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Master Thesis Artificial Intelligence

Evaluating Navigation Paths and Improving Performance in Educational Virtual Worlds

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Abstract

Virtual worlds are used more frequently for educational purposes. To make sure that these educational virtual worlds are being used in the most optimal way, it is important to know how well its users are doing and how engaged they are with the virtual world. This thesis explores the link between navigation paths and engagement and performance in an educational virtual world. Our research attempts to find a way of gauging both engagement levels and educational performance through navigational patterns. This link is found by letting users interact with a virtual world and then testing how much of the world has been remembered. The users' navigational patterns are used to provide hints to steer users through a virtual world in way that improves their performance. No links were found between engagement and navigation paths, but a link was found between improving navigational behaviour and performance. This thesis also provides avenues for further research to improve virtual worlds in learning contexts.

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Chapter 1 Introduction

A virtual world is a three-dimensional computer-simulated environment. It is populated by users and computer-simulated characters that are embodied by avatars and can interact with each other. Virtual worlds have similarities to the real world, usually in the form of physics, movement or topography that enhance the illusion of presence. This presence allows for intuitive interaction and experiential learning and can therefore be used to enhance education. A virtual world used for education is known as an educational virtual world. Educational virtual worlds have been used successfully in the past, most notably the online virtual world of Second Life [1]. According to Falloon, virtual worlds enable students to exhibit higher order thinking skills, like analysing and evaluating [2]. Educational virtual worlds can be used to make students use those higher order thinking skills. Virtual Worlds offer freedom of navigation for students to learn in their own pace, in their own way, and from a distance.

This research explores the link between navigational behaviour and performance within an educational virtual world.

The freedom of choice makes it difficult to keep students engaged at all times, they can feel overwhelmed by options and might get lost in the openness of the virtual world. This makes it difficult to assure that the learning goals are being achieved for every student.

We want to know if engagement is effected by navigational behaviour, so that engagement levels can be enhanced and thereby improve performance in learning tasks.

Moreover we want to research how navigational behaviour influences the performance of users with regard to the learning goals set within a virtual world. If there are any navigational patterns, we want to know if they can be influenced so that the performance improves. This research can improve the educational performance when using educational virtual worlds.

1.1 Research questions

Now that the research goal has been identified the research question can be defined:
How does engagement in combination with navigational patterns influence the performance in an educational virtual world?

A first question that arises is whether engagement influences performance.

Furthermore we want to know whether navigational paths can be categorized into certain types of navigational patterns. These patterns might be indicators how involved the users are in the virtual world. Recognizing certain patterns may also be used to influence navigational behaviour.

The question that then arises is whether those behaviours can predict how well the learning goals are achieved. If the behaviour is not a predictor then changing the behaviour would not have any effect on performance.

This then leads to a final question. If the performance can be predicted by navigational behaviour, will the improvement of navigational behaviours also improve performance?

The preceding three points make it so that the main research question can be divided up into three sub-questions, namely:

- Does engagement influence performance in an educational virtual world?
- Can educational performance be predicted based on navigational patterns in a virtual world?
- Can altering of navigational patterns improve educational performance?

1.2 Outline

This thesis will attempt to answer the research questions and the sub-questions that are defined previously. To this end, an overview of the literature is given in chapter 2. This overview will expand on the notions of engagement that are used within the thesis. The notions are engagement with relation to virtual worlds and engagement related to studies. Furthermore, chapter 2 will expand on previous research into navigational patterns and methods for improving navigational patterns.

Having an overview of previous research and definitions, the initial study is explained in chapter 3. This initial study let students interact with a virtual world and answers the first two sub-questions. In section 3.1 the methodology is given, how the study was conducted and set up. Afterwards, in sections 3.2 and 3.3 the results are given for a pilot and full study. In section 3.4 the results are discussed and connected to the first two sub-questions.

A second study that is based on the first study is given in chapter 4. Similar to the previous chapter it is broken up into methodology, followed by results and discussion. This chapter will answer the third sub-question.

Finally, in chapter 5 the research question will be answered, the thesis will be concluded and further work will be discussed.

Chapter 2 Literature Review

This chapter reviews the literature that is related to answering the main research question of the paper. The important terms related to this research are explained in this chapter.
In section 2.1 two notions of engagement are given and expanded upon. Additionally, methods used in existing research that measure different facets of engagement are discussed.
The relation between engagement and educational virtual worlds is examined in section 2.2. This section explores the advantages and disadvantages of using virtual worlds for education.
In section 2.3 an overview of how navigation paths are evaluated in previous studies is given. Finally, in section 2.4 we summarize the literature review.

2.1 Engagement

In the two studies in this thesis there are two distinct notions of engagement that are relevant. The first notion is *player engagement,* the engagement that a player has with a (video) game. The other notion is school engagement, which has to do with how much students are engaged with their studies.

2.1.1 Player Engagement

Schoenau-Fog (2011) [3] describes engagement of a player as the desire to keep playing. The reasons a player starts playing is known as the motivation, and is not part of the player's engagement [4]. Player engagement, however, are the reasons the player continues playing.

Many studies have been done into a players desire to keep playing. It has been linked to concepts of the game or virtual environment like flow [5, 6], and to the experiences of the player such as immersion [7, 8], pleasure [9], enjoyment [10, 11].

Immersion is a state of players where their attention is focused on the game [8]. When a player is engaged they become immersed and when they are immersed they lose awareness of their surroundings.

Vorderer et al. [10] associate engagement with enjoyment, and investigates the reasons players have for begin playing, keep playing and returning to play games. They propose a model that attempts to explain the process of enjoyment. The model consists of a sequence of situations where each situation features: possibilities to act, a necessity to act, and the player's attempt to resolve the necessity to act by applying the possibilities to act. The result of the player's action influences the enjoyment felt by the player.

Brockmyer et al. [12] view engagement as a more generic indicator of game enjoyment consisting of many different aspects. They propose a model that takes into account immersion, presence, flow, and absorption. Based on this model Brockmyer et al. have developed a questionnaire that measures these aspects, named the Game Engagement Questionnaire [12].

There have been studies to try and device methods of increasing the engagement in virtual environments. Avatars, virtual representations of characters, have been shown to enhance engagement in educational games [13]. Similarly, more social interaction during games leads to more engagement [14, 15].

In the context of virtual worlds used for education, there is more to engagement than just enjoyment and immersion. The goal of the educational virtual world is to have the player gain a skill or learn some information and not just to enjoy the experience.

2.1.2 School Engagement

In addition to player engagement there is a different type of engagement that is relevant to this study is the engagement that people have towards their education. School engagement is a concept that

attempts to capture the involvement that students have in their studies [16]. School engagement is a multifaceted concept that, according to Fredricks et al., can be split up into three subtypes [16]. The three subtypes are behavioural-, cognitive-, and emotional engagement. Behavioural engagement aspects refer to actions that students take in relation to their studies, the cognitive aspect is the willingness of the student to put in the effort to comprehend ideas and master skills, and finally emotional engagement aspects relate to the positive or negative emotional reactions the student has towards teachers, classmates, and school [16].

Appleton et al. [17] draw upon the existing notions of school engagement and redefine the concept into four subtypes. The four subtypes of school engagement according to Appleton et al. are: academic, behavioural, cognitive, and psychological. Academic engagement entails the academic achievements of a student, whereas behavioural engagement are things like class attendance and voluntary participation in the classroom [17]. Cognitive and psychological engagement are more subtle and internal indicators. Examples of psychological engagement are belonging and identification with school. Psychological engagement is related to emotional engagement described above and has to do with feelings of belonging at a school and relationships with teachers. Cognitive engagement relates to the student's view of themselves with relation to their education, for example their self-regulation and personal goals. [17].

Behavioural and academic engagement factors are independently observable, attendance and grades can be used as measurements to gauge a student's behavioural and academic engagement. Moreover, research has shown that cognitive and psychological engagement have a positive impact on academic achievements [18, 19]. Appleton et al. have devised the Student Engagement Instrument (SEI) that measures the psychological and cognitive subtypes of engagement [17]. The SEI is a questionnaire consisting of 33 questions that has been empirically verified [17, 20].

2.2 Educational Virtual Worlds (EVW)

A virtual world is a simulation of real or imagined events and is usually represented in 3-D space [21]. Virtual worlds come in many different forms and can serve many different functions. Virtual worlds have been used in entertainment, such as the well-known game *World of* Warcraft. The online virtual world *Second Life* is a virtual world that has an emphasis on social interaction. In a review of existing literature on the usage of virtual worlds by Duncan et al. [21] it was found that Second Life has often been used for education [1, 22]. An Educational Virtual World, as defined in this paper, is a virtual world that has an educational purpose. The user needs to learn something as a result of interacting with the EVW.

Advantages of using a virtual world for education is that an EVW is an intuitive approach in terms of interaction [21]. Baker et al. state that virtual worlds have the potential for school engagement [1]. EVWs are made to be similar to (part of) the real world, making it easier for someone to interact with the virtual world. Through this similarity, EVWs also lend themselves to experimental learning. Falloon [2] examined thinking skills that students exhibit when using virtual worlds. Falloon states that students exhibited higher order thinking skills, like analysing and evaluating, while using a virtual world [2]. Higher order thinking skills are the type of skills that are used for experimental learning, meaning that EVWs lend themselves for teaching those types of skills [21].

Virtual worlds are not perfect as education tools. Students can find it harder to concentrate, some virtual worlds have extra functionality which distracts the attention of participants [21, 23]. Extra functionality can also be too overwhelming and unguided for students, in which case it is possible that students are not able to get a meaningful experience from the interaction [24].

2.3 Navigation Paths

There have been numerous studies that provide methods of evaluation of navigation paths. The work of Ruddle and Lessels (2006) [25] specifies three levels of metrics for evaluating wayfinding tasks that are used in other studies involving navigational tasks in virtual worlds. In their research Ruddle and Lessels analyse a number of studies that evaluated various wayfinding tasks and create a framework from the metrics successfully used in those studies. They propose using three distinct levels of metrics to evaluate wayfinding; task performance, physical behaviour, and cognitive rationale [25].

The first level, task performance, is the most commonly used method of evaluating wayfinding [25]. The general method of measuring task performance is to take one measure that broadly corresponds to a users' performance of a task as a basis for statistical analysis. Examples of task performance metrics are time taken to complete a task, or distance travelled. There is a risk in using task performance metrics, because some proposed metrics may not be applicable to every study at hand. There may for example be a task where the user is better off taking time to plan their path instead of naively searching the environment.

Darken & Sibert (1996) [26] used task performance metrics in their research. Their study evaluated the performance of a wayfinding task where a user needed to find a target within a virtual world without any a priori knowledge, and then find their way back to the start. They used the time taken for each of the searches as a metric for the performance of the task. Darken & Sibert used the metric to evaluate the usefulness of navigational aids, namely a grid and a map, and found that participants without navigational aids spent more time on their task [26].

The second level, physical behaviour, is a set of metrics that relate to the physical actions of the user both in the virtual environment, and the real world. Part of the physical action level are observation metrics, which are measurements that are collected by observation by an examiner. This method records the user's real-world actions and relates them to their actions within the virtual environment. Gamberini et al. [27] use this method in their research to collect all real world physical and verbal actions and combine them with events within the virtual environment. The collected data could then be used to analyse both quantitatively and qualitatively.
Another method is time classification which takes the proportion of time spent doing different types of actions. Time classification metrics can be used to gain a different perspective on data [27]. For example, Sas et al. [28] suggest that travelling in shorter segments in a virtual environment leads to more efficient navigation.

Locomotion is an aspect of navigational behaviour that is difficult to develop metrics for, because the metrics need to combine movements of different users meaningfully or find a way of identifying patterns in the users' movements that don't seem to be following a similar pattern [25]. For this reason many different metrics have been devised and used in research. One metric is the amount of times each part of an environment is visited. If the virtual environment is shaped like a graph or road network, then the amount of time each vertex has been visited can be counted. Researchers have used the cumulative amount that each part of the environment has been visited as a metric [29]. Other researchers express the users' locomotion as the percentage of the environment that was visited more than a given number of times [30]. If the environment is not structured as a graph, but rather has an open structure, then the environment can be divided into zones. Then the amount of times each zone has been visited can be counted [26].

Locomotion can also be expressed as a series of separate events [25]. The events can be grouped and analysed. An example of such a metric is amount of rotations made where the rotation angle is bigger than 90° [28]. Another way in which information about the navigational paths can be expressed is in

plan views. Plan views are images where the whole path of a user is overlaid on a map of the environment. Paths of users can be combined to highlight commonalities in the paths [29] or users can be separated into categories and a plan view can be made for each of those categories [6].
Finally the path information can be expressed in terms of macro or micro heuristics. Macro heuristics are characterizations of the users' movement through the environment as a whole. Macro heuristics that have been used include: perimeter search, in which the users search through an environment by navigating along the perimeter of the environment [26]; or a lawnmower type search, which is when a user travels through the environment in long straight strips like a lawnmower [30]. Macro heuristics are assessed subjectively and therefore it is possible that they are loosely defined, instead of objectively [25]. Micro heuristics focus on smaller patterns within a navigation path. Commonly used micro heuristics are backtracking across previously visited paths and traveling in circles or loops [29, 30].

The last level, cognitive rationale, attempts to gain insight into the users' reasons for making their decision during wayfinding tasks. The most commonly used way to get this insight is to make users think out loud during the performance of their task [25-27]. Another way of gauging the cognitive rationale are post-task interviews and questionnaires. The thinking aloud method can give deeper insight during navigation, but risk that the task of thinking aloud impedes the wayfinding task. Post-navigation techniques do not run the risk of impeding the wayfinding task, but require the user to accurately remember their task afterwards. Both during- and post-navigation methods rely on the user being aware of the reason they make wayfinding decisions.

2.4 Summary

A player can experience engagement with a game in the form of a desire to keep playing. A player who is immersed and enjoying the experience within a game is more likely to be engaged and therefore more likely to keep playing [12]. If an EVW is able to keep the players engaged with it, it is more likely to achieve its educational goals. Virtual worlds can aid in education because they can be designed to be analogous to the real world which lends them to experiential learning. Students using EVWs exhibit higher order thinking skills [1, 2].

A different notion of engagement is school engagement, related to the involvement of a student with their education. School engagement can be broken up into four subcategories. The four subtypes of school engagement according to Appleton et al. are: academic, behavioural, cognitive, and psychological. The Student Engagement Instrument or (SEI) is a questionnaire that measures these four subcategories [17].

Navigational paths are commonly evaluated using different metrics. Metrics that are used might be on a micro-level, or on a macro-level over the whole navigation path taken. Attempts to gain insight in the rationale behind a navigational pattern or strategy can be done in the form of questionnaires or letting people talk out loud. A more low-level approach can also be taken by looking into the actions a user takes, how many times they take them and how much time there is in between them.

Chapter 3 Study 1: Navigational Paths

The first study that has been run was designed to investigate the nature of navigational patterns in educational virtual worlds in relation to memory performance and engagement. The goal of the study was to find navigational patterns that might be present in an educational virtual world scenario. Another goal was to find the relation between navigational patterns and educational performance. These patterns could then be used to try to improve the educational performance of the educational virtual world in the second study.

This chapter describes the methodology used in the first study in section 3.1. The study was split up into two parts: an initial pilot study and a full study. The results of the pilot study and the full study are discussed in sections 3.2 and 3.3 respectively. In section 3.4 the results of both studies are discussed.

The study was conducted at Macquarie University in Sydney Australia. Ethics approval of the study was given by Macquarie University's Human Research Ethics Committee.

3.1 Methodology

To find the link between navigational paths and engagement the following design was conceived to investigate if a link could be found. To be able to answer the raised research questions it was necessary to obtain the navigational data from using an educational virtual world. The educational virtual world used in the study is called Omosa, and has been developed at Macquarie University for teaching biology and science inquiry concepts.

The goal of the experiment was to find out navigational behaviour of the participants was linked to the performance of them in the virtual world. Those navigational behaviours could then further be used to investigate performance behaviour. Another goal was to explore how much influence student engagement has on the memory performance, which leads to Hypothesis 1.

Hypothesis 1: More engagement leads to a better performance in the questionnaires.

In the EVW the participants found out pieces of information from conversations with various characters. As a measure of memory performance and player engagement with the EVW, the participants were asked questions about the facts that were found in the virtual world. School engagement was measured with the Student Engagement Instrument (SEI) by Appleton et al. [17].

For ease of recruitment and to be able to have the most participants participate in the study, the study was designed to run online on most computers. Participants were recruited through a pool of psychology students at Macquarie University. The students in the participant pool were first year psychology students aged 17 to 40. The average age of the participants was 20. Through the participant pool the participants could access the study online. The website was hosted on the Qualtrics website, which is a website on which surveys can be created [31].

The EVW used in this study is called Omosa and is a fictitious island, where one is able to move around in the world, as well as teleport to any point on the island using a map of the island. See Figure 1 for a screenshot of the map of the world.

Figure 1: Map of Omosa

The island has 6 virtual characters on it, participants can engage in conversation with the characters, who give them facts about the island and the whereabouts of other characters. The conversations are in the form of multiple choices for the participant. A number of conversation options are given to the participants, one of which ends the conversation, the other options have one response from the virtual character after which the original choices appear again. At the start of the interaction with the virtual environment, the participants were given instruction how to play the game through dialogue with the first character they meet.

The goal for participants was to find out the facts about the virtual world, and answer the questions about the island in the questionnaire. Participants were not forced to follow the path suggested by the characters and could move anywhere in the world, and talk to the characters in any order.

Omosa was originally created at Macquarie University. For the EVW to fit in this study, it had to be adapted. Because the study was designed to run online the environment had to be upgraded. Originally, Omosa has been programmed in Unity 4. To run the program online it had to be upgraded to Unity 5. In Unity 5 it is possible to build the Omosa project for running on WebGL. WebGL is a JavaScript API for rendering 3D graphics within a web browser, and is compatible with most modern web browsers [32]. Using this method made it possible to have participants complete the study online on their own computers. In terms of content, Omosa had to be changed as well. The existing conversations were made for another unrelated study, and were not fit for the study at hand. For the purposes of our own

study it was necessary that there was not an excessive amount of information in the conversations. The participants needed to remember the most information and not be overloaded with it. Additionally, the questionnaire about the EVW needed to cover most of the information to reliably relay the amount of information that the participants remembered. Therefore the dialogue trees were simplified and largely rewritten to contain clearer information and cull a lot of unnecessary information so that the participants were not hindered in their abilities to remember the information. The new conversations let each character suggest which character to go to next. The suggested path from each character to the next formed an optimal way to go through the virtual world.

Following informed consent, the procedure took around 30 minutes and consisted of 5 parts:

A: Demographic Questionnaire (1 min.)
B: Interaction with EVW (10 min.)
C: EVW Questionnaire (10 questions - 5 min.)
D: Ten-Item Personality Inventory (TIPI) (10 questions - 5 min.)
E: Student Engagement Instrument (SEI) (33 questions - 10 min.)

Part A, the demographic questionnaire, asks participants to give their gender, cultural group, age, and how many hours they play computer games per week. This part of the survey is done to be aware of possible confounding factors. The expectation was that especially the amount of video games played could impact the performance of the participants, because the virtual world that was used follows some standard practices of 3D computer games, like for example the controls of the game.

The educational virtual world described previously was used in part B of the study. The navigation data of the participants was logged during interaction by collecting their position every second. Each of these data points can then be combined into a full navigation path of that participant. The navigation data were recorded at regular intervals so that not only the paths were captured, but also the time how long the participant was standing still. The conversations that participants have with virtual characters were logged as well, to allow further insight in the behaviour of the participants.

In part C, the ten questions are based on the conversations with the character, and the location of characters. One example of a question is, “What do the villagers usually eat?” The answer to this question can be gotten from one of the villagers. Since the island is fully fictitious there is no chance that participants were able to infer the answer to questions without seeing the conversations in the virtual world. The questionnaire was made using Qualtrics, which is a web site on which surveys can be created. The virtual world is embedded within the survey to let participants complete the survey without the need to leave the survey website. The full set of questions can be found in Appendix A.3.

In Part D participants answered the Ten Item Personality Instrument (TIPI). TIPI is a questionnaire consisting of 10 questions. TIPI allows for a quick measurement of the Big-Five personality dimensions, extraversion, agreeableness, conscientiousness, emotional stability, and openness to experiences [33]. The instrument was included in case the participant’s personality influences the likelihood of being engaged with the virtual world. The full set of questions can be found in Appendix A.2.

The student engagement instrument (SEI) by Appleton et al. [17] is the last part of the study (Part E). The SEI has been used to investigate if the SEI score and navigational patterns were related to each other, as described in chapter 2. The original SEI was intended to use on students in middle school, because this study is intended for university students the questions have been reworded to be more applicable for them. The full set of questions can be found in Appendix A.1.

3.2 Pilot Study Results

There were 12 participants in total in the study, the participants were all psychology students with ages ranging from 19 to 39 with a mean of 23 years.

To summarize the data for analysis, we divided and categorised the participants into groups according to how many answers they got correct. Divided into a group with 1 to 3, 4 to 6, and 7 to 10 correct answers named low-, middle-, and high-scoring groups respectively. There were 3 people in the low scoring group, 6 in the middle scoring group, and 3 in the high scoring group.

The navigation paths of the low-scoring group participants have in common that none of them have fully explored the world, only meeting part of the characters that conveyed the information needed to answer the questions.

The participants in the middle- and high-scoring groups visited most or all of the characters in the world, which means that most of the information needed for the questionnaire was given to them.

The optimal path is the path that is suggested by the characters in the virtual world, as explained in the previous section. If the participants exactly follow the instructions of the characters, the optimal path is the path that they will travel. When the navigation paths of the participants are layered over this suggested path, in a plan view, it is seen that the high scoring group is the closest to the suggested path than the other two groups (Figure 2). When we look at the amount of time the participants spent near one of the virtual characters we see similarly that those who spent more time near the characters have a higher score. On average the low-scoring group had 28 data points near character, against 51, and 89 for the middle- and high-scoring group respectively. In Figure 2, it is seen that one participant walked along the bottom of the map, which is not on the black optimal path. However, this participant still did navigate to, and converse with all characters.

Looking at the number of teleports the participants made using the map there is no clear connection between the number of teleports and performance in the questions. Every group had at least one participant that teleported twelve or more times. The teleporting participant in every group had the lowest score of that particular group, so a high usage of the teleport function might be an indication of a lower score.

We wanted to find out if the participants backtracked through the environment. To accomplish this the environment was divided into zones where each location in the environment had its own zone. This method is based on the metrics defined by Ruddle and Lessels [25]. A path is marked as backtracking when a zone is left and re-entered at any point during navigation.

In terms of backtracking and circling of participants there were no observed patterns in the data. No particular group of participants behaved differently in terms of navigational patterns to the other groups.

The TIPI questionnaire did not show any relation between personality and engagement, or personality and performance in the EVW.

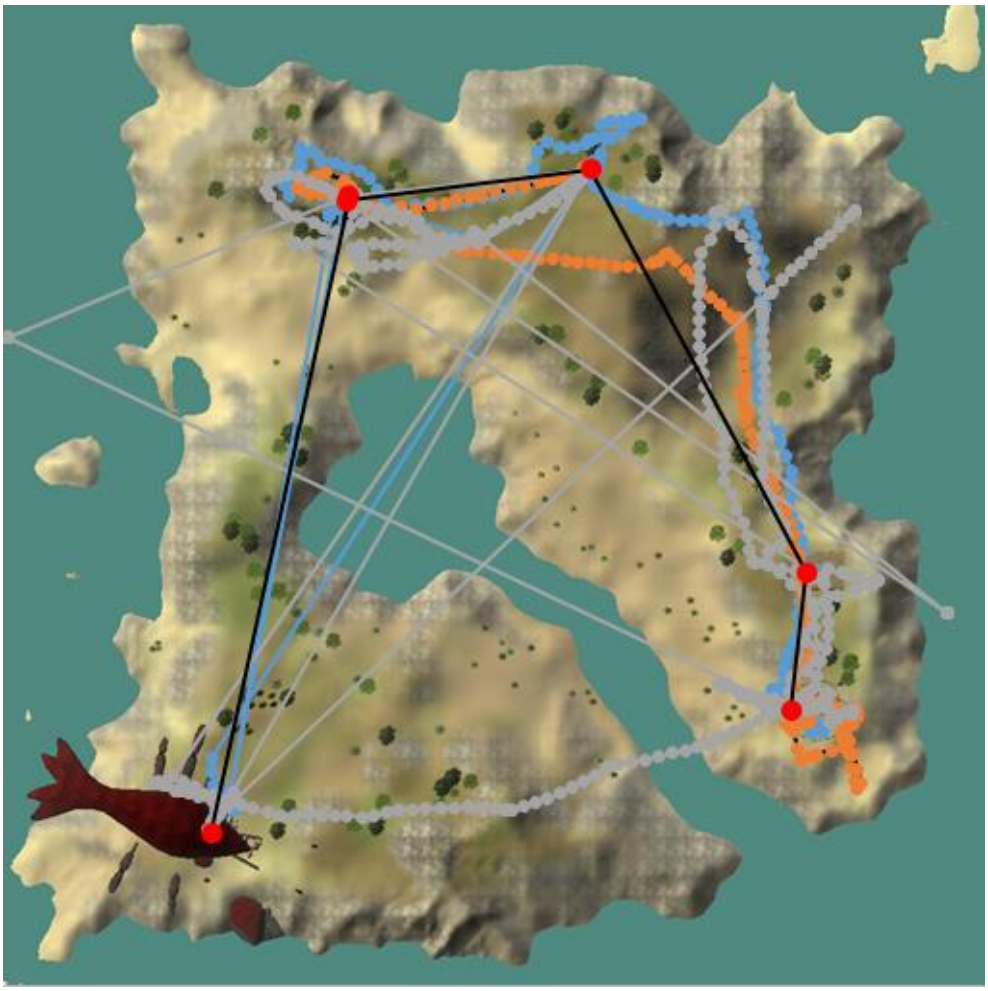

Figure 2: Navigation Paths for the High Scoring Group

Participants	Answers Correct	SEI score
3	**1-3**	3.02
6	**4-6**	2.86
3	**7-10**	2.70

Table 1: Study 1, Pilot study; Amount of Correct Answers and SEI score

The SEI data, shown in Table 1, is between 2.55 and 3.15, with a mean of 2.86. The scores did not directly indicate a connection between the SEI score and the amount of questions the participants answered correctly. Particularly the people in the middle scoring group had SEI scores that were far apart from each other.

3.3 Full Study Results

In the first full study there were 60 participants. The participants were all part of the psychology pool, and their age ranged from 17 to 40, with an average age of 20 years.

If the participants are split up in the same way as was done in the pilot study, namely with 0 to 3, 4 to 6, and 7 to 10 answers correct, the amount of participants in the low scoring group would be only 6, compared to 35 and 20 in the other two groups. Therefore the groups are reordered to have a more balanced amount of participants per group. The new groups are split up into 0 to 4, 5 to 6, and 7 to 10 correct answers with 18, 22, and 20 participants in them respectively, creating a more even balance in number of participants per group.

Participants	Answers Correct	Characters Visited
18	**1-4**	3.4
22	**5-6**	4.8
20	**7-10**	5.0

Table 2: Study 1, Full study; Amount of Correct Answers and Characters Visited

The participants in the low scoring group visited on average 3.4 out of the 6 characters in Omosa. While the middle- and high scoring participants visited 4.8 and 5.0 characters respectively. The participants that visited more characters had access to more information, and therefore had more information to answer the questions with. The high scoring group also spent more time talking to the characters compared to the other groups.

Participants	Answers Correct	Questions Asked
18	**1-4**	13.5
22	**5-6**	20.6
20	**7-10**	20.6

Table 3: Study 1, Full study; Amount of Correct Answers and Questions Asked

The 1-4 group asked on average 13.5 questions, the 5-6 group 20.6, and the 7-10 group 20.6. So it seems that the amount of questions that people ask during their gameplay influence the score, which is logical because the questions give the information needed.

Longer time is spent near each character (Village, garden, science centre, cliff, weather station) for higher scores, so possibly the participants paid more attention and therefore spent longer in conversation with the characters.

Participants	Answers Correct	Data points	Number of Steps	Number of Teleports
18	**1-4**	510	183	4.44
22	**5-6**	720	300	8.18
20	**7-10**	885	378	8.20

Table 4: Study 1, Full study; Participants, Answers Correct, Data Points, Number of Steps, Average number of teleports

When looking at the amount of data points, locations of the participants collected every second, the low scoring group (510) had less data points than the middle group (720), which in turn had less than the high group (885). The data points only tell part of the story since they are collected at specific intervals, whether the participant is moving or not. The number of steps that each participant takes have also

been counted. A step is counted as two data points that have a nonzero distance between them. The number of steps per group gives the same result as the data points, the low group had on average 183 steps, the middle group 300, and the high group 378 steps.

Participants in the 1-4 group teleported on average once per 42 steps, the 5-6 group once per 65 steps and the high-scoring 7-10 group once per 96 steps. When we look at how many times the participants jumped we see that both the middle- and high-scoring group had an average of 8.2 teleports. This suggests that participants that spend longer walking around before teleporting collect and retain more information in the VW.

Participants	Answers Correct	Gaming hours
18	**1-4**	1.3
22	**5-6**	4.8
20	**7-10**	2.1

Table 5: Study 1, Full study; Participants, Answers Correct, Gaming hours

The amount of gaming hours did not seem to indicate a better performance in the questionnaire. The 1-4 group had on average 1.3 hours, 5-6 had 4.8 hours, and 7-10 had 2.1 hours.

In terms of patterns, the following things have been found. Similar to the findings in the pilot study the high scoring participants followed the optimal path more closely than the lower and middle scorers. A common occurrence in the low scoring group was that they were missing sections entirely and only visited some of the character locations. The middle scoring participants were more likely to visit all characters but also wander off the suggested path along the way and take different routes to the characters, so not following the suggested path.

Only one person in the low group backtracked. Backtracking in this case is defined as traveling back to a character that they have already been. Another piece of behaviour that has been observed is that participants move around the red research facility in the lower left corner of the map.

As seen in Table 6 the average SEI data per group is 2.96 for the low scorers, 2.93 for the middle scorers, and 3.04 for the high scorers. The possible score ranges from 1 to 4. The minimum and maximum of the participants for the low group is 2.42 and 3.58, the middle group 2.49 and 3.76, and the high group 2.70 and 3.64.

Participants	Answers Correct	SEI score	Minimum	Maximum
18	**1-4**	2.96	2.42	3.58
22	**5-6**	2.93	2.49	3.76
20	**7-10**	3.04	2.70	3.64

Table 6: Study 1, Full study; Participants, Answers Correct, SEI score

3.4 Discussion

The study was started with the hypothesis that more engagement, i.e. a higher SEI score, leads to a better performance. The underlying idea was that the students that are more psychologically and cognitively engaged, pay closer attention to the virtual world. In both the pilot and the full study, the SEI scores did not differ significantly and did not imply that a people with a higher SEI score also perform better in the questionnaire. The SEI scores of all groups were similar and not significantly different.

The result of this research shows that this hypothesis is rejected: engagement is not an important influencing factor that enhances performance in an EVW.

A likely explanation for the similar scores is that the participants were all university students, who have made the choice to study and therefore have similar feelings of engagement towards studying.

The secondary goal of the study was to find out if there were patterns that could be linked to performance for further investigation. The patterns that were found were teleporting, backtracking and following the optimal path.

The teleporting pattern we found was that participants with lower scores did not necessarily teleport more, but they did teleport more often relative to how many steps they took. Teleporting more often relatively shows that those participants were paying less attention to their surroundings. Instead of collecting information from the location that they are in, they teleport to another place and thereby miss information that they need for the questionnaire.

In the pilot study it was found that the participants in the high scoring group stuck more to the suggested optimal path compared to the other groups. A similar pattern was also found in the full study where most of low scoring participants did not visit certain parts of the environment and the middle scoring groups were more likely to wander off the optimal path. This suggests that the low scoring group lost interest or engagement in a way that they did not want to play the game any further, whereas the middle scoring group lost interest in a way that they did continue playing but not pay attention to the conversations of the characters.

We also saw some participants that backtracked through the virtual world. This could be seen as a tactic used by disengaged people. People who paid attention to the characters conversations should know where to go next, and therefore have no reason to backtrack. However, backtracking does not necessarily have to be an indicator of disengagement. Engaged people can backtrack because they think that there was some information they missed in a previous location.

If these patterns are indeed indications of poorer performance, they could be used to detect when a user is not learning well in an EVW. The patterns found in the studies were used in the experiment described in chapter 4.

Besides answers to our research questions, there are some findings in study 1 that are worth mentioning.

Participants were asked to give how many hours they play games a week to make sure that those who play games more often do not have an advantage. When analysing the data the middle scoring group actually has the highest amount of gaming with 4.8 hours on average. Both the low and high scoring group had a lower average of gaming hours with 1.3 and 2.1 hours respectively. It is thus not a given that participants have a better performance when they have more experience with games compared to others.

These data suggest that there is no direct relation between gaming hours and performance (answers correct). It may be possible that participants that game a lot, score better on average so that they end in the middle scoring group, but it is not a given that participants have a better performance when they have more experience with games compared to others. Another study is necessary to see how gaming hours and performance are linked.

Since most of the information necessary for correctly filling in the questionnaire was near the characters, the behaviour of participants near characters was examined. The behaviour near the

characters consists of which and how many characters were visited, how long they were visited for, and how many questions were asked by the participants.

The amount of questions asked was the same for middle and high scoring groups with 20.6 questions asked on average, and the low scorers asked 13.5 questions on average. This suggests that asking more questions would not definitely lead to a higher score, but there is a minimum amount of questions that need to be asked to receive information from the characters.

A similar pattern is found when looking at how many characters were visited per group with the middle- and high-scoring group scoring a similar 4.8 and 5.0 characters on average respectively, and the low scoring group only visiting 3.6 characters on average.

Visiting the characters does not seem to be enough to get a high score, the information must also be received and remembered. A way to gauge how much a participant is paying attention to the conversations may be in how long they are in conversation with them. The data shows that participants in the high scoring group spent longer than both the middle and low scoring groups.

Chapter 4 Study 2: Hints to Improve Navigational Paths

The second study was an experiment based on the first study. The first study showed certain patterns in the navigation of participants, namely teleportation, backtracking and following the optimal path (see section 3.4). Based on these patterns the participants are given hints to change their navigational behaviour and the experiment was made to see if the hints improved the performance of participants.

4.1 Methodology

The experiment is set up in a similar fashion to the first study, using the same Omosa environment. Participants interact with the virtual world and answer the questions just like in the first study. After the first questionnaire they interact with the virtual world again and are given hints to help them perform better in the second questionnaire belonging to that interaction. The hints are given only to people who seem to need it according to their navigational behaviour in their first interaction.

One goal of the study is to see if the hints that are given improve the scores. A second goal is to see if the strategy of not giving hints to people who don't seem to need them is valid. In other words, people who do not seem to need the hints according to our system, perform as well as those who do receive hints.
This leads to two hypotheses:

Hypothesis 1: Participants that receive hints perform better than the control group in the second scenario.
Hypothesis 2: Participants that are deemed not to need any hints perform as well as those that did receive them.

To ensure that the experiment measured the efficacy of the hints it had to be designed to eliminate confounding factors. People interacting for the second time with virtual world have knowledge about the questions that are going to be asked and the information that is in the world. Therefore the second questionnaire is expected to be done better, because participants prior knowledge for it.

The solution to this confounding factor is to have two scenarios in the virtual world that each have different information in it, and two corresponding questionnaires for the scenarios. The two scenarios, called scenario 1 and scenario 2 each have different conversation options.

To make sure that the prior knowledge factor is eliminated, the answers to the questionnaires should only be found in the corresponding scenarios. For this experiment two scenarios were devised with corresponding questionnaires. The questionnaires can be found in Appendices A.4 and A.5. These scenarios were made to be similar in nature, with the same amount of characters, ten questions in both the questionnaires, and similar nature to questions.

The two different scenarios now introduce a new factor that could confound the data in the experiment. One scenario could be easier to answer correctly and therefore participants would likely do better than in the other scenario regardless of any hints that were provided. This factor can be eliminated by switching the order of the scenarios, some participants play scenario one first, the others scenario two.

Finally, to measure whether the hints work or not, there needs to be a control group of participants that do not receive any hints. People who do not receive hints are given the two scenarios the same as the participants that do receive hints, and the questionnaires stay the same as well.

These factors make for an experimental design with four different groups illustrated in Figure 3. Group 1 and 2 are the groups that play scenario 1 first, while group 3 and 4 play scenario 2 first. Then group 1 and 3 play their second scenario with hints, and group 2 and 4 play it without hints.

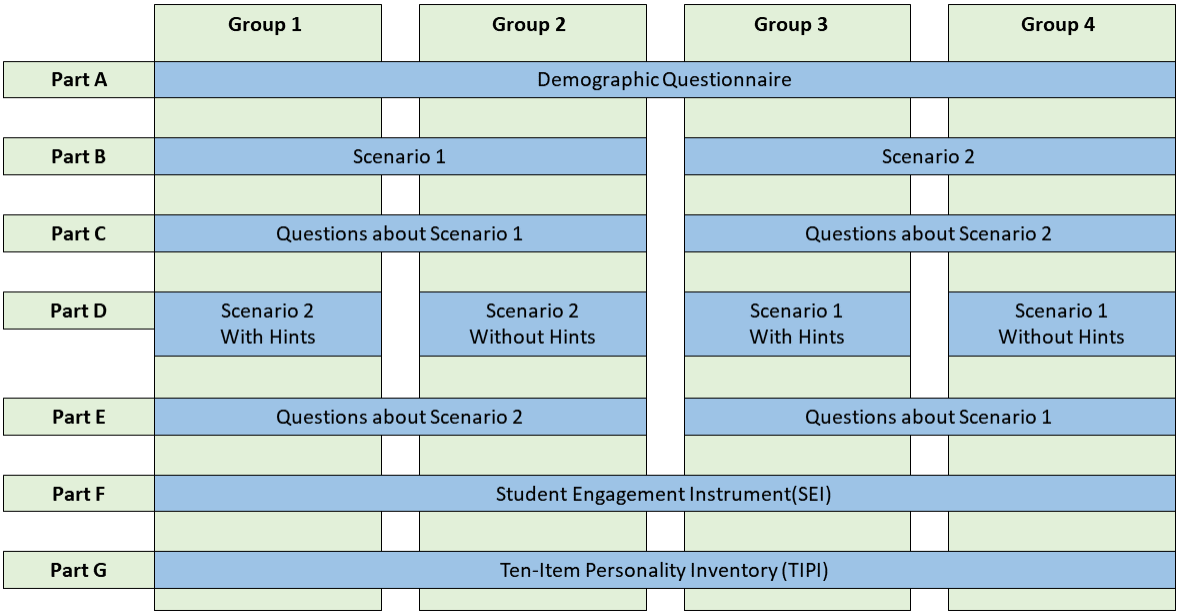

Figure 3: Experimental Groups in the Second Experiment

There are three different hints that were created for the study, all based on the results of the first study. The first hint was based on the amount of teleports that were done on the map. The player is able to teleport to any place on the map, and the amount of teleports was associated with performance. People who teleport more than a given threshold are given the hint at the start of the second interaction with Omosa. The threshold chosen for our study was 8, again based on the first study's results. Also, since there are 5 locations on the island that can be visited, and one of them is the starting position, all locations can be visited in 4 teleports. If the threshold is exceeded the following hint is given, "You teleported a lot in your last play-through, try and figure out where you are going instead of teleporting."

The second hint is based on the amount of backtracking a participant does. The environment is divided into zones where each location in the environment has its own zone, which is based on the metrics defined by Ruddle and Lessels [25]. A path is marked as backtracking when a zone is left and re-entered at any point during navigation. If a player has backtracked during their play-through the following hint is given, "You went back to a place you had already been, please try to discover new parts of the island."

The last hint is based on the optimal path that participants are able to follow. The characters in the virtual world give instructions on to where to find another character. If a player follows that path exactly they followed the optimal path. The following of the optimal path is calculated by taking the shortest distance to the path for each data point and if the distance is over a threshold that data point gets counted as *outside* the optimal path. If more than five percent of the data points are outside, the path is deemed as not optimal. The following hint then is shown at the next interaction, "Try and pay attention to what the people have to say, and try to follow their instructions."

For the second study the original conversations were adjusted and another similar set of conversations was made for the second scenario. The adjustments to the original scenario were made to make the two scenarios similar in amount of information and distribution of information over characters. The conversations had to be made in such a way that participants were not able to know information about the other scenario, except in cases where the information was not part of the questionnaire. For example the information that the island is named Omosa is present in both scenarios but not part of either of the questionnaires. The approximately even distribution of information over characters was done so that, if participants missed a character, it would not matter which character was missed in terms of amount of information not received.

Additionally, the starting locations were changed so that the optimal paths were different in the scenarios. In Figure 5 and Figure 4 the starting locations and optimal paths are given for scenario 1 and 2 respectively.

The questions about the scenarios in the virtual world were also changed according to the changes in the scenarios. The questions were made in such a way that they were similar in nature and location. For example a question in scenario 1 is, 'What do the villagers do to encourage growth of plants?', and a similar question is, 'What ritual do the villagers practice?'. The answer to both these questions is given by the same character and has the same subject namely the practices of the indigenous people. The locations for each question in the scenarios can be found in Figure 5 and Figure 4.

The questions were made similar to make both questionnaires equally difficult to complete correctly. In addition to questions about information given through dialogue there was also a question about the location of a character in each questionnaire, and two questions about things that could be seen in the environment itself. For example there is a collectable document with tree-ring data, and one of the questions asks where that document is located in the world. In this way the questions were not solely dependent on the characters, but also on the world itself, making sure that the participants also had to pay attention to the environment itself instead of just the conversations.

The setup of the study is similar to the first study, and consists of the following parts:

A: Demographic questionnaire (1 min)
B: Interaction with EVW (8 min)
C: EVW questionnaire (5 min)
D: Second interaction with EVW (8 min)
E: Second EVW questionnaire (5 min)
F: Ten-Item Personality Inventory (TIPI) (5 min)
G: Student Engagement Instrument (SEI) (10 min)

Parts A demographic questionnaire, F Ten-Item Personality Inventory, and G Student Engagement Instrument, are unchanged compared to the first study.

The EVW questionnaire was modified with the addition of a question that asks participants how much on a scale of 1 to 5 they found the experience enjoyable, with 1 being not enjoyable, and 5 enjoyable. This question is asked after every scenario, so two times per participant. Participants are also asked to elaborate why they thought the experience was enjoyable or not. This method allows for more insight to the behaviour of participants, so that more sophisticated interpretation of data was possible. The full list of questions are given in Appendices A.4 and A.5.

If a participant has been given hints at the start of a scenario the participant will also be asked if the hints were helpful. The question is, similarly to the enjoyment question, answered on a 1 to 5 scale, and

asked to elaborate on the reason for their answer. This question has also been added for the same reason as the enjoyment question, namely to allow for more insight to the usefulness of the hints, as well as the perception of helpfulness by the participants.

4.2 Expectation

For a good run-through of the environment where all the information is found it is expected that the paths given in Figure 5 and Figure 4 are followed for each scenario. The numbers in the figures signify where the answers to questions can be found. The participant starts at location A, and talks with the first character. It is expected that an engaged person reads the dialogue and remembers the information contained in it. After that they move in the direction given by the dialogue towards the next character. The participants are also told in the first dialogue that there are some objects in the game that can be picked up and examined, so some exploration is expected, especially in more cluttered areas where there are more objects present. It is also expected that an engaged person pays some attention to the surroundings within the environment. For example the path in scenario one between regions B and C go through a forest of burned trees, and in scenario two there are animals present near the cliff in region B. If this way of interacting with the environment is followed then it is expected that all the questions should be answerable by an engaged person.

It is also expected that if a person is engaged that none of the hints will be given after their first run. The engaged person should move relatively close to the path given in Figure 5 and Figure 4, so the optimal path hint should not be given. Similarly at any point the participant should know where to go from each region and therefore would not have to travel back to another region. Even if someone would not know where to go in a region, it is expected that they go back to the nearest character before moving towards a previously visited area. Similarly the teleportation is expected to only be used instead of travel between the regions, and therefore only 4 times during the run-through.

In contrast a disengaged person would be more likely to not know where they were going and therefore might travel backwards to find another way from an earlier region. This will obviously result in the backtracking hint triggering and possibly also the teleportation hint triggering if they choose to teleport during their search.

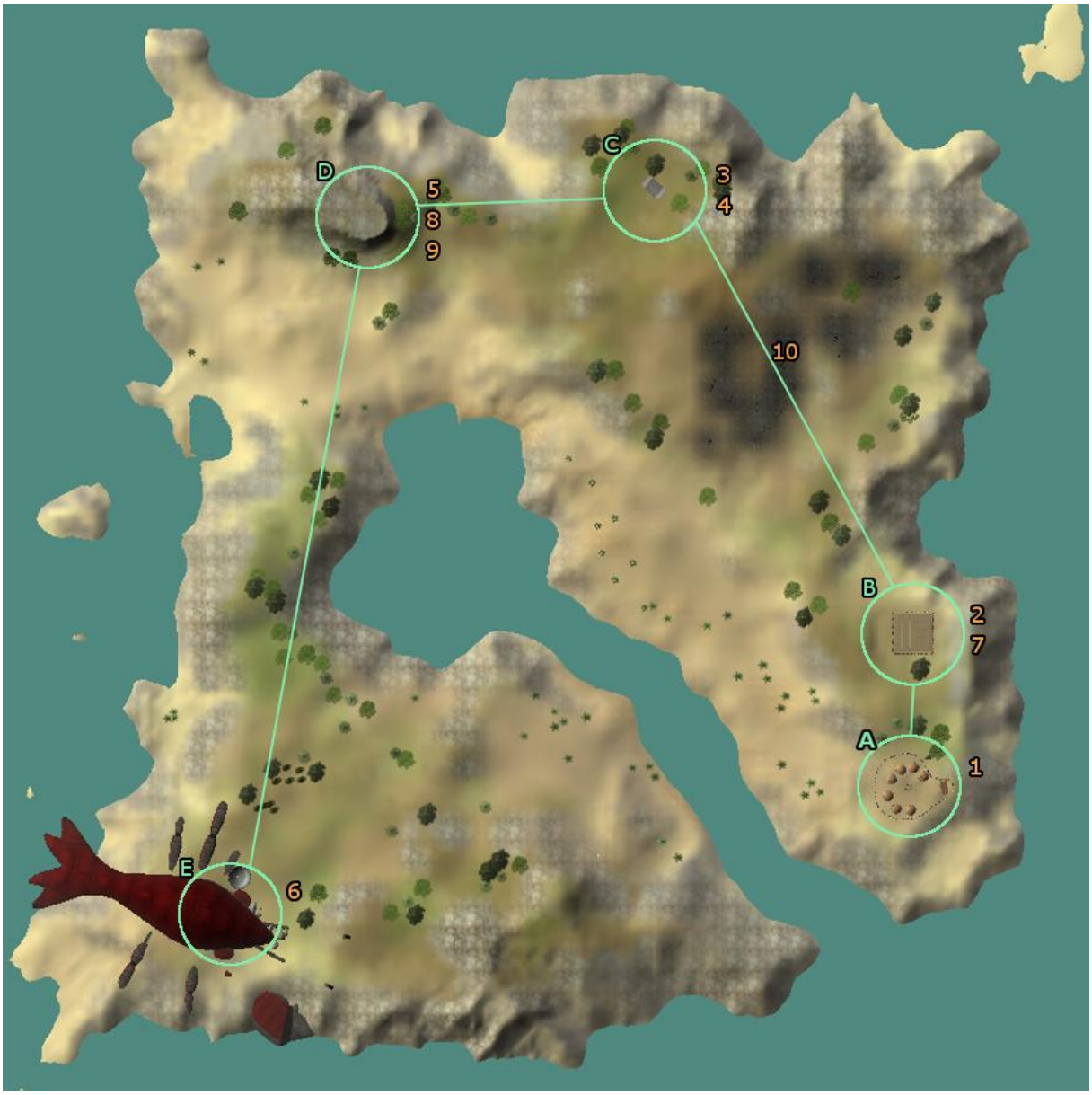

Figure 4: Scenario 1 Path and Questions

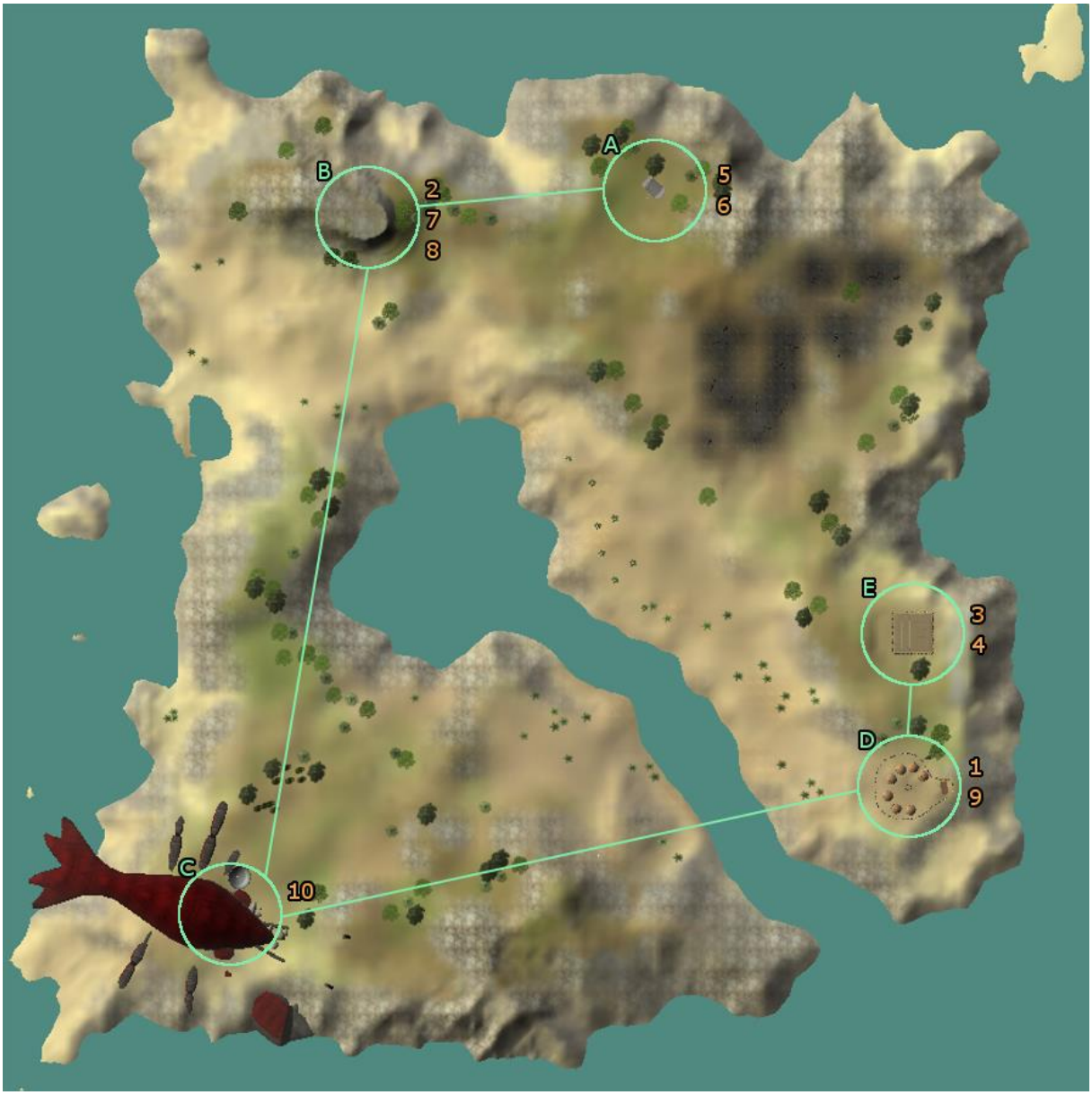

Figure 5: Scenario 2 Path and Questions

4.3 Study 2 Results

The second study had 115 participants in total. The participants are divided into four groups according to which scenario they played first and whether they received hints in between scenarios. There were 37 participants in the group that did scenario 1 first and received hints in scenario 2, this group corresponds to group 1 in Figure 3. There were 29 participants in group 2 that did scenario 1 first and scenario 2 without hints. In group 3 there were 25 participants who received hints in scenario 1, and in group 4 there were 24 participants who did not receive hints. Group 1 and 3 groups that received hints, and group 2 and 4 were the control groups.

This section first describes the general results of how the hints influenced the performance of the participants. The second section describes the performance of the individual questions.

4.3.1 General Results

Group	Number of Participants	Score	Average
Group 1	37	6.62	Scenario 1 = 4.47
Group 2	29	6.04	
Group 3	25	4.32	Scenario 2 = 6.23
Group 4	24	5.00	

Table 7: Study 2; Amount of Participants and Score per Group

Scenario 1 had an average of 4.47 correct answers per participant, while scenario 2 had an average of 6.23 correct answers per participant. Both scenarios were completed by all 115 participants. This data suggests that the second scenario and the second questionnaire was easier than the first one.

The average score for participants that played scenario 1 without hints had a score of 4.32, while those who did receive hints had a score of 5. The average score for people who played scenario 2 without hints was 6.04, while with hints the average score was 6.62.

Order of scenario	Score	Average
Scenario 1 first	4.53	Scenario 1 = 4.47
Scenario 1 second	4.39	
Scenario 2 first	5.84	Scenario 2 = 6.23
Scenario 2 second	6.52	

Table 8: Study 2; Score per Scenario in Order

The participants that did scenario 1 first had an average score of 4.53, playing it second lead to an average score of 4.39. Scenario 2 first was 5.84 correct answers on average, while playing it second lead to a score of 6.52.

Groups	Score first scenario	Score second scenario	Improvement
Group 1 and 3 (Hints)	5.34	5.97	0.63
Group 2 and 4 (Control)	4.79	5.19	0.40

Table 9: Study 2; Score and Improvement of Score per Hint and Control Group

Participants who received hints had a mean score of 5.34 in their first played scenario and 5.97 in their second scenario, an average improvement of 0.62. The participants in the control group, who did not receive hints had an average improvement of 0.39.

To test whether the difference between the two groups was significant a one-tailed t-test was used. A t-test is a statistical test to assess whether means of two groups are statistically different from each other. In this case a one-tailed t-test is used because the mean of the hint group is expected to be higher than the control group's mean. The t-test yield a p-value that is used to determine whether the null hypothesis can be rejected or not. If the p-value is equal to or below a certain threshold value then the result is taken to be statistically significant. In this case a threshold of 0.05 is used, meaning there is a 95% confidence that the null hypothesis can be rejected [34].

The specific hypothesis tested here is H1: *The participants in the hint group perform better than those in the control group.* The null hypothesis H0 is: *The participants in the hint group do not perform better*

than those in the control group. A t-test between these two groups revealed a p-value of p=0.863, higher than the threshold of 0.05, meaning there is no significant difference between performance of participants receiving hints and not receiving hints.

To investigate whether or not the hints improved the performance, the scores of people who received hints were compared to the performance of the control group. Because the scenarios did not seem equal in difficulty, only performance in the same scenario was compared. Similarly, because the data suggest that performance is different if a scenario is played second, only performance of the second questionnaire was compared. In summary the performance of group 1 was compared to group 2 and group 3 to group 4.

Groups	Participants	Score first scenario	Score second scenario
Group 1	37	4.57	6.62
Group 2	29	4.48	6.38
Group 3	25	6.48	5.00
Group 4	24	5.17	3.75

Table 10: Study 2; Score of First and Second Scenario per Group

Comparing group 1 to 2 gave the following results. The mean of the second scenario for the hint group was 6.62, and the mean of the control group was 6.38. A one-tailed t-test yields a p-value of 0.343, well above the 0.05 confidence interval. In other words the participants with hints did not do significantly better statistically then the control group.

Comparing group 3 to 4 gave the following results. The mean of the second scenario of group 3 was 5, and the mean of the control group was 3.75. A one-tailed t-test yields a p-value of 0.035, below the 0.05 confidence interval. Meaning that between those groups there was a significant difference between the performances of participants.

Groups	Participants	Kind of Hints	Number of hints
Group 1 and 3	37 and 25	Backtracking	40
		Teleporting	53
		Optimal path	53

Table 11: Study 2; Distribution of Hints Received

Of the participants who received hints 40 of them received the backtracking hint, 15 received the teleportation hint, and 53 received the optimal path hint.

Groups	Participants	Score
Group 2 (control)	29	6,38
Group 1, no hints	7	5
Group 1, all hints	30	7
Group 1, only optimal path hint	8	5

Table 12: Study 2; Score per Hint, Group 1 and 2

The scenario 1 control group had an average score of 6.38, while the 7 participants that were in the hint group but did not receive any hints only had an average score of 5. The reason these participants did not receive hints was because they did not backtrack or teleport too much and followed the optimal path in their first time playing the game. The other 30 participants who did receive hints had an average score of 7.00 in the second scenario. The 8 participants that only received the optimal path hint also had an average score of 5.00. This suggests that the optimal path hint was not a hint that increased the performance of the participants.

Groups	Participants	Score
Group 4 (control)	24	4.32
Group 3, only optimal path hint	7	3.57
Group 3, optimal path and backtracking hint	12	5.25
Group 3, all hints	6	6.17

Table 13: Study 2; Score per Hint, Group 3 and 4

In group 3 all 25 participants received the optimal path hint, 12 of them received the backtracking hint as well, and 6 received all three hints. Those who received only the optimal path hint had an average score of 3.57, below the average of 4.32 without hints. Those who received the backtracking and optimal path hint had an average score 5.25. Finally those who received all hints had an average score of 6.17 in their last questionnaire.

Groups	Participants	Score
Group 1, backtracking and teleportation hints	22	7.73
Group 2 (control)	29	6.38

Table 14: Study 2; Score per Backtracking and Teleportation Hint

Because the optimal path hint in both scenarios did not appear to improve the performance, the performance was re-examined. Instead of comparing the scores of the hint group versus the control group, the performance of people who received either the backtracking or the teleportation hint or both was compared to the control group. Group 1 had 22 participants that did receive those hints with an average score of 7.73, compared to the control group with an average of 6.38. A one-tailed t-test gives a p-value of 0.014, which means that the backtracking and teleportation hints significantly increase the score.

Groups	Participants	Score
Group 3, backtracking and teleportation hints	18	5.56
Group 4 (control)	24	3.75

Table 15: Study 2; Score per Backtracking and Teleportation Hint

The same test compared group 3, the control group consisting of 24 people, with group 4, the hint group consisting of 18 people. Group 3 had an average score of 3.75, versus group 4 with an average of 5.56. The p-value from a t-test between these two groups is 0.010. The previous two results show that the backtracking and teleportation hints significantly increase the scores in both scenarios. The participants performed better after they were given those hints.

Part of the efficacy of the devised system is the automatic detection of when hints are needed and giving them out only to participants that need them. To test whether the system was successful in this task the scores of participants that received hints was compared to the scores of participants that were determined to not need hints.

The participants in the control group that did not need hints according to the hint system are also included. If the hypothesis is correct then there should be no significant difference between the two groups. In groups 3 and 4 there were no participants in the hint group that did not receive any hints, so those groups cannot be analysed.

Groups	Participants	Score
Group without hints needed	14	5.00
Group that got hints	22	7.73

Table 16: Score per Group that got Hints and that did not need Hints

In groups 1 and 2 there were 14 participants that did not receive any hints, 7 participants from group 1 and 7 from group 2. They scored an average of 5.00 in the second test. The group of 22 participants that did receive hints scored an average of 7.73 in the second test. A two tailed t-test gives a p-value of 0.001 meaning that the scores of the participants that did not receive either the backtracking or teleportation hint were significantly worse than those that did receive those hints.

4.3.2 Individual Questions

To gather more insight in the navigational behaviour, the questions are examined individually. In Table 17 the percentage of correct answers per question is given for each of the groups and combined. The worst answered questions are questions 4, 6, 9, and 10 from the first scenario questionnaire and question 4 of the second questionnaire. The best answered questions are questions 1, 2, 6, 7, and 8 all from the second scenario questionnaire.

Question 1.6 and 2.4 are both questions that can be found in the last region of the respective scenarios. It is therefore likely that participants have not gone to that area or that they did not pay attention any more at that stage of the experiment and therefore had become disengaged. The only other question that was found in the last area of the scenarios was question 3 of the second scenario. This question was answered correctly by 53% of the participants. It could be that the 3rd question was easier to guess right or that the information could be found elsewhere in the environment. The question was *"What ritual do the villagers practice?"* with the answer that they dance around the fire in a festive ritual. This ritual itself is not found within the environment nor is there any other mention of it in the rest of the environment. If the people who did not visit the respective areas of the questions are left out, question 2.4 is answered correctly by 81% of them, while question 1.6 was only answered correctly by 41%. Apparently, question 2.4 was thereby easier than question 1.6.

Question 1.10 was *"What kind of plants could be found between the farm and the ecology lab?"* and could be found only by observation of the burned out forest in between region B and C of the first scenario (see Figure 4), and not through any conversation. It is possible that a majority of the participants moved past the region by teleportation and therefore did not enter the region at all or that they were simply not engaged enough with the environment to pay close attention to the details of it. In Figure 6 is a path taken by one of the participants that did not get the forest question correctly and also did not pass through the forest. This participant did indeed teleport past the forest and therefore missed the information needed to answer the question correctly. In fact only 22% of participants crossed the forest, meaning that the rest of the participants had to have guessed the answer correctly. If we look at the amount of people who actually visited the forest, we see that 69% of them gave a correct answer to

the question. So indeed the reason that this question was not answered correctly by so many people is because very few of them actually visited the necessary part of the environment.

Questions	Group 1	Group 2	Group 3	Group 4	Total
1.1	57%	59%	60%	38%	53%
1.2	57%	38%	60%	50%	51%
1.3	54%	41%	48%	33%	45%
1.4	38%	38%	32%	42%	37%
1.5	46%	62%	56%	54%	53%
1.6	32%	41%	48%	17%	34%
1.7	46%	38%	52%	33%	42%
1.8	54%	52%	72%	63%	59%
1.9	32%	45%	28%	17%	31%
1.10	41%	34%	44%	29%	37%
2.1	76%	86%	76%	67%	76%
2.2	76%	79%	84%	71%	77%
2.3	57%	66%	60%	25%	53%
2.4	49%	45%	20%	33%	38%
2.5	70%	55%	68%	54%	62%
2.6	70%	62%	88%	79%	73%
2.7	76%	79%	68%	42%	67%
2.8	86%	86%	80%	83%	84%
2.9	54%	34%	52%	21%	41%
2.10	49%	45%	52%	42%	47%

Table 17: Study 2; Performance of Individual Questions per Group

Question 1.4 was "*What did the ecologist find out about the plant life"*, the answer to which could be found in section C. The available answers were that there were more fire-loving, rain-loving, drought-loving or compost-loving plants in the environment. It could be that the correct answer, more fire-loving plants, was too difficult for people to get correctly, because they have not heard of fire-loving plants and therefore were less likely to guess this answer.

Question 1.9 could be found in section D and was "*The biologist thinks the animals are dying out for what reason?*" The correct answer was that the animals habitat was being disturbed, which was only answered by 31% of the participants. The majority with 46% actually picked option b, the weather has changed on the island. Since question 1.6 was about weather patterns on the island, it might be that it was assumed that the answer to 1.9 also had to do with weather patterns.

The best answered question 2.8 with 84% correct answers was, like question 1.10, an observation question. The answer to this question could be found near section B in the second scenario, which 71% of participants visited. The reason that this observation question was answered so well in contrast to the other observation question likely lies in the fact that this location was visited by more participants. The reason this location was visited by more participants is likely because it is close to a character, whereas the forest location was quite a way away from the characters it lies in between.

Question 2.6 was found in section C, where the second scenario starts so it is no surprise that this question was answered well.

Questions 2.2 and 2.7 were both questions about the behaviour of animals. It could be that these questions were answered well because the participants paid more attention to information pertaining to the animals. Indeed one of the participants informed us in the feedback form that they assumed that the goal of Omosa was to find information about the animals. It could be that more people made this assumption and therefore paid more attention to information about the animals.

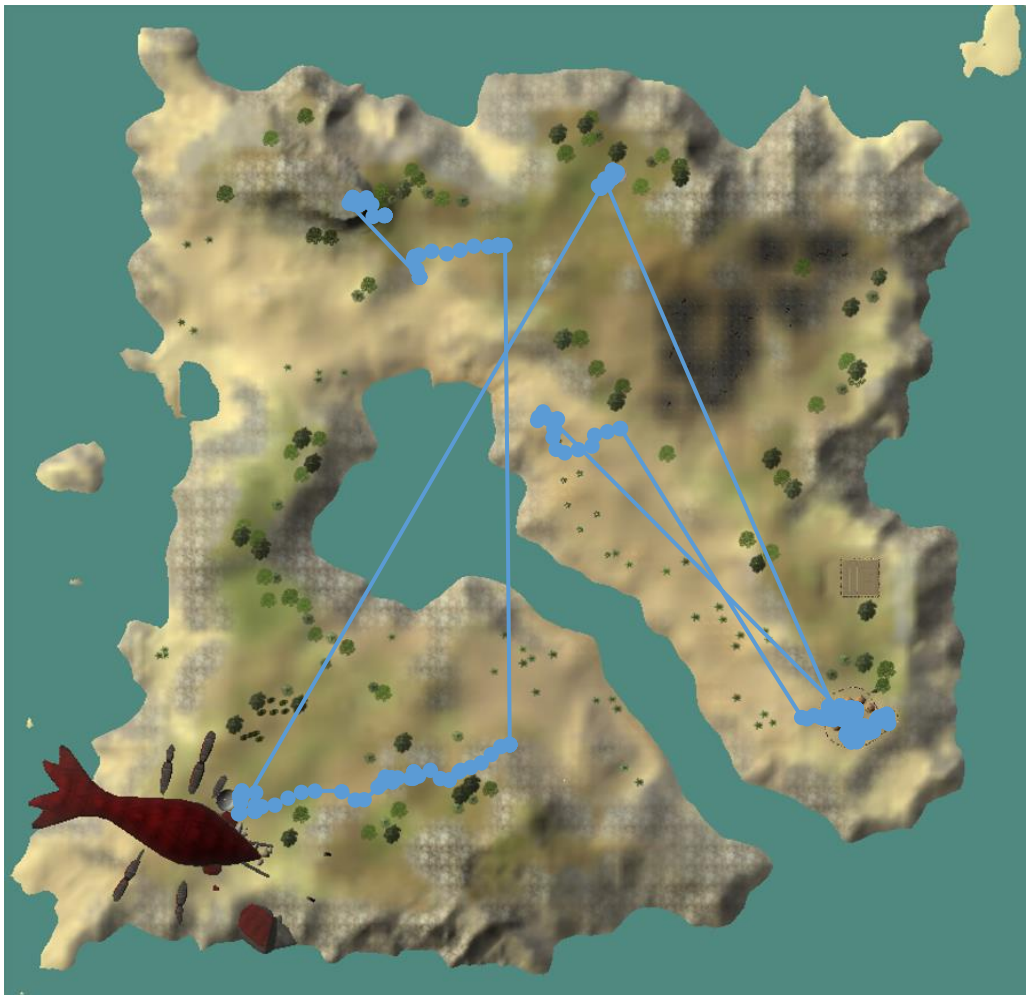

Figure 6: Path that Avoids the Forest

4.3.3 Feedback

Participants were able to leave comments stating if and why they found the tips helpful or not. There were 58 comments about why participants found the tips helpful (35) or not helpful (23). Comments for why the tips were not helpful include that they did not provide enough information (8), the task was confusing/difficult (10) or did not help with navigation or finding things (5). Two insightful comments were:

"It told us to continue search for more information but that was the only hint. It didn't state what else to do other than do the same things that I did before that. It did not state objectives or aims or mission for the game." and

"The tip was unhelpful as informing me to not go back to the place I started was something that was already clear to me. The large size of the game, poor map and lack of a compass make it difficult not to do so."

Those that found the hints useful commented on clarity (10), guidance and direction provided (22), and how to navigate/play the game (5). Specific longer comments include:

"Very helpful, I thought it was intended for me to only teleport from place to place as opposed to actually run around the island and I ended up having a lot more success finding clues when I actually explored the whole place." and

"The tip about not teleporting helped me observe more of the landscape and not focus solely on the people (made it more enjoyable rather and a task it was like an exploration). The teleporting also reminded me of the other features like the backpack that I didn't use the first time (it helped give direction and focus – a goal to get all the information."

4.4 Discussion

The goal of study was to see if the performance could be improved through hints, and if the strategy of giving hints to only those that exhibit certain behaviour works. Remember that the experiment started with two hypotheses. The experiment had a couple of interesting results, which are discussed in this section.

Hypothesis 1: Participants that receive hints perform better than the control group in the second scenario.

In general we have to reject hypothesis 1, because the participants that were in the hint groups (group 1 and 3) in general did not do significantly better than those in the control groups.

Additionally, the people in group 1 that first played scenario 1 and then played scenario 2 with hints, did not do significantly better than the corresponding control group either (group 2).

However when we look more closely we see that hints do make a difference for one group. The people in group 3 who first played scenario 2 and then scenario 1 with hints did do better than those who played scenario 1 without hints (group 4).

This result can be explained in a couple of different ways:

Scenario 1 is the harder one of the two scenarios, so the hints could be more helpful in a harder scenario. If you play a harder scenario first (group 1 and 2) then you already have more experience than the other groups 3 and 4. This could mean that hints do not really make the difference when playing the easier scenario 2.
The people who played the easy scenario 2 (group 3 and 4) first, need more hints in the second more difficult scenario 1.

A second explanation may be simply that the participants that were in group 4 were worse at the game in general compared to the others. For example scenario 2 had an average score of 6.5 by the other three groups, but group 4 only had an average score of 5.2. And the same for scenario 1 where the other three groups had 4.8 average against a 3.8 average by group 4. To find out if this is the case more data is needed.

We also examined if there was a difference between the hints given on backtracking and/or teleporting and/or optimal path. Looking at the performance per hint the optimal path hint does not seem to be useful. Participants who received the optimal path hints did not perform better than without hints.

This data can mean that either the optimal path hint was not a hint that improves performance, or the hint is not given at the right times by the program.

When finally the performance of the people receiving the backtracking and teleport hint are compared to the performance of the control group it is shown that the people who received the hints perform significantly better for both scenarios. This suggests that the two hints were helpful in the scenarios for the Omosa virtual world.

Hypothesis 2: Participants that are deemed not to need any hints perform as well as those that did receive them.

In this research groups were identified beforehand to get hints (group 1 and 3) or not to get hints (group 2 and 4). But in group 1 and 3 not all people actually got hints, only those who showed navigational behaviour that suggested that they needed hints. This selection was done by the system.

The hypothesis compares on one side people who did not get hints and did not exhibit behaviour that suggested they needed hints. This includes people from the control groups (group 2 and 4) who did not need hints according to their navigational behaviour. On the other side this group is compared to the people who did receive hints.

If the hypothesis is correct then there should be no significant difference between the two groups. The results show that the people who did receive hints do perform significantly better. This means that hypothesis 2 is rejected.

This could be explained by the fact that the automatic detection of when hints are needed is not necessarily valid. Perhaps it is never a good decision not to give hints to people; people always seem to benefit from hints, even when their navigational behaviour suggests otherwise. Participants that received all hints performed better than those that did not receive any hints, leading to the conclusion that the hints were better given out to everyone instead of trying to only give them out to people who did not seem to need them according to the program.

Further research is needed to find out whether giving out hints to some and not to others is valid strategy. Are hints helpful even if people did not exhibit the behaviour the hint is made to prevent? Are there circumstances where hints are a detriment to the performance?

The comments left by participants give further indication that the hints might not always indicate a point where improvement was needed for a candidate. It is therefore not necessarily reasonable to reject the usage of tips for improving of navigational paths, but rather the specific tips used in this study.

Chapter 5 Conclusion

This research explored the link between navigational behaviour and performance within an educational virtual world. We wanted to know if engagement is effected by navigational behaviour, so that engagement levels can be enhanced and thereby improve performance in learning tasks.

Moreover we wanted to research how navigational behaviour influences the performance of users with regard to the learning goals set within a virtual world. We wanted to know if navigational patterns can be influenced so that the performance improves.

The research question defined at the start of the research was '*How does engagement in combination with navigational patterns influence the performance in an educational virtual world?*' This final chapter will answer the research question and discuss future work.

5.1 Research question

The research question was divided into three sub-questions. Each sub-question will be answered to finally answer the main research question.

Does engagement influence performance in an educational virtual world?
To find out whether engagement influenced performance, we let students interact with our EVW and measured their engagement. Engagement did not seem to be of influence in the performance of the participants.

Can educational performance be predicted based on navigational patterns in a virtual world?
The initial study described in Chapter 3 investigated whether there are useful navigational patterns that are related to performance. Some patterns were found at the micro-level, like backtracking through the environment and circling around certain buildings. Other patterns were found at the macro-level, like the amount of teleports, length of paths and following the suggested path.

Three navigational patterns were found to be of importance in the study, namely teleporting, backtracking and straying from the optimal path. These three patterns were found to be indicators of poor performance, and might be used to detect performance and engagement.

Can altering of navigational patterns improve educational performance?
The second study used these patterns in a hint system. The hint system attempted to detect the navigational patterns that were found to be indicators of bad performance in the first study, and gave hints that correct the navigational paths.

The results show that participants that received hints in general did not perform better than those who did not receive hints. However, for one group the hints did make a difference. This one group may have performed better because started with an easy scenario and got hints for the harder scenario.

Additionally the backtracking and teleportation hint proved to be effective hints in both scenarios, whereas the optimal path hint did not.

We also researched if people who did not get hints and did not exhibit behaviour that suggested they needed hints did perform as well as those who got hints. The results show that the people who did receive hints do perform significantly better.

In conclusion, our research did not show a link between engagement and performance in an EVW. But there are navigational patterns that might influence the performance in an EVW. Our research especially showed that backtracking and teleporting hints improved performance.

5.2 Future Work

This research had a limited research group of university students at Macquarie University in Sydney. This limited research group may have influenced findings. The most important one was that we could not establish a relation between engagement (i.e. SEI score) and performance. It is worth trying to research this relation in a more differentiated group.

We could not establish a direct relation between receiving hints and performance. However for specific groups, scenarios, navigational patterns we could see a relation. New research could be based on these findings as to specify more clearly what helps to improve performance via educational virtual worlds and in what way hints can help to improve performance.

The feedback on the hints in this research make it clear that hints are useful, but they need to be more specific. Tips that would have made clear that the purpose of the game was to find out as much information and to carefully follow the characters instruction would have been helpful. More research is necessary to know how hints should best be formulated.

Research to improve navigational behaviour using other methods besides hints can be useful. There are other ways to improve navigation that we did not use in this research. One of those ways is to not allow players to move away from an area if they have not talked to certain characters yet. This would let them know not only that there is information to be found in the current area, but also that they do not have to continue searching if they are allowed to leave the area. Other navigational aids such as compasses or mini-maps could improve performance as well.

We have set up our experiments to give the players lots of freedom to navigate throughout Omosa. Another interesting avenue would be to find a balance between limiting the players' navigation and giving them the freedom to explore. A player that is left completely free is unlikely to find every part of the virtual world, and is likely to miss information. On the other hand a player that is so limited that all the virtual world can only be traversed in one way will not have the benefit of the virtual world at all. If we find a balance educational virtual worlds can be used more effectively as a learning tool.

References

1. Baker, S.C., R.K. Wentz, and M.M. Woods, *Using Virtual Worlds in Education: Second Life as an Educational Tool.* Teaching of Psychology, 2009. **36**(1): p. 59-64.
2. Falloon, G., *Using avatars and virtual environments in learning: What do they have to offer?* British Journal of Educational Technology, 2010. **41**(1): p. 108-122.
3. Schoenau-Fog, H. *The player engagement process–an exploration of continuation desire in digital games*. in *Think Design Play: Digital Games Research Conference*. 2011.
4. Rigby, S. and R.M. Ryan, *Glued to games: How video games draw us in and hold us spellbound: How video games draw us in and hold us spellbound*. 2011: ABC-CLIO.
5. Csikszentmihalyi, M., *Finding flow: The psychology of engagement with everyday life*. 1997: Basic Books.
6. Hanna, N., et al., *Towards Quantifying Player's Involvement in 3D Games Based-on Player Types*, in *Proceedings of the 2014 Conference on Interactive Entertainment*. 2014, ACM: Newcastle, NSW, Australia. p. 1-10.
7. McMahan, A., *Immersion, Engagement, and Presence: A method for Analysing 3-D Video Games The video game theory reader'.* The video game theory reader, Routledge, New York, NY, US, 2003.
8. Jennett, C., et al., *Measuring and defining the experience of immersion in games.* International journal of human-computer studies, 2008. **66**(9): p. 641-661.
9. Costello, B. and E. Edmonds. *A tool for characterizing the experience of play*. in *Proceedings of the Sixth Australasian Conference on Interactive Entertainment*. 2009. ACM.
10. Vorderer, P., T. Hartmann, and C. Klimmt. *Explaining the enjoyment of playing video games: the role of competition*. in *Proceedings of the second international conference on Entertainment computing*. 2003. Carnegie Mellon University.
11. IJsselsteijn, W., et al. *Measuring the experience of digital game enjoyment*. in *Proceedings of Measuring Behavior*. 2008. Noldus Information Tecnology Wageningen, Netherlands.
12. Brockmyer, J.H., et al., *The development of the Game Engagement Questionnaire: A measure of engagement in video game-playing.* Journal of Experimental Social Psychology, 2009. **45**(4): p. 624-634.
13. Kao, D. and D.F. Harrell. *Toward avatar models to enhance performance and engagement in educational games*. in *Computational Intelligence and Games (CIG), 2015 IEEE Conference on*. 2015. IEEE.
14. Brondi, R., et al. *Evaluating the impact of highly immersive technologies and natural interaction on player engagement and flow experience in games*. in *International Conference on Entertainment Computing*. 2015. Springer.
15. Lindley, S.E., J. Le Couteur, and N.L. Berthouze. *Stirring up experience through movement in game play: effects on engagement and social behaviour*. in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 2008. ACM.
16. Fredricks, J.A., P.C. Blumenfeld, and A.H. Paris, *School engagement: Potential of the concept, state of the evidence.* Review of Educational Research, 2004. **74**(1): p. 59-109.
17. Appleton, J.J., et al., *Measuring cognitive and psychological engagement: Validation of the student engagement instrument.* Journal of School Psychology, 2006. **44**(5): p. 427-445.
18. Greene, B.A. and R.B. Miller, *Influences on achievement: Goals, perceived ability, and cognitive engagement.* Contemporary Educational Psychology, 1996. **21**(2): p. 181-192.
19. Goodenow, C., *The Psychological Sense of School Membership among Adolescents - Scale Development and Educational Correlates.* Psychology in the Schools, 1993. **30**(1): p. 79-90.

20. Betts, J.E., et al., *A Study of the Factorial Invariance of the Student Engagement Instrument (SEI): Results From Middle and High School Students.* School Psychology Quarterly, 2010. **25**(2): p. 84-93.
21. Duncan, I., A. Miller, and S.Y. Jiang, *A taxonomy of virtual worlds usage in education.* British Journal of Educational Technology, 2012. **43**(6): p. 949-964.
22. Boulos, M.N.K., L. Hetherington, and S. Wheeler, *Second Life: an overview of the potential of 3-D virtual worlds in medical and health education.* Health Information & Libraries Journal, 2007. **24**(4): p. 233-245.
23. A., M.-D., *Survey of e-business module (MN5553)*, in *School of Management report*. 2008, St Andrews University: St Andrews, Scotland.
24. Jestice, R. and S.S. Kahai. *The Effectiveness of Virtual Worlds for Education: An Empirical Study*. in *AMCIS*. 2010.
25. Ruddle, R.A. and S. Lessells, *Three levels of metric for evaluating wayfinding.* Presence-Teleoperators and Virtual Environments, 2006. **15**(6): p. 637-654.
26. Darken, R.P. and J.L. Sibert, *Navigating large virtual spaces.* International Journal of Human-Computer Interaction, 1996. **8**(1): p. 49-71.
27. Gamberini, L., et al., *Responding to a fire emergency in a virtual environment: different patterns of action for different situations.* Ergonomics, 2003. **46**(8): p. 842-858.
28. Sas, C., G. O'Hare, and R. Reilly, *A performance analysis of movement patterns.* Computational Science - Iccs 2004, Pt 3, Proceedings, 2004. **3038**: p. 954-961.
29. Elvins, T.T., et al., *Worldlets: 3-D thumbnails for wayfinding in large virtual worlds.* Presence-Teleoperators and Virtual Environments, 2001. **10**(6): p. 565-582.
30. Ruddle, R.A. and P. Peruch, *Effects of proprioceptive feedback and environmental characteristics on spatial learning in virtual environments.* International Journal of Human-Computer Studies, 2004. **60**(3): p. 299-326.
31. Qualtrics LLC. *Qualtrics Website*. [cited 2017 5 May]; Available from: http://www.qualtrics.com/.
32. Mozilla Foundation. *WebGL*. 2017 [cited 2017 28 April]; Available from: https://developer.mozilla.org/en-US/docs/Web/API/WebGL_API.
33. Gosling, S.D., P.J. Rentfrow, and W.B. Swann, *A very brief measure of the Big-Five personality domains.* Journal of Research in personality, 2003. **37**(6): p. 504-528.
34. Nikulin, M.S. *Student test*. Encyclopedia of Mathematics 2011 [cited 2017 11 August]; Available from: http://www.encyclopediaofmath.org/index.php?title=Student_test&oldid=17068.

Appendix A: Questionnaires

A.1 Student Engagement Instrument (SEI)

All questions are answered on a 4 point Likert scale as follows:

1: Strongly Agree 2: Agree 3: Disagree 4: Strongly Disagree

1. Overall, staff members at my university treat students fairly.
2. Staff members at my school listen to the students.
3. At my university, lecturers care about students.
4. My lecturers are there for me when I need them.
5. The university rules are fair.
6. Overall, my lecturers are open and honest with me.
7. I enjoy talking to the lecturers here.
8. I feel safe at the university.
9. Most lecturers at my school are interested in me as a person, not just as a student.
10. The exams in my classes do a good job of measuring what I'm able to do.
11. Most of what is important to know you learn in school and university.
12. The grades in my classes do a good job of measuring what I'm able to do.
13. What I'm learning in my classes will be important in my future.
14. After finishing my coursework I check it over to see if it's correct.
15. When I do coursework I check to see whether I understand what I'm doing.
16. Studying is fun because I get better at something.
17. When I do well at university it's because I work hard.
18. I feel like I have a say about what happens to me at the university.
19. Others students at the university care about me.
20. Students at my university are there for me when I need them.
21. Other students here like me the way I am.
22. I enjoy talking to the students here.
23. Students here respect what I have to say.
24. I have some friends at the university.
25. Going to university is important for achieving my future goals.
26. My education will create many future opportunities for me.
27. I am hopeful about my future.
28. My family are there for me when I need them.
29. When I have problems at the university my family are willing to help me.
30. When something good happens at the university, my family want to know about it.
31. My family want me to keep trying when things are tough at university.
32. I'll learn, but only if my family gives me a reward.
33. I'll learn, but only if the lecturer gives me a reward.

A.2 Ten Item Personality Inventory (TIPI)

Here are a number of personality traits that may or may not apply to you. Please write a number next to each statement to indicate the extent to which you agree or disagree with that statement. You should rate the extent to which the pair of traits applies to you, even if one characteristic applies more strongly than the other.

Disagree strongly	Disagree moderately	Disagree a little	Neither agree nor disagree	Agree a little	Agree moderately	Agree strongly
1	2	3	4	5	6	7

I see myself as:

1. Extraverted, enthusiastic.
2. Critical, quarrelsome.
3. Dependable, self-disciplined.
4. Anxious, easily upset.
5. Open to new experiences, complex.
6. Reserved, quiet.
7. Sympathetic, warm.
8. Disorganized, careless.
9. Calm, emotionally stable.
10. Conventional, uncreative.

A.3 Study 1 Questionnaire

1. **What is the occupation of the woman in the village?**
    a. *Hunter.*
    b. Cook.
    c. Village chief.
    d. Biologist.

2. **What do the villagers do to encourage growth of plants?**
    a. *Fire-stick farming.*
    b. Compost.
    c. Irrigation.
    d. Shifting cultivation.

3. **What plants do the villagers encourage to grow?**
    a. *Trees with fruit and nuts.*
    b. Corn.
    c. Bushes with fruit.
    d. Palm trees.

4. **What did the ecologist find out about the plant life?**
    a. *That there are more fire-loving plants.*
    b. That there are more rain-loving plants.
    c. That there are more drought-loving plants.
    d. That there are more compost-loving plants.

5. **How did the behaviour of the animals change?**
    a. *The animals travel more to find food.*
    b. The animals travel less to conserve energy.
    c. The animal packs are less dense to find more food.
    d. The animal packs are more dense to protect against predators.

6. **What is the weather pattern in Omosa?**
    a. *Long wet seasons and long dry seasons alternate.*
    b. Wet seasons with short dry seasons.
    c. Dry seasons with short wet seasons.
    d. Always dry weather.

7. **The old man near the farm says that the hunting practices changed over time. How did the hunting practices change?**
    a. *People hunt in places where it used to be forbidden to hunt.*
    b. People are forbidden to hunt in places where they used to hunt.

c. People use traps to hunt animals, but used only bows in the past.
d. People only use bows to hunt, but used to hunt with traps.

8. Where was the biologist who was looking at the behaviour of the animals located?

a. On the cliffs.
b. Near the farm.
c. In the village.
d. In the red research facility.

9. The biologist thinks the animals are dying out for what reason?

a. Their habitat is being disturbed.
b. The weather conditions have changed.
c. There are too many predators.
d. Visitors have brought diseases from overseas.

10. What do the villagers usually eat?

a. Meat from the animals they hunt.
b. Fish from the ocean.
c. Nuts and berries they gather.
d. Fruit from the trees.

A.4 Study 2 Scenario 1 Questionnaire

1. **What is the occupation of the woman in the village?**
    a. *Hunter.*
    b. Cook.
    c. Village chief.
    d. Biologist.

2. **What do the villagers do to encourage growth of plants?**
    a. *Fire-stick farming.*
    b. Compost.
    c. Irrigation.
    d. Shifting cultivation.

3. **Where could you find the tree-ring data?**
    a. *In the building near the cliff.*
    b. In the village hall.
    c. On top of the cliff.
    d. In the forest.

4. **What did the ecologist find out about the plant life?**
    a. *That there are more fire-loving plants.*
    b. That there are more rain-loving plants.
    c. That there are more drought-loving plants.
    d. That there are more compost-loving plants.

5. **How did the behaviour of the animals change?**
    a. *The animals travel more to find food.*
    b. The animals travel less to conserve energy.
    c. The animal packs are less dense to find more food.
    d. The animal packs are more dense to protect against predators.

6. **What is the weather pattern in Omosa?**
    a. *Long wet seasons and long dry seasons alternate.*
    b. Wet seasons with short dry seasons.
    c. Dry seasons with short wet seasons.
    d. Always dry weather.

7. **The old man near the farm says that the hunting practices changed over time. How did the hunting practices change?**
    a. *People hunt in places where it used to be forbidden to hunt.*
    b. People are forbidden to hunt in places where they used to hunt.

c. People use traps to hunt animals, but used only bows in the past.
d. People only use bows to hunt, but used to hunt with traps.

8. Where was the biologist who was looking at the behaviour of the animals located?

a. On the cliffs.
b. Near the farm.
c. In the village.
d. In the red research facility.

9. The biologist thinks the animals are dying out for what reason?

a. Their habitat is being disturbed.
b. The weather conditions have changed.
c. There are too many predators.
d. Visitors have brought diseases from overseas.

10. What kind of plants could be found between the farm and the ecology lab?

a. Burnt trees.
b. Lush trees with fruit.
c. Low brushes.
d. There are no plants between the farm and ecology lab.

A.5 Study 2 Scenario 2 Questionnaire

1. **What do the villagers keep in the town hall?**
    a. *Trophy heads of animals they hunted.*
    b. Paintings that were given to them by the researchers.
    c. Rugs that they wove themselves.
    d. Big shells that they found on the beach.

2. **What has the animal behaviourist found out about the prey animals?**
    a. *Prey animals move in tighter packs.*
    b. Prey animals have learned to swim.
    c. Prey animals started living more solitary.
    d. Prey animals have not changed their behaviour in years.

3. **What ritual do the villagers practice?**
    a. *They dance around the fire in a festive ritual.*
    b. They go hunting at night once a year.
    c. They meditate to communicate with the dead.
    d. They drink a traditionally distilled alcoholic drink.

4. **Why does the farm near the old man not have any crops on it?**
    a. *There has just been a harvest.*
    b. The farm flooded over a little while ago.
    c. The harvest failed because of a plant disease.
    d. The farm is only used in the winter.

5. **What has the ecologist found out about the plant life and the climate?**
    a. *The dry climate makes the plants grow slower.*
    b. The dry climate makes the plants grow faster.
    c. The quick oscillation between wet and dry season makes the plants bloom faster.
    d. The quick oscillation between wet and dry season makes the plants grow faster.

6. **Where was the ecologist located?**
    a. *In the building where you started.*
    b. Near the village.
    c. On the cliff.
    d. In the forest.

7. **What has the animal behaviourist found out about the predatory animals?**
    a. *The predators are hunting more aggressively.*
    b. The predators are starting to eat more plants.
    c. The predators are hunting in packs more.

d. The predators have learned how to swim.

8. What do the animals near the cliff look like?

a. They look like antelopes with their long horns.
b. They look like zebras with their striped skin.
c. They look like bears.
d. They look like horses with green scaly skin.

9. Where could you find the book with field notes of the flora and fauna of the island?

a. In the village hall.
b. Next to the old man.
c. In the building where you started.
d. On top of the cliff.

10. What has the climatologist, in the red research facility, found out?

a. That the last wet season was home to a massive flooding of the hunting grounds.
b. That the last dry season was the cause of a mass migration of birds.
c. That the unchanging season has made living conditions for animals harder.
d. That the rapidly changing seasons have caused more tornadoes.