player's ability to apply the skill learned by playing the game beyond the learning environment*

Further to the data gathered in **Figure 4.14**, in **Figure 4.15**, this heuristic was ranked below average by 60% of the evaluators while the other 40% ranked the heuristic as poor. After analyzing the data gathered, the help feature that was added from earlier evaluation, also included an explanation of the game's objective.

In **Figure 4.16**, 80% of the evaluators stated that the engagement level between the player and the game was implemented excellently while the other 20% stated that it was above average. No additional comments were received regarding this heuristic and no other features were implemented. Results show that, as the majority of the respondents were in favour of the practice and engagement of the game, data collected from the second phase was ensured to be more credible.

In **Figure 4.17**, the majority of the evaluators (80%) stated that the presentation of content and navigation between pages were executed excellently while the rest (20%) ranked this heuristic as average. One of the evaluators suggested to add an exit button while the game is running.

This suggestion had been already noted from the data derived in **Figure 4.7** and was implemented to the game. This feature helped to lower the frustration levels of players while trying to exit a match.

In **Figure 4.18**, the majority of the evaluators (60%) ranked the heuristic as above average while 40% of the responses stated that the difficulty throughout the games were structured excellently, while still delivering meaningful chunks of knowledge. These results concluded that the different difficulties in the endless runner game and the different levels of the level-based game were well structured and offer the right amount of challenge. This confirms that the data derived from the participants while playing the different difficulties was correct, since the games are offering the right amount of difficulty to complete, depending on the difficulty level played and the player's skill.

Figure 4.19 shows the data gathered from the heuristic regarding the monitoring and collection of data from participants. The majority of the respondents (80%) ranked the heuristic as above average while the other 20% ranked it as average. These results concluded that that data was being logged correctly while the participants were playing the prototypes. This data was used to answer the hypothesis of the study.

In **Figure 4.20**, the evaluators commented on how there was no element of achievement while playing the prototypes. They also stated that this had an impact on their motivation to keep challenging themselves to achieve better scores and play more games. The majority of the respondents (60%) ranked this heuristic as poor, 20% declared it as below average and the other 20% ranked the heuristic as average. Since the results obtained from the game are affected by the number of games played, the importance level of this heuristic was considered to be necessary.

The prototypes were amended to notify the player whenever a new higher score was achieved. This implementation assisted the participants to be more motivated to replay the same difficulties and to achieve a high score.

Figure 4.21 shows that the correct in-game variables were monitoring the player's performance and adjusting the game according to the player's skill. The majority of the respondents (60%) ranked the implementation of this heuristic above average while 20% average. The remaining 20% of the responses ranked this heuristic as excellent. Since the majority of the evaluators confirmed that this heuristic was well implemented in the prototypes, there was no need for future improvements.

In **Figure 4.22**, all of the evaluators ranked this heuristic as excellent. This data showed how the skills acquired from this game, can also be applied in real-life situations. This data confirms that the implemented prototypes were indeed educational. This was vital since the hypothesis of this study was to calculate the effectiveness of DDA in learning applications.

4.2 Second Phase

In this phase, the data gathered from the final implementations of the prototypes are analyzed and compared to calculate the impact of different difficulties and game types on the participants (See Appendix A.3.3). Furthermore, results gathered from the post-questionnaires were compared to measure the enjoyment and frustration levels of the participants (See Appendix A.4.3 and Appendix A.4.4).

In **Figure 4.23**, the majority of the participants who played endless runner were female (60%) while the majority who played level-based were male (60%).

PARTICIPANTS

	ENDLESS RUNNER		LEVEL BASED	
TOTAL	MALE	FEMALE	MALE	FEMALE
30	6	9	9	6
%	40%	60%	60%	40%

Figure 4.23: *Participants summary – gender*

4.2.1 Prototypes

4.2.1.1 Endless Runner: Non-Adaptive Version (Easy and Hard)

ENDLESS RUNNER (VERSION 1)

	EASY	HARD
TOTAL GAMES	49	49
TOTAL GAMES / TOTAL PARTICIPANTS (MEAN)	3.27	3.27
TOTAL QUESTIONS	1388	1219
TOTAL QUESTIONS / TOTAL PARTICIPANTS (MEAN)	92.53	81.27
CORRECT QUESTIONS	1252	829
CORRECT QUESTIONS / TOTAL GAMES(MEAN)	25.55	16.92
INCORRECT QUESTIONS	90	343
INCORRECT QUESTIONS / TOTAL GAMES (MEAN)	1.84	7
TOTAL TIME PLAYED	02:48:02	01:10:06
TOTAL TIME PLAYED / TOTAL PARTICIPANTS (MEAN)	00:11:12	00:04:40

Figure 4.24: *Table representation of the results gathered from the first version of the Endless Runner prototype, featuring non-adaptive difficulty*

4.2.1.2 Endless Runner: Adaptive Version (Dynamic)

ENDLESS RUNNER (VERSION 2)

	DYNAMIC
TOTAL GAMES	101
TOTAL GAMES / TOTAL PARTICIPANTS (MEAN)	6.73
TOTAL QUESTIONS	4208
TOTAL QUESTIONS / TOTAL PARTICIPANTS (MEAN)	280.53
CORRECT QUESTIONS	3503
CORRECT QUESTIONS / TOTAL GAMES (MEAN)	34.68
INCORRECT QUESTIONS	554
INCORRECT QUESTIONS / TOTAL GAMES (MEAN)	5.49
TOTAL TIME PLAYED	07:52:13
TOTAL TIME PLAYED / TOTAL PARTICIPANTS (MEAN)	00:31:29

Figure 4.25: *Results gathered from the second version of the Endless Runner prototype, featuring adaptive difficulty adjustment*

4.2.1.3 Endless Runner: Non-Adaptive vs Adaptive

COMPARISON BETWEEN NON-ADAPTIVE AND ADAPTIVE VERSIONS IN THE ENDLESS RUNNER PROTOTYPE

	NON-ADAPTIVE (Static)	ADAPTIVE (Dynamic)
TOTAL GAMES	98	101
TOTAL GAMES / TOTAL PARTICIPANTS (MEAN)	6.53	6.73
TOTAL QUESTIONS	2607	4208
TOTAL QUESTIONS / TOTAL PARTICIPANTS (MEAN)	173.80	280.53
CORRECT QUESTIONS	2081	3503
CORRECT QUESTIONS / TOTAL GAMES (MEAN)	21.23	34.68
INCORRECT QUESTIONS	433	554
INCORRECT QUESTIONS / TOTAL GAMES (MEAN)	4.42	5.49
TOTAL TIME PLAYED	03:58:08	07:52:13
TOTAL TIME PLAYED / TOTAL PARTICIPANTS (MEAN)	00:15:52	00:31:29

Figure 4.26: *Representation of the summed data gathered from the first and second versions of the Endless Runner prototype*

4.2.1.4 Level Based: Non-Adaptive vs Adaptive

COMPARISON BETWEEN NON-ADAPTIVE AND ADAPTIVE VERSIONS IN THE LEVEL BASED PROTOTYPE

	NON-ADAPTIVE	ADAPTIVE
TOTAL GAMES	169	167
TOTAL GAMES / TOTAL PARTICIPANTS (MEAN)	11.27	11.13
TOTAL QUESTIONS	1910	2734
TOTAL QUESTIONS / TOTAL PARTICIPANTS (MEAN)	127.33	182.27
CORRECT QUESTIONS	1740	2319
CORRECT QUESTIONS / TOTAL GAMES (MEAN)	10.30	13.89
INCORRECT QUESTIONS	76	125
INCORRECT QUESTIONS / TOTAL GAMES (MEAN)	0.45	0.75
TOTAL TIME PLAYED	03:57:36	05:05:18
TOTAL TIME PLAYED / TOTAL PARTICIPANTS (MEAN)	00:15:50	00:20:21

Figure 4.27: *Representation of the summed data gathered from the non-adaptive and adaptive versions of the Level-Based prototype*

4.2.1.5 Endless Runner: Adaptive vs Level Based: Adaptive

COMPARISON BETWEEN THE ADAPTIVE VERSIONS OF BOTH ENDLESS RUNNER AND LEVEL BASED PROTOTYPES

	ENDLESS RUNNER	LEVEL BASED
TOTAL GAMES	101	167
TOTAL GAMES / TOTAL PARTICIPANTS (MEAN)	6.73	11.13
TOTAL QUESTIONS	4208	2734
TOTAL QUESTIONS / TOTAL PARTICIPANTS (MEAN)	280.53	182.27
CORRECT QUESTIONS	3503	2319
CORRECT QUESTIONS / TOTAL GAMES (MEAN)	34.68	13.89
INCORRECT QUESTIONS	554	125
INCORRECT QUESTIONS / TOTAL GAMES (MEAN)	5.49	0.75
TOTAL TIME PLAYED	07:52:13	05:05:18
TOTAL TIME PLAYED / TOTAL PARTICIPANTS (MEAN)	00:31:29	00:20:21

Figure 4.28: *Graph summary of the data gathered from the adaptive versions of both the Endless Runner and Level Based prototypes*

The mean score of the results, from **Figure 4.24** to **Figure 4.28**, were either calculated by dividing the number of the summed results by total participants (15) or by total number of games played.

Figure 4.24 represent the results gathered from the first version of the endless runner game, featuring non-adaptive difficulties, easy and hard. Furthermore, the results gathered from both difficulties were interpreted and compared to identify any difference in the participant's progression during the first version of the game. In this figure, the total games played in endless runner were the same amounts for both easy and hard. The average amount of games played on both difficulties per participant was 3.27. Although both difficulties had the same amount of games played, a more significant amount of questions were generated while playing on easy difficulty, totalling the amount of 1388 questions, while hard difficulty had a total of 1219 questions. One of the reasons for having a significant difference in the amount of generated questions was that per participant spent 11m12s in total playing on easy difficulty while each participant only spent an average of 4m40s playing on hard difficulty. The average amount of questions that were correctly answered per game varied between difficulties. A total of 1252 questions were answered correctly on easy difficulty (resulting in an average of 25.55 questions per game), while on Hard difficulty a total of 829 questions were answered correctly (resulting in an average of 16.92 questions per game). On the other hand, a total of 90 questions were answered incorrectly on easy difficult (resulting in an average of 1.84 questions per game), while on hard difficulty a total of 343 questions were answered incorrectly (resulting in an average of 7 questions per game).

It was concluded that the results from the easy difficulty were more effective than the hard difficulty. The reason being was that although both difficulties had the same number of games, participants answered a greater amount of questions, achieved better scores and also spent more time playing on the easy difficulty.

Figure 4.25 illustrates the results gathered during the second version of the endless runner prototype, featuring adaptive difficulty. The total number of games played by participants on dynamic difficulty was 101 (with an average of 6.73 games per person). A total amount of 4208 questions were randomly generated, which 3503 (with an average of 34.68 games per game) of the questions were answered correctly, while 554 (with an average of 5.49 games per game) questions were answered incorrectly. Finally, the average time that participants spent playing on dynamic difficulty was of 41m29s, equating to a total of 7h52m13s played by all participants.

The data achieved from the easy and hard difficulties from **Figure 4.24** (of endless runner game, version 1), were summed up into one category and compared to the results presented in **Figure 4.25** from the dynamic difficulty (of endless runner game, version 2) into **Figure 4.26**. **Figure 4.26** presents the data gathered from both versions of the prototypes, featuring non-adaptive and adaptive difficulties. Data showed that there was an increase of 0.2 in the average number of games played on adaptive difficulty when compared to the other version. In the non-adaptive version, 1601 questions were less generated than the amount of the adaptive version (resulting in an average of 106.73 more generated questions by each participant). Participants answered a more considerable amount of correct questions in the adaptive difficulty, amounting to 3503 questions (average of 34.68 correct answers per game) while non-adaptive difficulty had a total of 2081 correctly answered questions (average of 21.23 correct answers per game). Despite this, participants' average score of incorrect answers per game in the adaptive version was also larger than that of the non-adaptive (average amount of incorrect

answers per game in the adaptive version was 5.49 while the average per game in the non-adaptive version was 4.42). A reason that may have affected this discrepancy between results is the difference in duration played per participant. Participants spent a total amount of 7h52m13s playing on adaptive version (resulting in an average of 41m29s per participant), while on the non-adaptive version, participants played a total amount of 3h58m8s (resulting in an average of 15m52s per participant). After evaluating the results between the two versions of the endless runner game, it was concluded that, the adaptive version, featuring dynamic difficulty, had yielded better results than from the non-adaptive version (easy and hard difficulties). The reason why adaptive version was concluded to be better than the non-adaptive version was that there is a greater number of played games, which generated more questions, with a higher score in correct questions and more time spent by participants playing this version.

Figure 4.27, summarizes the data gathered from the different versions of the level-based prototype. The results of all participants are summed and categorized. After analyzing the data gathered from this figure, it was clear that despite both versions had almost the same number of played games (169 games on the non-adaptive version and 167 games on the adaptive version), the total number of questions asked during the adaptive version was greater than that of the other version. The average of questions generated by participants was 54.94. A reason behind the difference of generated questions between versions is because, while participants progressed through the adaptive version, the difficulty of the levels was adapted dynamically by increasing the total amount of questions to complete a level. Furthermore, the total amount of correct questions per level in the non-adaptive version was 1740 (resulting in an average of 10.30 correct questions per level) while the total amount of correct questions in the adaptive version was 2319 (resulting in an average of 13.89 correct questions per level). Results showed that more correct questions were answered during the adaptive version.

Despite this, the total amount of incorrect questions per level in the non-adaptive version was 76 (resulting in an average of 0.45 incorrect questions per level), while the total amount of incorrect questions in the adaptive version was 125 (resulting in an average of 0.75 incorrect questions per level). The difference in results could have been affected by the total time spent by participants playing the different versions. Participants while playing the adaptive version spent on average 4m41s more than the amount of time spent on the non-adaptive version.

After analyzing the results gathered from **Figure 4.27**, it was clear that the adaptive version of the level-based game was more effective and yielded better results than the non-adaptive version. Although both versions did not have a significant difference in the number of games played, the average of total questions and scores achieved by participants in the adaptive version was greater than the non-adaptive version. The participants were also willing to spend more time playing this version. This could have been affected by multiple factors, such as feeling more immersed while playing, challenging themselves to complete levels on greater difficulties, or because they felt more comfortable playing levels since the game had adapted to their skill level.

Figure 4.28 summarized the data gathered from the adaptive versions of both the endless runner game and level-based game. The total number of games played in the endless runner amounted to 101 while the total number of games played in the level-based game amounted to 167. Data illustrated that the endless runner had a significantly lower amount of games played (resulting in a mean difference of 4.4 more games played per participants in the level-based game). Furthermore, the total number of generated questions in the adaptive version of the level-based game amounted to 2734 (resulting in an average of 182.27 questions per participant) while the total number of generated questions in the adaptive version of the endless runner game was 4208 (resulting in an average of 280.53 questions per participant).

Despite the level-based game had a more significant number of played games, participants who played the endless runner game had generated more questions. In addition, the total amount of correct questions in the endless runner game was 3503 (resulting in an average of 34.68 correct questions per game), while the total amount of correct questions in the level-based game was 2319 (resulting in an average of 13.89 correct questions per game). Despite that the endless runner game had a more considerable amount of correct questions with an average of 20.79 correct questions per game, the level-based game had a lower amount of incorrect questions with an average of 4.74 incorrect questions per game. In regards to the above, the total amount of incorrect questions in the endless runner game was 554 (resulting in an average of 5.49 incorrect questions per game), while the total amount of incorrect questions in the level-based game was 125 (resulting in an average of 0.75 incorrect questions per game). The significant difference between the results of the adaptive versions of both games may have been affected by the different game types. As each level in the level-based game featured a predefined amount of questions according to the level number, together with the participant's player model, participants were only encouraged to complete the uncompleted levels. On the other hand, the endless runner game had no levels or an ending. Therefore, participants were encouraged to keep replaying the game for a larger duration to try and achieve a higher score. This fact can be proven by the lack of replayability of the same levels throughout the level-based game and the significant variation in the duration that participants spent playing both games. Participants who took part in the endless runner game spent 7h52m13s playing the game (an average of 31m29s per participant), while the level-based game had a total of 5h5m18s of play-through (an average of 20m21s per participant).

It was concluded that the endless runner implementation of dynamic difficulty adjustment was more effective than that of the level-based game. The reason was that despite the level-based game had a more significant total number of games, than the endless runner, with a lower mean score of incorrect answers per game, the endless runner game had a significantly higher value in total generated questions, score and duration that participants spent playing.

4.2.2 Post-Questionnaire

4.2.2.1 Endless Runner: Non-Adaptive vs Adaptive

Comparison of player experience for NON-ADAPTIVE and ADAPTIVE Versions in Endless Runner Prototype

		Version 1		Version 2	
Set	**Factors**	**Sum**	**Mean**	**Sum**	**Mean**
1	**Enjoyment**	236	11.24	289	13.76
1	**Frustration**	115	8.21	74	5.29
1	**CEGE**	2419	10.78	2423	10.83
1	**Puppetry**	1530	10.93	1546	11.04
1	**Videogame**	889	11.55	877	11.39
2	**Control**	647	11.55	683	12.20
2	**Facilitators**	364	10.40	359	10.26
2	**Ownership**	514	12.24	521	12.40
2	**Environment**	488	13.94	486	13.89
2	**Gameplay**	401	11.46	391	11.17

Figure 4.29: *Results obtained from the post-questionnaires of both Endless Runner prototype versions*

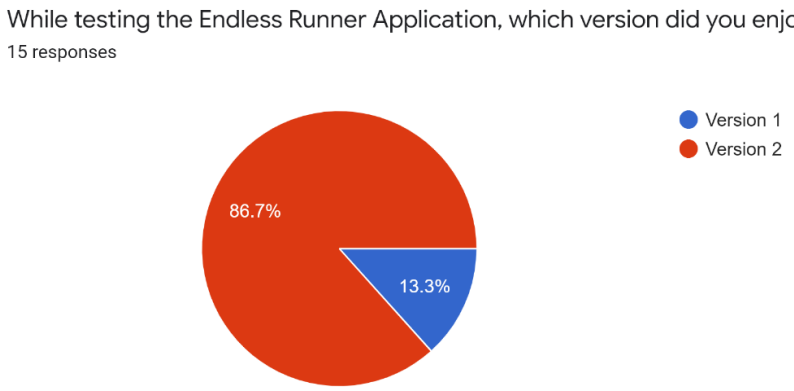

Figure 4.30: *Graph representation regarding the participants preferred version in the Endless Runner prototype, Version 1 - Non-Adaptive Version; Version 2 - Adaptive Version*

4.2.2.2 Level Based: Non-Adaptive vs Adaptive

Comparison of player experience for NON-ADAPTIVE and ADAPTIVE Versions in the Level Based Prototype

		Version 1		Version 2	
Set	**Factors**	**Sum**	**Mean**	**Sum**	**Mean**
1	**Enjoyment**	262	12.48	284	13.52
1	**Frustration**	58	4.14	68	4.86
1	**CEGE**	2350	10.50	2394	10.69
1	**Puppetry**	1541	11.01	1558	11.13
1	**Videogame**	809	10.51	836	10.86
2	**Control**	676	12.07	690	12.32
2	**Facilitators**	377	10.77	375	10.71
2	**Ownership**	505	12.02	512	12.19
2	**Environment**	452	12.91	462	13.20
2	**Gameplay**	357	10.20	374	10.69

Figure 4.31: *Comparison between the results obtained from the post-questionnaires of the different versions in the Level Based prototype*

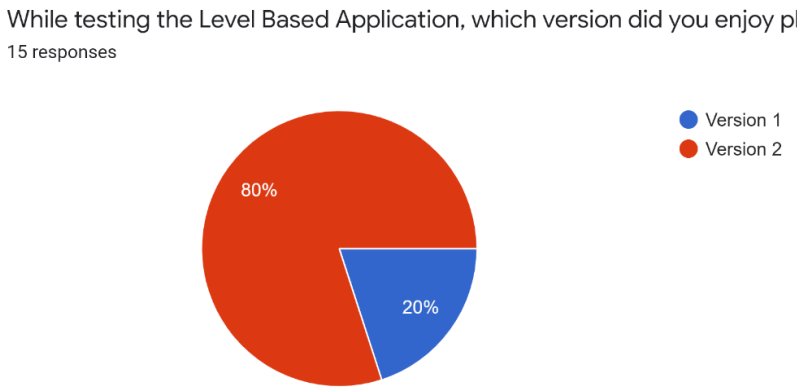

Figure 4.32: *Participants preference between non-adaptive and adaptive versions in the Level Based prototype, Version 1 - Non-Adaptive Version; Version 2 - Adaptive Version*

4.2.2.3 Endless Runner: Adaptive vs Level Based: Adaptive

Comparison of player experience for ADAPTIVE Versions in the Endless Runner and Level Based Prototypes

		ENDLESS RUNNER		LEVEL BASED	
Set	Factors	Sum	Mean	Sum	Mean
1	Enjoyment	289	13.76	284	13.52
1	Frustration	74	5.29	68	4.86
1	CEGE	2423	10.83	2394	10.69
1	Puppetry	1546	11.04	1558	11.13
1	Videogame	877	11.39	836	10.86
2	Control	683	12.20	690	12.32
2	Facilitators	359	10.26	375	10.71
2	Ownership	521	12.40	512	12.19
2	Environment	486	13.89	462	13.20
2	Gameplay	391	11.17	374	10.69

Figure 4.33: *Comparison of the post-questionnaires on the adaptive versions of both Endless Runner and Level Based prototypes*

Figure 4.29, **Figure 4.31** and **Figure 4.33** showed the summarized results from the post-questionnaires based on the CEGE framework (Eduardo et al., 2010), which was used to measure the difference in the participants' gaming experience. The values of each question were summed and sorted accordingly to each set of constructor variables (Factors), as shown in **Figure 3.7** (from the methodology). As mentioned in the study (Eduardo et al., 2010), if a positive player experience occurs, the frustration levels must be low. CEGE refers both to puppetry and videogame, which are the most crucial variables from set 1 as regarding player enjoyment. On the other hand, environment and game-play are the essential variables that correlate to enjoyment from set 2.

In addition to the questions used from the CEGE model (Eduardo et al., 2010), another question was implemented to gather data regarding the most preferred version, of the games (endless runner or level-based), by participants.

Figure 4.29 showed the summarized results from the post-questionnaire, answered by the participants who played the different versions of the endless runner prototype. Version 1 referred to the non-adaptive (static) version, while version 2 referred to the adaptive (dynamic) version of the prototype.

The data obtained in **Figure 4.29** showed that the majority of respondents preferred playing the adaptive version of the game. Meaning that the enjoyment's mean score obtained in version 2 was 2.52 higher than that in version 1. Furthermore, the frustration score from the adaptive version of the game was also lower than that of the static version (version 1), meaning that participants were less annoyed while playing.

After analyzing the values in set 1, it was clear that, although the CEGE values in the second version of the prototype were higher than that of the first, there was no significant difference in the puppetry and video-games values of both versions. Furthermore, there was also no significant difference in the environment and game-play values from set 2.

The data in **Figure 4.30** showed the preferred version in the endless runner game. It was clear that the majority (86.7%) of the participants had a more enjoyable experience playing the second version (featuring adaptive difficulty), while 13.3% of the participants chose the first version (featuring non-adaptive difficulty) instead.

From the data gathered in **Figure 4.29** and **Figure 4.30**, it was concluded, that the adaptive version of the endless runner game was more enjoyable by participants than that of the non-adaptive version.

Figure 4.31 showed the data acquired from the participants experience while playing both versions of the level-based prototype. Version 1 referred to the non-adaptive version of the prototype, while version 2 referred to the adaptive version.

From **Figure 4.31**, it was clear that the frustration level of both the prototype's versions were very low when compared to the CEGE. However, the frustration level of the non-adaptive version (58) was lower than that of the adaptive version (68). Despite this, the enjoyment and CEGE scores of the adaptive version were still higher than the other version, which means that participants still had a more enjoyable experience playing on the adaptive version (adaptive version – 2394, non-adaptive version – 2350). The environment and game-play factors of the adaptive version were also higher by 0.29 and 0.49 in the mean score, respectively, when compared to the non-adaptive version.

In **Figure 4.32**, the majority of the participants 80% had preferred playing the adaptive version, while the other 20% preferred the non-adaptive version.

After analyzing and comparing the results from **Figure 4.31** and **Figure 4.32**, it was concluded that participants were more immersed in the level-based game while playing on the adaptive version because the results that correlate to the enjoyment level of participants were all higher than those of the non-adaptive version.

Figure 4.33 summarized the results obtained from the post-questionnaires of both the endless runner and level-based adaptive versions. The results were compared to each other to highlight any difference in the participants' experience throughout two different implementations of dynamic difficulty adjustment (DDA).

From **Figure 4.33**, the frustration level of participants in the level-based (68) implementation was lower than that of the endless runner (74) by the average mean of 0.43. Despite this, the summarized values of enjoyment (289) and CEGE (2423) factors in the endless runner were higher than the ones of the level-based game by the average mean of 0.24 (enjoyment) and 0.14 (CEGE) respectively.

Furthermore, the environment and game-play average values obtained in the endless runner were 13.89 and 11.17, respectively, while the values in the level-based implementation were 13.20 and 10.69, respectively. These values concluded that despite the sum value of the frustration level in the level-based game were lower than those of the endless runner, participants had a more enjoyable and immersive experience playing the adaptive version implemented in the endless runner game.

4.3 Comparing Results To Other Studies

By comparing the results obtained from the study by Segundo et al. (2015) and the study by Araujo and Feijo (2013) with the results of this study, it was clear that there were some similarities. Further to the data acquired from the initial questionnaire, **Figure 4.3** and **Figure 4.4**, and the prototypes, **Figure 4.30** and **Figure 4.32**, the majority of the responses chose dynamic difficulty as the best difficulty, similar to the data acquired from the study (Segundo, Calixto and Gusmao, 2015).

In the study (Segundo, Calixto and Gusmao, 2015), it was recorded that 50% of the participants had achieved better scores while playing on dynamic difficulty. When compared to the results obtained in this study, **Figure 4.26** and **Figure 4.27**, there was over an 8% increase in the number of participants who scored better results while playing the adaptive versions of the prototypes.

In the other study (Araujo and Feijo, 2013), it was analyzed that, although those who classified as hardcore players experienced less frustration levels while playing dynamic difficulty, the casual players had less enjoyment levels and were more frustrated playing the same version.

In contrary to the results obtained by Araujo and Feijo (2013), in my study, a more significant percentage of participants had reported that they had a more enjoyable and immersive experience while playing the adaptive versions. As regards to the concluding statement by Araujo and Feijo (2013), my study was also successful in the implementation of DDA in both prototypes, which was proven by the difference in the scores of both adaptive and non-adaptive versions, **Figure 4.26** and **Figure 4.27**.

4.4 Concluding Discussion

By making use of heuristic evaluation, multiple functionalities were amended to the prototypes to improve the enjoyment and frustration levels of participants while playing. This process was helpful to improve the credibility of results obtained from the post-questionnaires, used to measure the player experience between the non-adaptive and adaptive version of the games. The credibility was improved by eliminating any elements that were negatively affecting the players' experience, which did not relate to the different difficulties of the prototypes. The data from the prototypes concluded that the scores in the adaptive version were more effective than those in the non-adaptive version. The post-questionnaires also concluded that participants had a more enjoyable and immersive experience playing the adaptive versions of the prototypes. The participants who played the endless runner game had acquired better results than those who played the level-based game.

As there were not many studies which relate to the use of DDA in learning applications, comparing results with other studies was limited. Furthermore, there was a lack of credibility when comparing results from other studies since DDA implementations vary from one study to another and each different study makes use of data obtained from different developed games while using different functionalities and themes. This bias in data occurs as results were not obtained from the same use of games, algorithms and environments. Thus, various factors may have affected the results obtained in each study. The difference in game implementations can be seen in various studies. The study by Bétrancourt (2011), made use of adaptive difficulty in a Tetris game. In another study, Hunicke and Chapman (2004) had developed a 3D zombie game called "Case Closed" to test their implementation of DDA while making use of the hamlet system. Finally, in the study by Segundo et al. (2015), a 2D space shooter game was developed using dynamic scripting.

Chapter 5

Conclusion

In this chapter, the research hypothesis and questions, as stated in the Introduction chapter, are answered by evaluating the results gathered from the previous section. Along with future recommendations on this study, the limitations encountered are also mentioned.

5.1 Summary of the Data

5.1.1 First Phase

In this phase, the gathered results helped in the execution of data gathering and the development of the prototypes.

5.1.1.1 Initial Questionnaire

From the initial questionnaire, the age group of participants for the second phase of data collection was decided, as well as the device used to conduct the experiment.

The prototypes were built for smartphones since 57.8% of the responses preferred them over other gaming devices. Respondents were also asked about their preferred difficulty levels in games.

In addition, the results gathered from the questionnaire show that the respondents were already in favour of adaptive games.

5.1.1.2 Heuristic Evaluation

Apart from the data that was collected from the questionnaire, the evaluators included several constructive criticisms. By making use of Nielsen's and Quinn's heuristic principles, certain game elements were improved to increase the player's experience regarding gameplay, enjoyment and frustration. It also helped to acquire more accurate results from the prototypes. Such improvements included feedback to players when reaching specific goals and also removed bugs that were affecting the prototypes' gameplay and responsiveness.

5.1.2 Second Phase

In this phase, the results from the prototypes were compared to distinguish the effects of different game difficulties and implementations. Also, the results from the post questionnaires were summed to calculate the user experience throughout the process.

5.1.2.1 Prototypes

Both the endless runner and level based games acquired varied results.

5.1.2.1.1 Endless Runner: Non-Adaptive vs Adaptive

In the endless runner game, the same amount of games were played by participants on the non-adaptive version. The non-adaptive version of this game consisted of easy and hard difficulties. Although both difficulties had the same amount of games, players answered more questions on easy difficulty instead of hard. The mean score of questions answered correctly in each game by participants was higher by 8.63 on the Easy difficulty.

Unexpected results were gathered when the data of the non-adaptive version was compared to the adaptive version. Although there was no significant difference in total games played between both versions, the average amount of questions generated in the adaptive version was higher by 106.73 per participant. The adaptive version of the game also had a total of 1422 more correctly answered questions from the other version. Finally, participants spent more time playing the adaptive version than the non-adaptive version.

5.1.2.1.2 Level Based: Non-Adaptive vs Adaptive

Participants played more games on the non-adaptive version than the adaptive version. Despite the difference between the games played in both versions, players spent more time playing the adaptive version. Less questions were generated on the non-adaptive version, while on the adaptive version the mean score of correct answers per game is also higher.

5.1.2.1.3 Endless Runner: Adaptive vs Level-Based: Adaptive

When comparing the endless runner to the level-based game, results showed that the level-based game was played several more times. However, the endless runner game was played for a longer duration, as more questions were generated. On the other hand, the level-based game obtained a significantly lower score of incorrect answers.

5.1.2.2 Post-Questionnaire

By making use of the CEGE model, post questionnaires were used to calculate the user experience while playing each version of the prototypes. The results acquired from the 7-point Likert scale were summed and compared to analyze the difference in the participants' experience throughout the process.

5.1.2.2.1 Endless Runner: Non-Adaptive vs Adaptive

The results acquired from both versions of the endless runner game stated that the enjoyment factor in the adaptive version is higher than that of the non-adaptive. The frustration factor in the adaptive version was also lower. By comparing other factors, including puppetry, videogame, environment and gameplay, it was concluded that participants had a more enjoyable experience in the adaptive version of the endless runner game.

5.1.2.2.2 Level Based: Non-Adaptive vs Adaptive

Similar to the results obtained in the endless runner game, the adaptive version of the level based game scored better results in the enjoyment, puppetry, videogame, environment and gameplay factors. Despite that, the frustration level in the adaptive version was higher than that of the non-adaptive.

5.1.2.2.3 Endless Runner: Adaptive vs Level Based: Adaptive

Finally, the results obtained from the post-questionnaires for both the prototypes' adaptive versions were compared to distinguish the participant's experience. It was concluded that, although there was no significant difference between the results, the endless runner adaptive version had the best overall score in the enjoyment factor.

5.2 Hypothesis Conclusion and Anticipated Contribution

One of the main objectives of this study was to identify whether the use of games with dynamic difficulty adjustment yields better results than non-adaptive games in learning applications. The results gathered from both endless runner and level-based games, showed that the adaptive version of both prototypes were more effective than the non-adaptive versions.

Another objective of this study was to analyze any differences between both implementations of dynamic difficulty adjustment. It was concluded that the use of dynamic scripting in the endless runner game was more effective than the use of player modelling in the other game. The endless runner game obtained the majority score in total questions, time played and player score.

The final objective was to identify whether players are more immersed and interested in games with adaptive difficulty as apposed to non-adaptive difficulty. From all the results gathered from the questionnaires and prototypes, players were always in favour of games with adaptive difficulty.

The anticipated contribution of this study is to provide an alternative means to current educational games. The results obtained from this study prove that more definite results are obtained from the games featuring adaptive algorithms to match the player's skill. The conducted study also proved that DDA offers an increased sense of player immersion and engagement towards the application.

5.3 Future Work

One limitation encountered during data collection included the time taken to collect all the required data. As people were asked to download and play the prototypes on their devices, some participants took longer than required to play the games. As the experiments were unsupervised, some participants put less effort than others during the experiment, which ultimately affected the results obtained from the prototypes. The time frame given to conduct the study was also limited, as only two types of DDA implementations could be implemented into this study.

One of the future recommendations of this study could include the implementation of more DDA methods, such as the use of Reinforcement Learning and Probabilistic Methods. The results acquired from these methods could then be compared to those obtained in this study. Another future recommendation is to calculate the effectiveness of DDA methods on a broader range of educational game genres featuring different themes, storyline and functionality to identify whether results of different DDA methods vary according to different game types. Finally, existing input devices, such as temperature and heart rate sensors, could be modified to monitor the behaviour of participants while playing. The objective would be to obtain more definitive results when calculating the user's experience.

Chapter 6

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Appendix A

Appendix

A.1 Initial Questionnaire

A.1.1 Initial Questionnaire - Questionnaire

Gamification with Dynamic Difficulty Adjustment for Learning Applications

I am a student undergoing the course "Multimedia and Software Development" at MCAST, completing my last year of study.

This survey will help me gather different opinions and views regarding Video Games and will also help me build analytic data which will be used as part of my dissertation which focuses on the use of Gamification in Learning Applications with Dynamic Difficulty.

THANK YOU FOR YOUR PARTICIPATION!
*Required

1. 1. What is your gender? *

   Mark only one oval.

   - ◯ Male
   - ◯ Female
   - ◯ Other

2. 2. How old are you? *

   Mark only one oval.

   - ◯ Less than 15
   - ◯ 16 - 25
   - ◯ 26 - 35
   - ◯ 36 - 45
   - ◯ 46 - 55
   - ◯ 56 and older

3. 3. Do you think Video Games have a Positive or Negative effect on People? *

Mark only one oval.

- ◯ Positive
- ◯ Negative

4. 4. Do you agree that Video Games can be tailored to meet different needs of different people? *

Mark only one oval.

- ◯ Agree
- ◯ Neither Agree nor Disagree
- ◯ Disagree

5. 5. What is your opinion of Video Games being used to teach in School or/and After-School activities? *

Mark only one oval.

- ◯ Positive
- ◯ Neutral
- ◯ Negative

6. 6. I play Video Games regularly *

Mark only one oval.

- ◯ 8+ hours a week
- ◯ 1-2 hours a week
- ◯ 3-4 hours a week
- ◯ 5-6 hours a week
- ◯ 7-8 hours a week
- ◯ I do not play Video Game at all

7. 7. Which devices do you play on? (Tick all that are applicable) *

Tick all that apply.

- [ ] Nintendo Switch
- [ ] Playstation
- [ ] X-Box
- [ ] PC
- [ ] SmartPhone
- [ ] None

Other: [ ] _____

8. 8. What kind of games do you like to play? (Tick all that are applicable) *

Tick all that apply.

- [ ] Endless Runners
- [ ] Real Time Strategy
- [ ] Level Based
- [ ] Educational
- [ ] Puzzle
- [ ] Augmented Reality
- [ ] Action
- [ ] Other

9. 9. I prefer to play games that ... *

Mark only one oval.

- ( ) are Easy and require no challenge to complete.
- ( ) are Difficult and almost impossible to complete.
- ( ) adjust's the difficulty dynamically to match the player's skill

10. 10. What is your opinion on games that can automatically adjust their difficulty to match the player's skill?

Mark only one oval.

- Positive
- Somewhat Positive
- Neither Positive nor Negative
- Somewhat Negative
- Negative

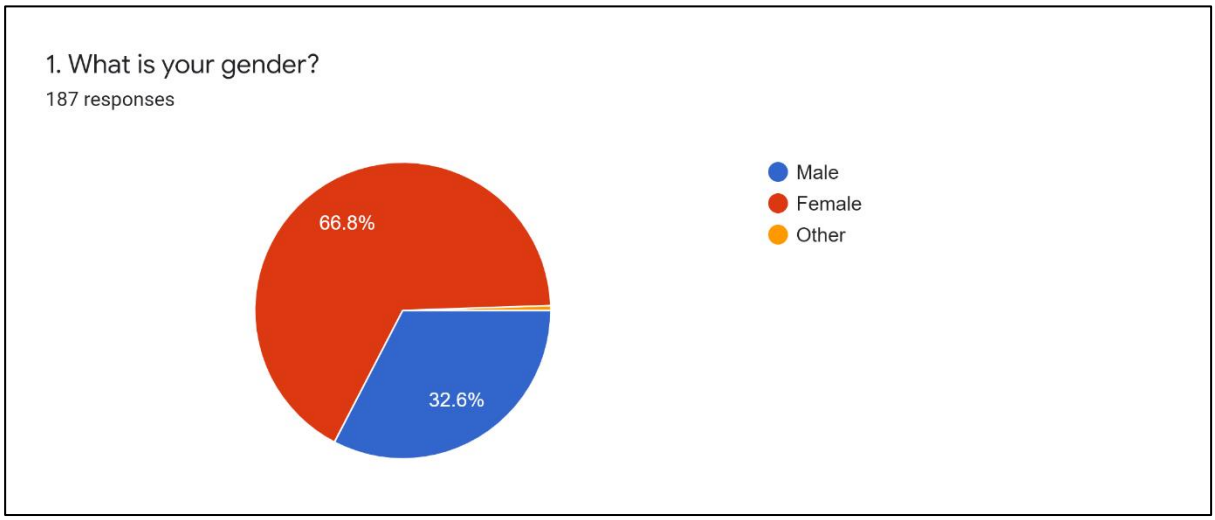
11. 11. Would you like to see more Educational Games with dynamic difficulty, were difficulty adapts automatically to provide challenging and progressive game play?

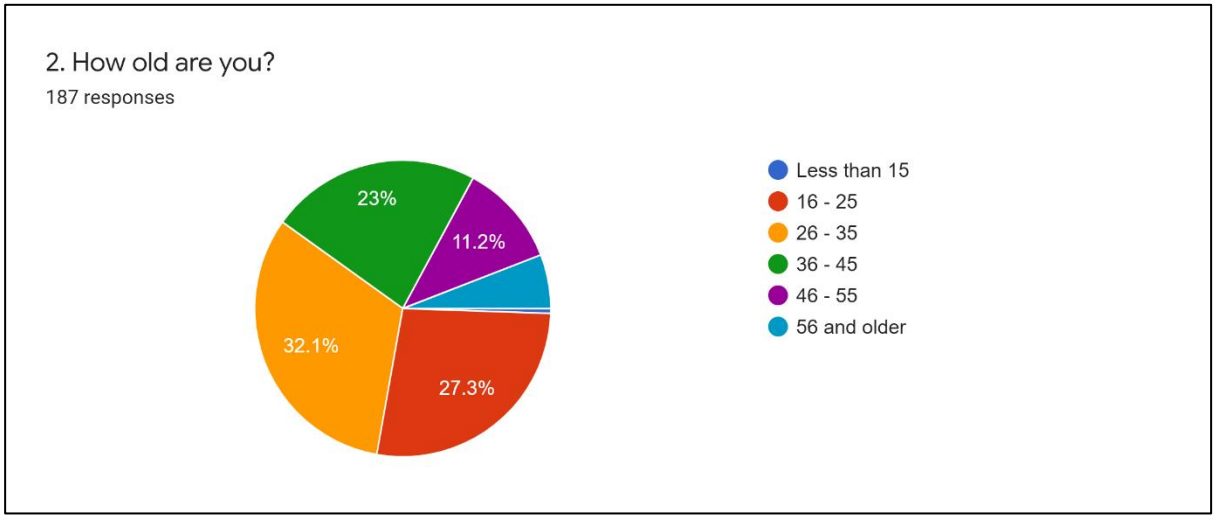
Mark only one oval.

- Yes
- No
- Maybe

A.1.2 Initial Questionnaire - Results

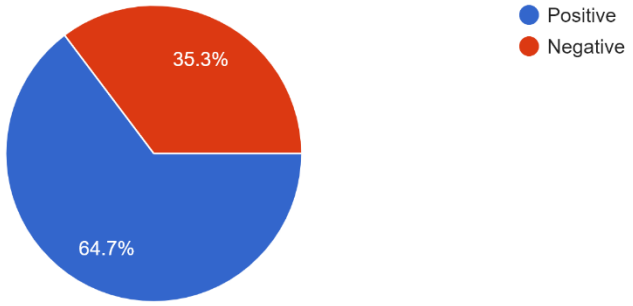
Educational Games with Dynamic Difficulty





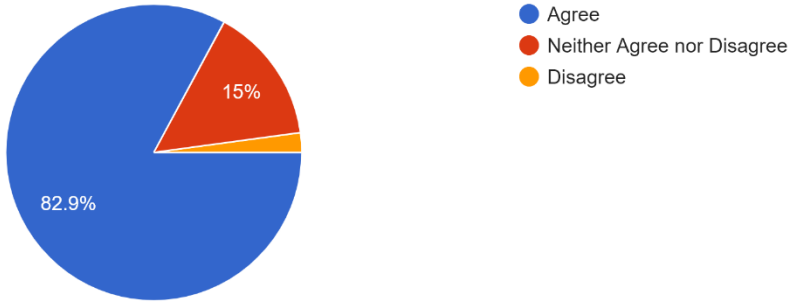
3. Do you think Video Games have a Positive or Negative effect on People?

187 responses



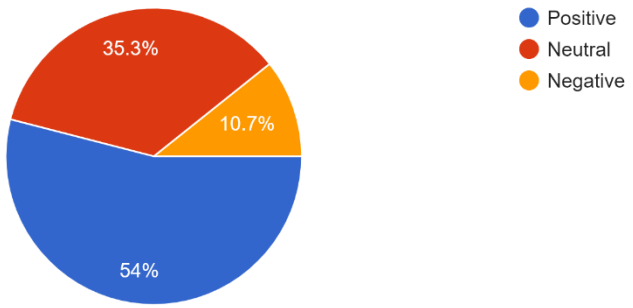
4. Do you agree that Video Games can be tailored to meet different needs of different people?

187 responses



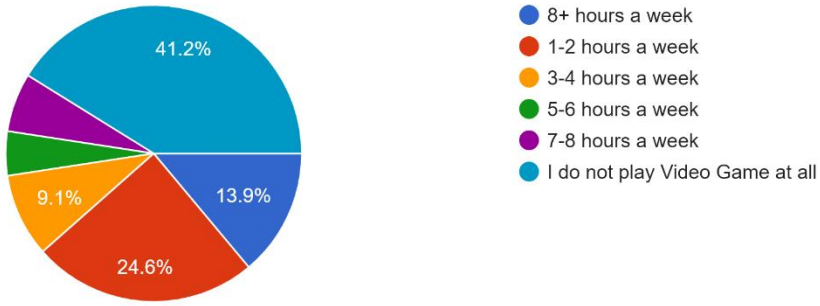
5. What is your opinion of Video Games being used to teach in School or/and After-School activities?

187 responses



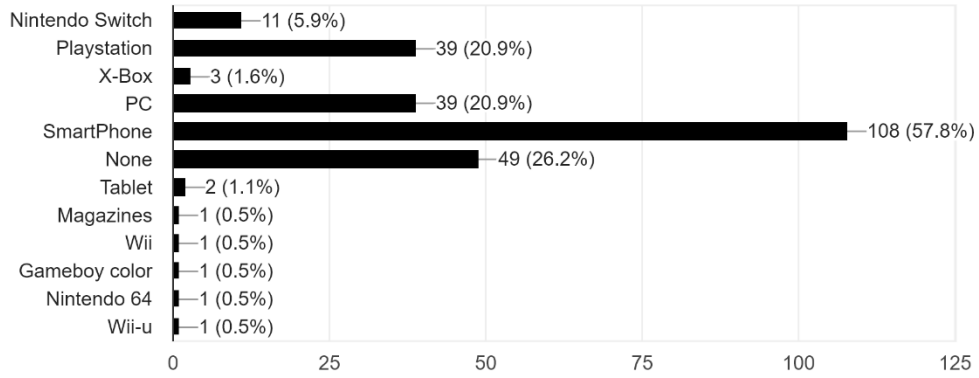
6. I play Video Games regularly

187 responses



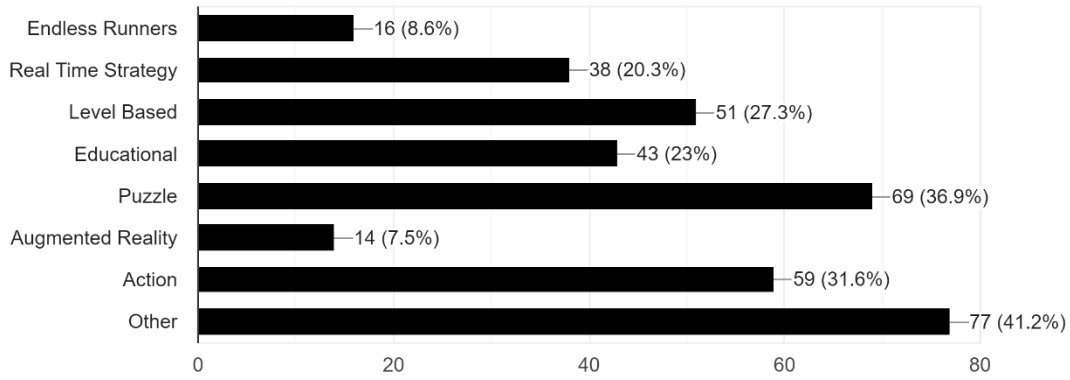
7. Which devices do you play on? (Tick all that are applicable)

187 responses



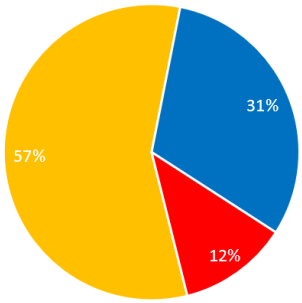
8. What kind of games do you like to play? (Tick all that are applicable)

187 responses



9. I prefer to play games that ...

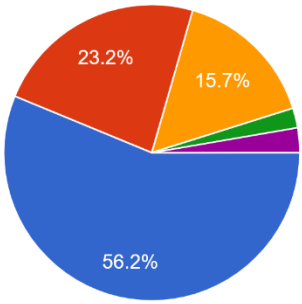
187 responses



- are Easy and require no challenge to complete.
- are Difficult and almost impossible to complete.
- adjust's the difficulty dynamically to match the player's skill

10. What is your opinion on games that can automatically adjust their difficulty to match the player's skill?

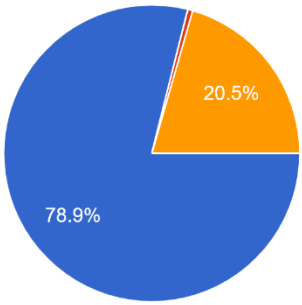
185 responses



- Positive
- Somewhat Positive
- Neither Positive nor Negative
- Somewhat Negative
- Negative

11. Would you like to see more Educational Games with dynamic difficulty, were difficulty adapts automatically to provide challenging and progressive game play?

185 responses



- Yes
- No
- Maybe

A.2 Heuristic Evaluation & Additional Comments

A.2.1 Heuristic Evaluation - Questionnaire

Prototype Evaluation

I am a student undergoing the course "Multimedia and Software Development" at MCAST, completing my last year of study.

This form makes use of Heuristic Evaluation to evaluate the Prototype Application functionality and features.
Two different type of Heuristics will be used to evaluate both the interface design of the application and the educational design.The data gathered from this form will help me to adjust the Prototype as needed to fix any issues.

THANK YOU FOR YOUR PARTICIPATION!

*Required

Nielsen's Interface Heuristics

ON A SCALE OF 1 TO 5 , 1 = POOR IMPLEMENTATION, 5 = EXCELLENT IMPLEMENTATION

HOW DO YOU RATE THE FOLLOWING HEURISTICS ACCORDING TO THE PROTOTYPE'S EVALUATION:

1. The Application keeps the Player updated with his/her progress. *

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

2. Information is displayed clearly and in an understandable format.

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

3. Users always have control to enter and exit different pages without any constraints.

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

4. Consistency of terms are applied, users do not have to wonder whether different words and actions mean the same thing.

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

5. The Application runs smoothly without any errors occurring while the user is playing.

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

6. Information is always visible and accessible without having to rely on memory .

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

7. Application is flexible and allows users to change settings.

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

8. The application's design is consistent and does not contain irrelevant information.

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

9. Any Errors that occur are displayed and understandable by a typical user and also suggest solutions.

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

10. The Application provides accessible help which is related to any user difficulty.

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

Quinn's Educational Heuristics

ON A SCALE OF 1 TO 5 , 1 = POOR IMPLEMENTATION, 5 = EXCELLENT IMPLEMENTATION

HOW DO YOU RATE THE FOLLOWING HEURISTICS ACCORDING TO THE PROTOTYPE'S EVALUATION:

11. The Application makes it clear of what is to be accomplished.

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

12. The game-play throughout the application is situated in practice and also engaging to the learner.

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

13. Content is clearly represented and navigable.

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

14. User's activities are structured while still receiving meaningful chunks of knowledge.

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

15. Elicit learner understandings.

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

16. Application provides feedback to the player's achievements.

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

17. Performance is clearly measured.

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

18. Players are able to apply skills they acquired from the application beyond the learning environment.

Mark only one oval.

	1	2	3	4	5	
Poor	◯	◯	◯	◯	◯	Excellent

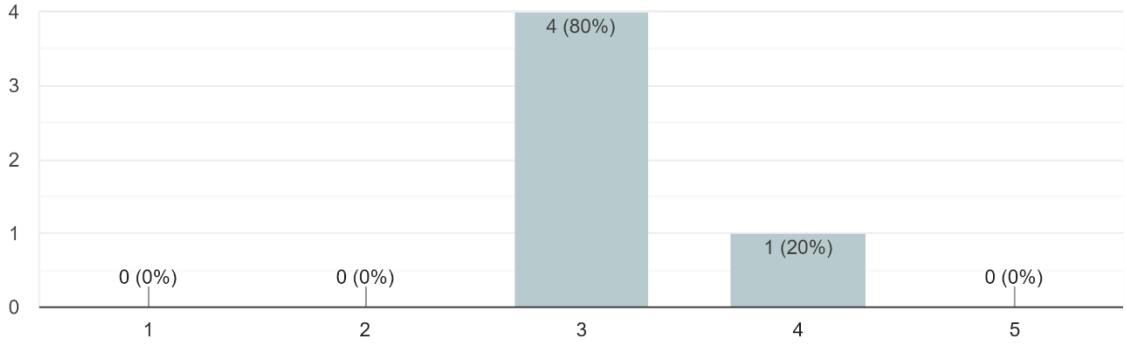
A.2.2 Heuristic Evaluation - Results

Prototype Evaluation

NIELSEN'S INTERFACE HEURISTICS

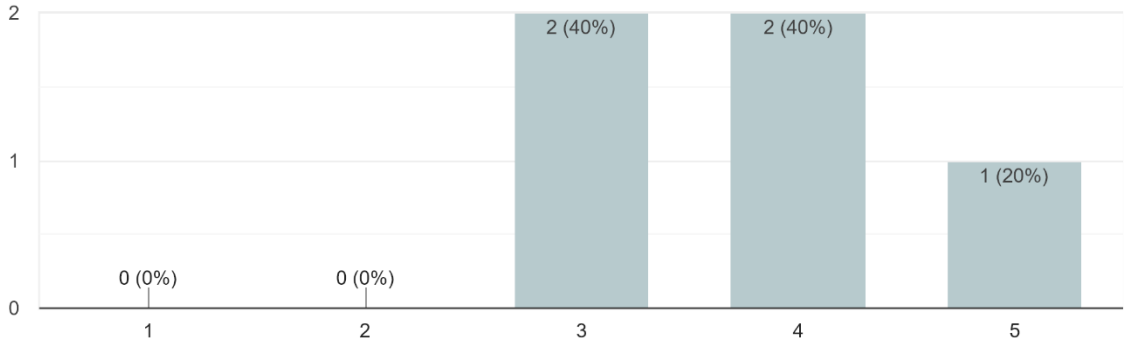
The Application keeps the Player updated with his/her progress.

5 responses



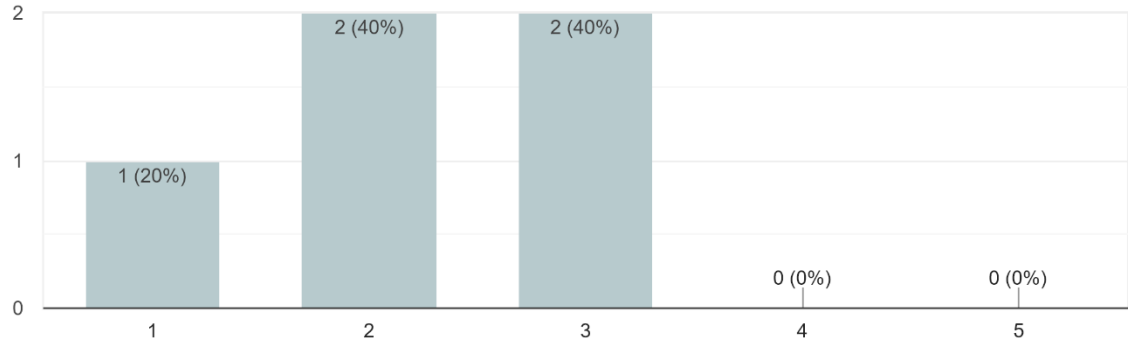
Information is displayed clearly and in an understandable format.

5 responses



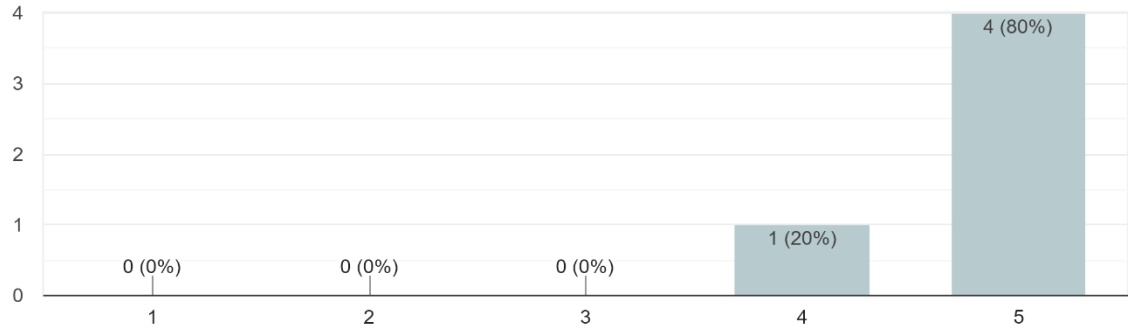
Users always have control to enter and exit different pages without any constraints.

5 responses



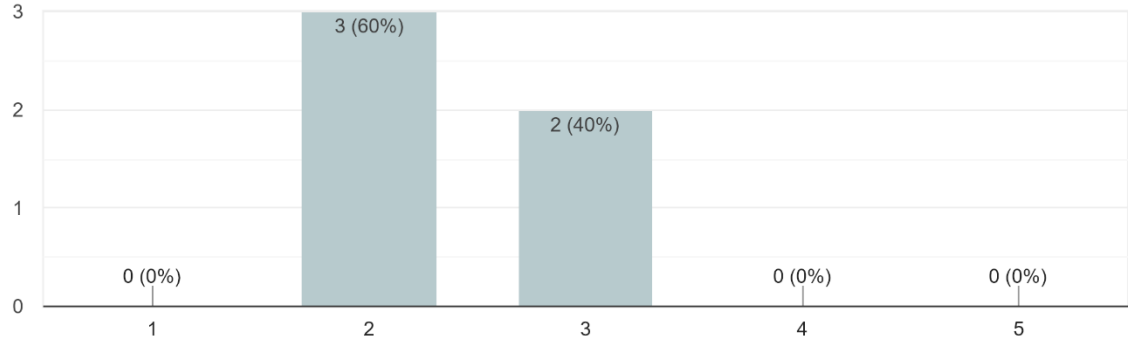
Consistency of terms are applied, users do not have to wonder whether different words and actions mean the same thing.

5 responses



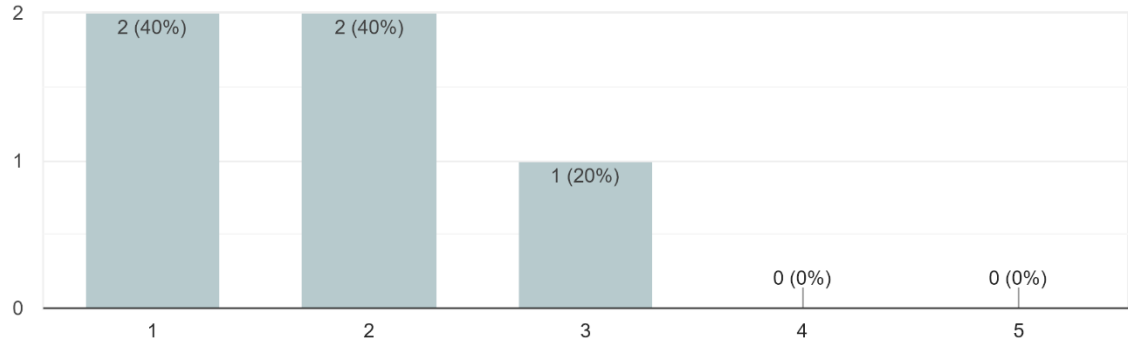
The Application runs smoothly without any errors occurring while the user is playing.

5 responses



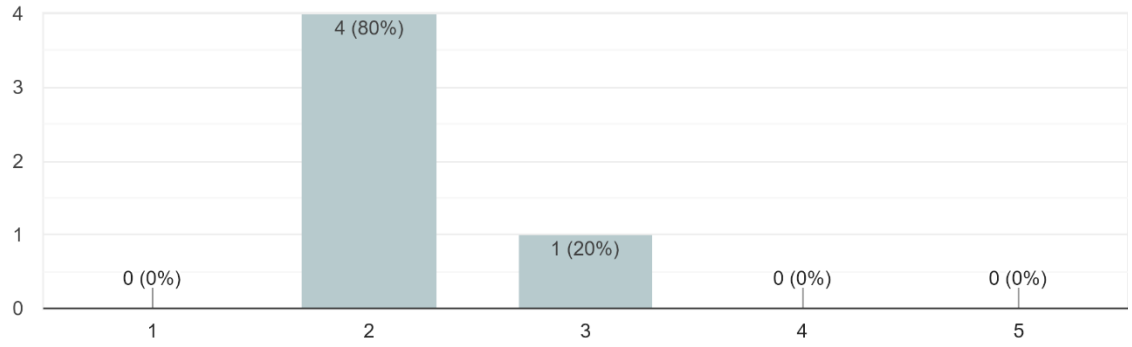
Information is always visible and accessible without having to rely on memory .

5 responses



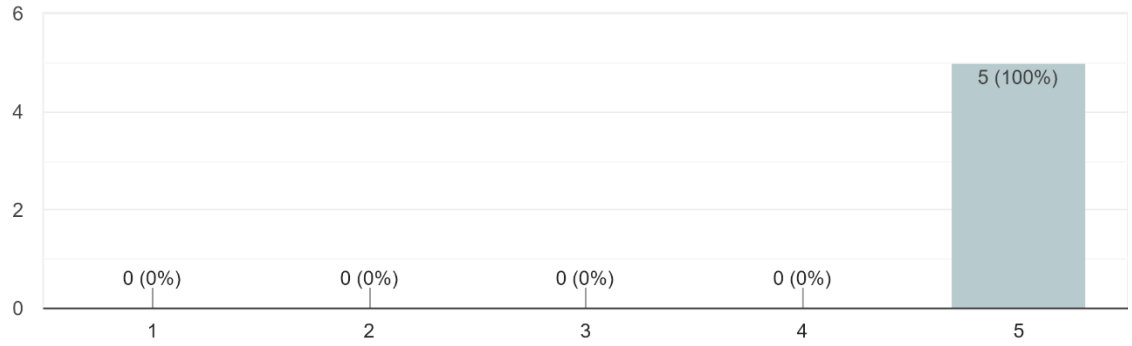
Application is flexible and allows users to change settings.

5 responses



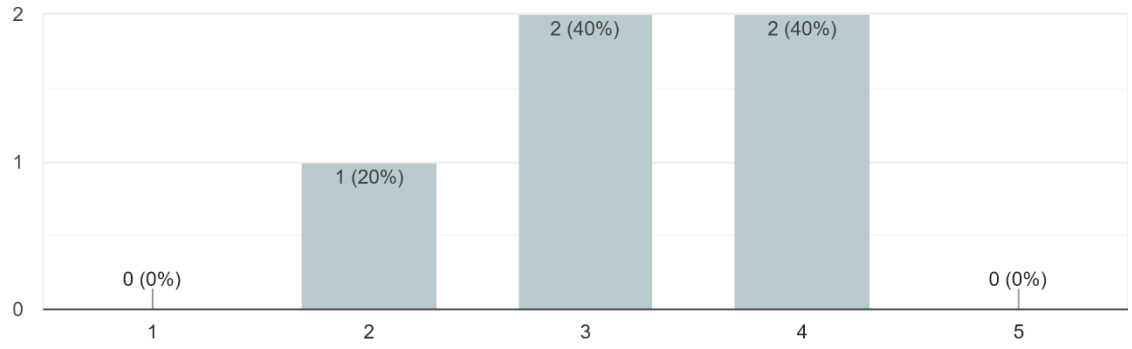
The application's design is consistent and does not contain irrelevant information.

5 responses



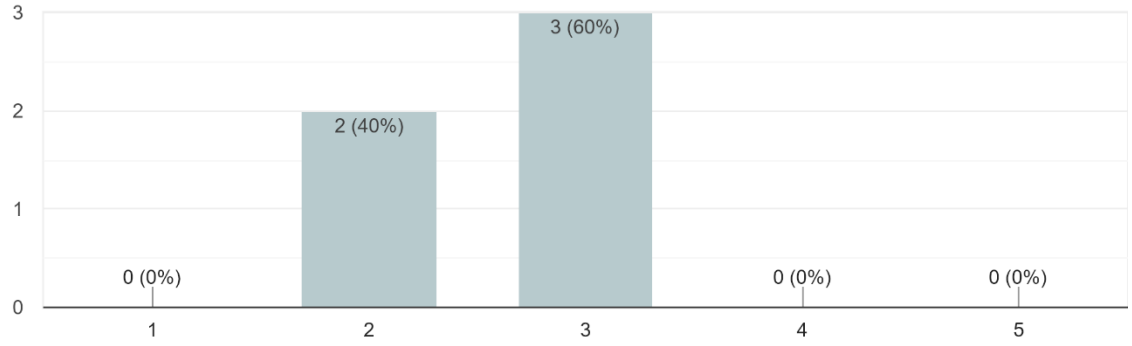
Any Errors that occur are displayed and understandable by a typical user and also suggest solutions.

5 responses



The Application provides accessible help which is related to any user difficulty.

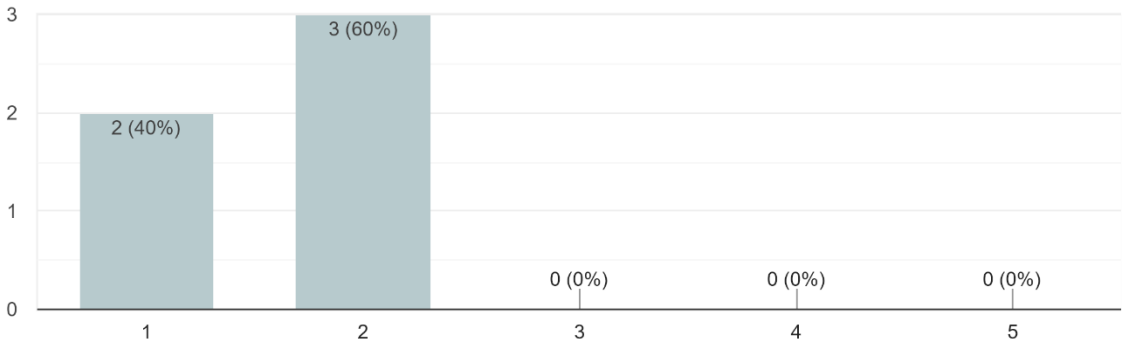
5 responses



QUINN'S EDUCATIONAL HEURISTICS

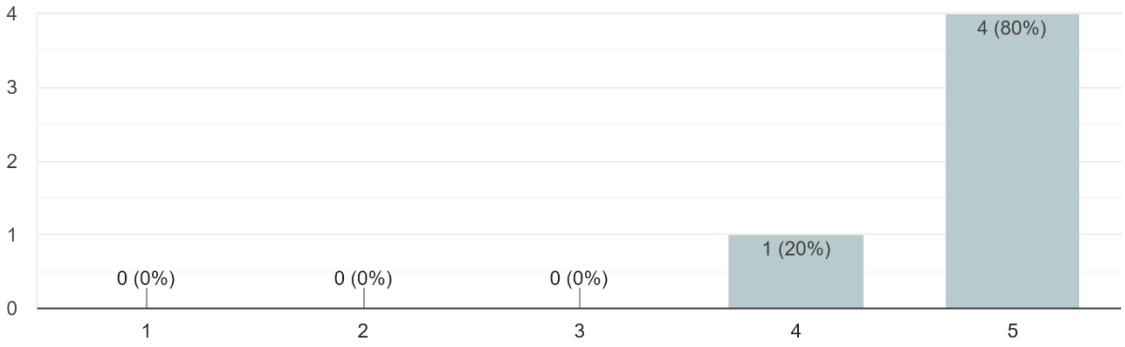
The Application makes it clear of what is to be accomplished.

5 responses



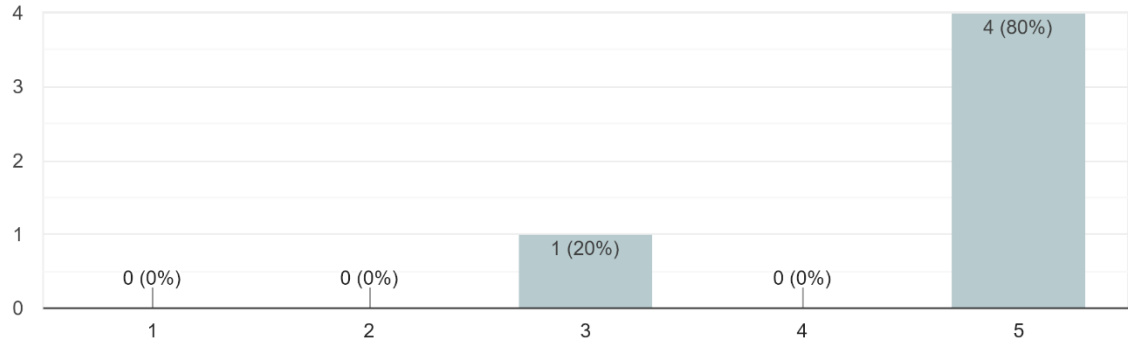
The game-play throughout the application is situated in practice and also engaging to the learner.

5 responses



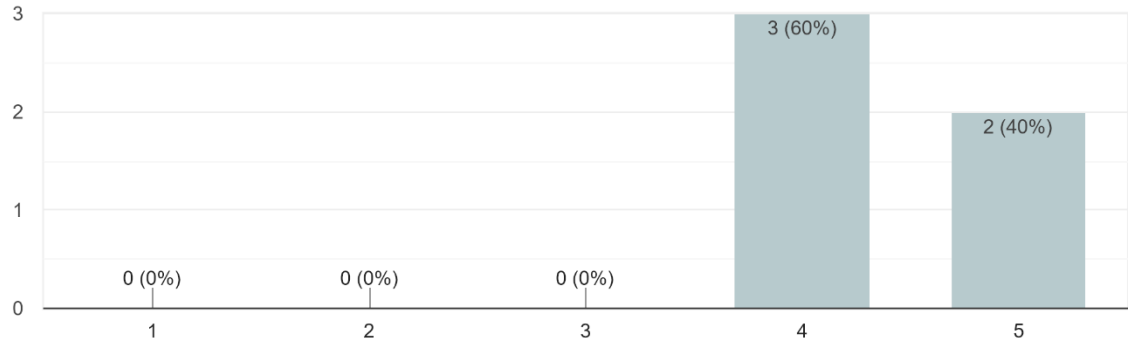
Content is clearly represented and navigable.

5 responses



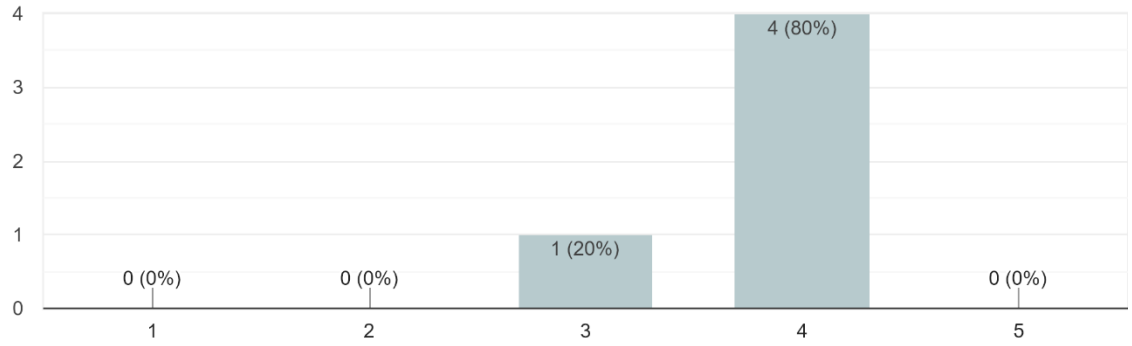
User's activities are structured while still receiving meaningful chunks of knowledge.

5 responses



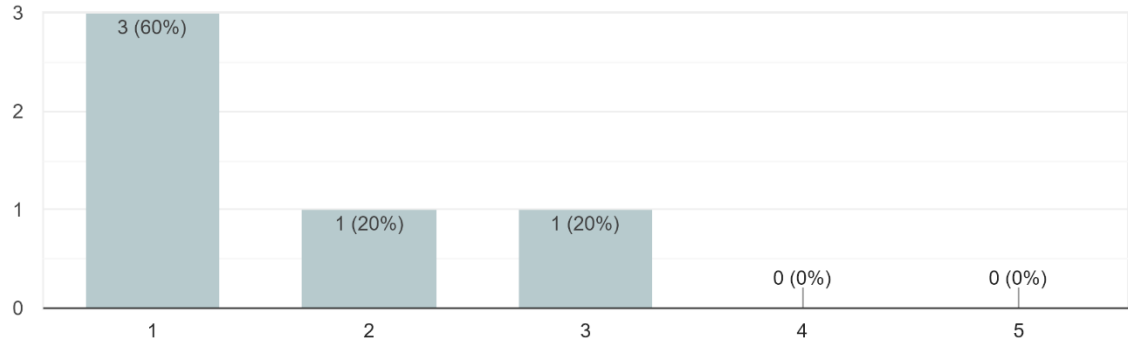
Elicit learner understandings.

5 responses



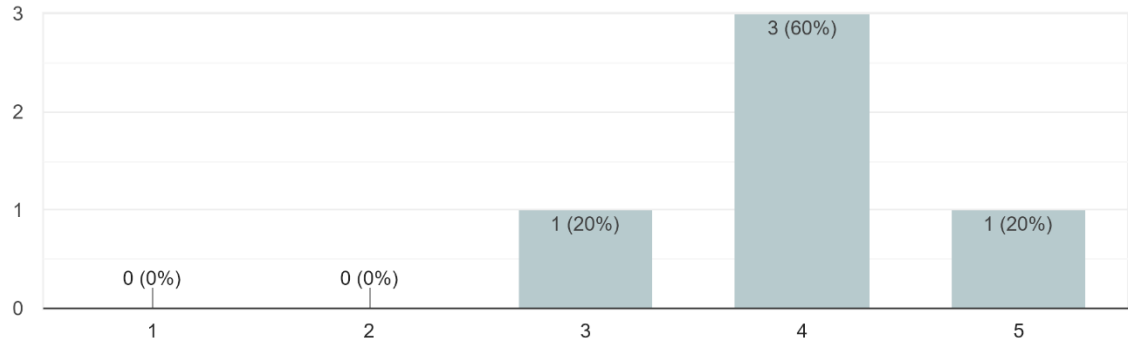
Application provides feedback to the player's achievements.

5 responses



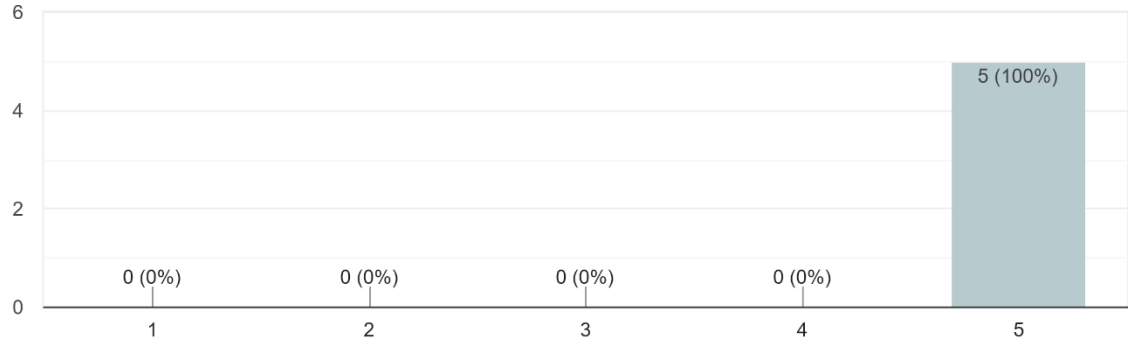
Performance is clearly measured.

5 responses



Players are able to apply skills they acquired from the application beyond the learning environment.

5 responses



A.2.3 Evaluators' Comments

Comments From The Evaluators

“Instead of using the current menu to show the player’s score and time, you should make use of a side menu. This will remove the need to break the game’s immersion while playing and players will also be able to keep track of their scores without sacrificing gameplay.”

“I really liked the navigation between different pages, especially the sliding animation between one page and another, but while playing it got frustrated at times when I had to either wait until I lose all my lives or close the application to be able to exit. You should think of adding a button which stops the match and returns the player to the Main Menu.”

“After playing on Hard difficulty in the Endless Runner game, I came across an issue where the other levels were not functioning properly. You should fix this bug since it was affecting the gameplay during different difficulties.”

“I was testing the game’s functionality when I came across a bug that seemed odd. When I intentionally answered questions wrongly during the dynamic difficulty, some questions and answers were showing negative values.”

“I tested the games on different devices with different screen resolutions. On some devices, that placement of game elements and game borders were not being placed properly. In some instances, I could also move the character out of the screen and since I would not have answered the question, no new questions gets generated.”

"You should add a screen with previous scores acquired from the player. This will help the players to keep track of their progress in games and even create their own objective to beat. This feature will entice players to be more competitive with themselves, ultimately encouraging them to spend more time playing games."

"One pressing issue that I had encountered while evaluating the prototypes was that my device's temperature was rising too quickly and at certain times, the game was also slowing down. You should try to remove any excess code or functionalities happening at once in the game."

"I suggest that you would add a graphic option which allows players to switch off the particles from the game. Although the particle effects are interesting, when reaching a certain level in the game the particle's speed was getting too distracting."

"It was noticed that when some run-time bugs occurred in the game, there was no notification regarding the errors. As the errors were not too severe and were also not affecting that data being collected, I would not focus too much on this issue."

"I also came across the issue that there was no screen which explained the objective of the game or player's controls or even any help feature. Although it may not be as important for data gathering, I suggest that you should add a help screen with basic information which would help the user become more familiar with the application more quickly."

"After spending a good amount of time answering questions in games, I got un-motivated to spend more time in the game since I had no objective to beat. I suggest that you add a Highscore functionality which keeps track of the player's progress and notifies him/her of their new high scores."

A.3 Prototypes: Code Snippets

A.3.1 Endless Runner

Endless Runner: Code Snippets

SETTING WEIGHT PARAMETERS FOR ADAPTIVE (DYNAMIC) DIFFICULTY.

```
starMinSpeed = 0.9f;
starMaxSpeed = 2f;

maxWeight_Add = 21;
minWeight_Add = 6;

minWeight_Multi = 3;
maxWeight_Multi = 6;

if(SceneScript.easy == true || SceneScript.dynamic == true)
{
    obstacleSpeed = 2f;

    starMinSpeed += 1.8f;
    starMaxSpeed += 2.3f;

    var v = QuestionScript.starsSpeed.main;
    v.startSpeed = new ParticleSystem.MinMaxCurve(starMinSpeed, starMaxSpeed);
}
```

```
int addition_a = Random.Range(NextQuestionScript.minWeight_Add, NextQuestionScript.maxWeight_Add);
int addition_b = Random.Range(NextQuestionScript.minWeight_Add, NextQuestionScript.maxWeight_Add);
```

SETTING WEIGHT PARAMETERS FOR NON-ADAPTIVE (EASY & HARD) DIFFICULTY.

```
if(SceneScript.easy == true || SceneScript.dynamic == true)
{
    obstacleSpeed = 2f;

    starMinSpeed += 1.8f;
    starMaxSpeed += 2.3f;

    var v = QuestionScript.starsSpeed.main;
    v.startSpeed = new ParticleSystem.MinMaxCurve(starMinSpeed, starMaxSpeed);
}

else if(SceneScript.hard == true)
{
    obstacleSpeed = 8f;

    starMinSpeed += 7.2f;
    starMaxSpeed += 9.2f;

    minEmmitt += 15;
    maxEmmitt += 19;

    var v = QuestionScript.starsSpeed.main;
    v.startSpeed = new ParticleSystem.MinMaxCurve(starMinSpeed, starMaxSpeed);

    var e = QuestionScript.starsSpeed.emission;
    e.rateOverTime = new ParticleSystem.MinMaxCurve(minEmmitt, maxEmmitt);
}
```

ADAPTING WEIGHT VALUES ON CORRECT AND INCORRECT ANSWERS IN THE ADAPTIVE (DYNAMIC) DIFFICULTY

CORRECT ANSWERS

```
if(SceneScript.dynamic == true && SceneScript.mixed == true && ScoreScript.scoreValue % 2 == 0)
{

    if(SceneScript.dynamic == true && obstacleSpeed <= 8)
    {
        obstacleSpeed = obstacleSpeed + 0.5f;

        starMinSpeed = obstacleSpeed - 0.3f;
        starMaxSpeed = obstacleSpeed + 0.3f;

        minEmmitt += 2;
        maxEmmitt += 2;

        var v = QuestionScript.starsSpeed.main;
        v.startSpeed = new ParticleSystem.MinMaxCurve(starMinSpeed, starMaxSpeed);

        var e = QuestionScript.starsSpeed.emission;
        e.rateOverTime = new ParticleSystem.MinMaxCurve(minEmmitt, maxEmmitt);
    }

    if(maxWeight_Add < 500)
    {
        minWeight_Add += 3;
        maxWeight_Add += 20;
    }

    if(maxWeight_Multi < 16)
    {
        minWeight_Multi += 1;
        maxWeight_Multi += 1;
    }

}
```

INCORRECT ANSWERS

```
else if(int.Parse(text.text) != QuestionScript.correctAnswer)
{
    Debug.Log("Wrong Answer");
    anim2.Play("BadAnswer");

    ScoreScript.incorrectAnswers += 1; //Increments incorrectAnswers value

    if(currentHealth > 0f)
    {
        float damageValue;

        if(ScoreScript.scoreValue <= 15)
        {
            damageValue = 0.1f;
        }
        else if (ScoreScript.scoreValue > 15 && ScoreScript.scoreValue <= 30)
        {
            damageValue = 0.2f;
        }
        else
        {
            damageValue = 0.3f;
        }

        //MANAGE HEALTHBAR HERE
        currentHealth = currentHealth - damageValue;
        print(currentHealth);
        SetSize(currentHealth, health);

        forceField.color = new Color(1f,1f,1f,currentHealth - 0.1f);
    }

    if(SceneScript.dynamic == true && obstacleSpeed > 4f)
    {
        obstacleSpeed = obstacleSpeed - 0.5f;

        starMinSpeed = obstacleSpeed - 0.3f;
        starMaxSpeed = obstacleSpeed + 0.3f;
```

```
        minEmmitt -= 2;
        maxEmmitt -= 2;

        var v = QuestionScript.starsSpeed.main;
        v.startSpeed = new ParticleSystem.MinMaxCurve(starMinSpeed, starMaxSpeed);

        var e = QuestionScript.starsSpeed.emission;
        e.rateOverTime = new ParticleSystem.MinMaxCurve(minEmmitt, maxEmmitt);
    }

    if(SceneScript.dynamic == true && SceneScript.mixed == true)
    {
        if(minWeight_Add > 12 && (maxWeight_Add - minWeight_Add) >= 36)
        {
            minWeight_Add -= 6;
            maxWeight_Add -= 40;
            print("MIN ADD: " + minWeight_Add);
        }

        if(minWeight_Multi > 4)
        {
            minWeight_Multi -= 2;
            maxWeight_Multi -= 2;
            print("MIN MULTI: " + minWeight_Multi);
        }
    }
```

A.3.2 Level Based

Level Based: Code Snippets

SETTING WEIGHT PARAMETERS FOR NON-ADAPTIVE DIFFICULTY IN DIFFERENT LEVELS.

```
switch(levelNum)
{
    case 1:
        backgroundSpeed = 1.8f;
        meteorSpeed = 2f;
        starMinSpeed = 1.8f;
        starMaxSpeed = 2.3f;

        minEmmitt = 2;
        maxEmmitt = 6;

        maxWeight_Add = 11;
        minWeight_Add = 1;
        answerRange_Add = 3;

        maxWeight_Multi = 3;
        minWeight_Multi = 1;
        answerRange_Multi = 4;

        lives = 3;
        totalQuestions = 5;
    break;

    case 2:
        backgroundSpeed = 1.8f;
        meteorSpeed = 2f;
        starMinSpeed = 1.8f;
        starMaxSpeed = 2.3f;

        minEmmitt = 2;
        maxEmmitt = 6;

        maxWeight_Add = 16;
        minWeight_Add = 3;
        answerRange_Add = 3;

        maxWeight_Multi = 5;
        minWeight_Multi = 1;
        answerRange_Multi = 4;

        lives = 3;
        totalQuestions = 5;
    break;
```

SETTING WEIGHT PARAMETERS FOR ADAPTIVE DIFFICULTY IN DIFFERENT LEVELS.

```
//-------------------------Adjusting Level Settings---------------//
switch(levelNum)
{
    case 1:
        backgroundSpeed = 1.8f + speedAdaptive;
        meteorSpeed = 2f + speedAdaptive;
        starMinSpeed = 1.8f + speedAdaptive;
        starMaxSpeed = 2.3f + speedAdaptive;

        minEmmitt = 2 + emittAdaptive;
        maxEmmitt = 6 + emittAdaptive;

        maxWeight_Add = 11 + addAdaptive;
        minWeight_Add = 1 + addAdaptive;
        answerRange_Add = 3;

        maxWeight_Multi = 3 + multiAdaptive;
        minWeight_Multi = 1 + multiAdaptive;
        answerRange_Multi = 4;

        lives = 3 - livesAdaptive;
        totalQuestions = 5 + questionsAdaptive;
    break;

    case 2:
        backgroundSpeed = 1.8f + speedAdaptive;
        meteorSpeed = 2f + speedAdaptive;
        starMinSpeed = 1.8f + speedAdaptive;
        starMaxSpeed = 2.3f + speedAdaptive;

        minEmmitt = 2 + emittAdaptive;
        maxEmmitt = 6 + emittAdaptive;

        maxWeight_Add = 16 + addAdaptive;
        minWeight_Add = 3 + addAdaptive;
        answerRange_Add = 3;

        maxWeight_Multi = 5 + multiAdaptive;
        minWeight_Multi = 1 + multiAdaptive;
        answerRange_Multi = 4;

        lives = 3 - livesAdaptive;
        totalQuestions = 5 + questionsAdaptive;
    break;
```

ADAPTING WEIGHT VALUES ON PARAMETERS IN THE ADAPTIVE DIFFICULTY

```
//-------------------------ADAPTIVE DIFFICULTY-------------------------//
if(PlayerPrefs.GetInt("WinStreak") < 2)
{
    addAdaptive = 0;
    multiAdaptive = 0;
    speedAdaptive = 0;
    emittAdaptive = 0;
    questionsAdaptive = 0;
    livesAdaptive = 0;
}
else
{
    questionsAdaptive = 1 * PlayerPrefs.GetInt("WinStreak");

    if(PlayerPrefs.GetInt("WinStreak") % 3 == 0)
    {
        addAdaptive = 25 * PlayerPrefs.GetInt("WinStreak");
        multiAdaptive = 1 * (PlayerPrefs.GetInt("WinStreak") / 3);
        speedAdaptive = 1 * (PlayerPrefs.GetInt("WinStreak") / 3);
        emittAdaptive = speedAdaptive * 2;
    }
}

if(PlayerPrefs.GetInt("WinStreak") >= 10)
{
    livesAdaptive = 1;
}
```

A.3.3 Data Collected From Prototypes

Reading Prototype Data From Firebase

ENDLESS RUNNER DATA

ENDLESS RUNNER

	EASY	HARD	DYNAMIC
TOTAL GAMES	49	49	101
TOTAL QUESTIONS	1388	1219	4208
TOTAL CORRECT ANS	1252	829	3503
TOTAL INCORRECT ANS	90	343	554
TOTAL TIME	168m:2s	130m:6s	472m:13s

CODE SNIPPET

```
// Set up the Editor before calling into the realtime database.
FirebaseApp.DefaultInstance.SetEditorDatabaseUrl("https://space-mathematic-project.firebaseio.com/");

// Get the root reference location of the database.
reference = FirebaseDatabase.DefaultInstance.RootReference;

reference.Child("Users").GetValueAsync().ContinueWith(task => {
    if (task.IsFaulted) {
        Debug.Log("ERROR");
    }
```

```
else if (task.IsCompleted) {
DataSnapshot snapshot = task.Result; //snapshot = all users
    foreach ( DataSnapshot user in snapshot.Children){ //user = per player
        foreach (DataSnapshot game in user.Children) //game = game per player
        {
            if(game.Child("Game Difficulty").Value.ToString() == "Easy")
            {
                totalGames_Easy += 1;
                totalCorrectAns_Easy += int.Parse(game.Child("Correctly Answered").Value.ToString());
                totalQuestions_Easy += int.Parse(game.Child("Total Questions").Value.ToString());
                totalIncorrectAns_Easy += int.Parse(game.Child("Wrongly Answered").Value.ToString());

                if(game.Child("Time Played").Value.ToString().Length == 5)
                {
                    int minutesToSeconds = int.Parse(game.Child("Time Played").Value.ToString().Substring(0,1)) * 60;
                    totalTime_Easy += int.Parse(game.Child("Time Played").Value.ToString()[3].ToString()) + minutesToSeconds;
                }
```

LEVEL BASED DATA

LEVEL BASED

	ADAPTIVE	NON-ADAPTIVE
TOTAL LEVELS	167	169
TOTAL QUESTIONS	2734	1910
TOTAL CORRECT ANS	2319	1740
TOTAL INCORRECT ANS	125	76
TOTAL TIME	305m:18s	237m:36s

CODE SNIPPET

```
// Set up the Editor before calling into the realtime database.
FirebaseApp.DefaultInstance.SetEditorDatabaseUrl("https://space-mathematic-levelbased.firebaseio.com/");

// Get the root reference location of the database.
reference = FirebaseDatabase.DefaultInstance.RootReference;

reference.Child("Users").GetValueAsync().ContinueWith(task => {
    if (task.IsFaulted) {
        Debug.Log("ERROR");
    }
```

```
else if (task.IsCompleted) {
DataSnapshot snapshot = task.Result; //snapshot = all users
    foreach ( DataSnapshot user in snapshot.Children){ //user = per player
        foreach (DataSnapshot game in user.Children) //game = game per player
        {
            if(game.Child("Game Version").Value.ToString() == "ADAPTIVE")
            {
                totalLevels_ADAPT += 1;
                totalCorrectAns_ADAPT += int.Parse(game.Child("Score").Value.ToString());
                totalQuestions_ADAPT += int.Parse(game.Child("Total Questions").Value.ToString());
                totalIncorrectAns_ADAPT += int.Parse(game.Child("Wrong Answered").Value.ToString());

                if(game.Child("Time Played").Value.ToString().Length == 5)
                {
                    int minutesToSeconds = int.Parse(game.Child("Time Played").Value.ToString().Substring(0,1)) * 60;
                    totalTime_ADAPT += int.Parse(game.Child("Time Played").Value.ToString()[3].ToString()) + minutesToSeconds;
                }
```

A.4 CEGE Post-Questionnaires

A.4.1 Post-Questionnaire (Version 1)

CEGE Framework - Post Questionnaire (Version 1)

1. 1. I enjoyed playing the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

2. 2. I was frustrated at the end of a match

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

3. 3. I was frustrated whilst playing the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

4. 4. I liked the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

5. 5. I would play this game again

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

6. 6. I was in control of the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

7. 7. Application responded as expected

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

8. 8. I remember how to control the player

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

9. 9. I was able to see on the screen everything I needed during the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

10. 10. The opinion of the game that I had, spoiled my experience

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

11. 11. I knew what I was supposed to do to win the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

12. 12. There was a time when I was doing nothing in the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

13. 13. I liked the way that the game looked

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

14. 14. The graphics of the game were plain

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

15. 15. I do not like this type of game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

16. 16. I liked spending time playing this game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

17. 17. I got bored playing this game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

18. 18. I usually do not choose this type of game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

19. 19. I did not have a strategy to win the game.

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

20. 20. The game kept motivating me to keep playing

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

21. 21. I felt what was happening in the game was my own doing

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

22. 22. I challenged myself even if the game did not require it

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

23. 23. I played with my own rules

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

24. 24. I felt guilty for certain actions I took in the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

25. 25. I knew how to manipulate the game to keep moving forward

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

26. 26. The graphics were appropriate for the type of game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

27. 27. The sound effects of the game were appropriate

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

28. 28. I did not like the music of the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

29. 29. The graphics of the game were related to the scenario

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

30. 30. The graphics and sound effects of the game were related

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

31. 31. The sound of the game affected the way I was playing

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

32. 32. The game was unfair

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

33. 33. I understood the rules of the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

34. 34. The game was challenging

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

35. 35. The game was difficult

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

36. 36. The scenario of the game was interesting

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

37. 37. I did not like the scenario of the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

38. 38. I knew all the actions that could be performed in the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

A.4.2 Post-Questionnaire (Version 2)

CEGE Framework - Post Questionnaire (Version 2)

1. 1. I enjoyed playing the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

2. 2. I was frustrated at the end of a match

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

3. 3. I was frustrated whilst playing the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

4. 4. I liked the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

5. 5. I would play this game again

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

6. 6. I was in control of the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

7. 7. Application responded as expected

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

8. 8. I remember how to control the player

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

9. 9. I was able to see on the screen everything I needed during the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

10. 10. The opinion of the game that I had, spoiled my experience

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

11. 11. I knew what I was supposed to do to win the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

12. 12. There was a time when I was doing nothing in the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

13. 13. I liked the way that the game looked

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

14. 14. The graphics of the game were plain

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

15. 15. I do not like this type of game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

16. 16. I liked spending time playing this game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

17. 17. I got bored playing this game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

18. 18. I usually do not choose this type of game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

19. 19. I did not have a strategy to win the game.

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

20. 20. The game kept motivating me to keep playing

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

21. 21. I felt what was happening in the game was my own doing

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

22. 22. I challenged myself even if the game did not require it

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

23. 23. I played with my own rules

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

24. 24. I felt guilty for certain actions I took in the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

25. 25. I knew how to manipulate the game to keep moving forward

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

26. 26. The graphics were appropriate for the type of game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

27. 27. The sound effects of the game were appropriate

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

28. 28. I did not like the music of the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

29. 29. The graphics of the game were related to the scenario

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

30. 30. The graphics and sound effects of the game were related

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

31. 31. The sound of the game affected the way I was playing

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

32. 32. The game was unfair

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree								Strongly Agree

33. 33. I understood the rules of the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

34. 34. The game was challenging

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

35. 35. The game was difficult

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

36. 36. The scenario of the game was interesting

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

37. 37. I did not like the scenario of the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

38. 38. I knew all the actions that could be performed in the game

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	◯	◯	◯	◯	◯	◯	◯	Strongly Agree

39. While testing the Prototype, which version did you enjoy playing most?

Mark only one oval.

- ◯ Version 1
- ◯ Version 2

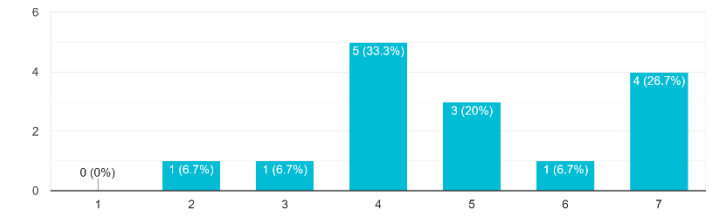
A.4.3 Post-Questionnaire Results: Endless Runner

A.4.3.1 Endless Runner: Non-Adaptive (Version 1)

Endless Runner Version 1 [NON-ADAPTIVE] (RESPONSES)

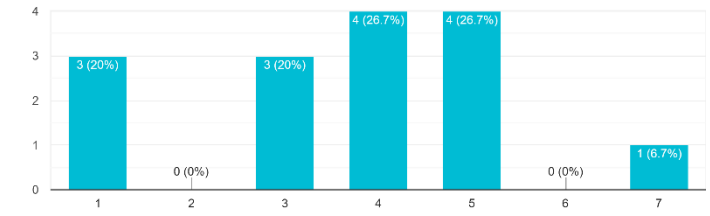
1. I enjoyed playing the game

15 responses



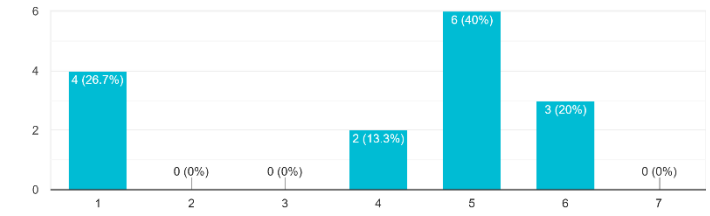
2. I was frustrated at the end of a match

15 responses



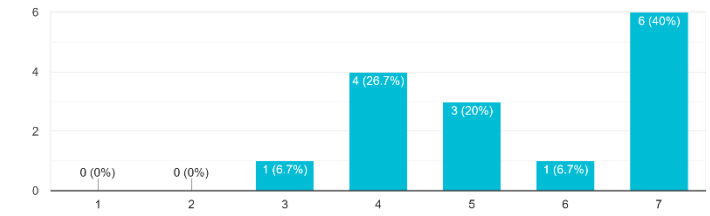
3. I was frustrated whilst playing the game

15 responses



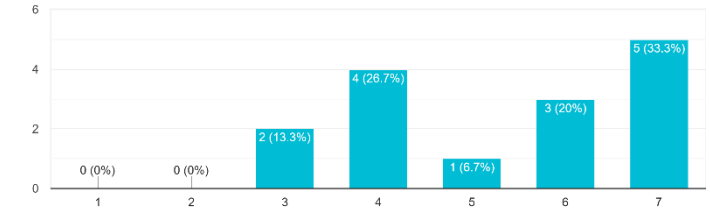
4. I liked the game

15 responses



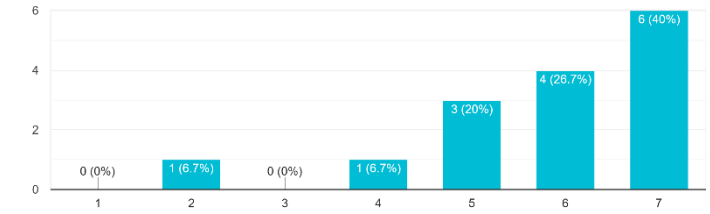
5. I would play this game again

15 responses



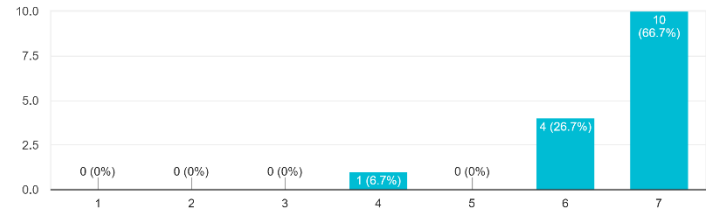
6. I was in control of the game

15 responses



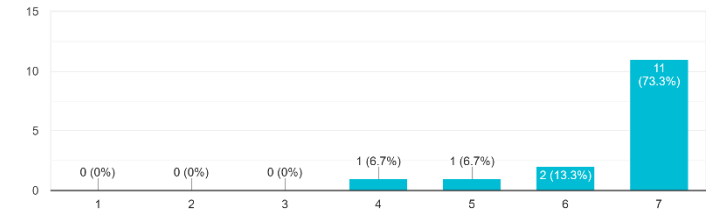
7. Application responded as expected

15 responses



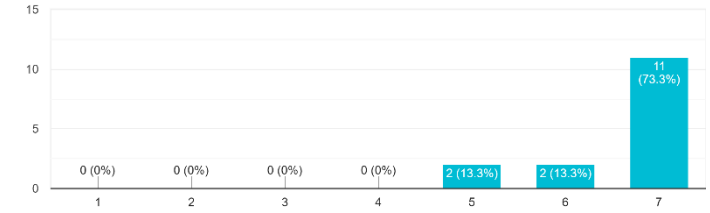
8. I remember how to control the player

15 responses



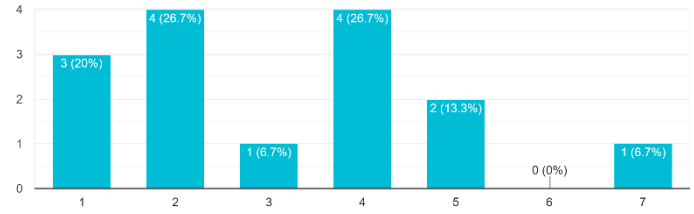
9. I was able to see on the screen everything I needed during the game

15 responses



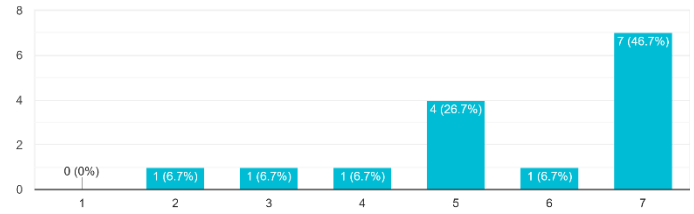
10. The opinion of the game that I had, spoiled my experience

15 responses



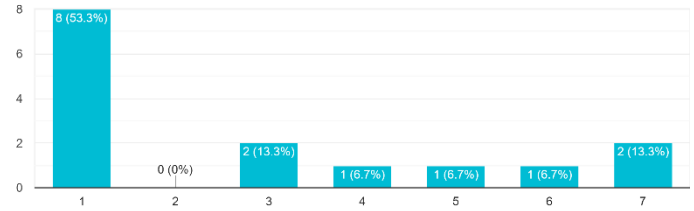
11. I knew what I was supposed to do to win the game

15 responses



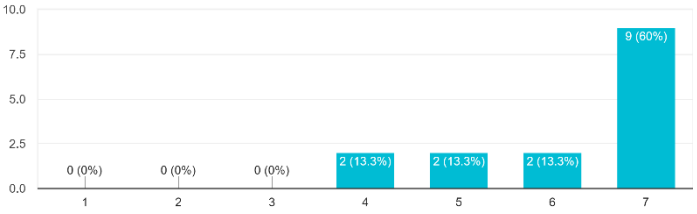
12. There was a time when I was doing nothing in the game

15 responses



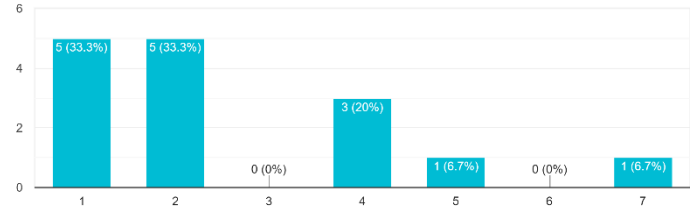
13. I liked the way that the game looked

15 responses



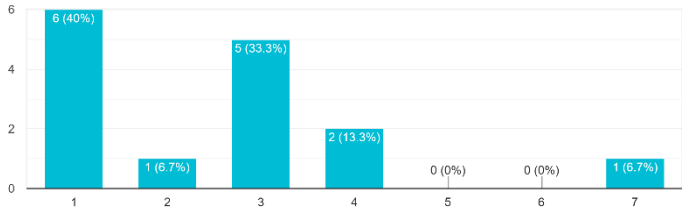
14. The graphics of the game were plain

15 responses



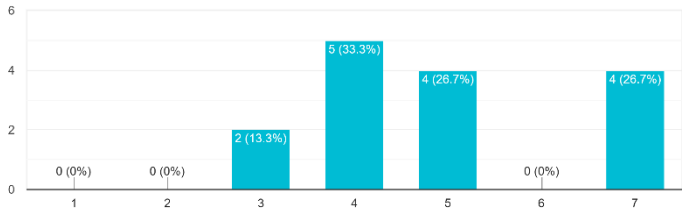
15. I do not like this type of game

15 responses



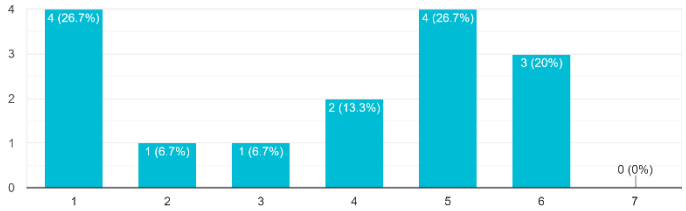
16. I liked spending time playing this game

15 responses



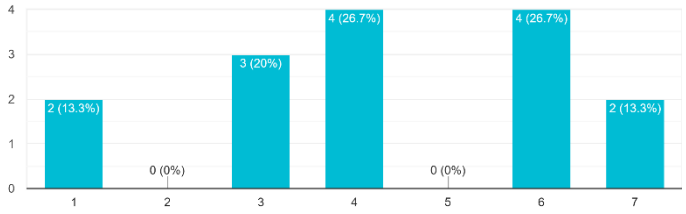
17. I got bored playing this game

15 responses



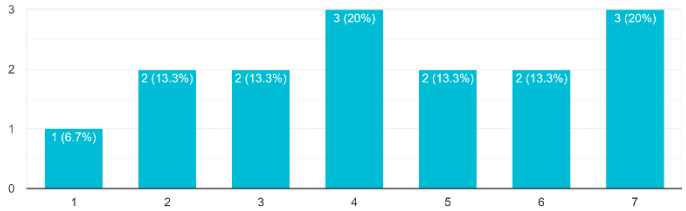
18. I usually do not choose this type of game

15 responses



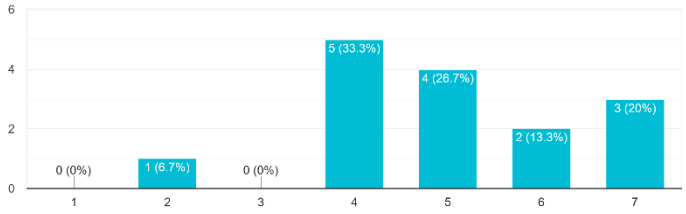
19. I did not have a strategy to win the game.

15 responses



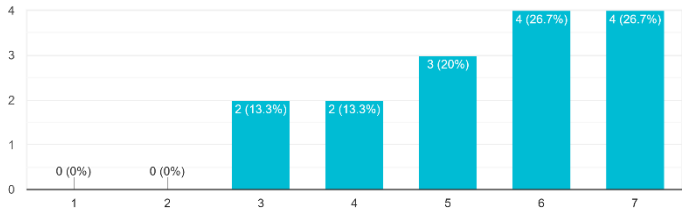
20. The game kept motivating me to keep playing

15 responses



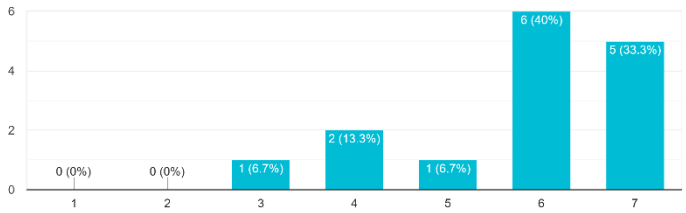
21. I felt what was happening in the game was my own doing

15 responses



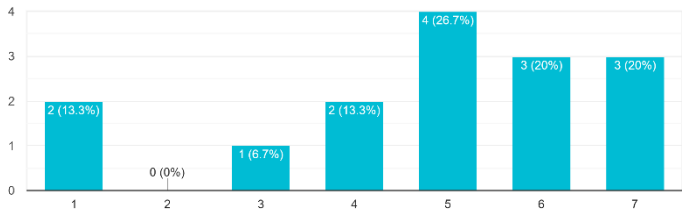
22. I challenged myself even if the game did not require it

15 responses



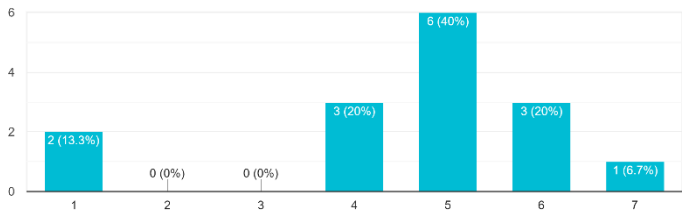
23. I played with my own rules

15 responses



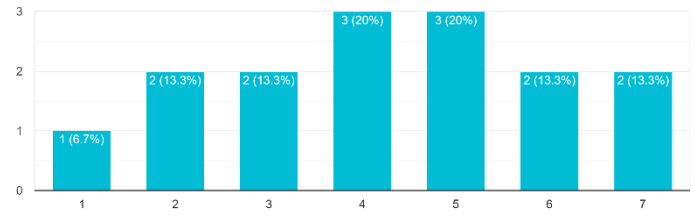
24. I felt guilty for certain actions I took in the game

15 responses



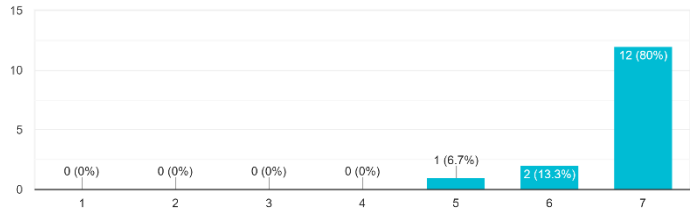
25. I knew how to manipulate the game to keep moving forward

15 responses



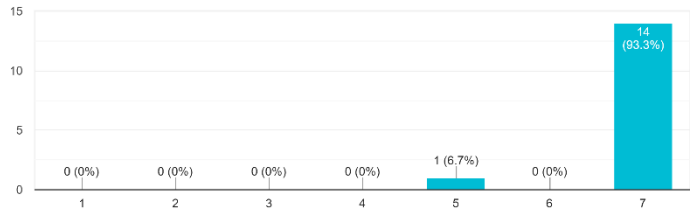
26. The graphics were appropriate for the type of game

15 responses



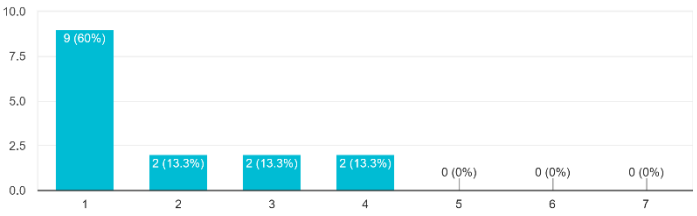
27. The sound effects of the game were appropriate

15 responses



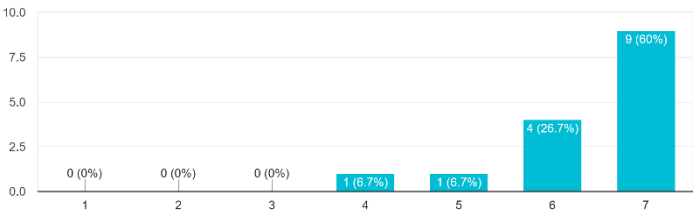
28. I did not like the music of the game

15 responses



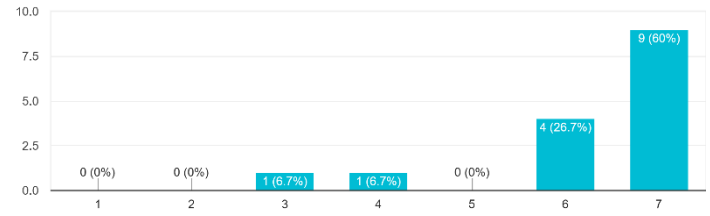
29. The graphics of the game were related to the scenario

15 responses



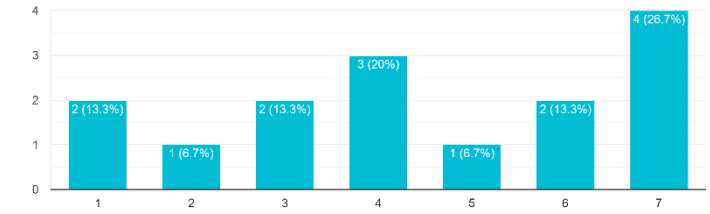
30. The graphics and sound effects of the game were related

15 responses



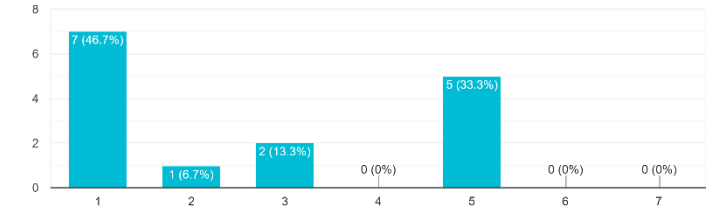
31. The sound of the game affected the way I was playing

15 responses



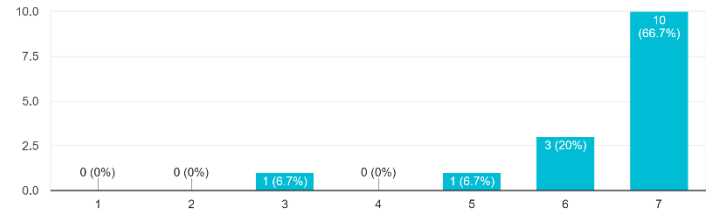
32. The game was unfair

15 responses



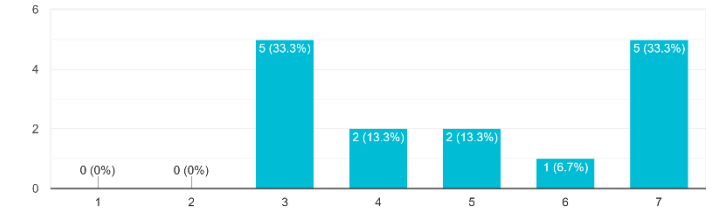
33. I understood the rules of the game

15 responses



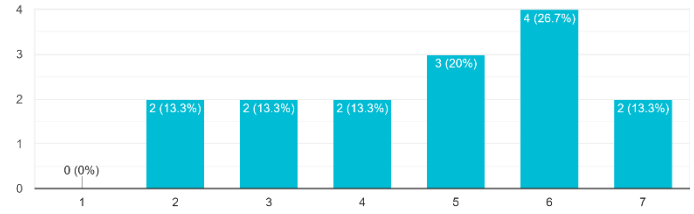
34. The game was challenging

15 responses



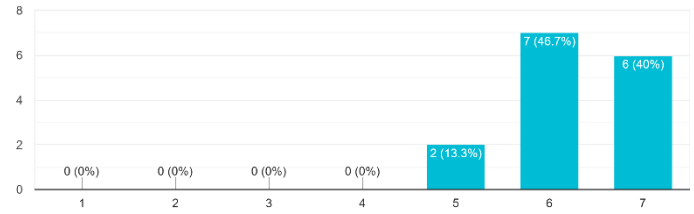
35. The game was difficult

15 responses



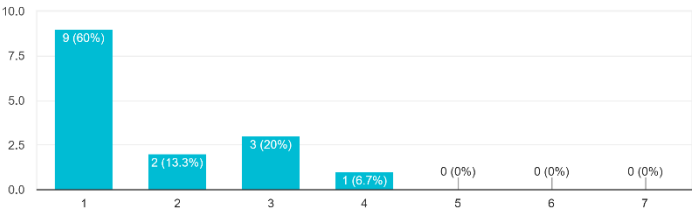
36. The scenario of the game was interesting

15 responses



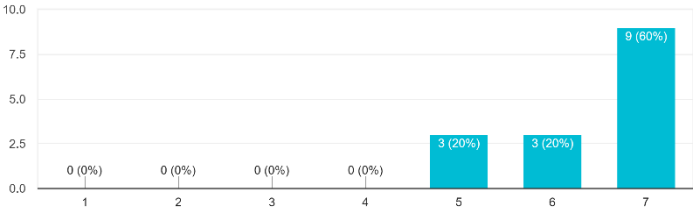
37. I did not like the scenario of the game

15 responses



38. I knew all the actions that could be performed in the game

15 responses

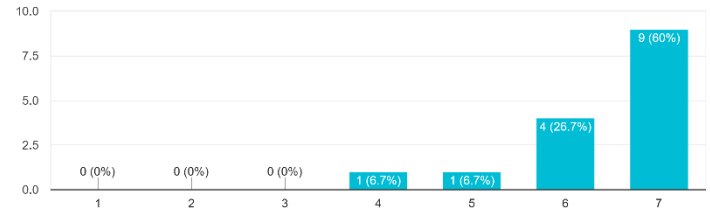


A.4.3.2 Endless Runner: Adaptive (Version 2)

Endless Runner Version 2 [ADAPTIVE] (RESPONSES)

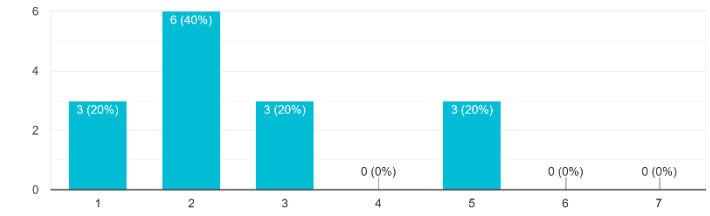
1. I enjoyed playing the game

15 responses



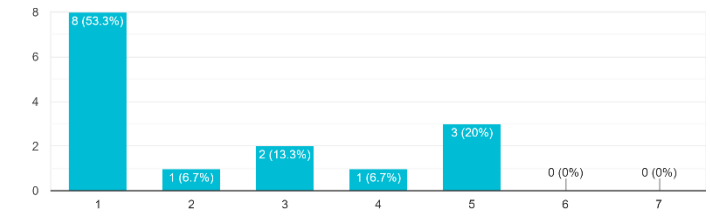
2. I was frustrated at the end of a match

15 responses



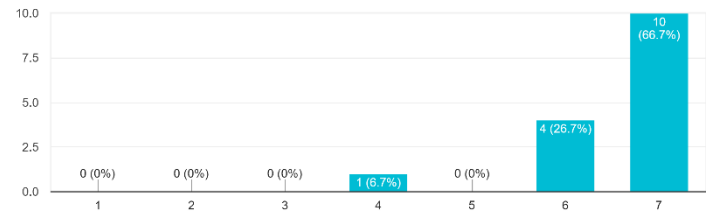
3. I was frustrated whilst playing the game

15 responses



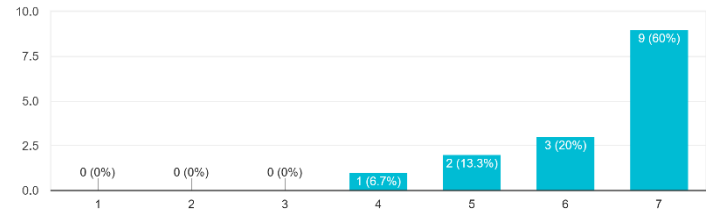
4. I liked the game

15 responses



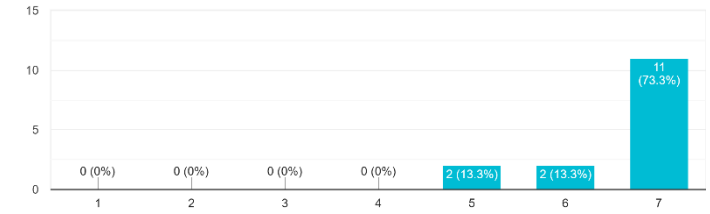
5. I would play this game again

15 responses



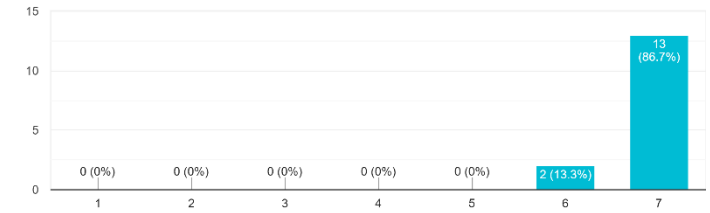
6. I was in control of the game

15 responses



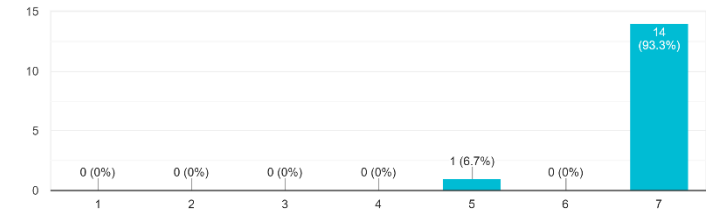
7. Application responded as expected

15 responses



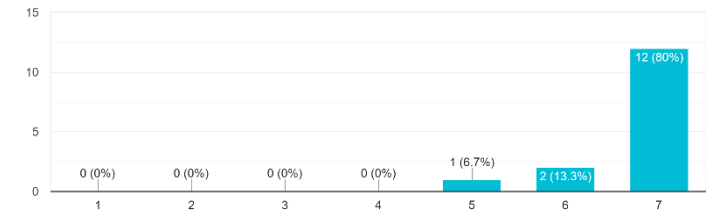
8. I remember how to control the player

15 responses



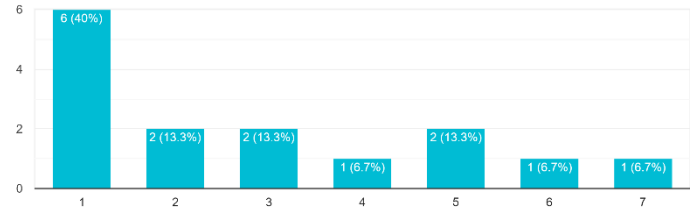
9. I was able to see on the screen everything I needed during the game

15 responses



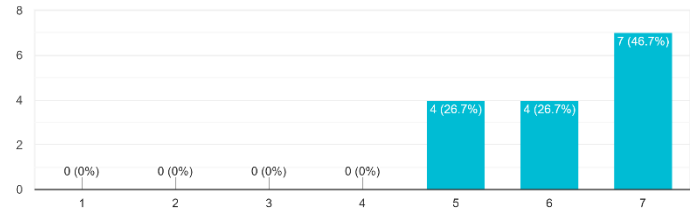
10. The opinion of the game that I had, spoiled my experience

15 responses



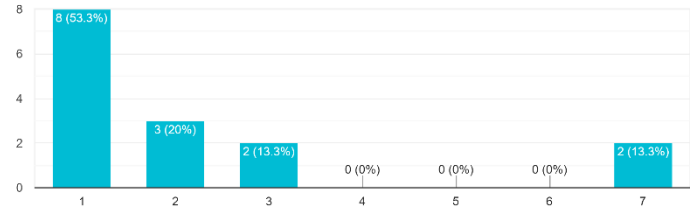
11. I knew what I was supposed to do to win the game

15 responses



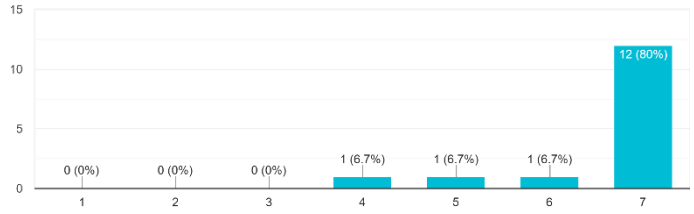
12. There was a time when I was doing nothing in the game

15 responses



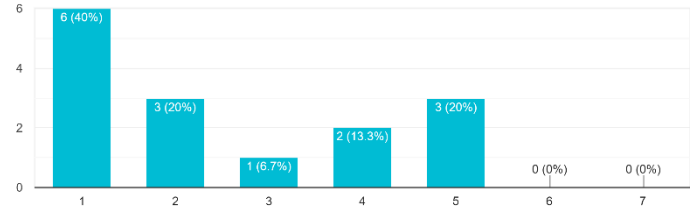
13. I liked the way that the game looked

15 responses



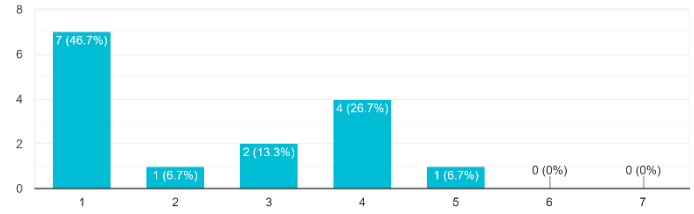
14. The graphics of the game were plain

15 responses



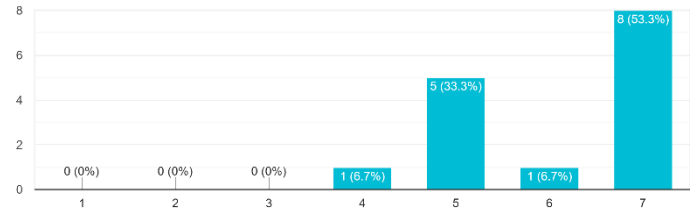
15. I do not like this type of game

15 responses



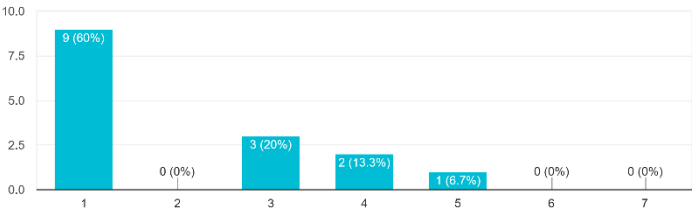
16. I liked spending time playing this game

15 responses



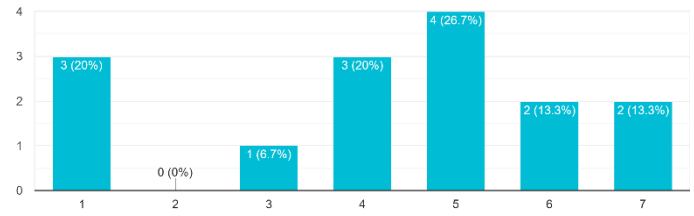
17. I got bored playing this game

15 responses



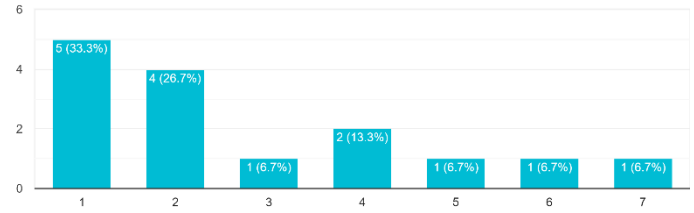
18. I usually do not choose this type of game

15 responses



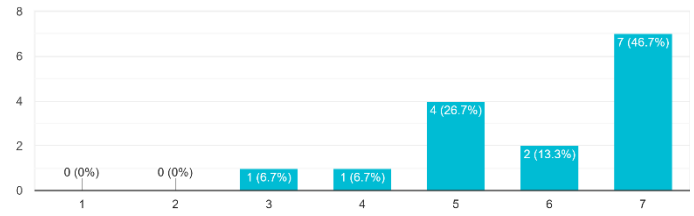
19. I did not have a strategy to win the game.

15 responses



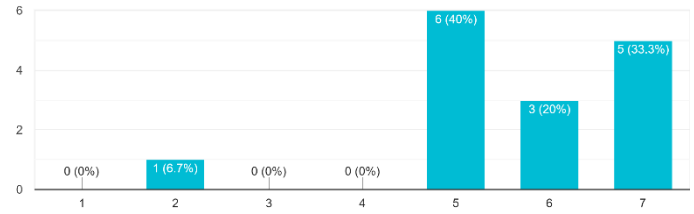
20. The game kept motivating me to keep playing

15 responses



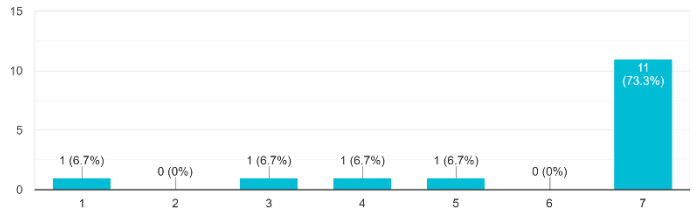
21. I felt what was happening in the game was my own doing

15 responses



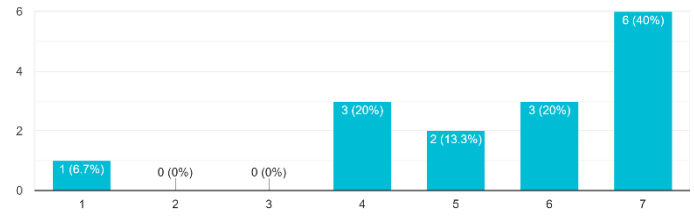
22. I challenged myself even if the game did not require it

15 responses



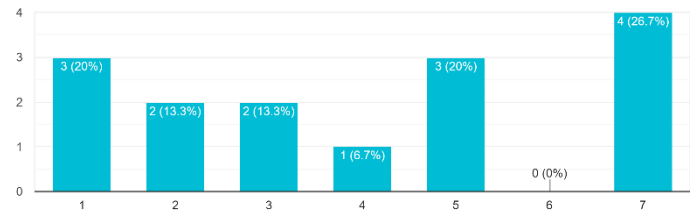
23. I played with my own rules

15 responses



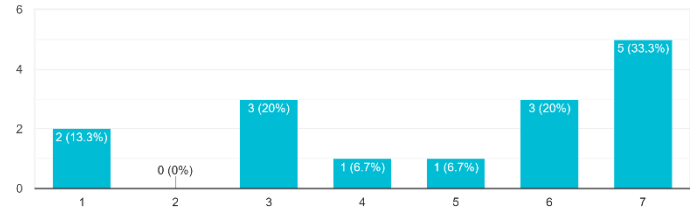
24. I felt guilty for certain actions I took in the game

15 responses



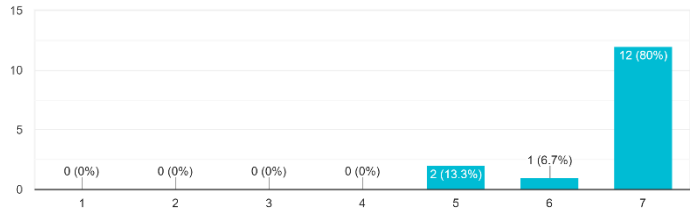
25. I knew how to manipulate the game to keep moving forward

15 responses



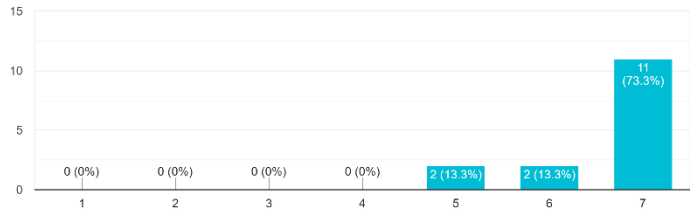
26. The graphics were appropriate for the type of game

15 responses



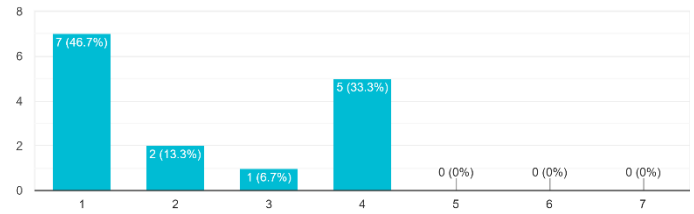
27. The sound effects of the game were appropriate

15 responses



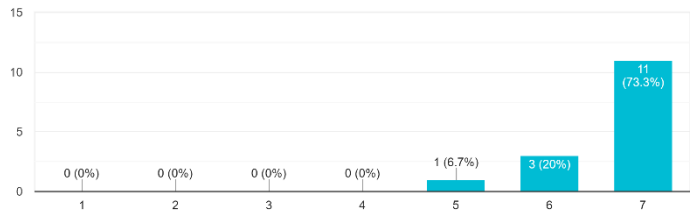
28. I did not like the music of the game

15 responses



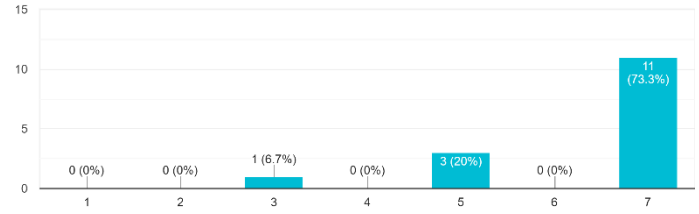
29. The graphics of the game were related to the scenario

15 responses



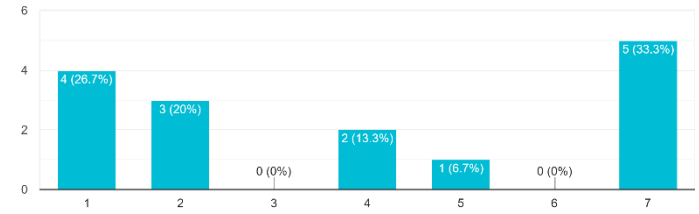
30. The graphics and sound effects of the game were related

15 responses



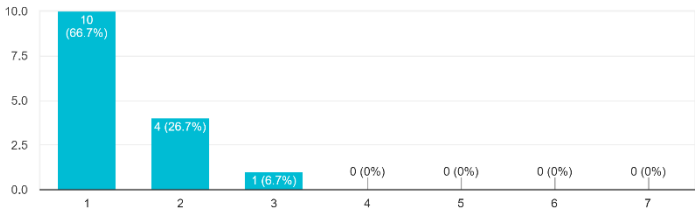
31. The sound of the game affected the way I was playing

15 responses



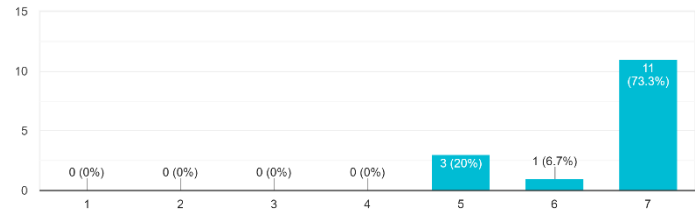
32. The game was unfair

15 responses



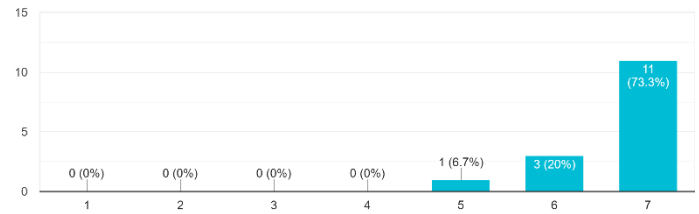
33. I understood the rules of the game

15 responses



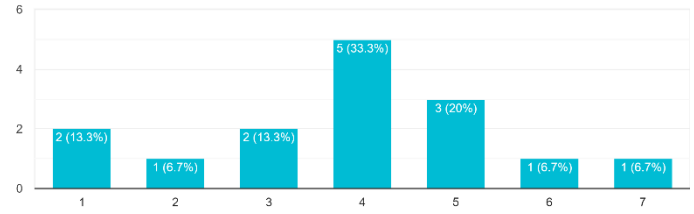
34. The game was challenging

15 responses



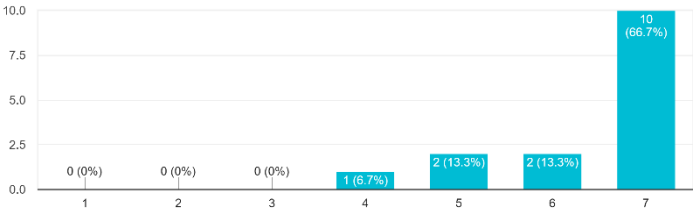
35. The game was difficult

15 responses



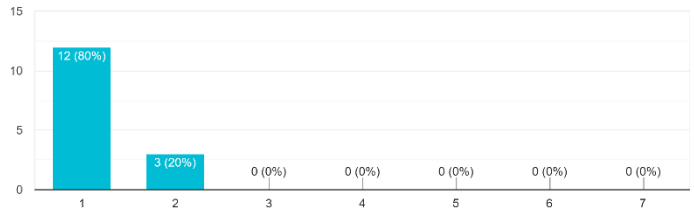
36. The scenario of the game was interesting

15 responses



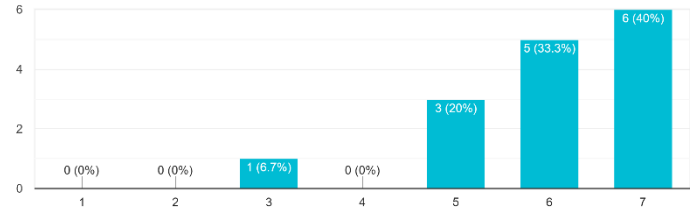
37. I did not like the scenario of the game

15 responses



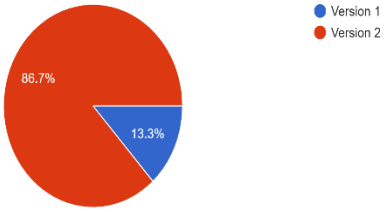
38. I knew all the actions that could be performed in the game

15 responses



While testing the Endless Runner Application, which version did you enjoy playing most?

15 responses



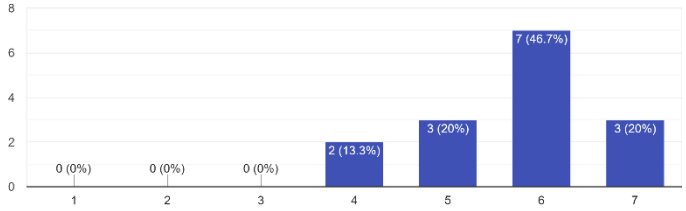
A.4.4 Post-Questionnaire Results: Level Based

A.4.4.1 Level Based: Non-Adaptive (Version 1)

Level Based Version 1 [NON-ADAPTIVE] (RESPONSES)

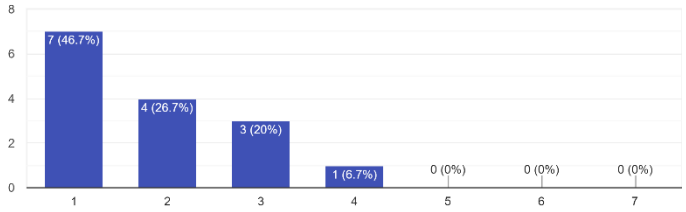
1. I enjoyed playing the game

15 responses



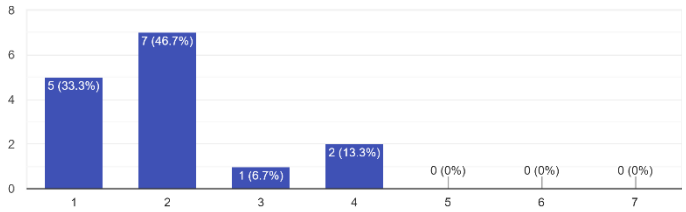
2. I was frustrated at the end of a match

15 responses



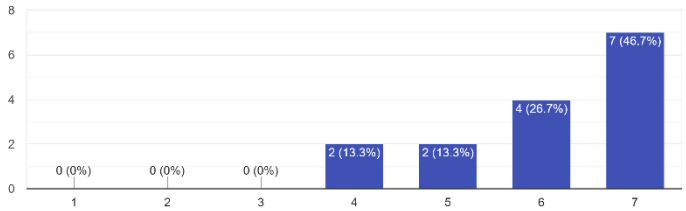
3. I was frustrated whilst playing the game

15 responses



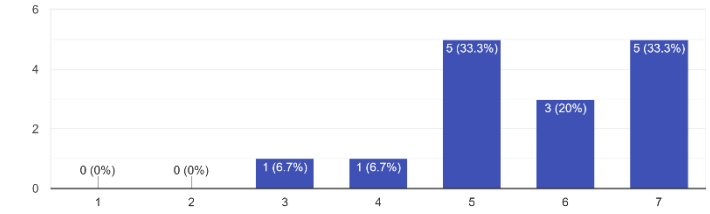
4. I liked the game

15 responses



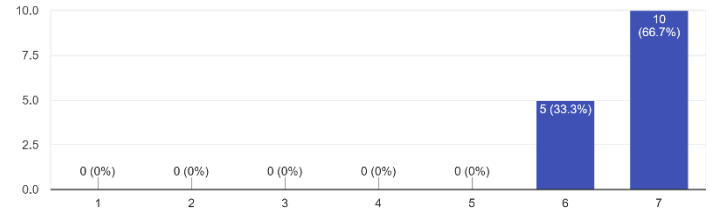
5. I would play this game again

15 responses



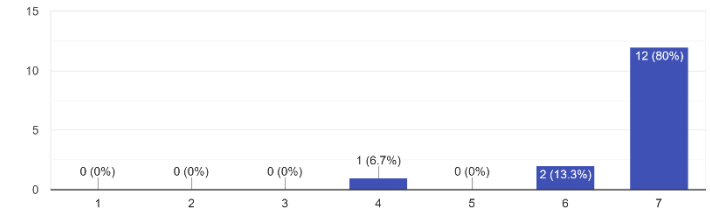
6. I was in control of the game

15 responses



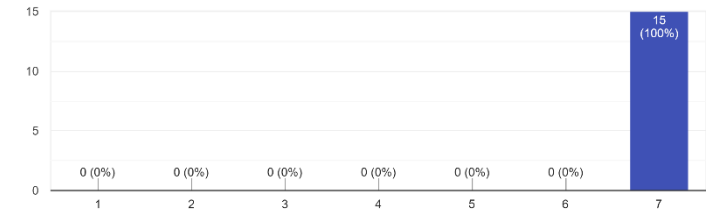
7. Application responded as expected

15 responses



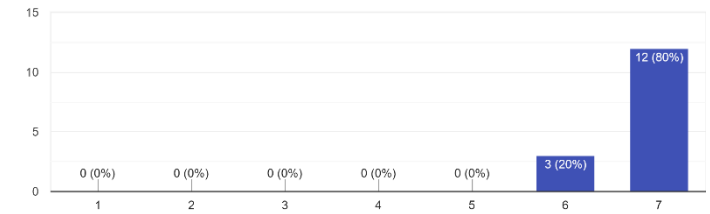
8. I remember how to control the player

15 responses



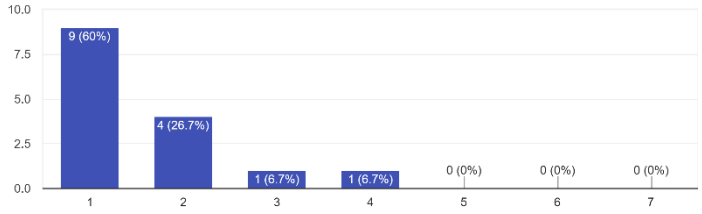
9. I was able to see on the screen everything I needed during the game

15 responses



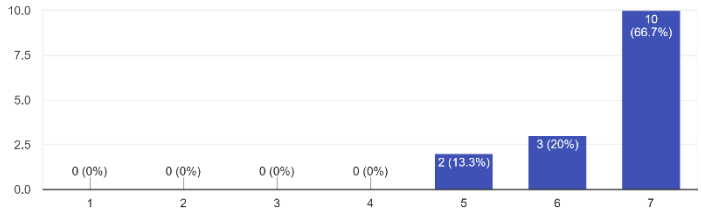
10. The opinion of the game that I had, spoiled my experience

15 responses



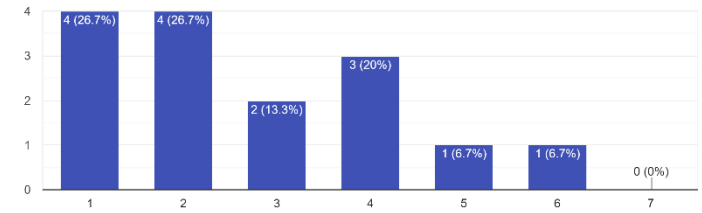
11. I knew what I was supposed to do to win the game

15 responses



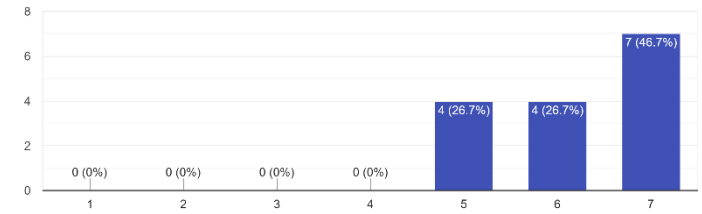
12. There was a time when I was doing nothing in the game

15 responses



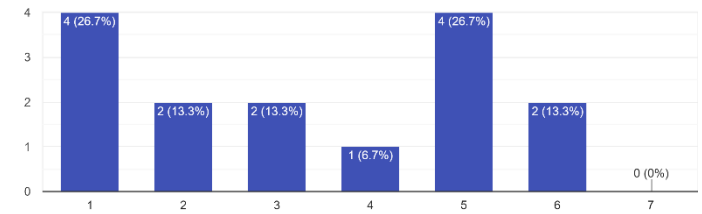
13. I liked the way that the game looked

15 responses



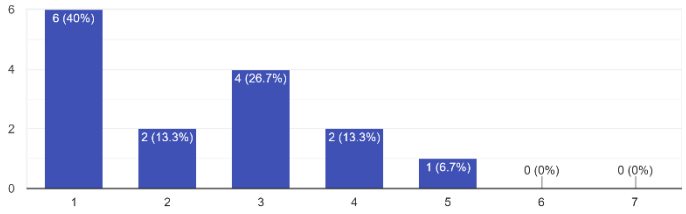
14. The graphics of the game were plain

15 responses



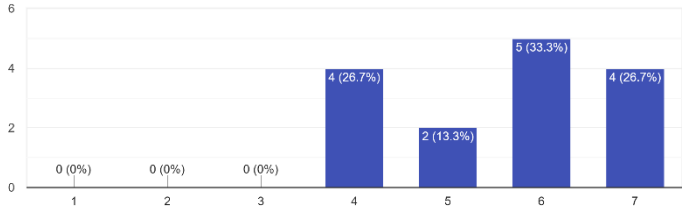
15. I do not like this type of game

15 responses



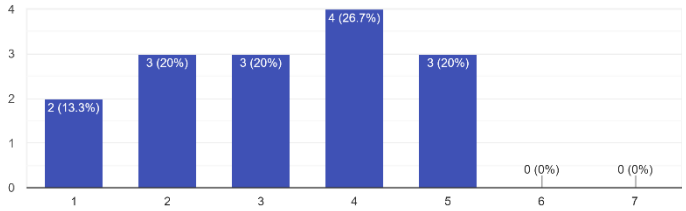
16. I liked spending time playing this game

15 responses



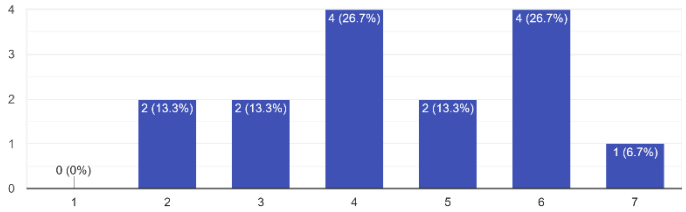
17. I got bored playing this game

15 responses



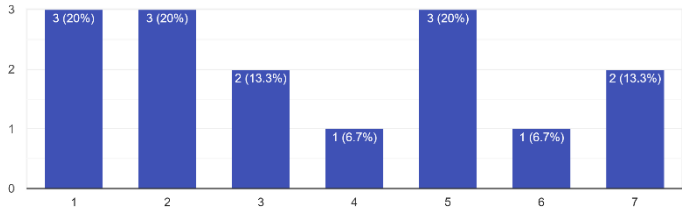
18. I usually do not choose this type of game

15 responses



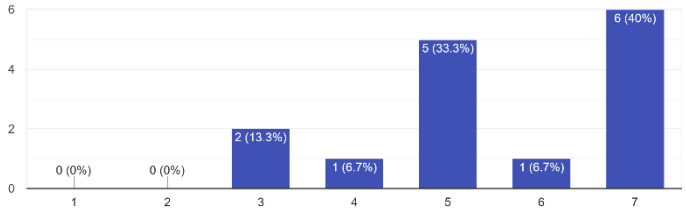
19. I did not have a strategy to win the game.

15 responses



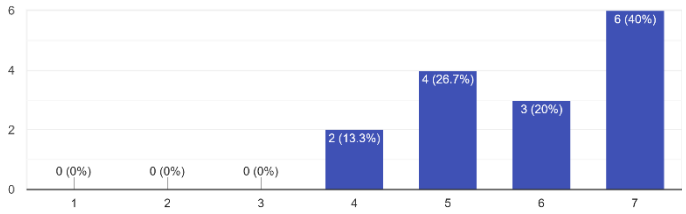
20. The game kept motivating me to keep playing

15 responses



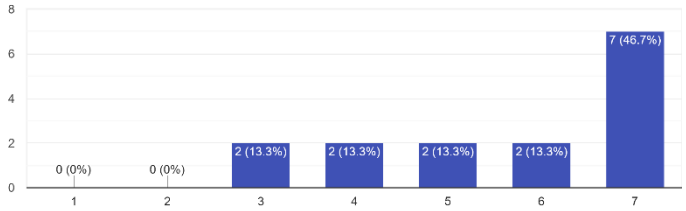
21. I felt what was happening in the game was my own doing

15 responses



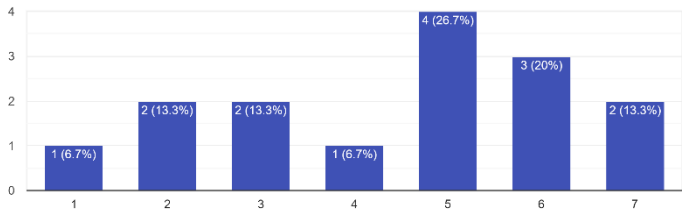
22. I challenged myself even if the game did not require it

15 responses



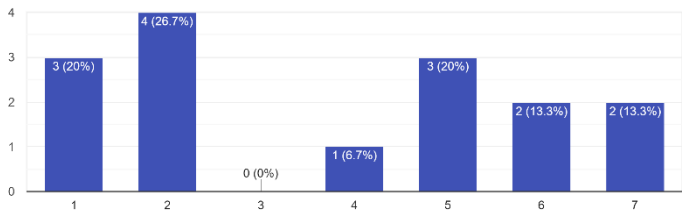
23. I played with my own rules

15 responses



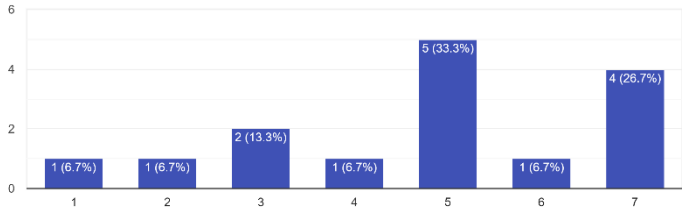
24. I felt guilty for certain actions I took in the game

15 responses



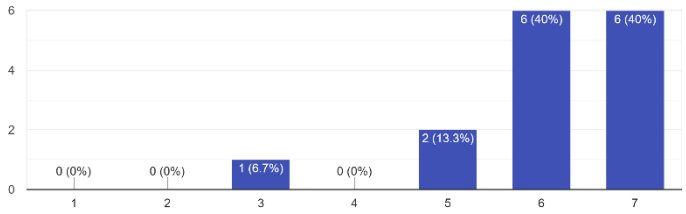
25. I knew how to manipulate the game to keep moving forward

15 responses



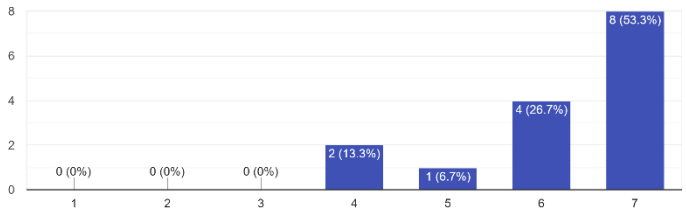
26. The graphics were appropriate for the type of game

15 responses



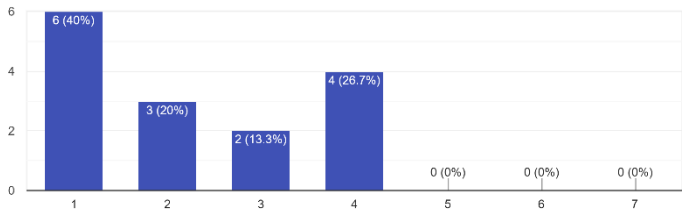
27. The sound effects of the game were appropriate

15 responses



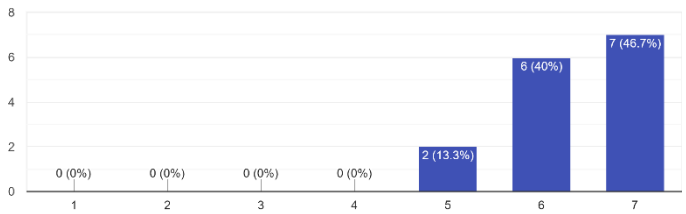
28. I did not like the music of the game

15 responses



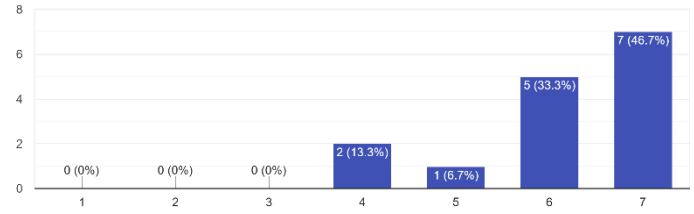
29. The graphics of the game were related to the scenario

15 responses



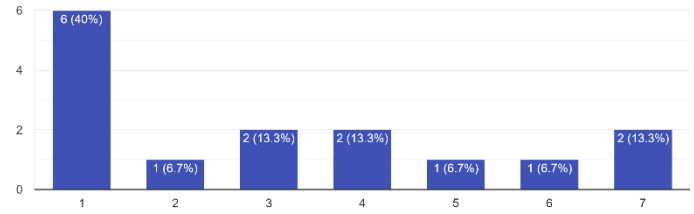
30. The graphics and sound effects of the game were related

15 responses



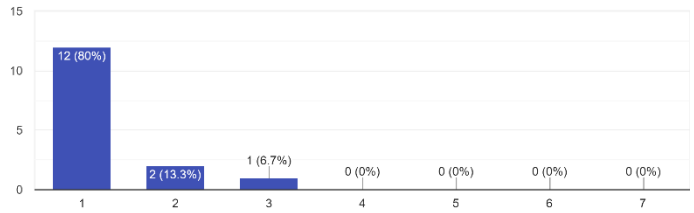
31. The sound of the game affected the way I was playing

15 responses



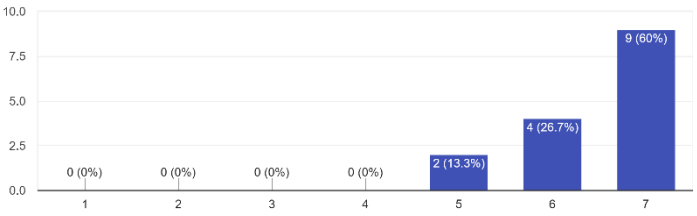
32. The game was unfair

15 responses



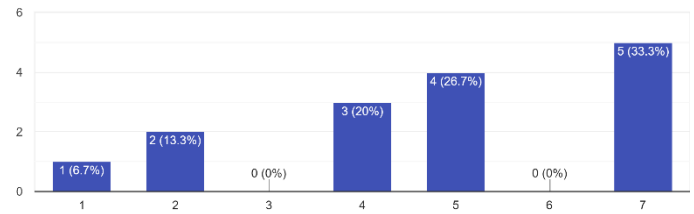
33. I understood the rules of the game

15 responses



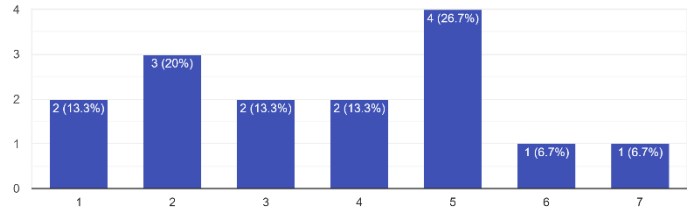
34. The game was challenging

15 responses



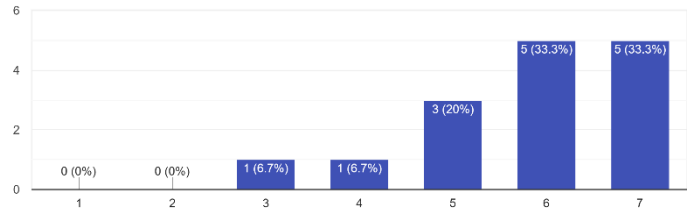
35. The game was difficult

15 responses



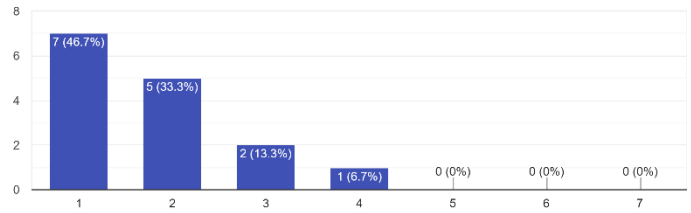
36. The scenario of the game was interesting

15 responses



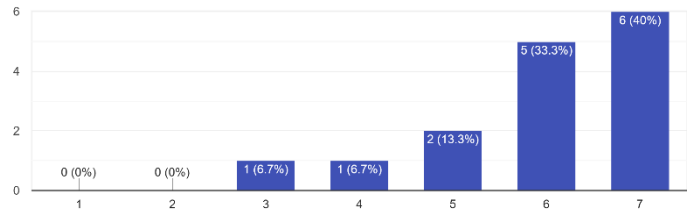
37. I did not like the scenario of the game

15 responses



38. I knew all the actions that could be performed in the game

15 responses

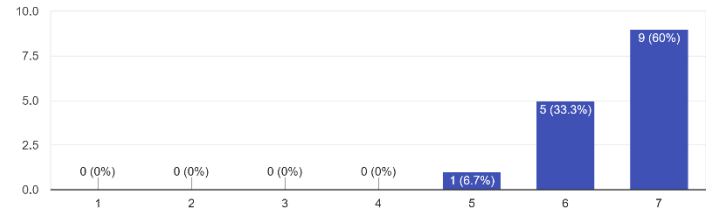


A.4.4.2 Level Based: Adaptive (Version 2)

Level Based Version 2 [ADAPTIVE] (RESPONSES)

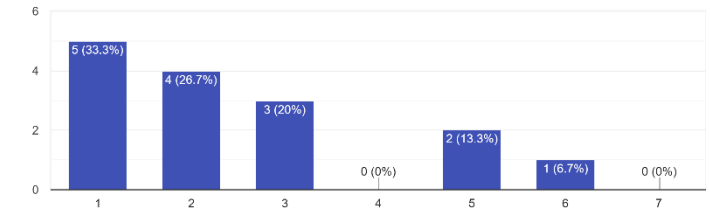
1. I enjoyed playing the game

15 responses



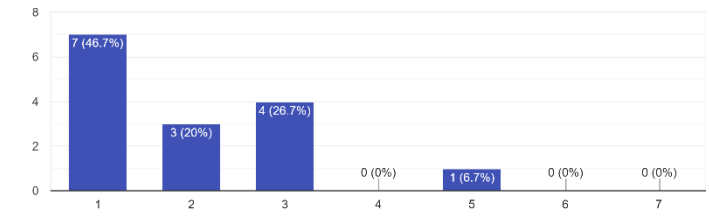
2. I was frustrated at the end of a match

15 responses



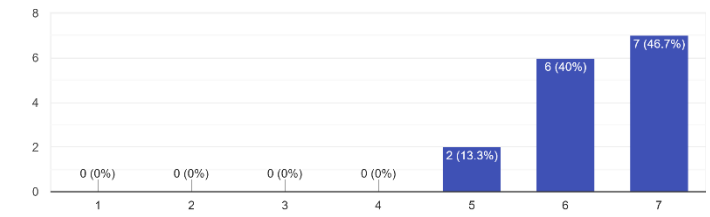
3. I was frustrated whilst playing the game

15 responses



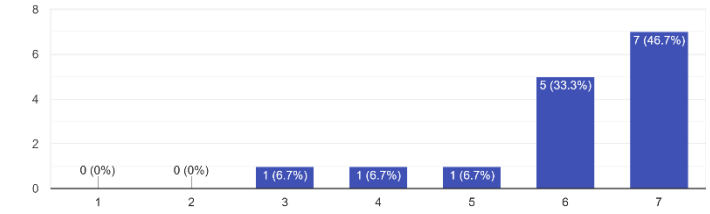
4. I liked the game

15 responses



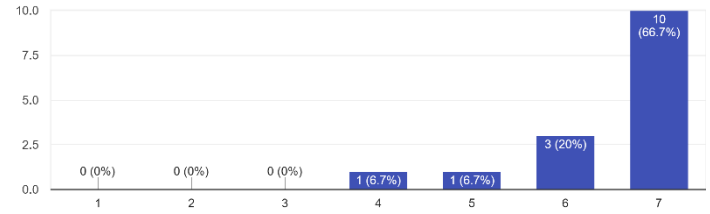
5. I would play this game again

15 responses



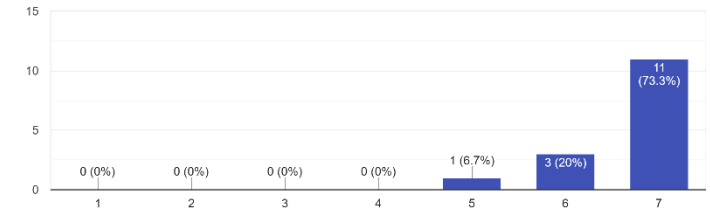
6. I was in control of the game

15 responses



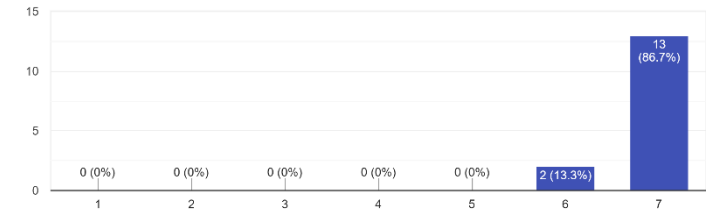
7. Application responded as expected

15 responses



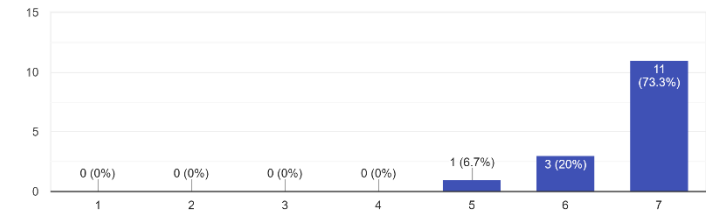
8. I remember how to control the player

15 responses



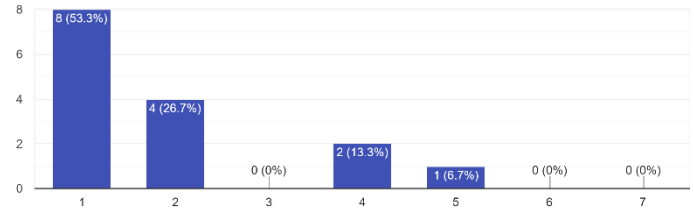
9. I was able to see on the screen everything I needed during the game

15 responses



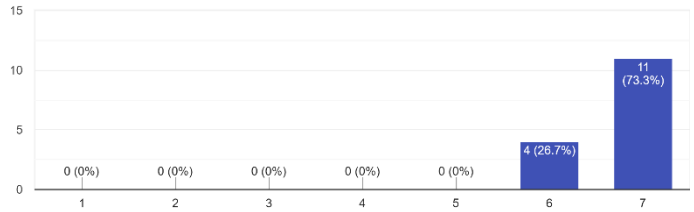
10. The opinion of the game that I had, spoiled my experience

15 responses



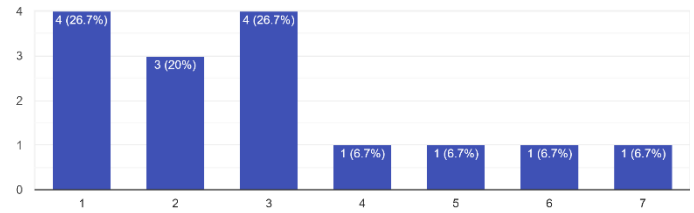
11. I knew what I was supposed to do to win the game

15 responses



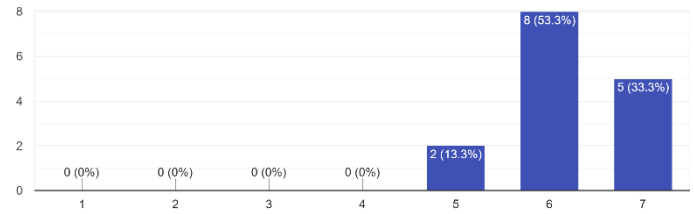
12. There was a time when I was doing nothing in the game

15 responses



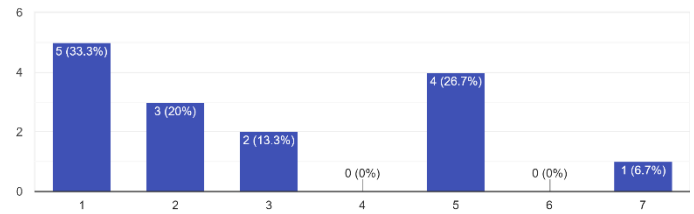
13. I liked the way that the game looked

15 responses



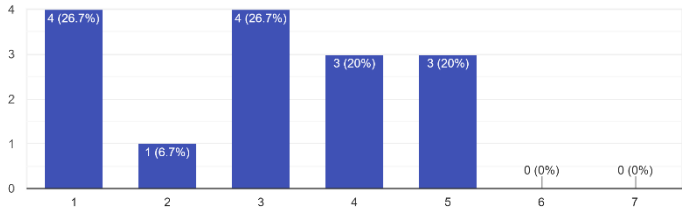
14. The graphics of the game were plain

15 responses



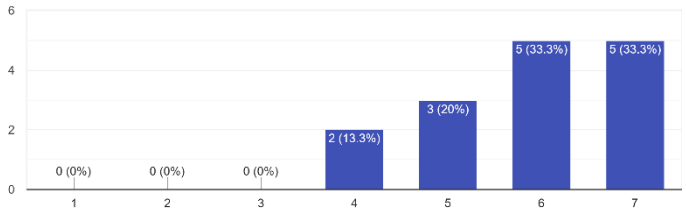
15. I do not like this type of game

15 responses



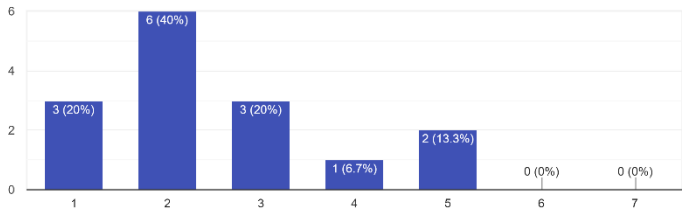
16. I liked spending time playing this game

15 responses



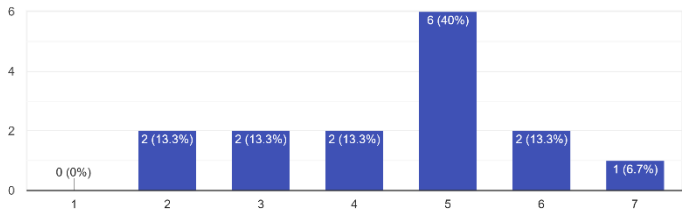
17. I got bored playing this game

15 responses



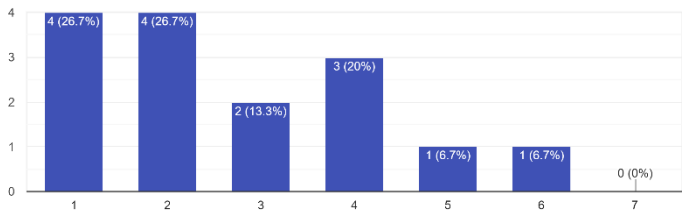
18. I usually do not choose this type of game

15 responses



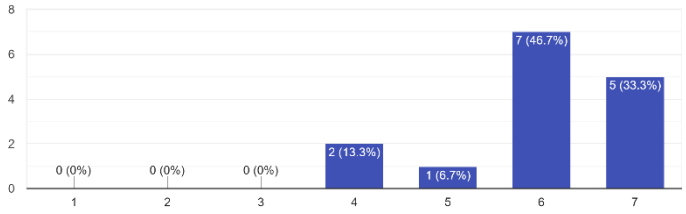
19. I did not have a strategy to win the game.

15 responses



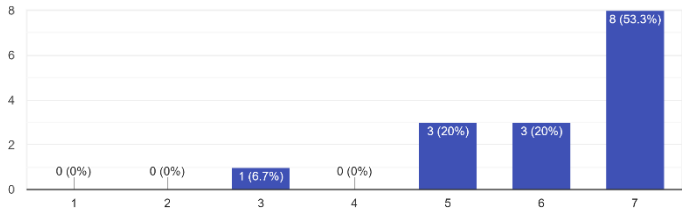
20. The game kept motivating me to keep playing

15 responses



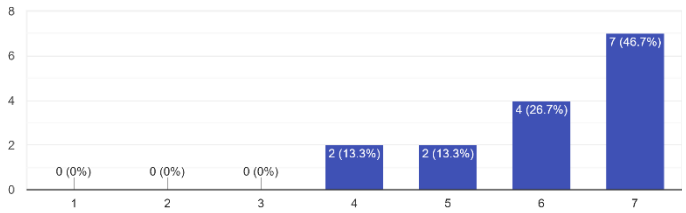
21. I felt what was happening in the game was my own doing

15 responses



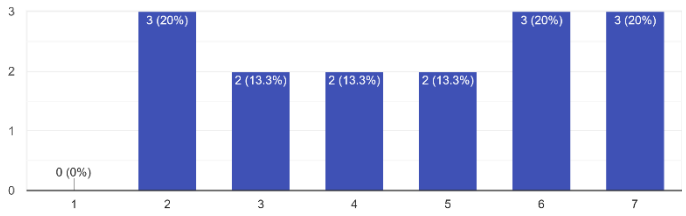
22. I challenged myself even if the game did not require it

15 responses



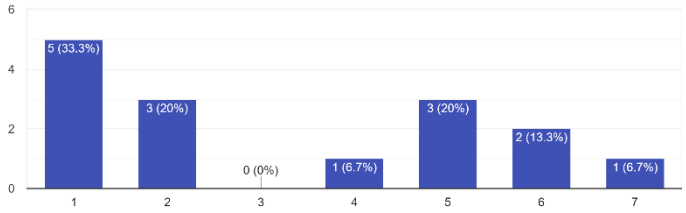
23. I played with my own rules

15 responses



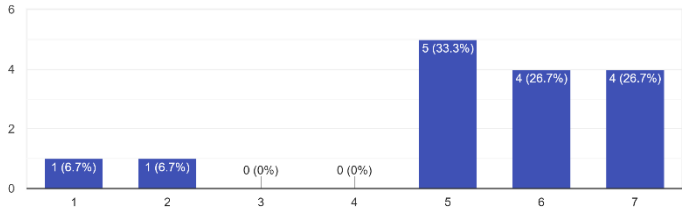
24. I felt guilty for certain actions I took in the game

15 responses



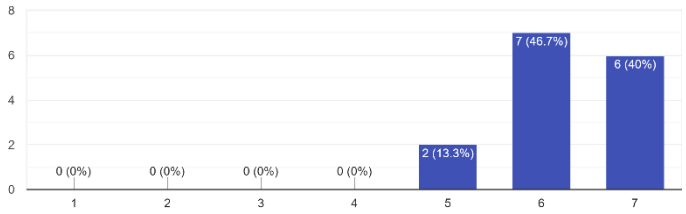
25. I knew how to manipulate the game to keep moving forward

15 responses



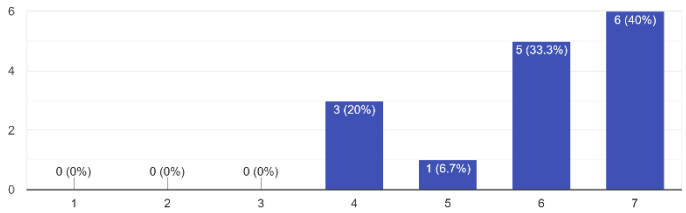
26. The graphics were appropriate for the type of game

15 responses



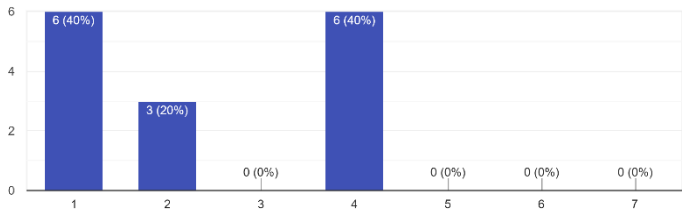
27. The sound effects of the game were appropriate

15 responses



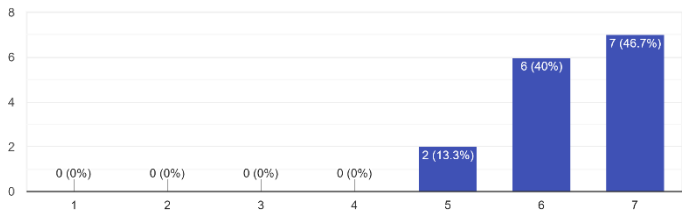
28. I did not like the music of the game

15 responses



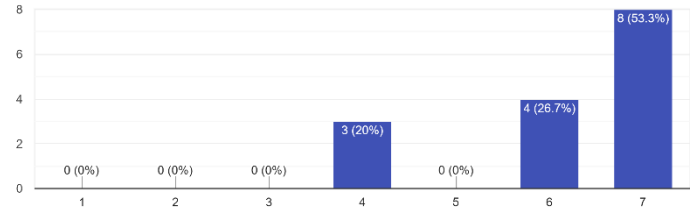
29. The graphics of the game were related to the scenario

15 responses



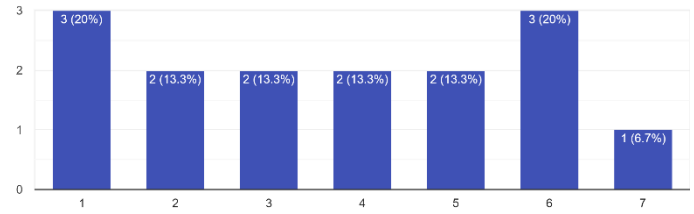
30. The graphics and sound effects of the game were related

15 responses



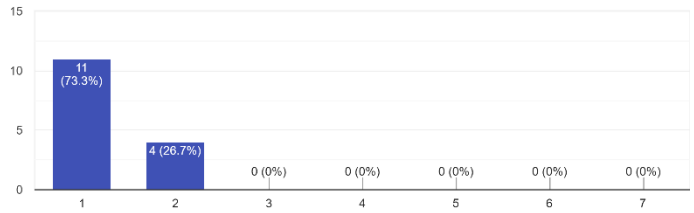
31. The sound of the game affected the way I was playing

15 responses



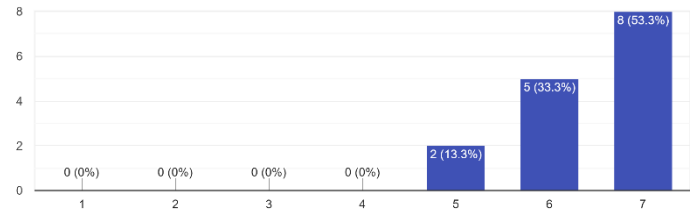
32. The game was unfair

15 responses



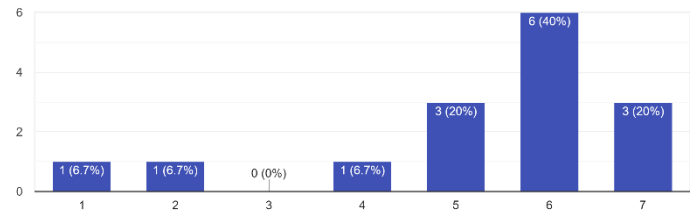
33. I understood the rules of the game

15 responses



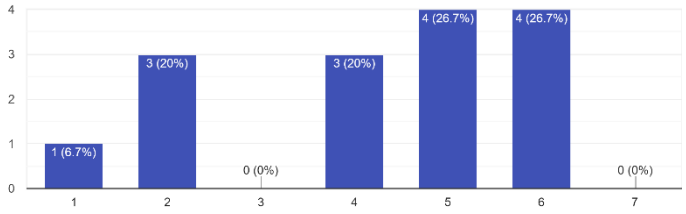
34. The game was challenging

15 responses



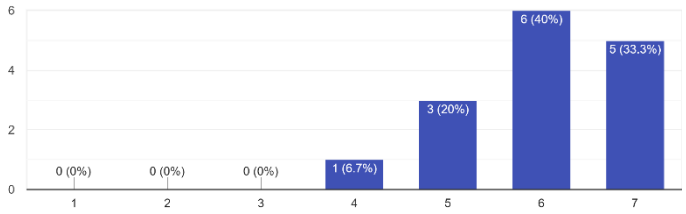
35. The game was difficult

15 responses



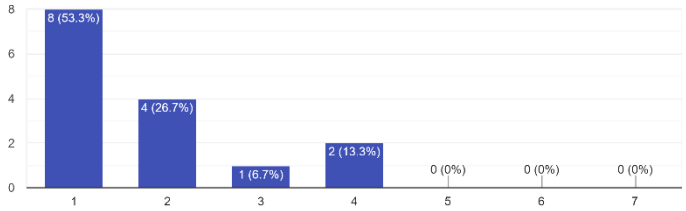
36. The scenario of the game was interesting

15 responses



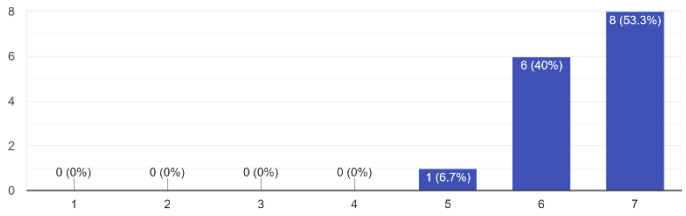
37. I did not like the scenario of the game

15 responses



38. I knew all the actions that could be performed in the game

15 responses



While testing the Level Based Application, which version did you enjoy playing most?

15 responses