Investigating the impact of Virtual Reality in developing Situation Models and supporting Reading Comprehension

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A dissertation submitted to the University of Dublin, Trinity College, in partial fulfilment of the requirements for the degree of Master of Science in Technology and Learning

Declaration

I declare that the work described in this dissertation is, except otherwise stated, entirely my own work and has not been submitted as an exercise at this or any other university.

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Abstract

The goal of reading comprehension is to develop an overall understanding of what is described in text. Readers construct mental representations of situations portrayed in text as they read. Envisioning the events as they occur in text is essential for generating an accurate situation model of the narrative.

As reading comprehension is a complex cognitive process, there are many instances where difficulties arise that result in comprehension failure. Research notes that the development of situation models is one of the most difficult aspects of reading comprehension for less-skilled readers (Woolley, 2010). Given the favourable outcomes that visual supports have on the development of situation models (Rakes & Smith, 1995), and the perceived affordances of virtual reality on the generation of mental representations (Rapp, 2005; Russell & Kozma, 2005); the researcher hypothesises that the use of virtual reality can support the creation of accurate situation models and thus improve reading comprehension.

In order to investigate the hypothesis, a research study was devised which assessed the situation models of primary school pupils when using virtual reality as a comprehension support. A mixed methods exploratory case study was implemented to enable the researcher to gain a comprehensive insight into the impact of virtual reality on the generation of situation models. The study implemented constructivist methodologies focusing on the accurate visualisation of narrative text.

The qualitative and quantitative data generated and analysed in this study suggests that the intervention had a positive impact on the generation of coherent situation models and

on participants' reading comprehension. The research recommends that further research is undertaken in this area to fully investigate this phenomenon further.

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Chapter 1: Introduction

1.1 Background and Context

Children's literacy skills, their ability to comprehend text and communicate ideas, begin to develop even before they enter primary school. As students progress through each class level, literacy skills become essential to learning in every subject, and students who lack these skills risk academic failure.

Reading comprehension is essential for success in life and is broadly defined as 'understanding, using, reflecting on and engaging with written texts, in order to achieve one's goals, to develop one's knowledge and potential, and to participate in society' (OECD, 1999). The significance of reading comprehension has been established in the vast knowledge base that has been established in the fields of psychology, education and cognitive sciences.

Unfortunately, as reading comprehension involves a vast range of cognitive processes, there are many occasions where difficulties arise that lead to comprehension failure. Within an Irish context, a 2012 Programme for International Student Assessment (PISA) report published by the Organisation for Economic Cooperation and Development (OECD) suggests that one in ten Irish children leave primary school unable to read (OECD, 2014). Children who have reading comprehension impairments are likely to struggle throughout their school career and experience difficulties with employment, social functioning in society, and other aspects of daily life (RAND Reading Study Group, 2002).

Research suggests that comprehension impairments may be due in part to difficulties creating and maintaining situation models. Generally, readers generate mental representations of narrative texts as they read. However, in the case of highly spatial texts, the focus of this study, readers often lack the necessary prior knowledge of the locations in question, and such, situation models are inaccurate and incorrect (Blanc & Tapiero, 2001).

Literature notes that less skilled readers have more issues integrating information from text and constructing coherent, accurate situation models (Morrow, Bower, & Greenspan, 1989). Given the favourable outcomes that visual supports can have on the development of situation models (Rakes & Smith, 1995), and that interactivity can improve visuospatial awareness (Mayer, 2005b), the researcher hypothesises that the use of virtual reality alongside narrative instruction can support the development of accurate situation models and consequently improve reading comprehension.

Virtual reality has garnered a lot of interest in the field of educational research. Although virtual reality has been explored in the areas of human rights and ethical education (Pan, Cheok, Yang, Zhu, & Shi, 2006), science instruction (Kartiko, Kavakli, & Cheng, 2010) and online tuition (Sharma, Agada, & Ruffin, 2013), it remains relatively uncharted in the area of literacy instruction. Accordingly, a framework and research project was devised to investigate the following research question:

Is virtual reality an effective tool in improving reading comprehension in primary school students?

The following sub-question was also considered:

Can virtual reality improve visualisation skills in primary school students?

Is it feasible for the proposed framework to be suitably adopted in a regular primary school environment?

1.2 Research Aim

This project will attempt to use virtual reality as a tool to support the development of situation models when reading narrative texts. In doing so, it is hoped that learners' overall visualisation skills and reading comprehension will be improved.

1.3 Research Objectives

The design objectives of this project are:

1. The establishment of an immersive, visual support to assist the development of accurate situation models.
2. Provide a tool to equip learners with the relevant prior knowledge necessary to generate coherent mental representations of narrative texts.
3. Investigate whether VR is a feasible tool to support reading comprehension in primary school students.

1.4 Road Map to Chapters

The concept of reading comprehension and the development of situation models is analysed in the literature review. The significance of situation models in terms of reading comprehension is addressed. The chapter also analyses how previous attempts were made to support visualisation using various technologies.

The perceived benefits of utilising VR as an educational tool are explored further in the literature review. Piaget's schema theory is explained as an explanation for the facilitative effect of prior knowledge on reading comprehension (Piaget, 1964). Constructivist theory and Csikszentmihalyi's (1975) Optimal Experience Theory are considered as a theoretical basis for this research project.

The design chapter is informed by the elements adhered to in the literature review and outlines the steps taken by the researcher to devise the learning experience. This chapter also gives a detailed account the scholarly and theoretical influences on the implementation of the study.

The methodology chapter outlines the reasoning behind choosing an exploratory case study approach to answering the projects research questions. The procedure of the learning experience and rationale for data collection tools are also explored in this section.

The dissertation concludes with a chapter revealing the findings of the research project and an analysis of the data collected. The effectiveness of using virtual reality as a tool to support reading

comprehension is explored, and the practicalities, advantages and disadvantages for an educational context are considered. Finally, the chapter investigates the limitations of the study and highlight possible areas in which to conduct future research.

1.5 Conclusion

The primary school undertaking this research project was supplied with iPod Touches and Google Cardboard headsets on a loan basis. The Google Street View app was subsequently downloaded to each iPod Touch in order to assess the usefulness or otherwise of virtual reality as a tool to support reading comprehension.

Chapter 2: Literature Review

2.1 Introduction

This project aims to investigate whether augmented reality can enhance the accuracy of situation models and support reading comprehension. Literature relating to augmented reality and the significance of situation models in terms of reading comprehension will be reviewed in this section.

2.2 Reading Comprehension

One of the world's greatest philosophers once mused, *'It is impossible to even think without a mental picture'* (Aristotle, trans. 1931). This is particularly true for all levels of reading, as without the correct mental representation, little comprehension or understanding is achieved.

Reading is an essential skill for academic success (Levine, Ferenz, & Reves, 2000). It is not only an important skill in academic contexts, but it is also crucial in daily life as people read to get information about specific topics (Rahimi & Ghanbari, 2011). Teaching children to read with accuracy, fluency and with adequate comprehension is one of the principal aims of primary education (Hulme & Snowling, 2011). Understanding and learning from written information is of significant importance to academic success (McNamara, 2007).

Readers rely primarily on background knowledge and their vocabulary knowledge in order to comprehend reading materials and to make logical conclusions and deductions (Snowling & Hulme, 2008). A perspective of reading was presented by Lev Vygotsky (1978) through the socio-cultural theory of learning (Rueda, MacGillivray, Monzó, & Arzubiaga, 2000). As a result, reading is viewed as a social skill that requires active participation, interaction and involvement of learners (Samar & Dehqan, 2013).

Reading comprehension can be divided into a number of elements, one of which is visualisation. Without an accurate mental representation of the portrayed events in a narrative, understanding of text can be inaccurate and erroneous.

Many factors contribute to difficulties faced by children in accurately comprehending written material. The specific interest of this study is to examine the effects of virtual reality on visualisation and reading comprehension.

2.3 Visualisation: A Crucial Component of Reading Comprehension

Understanding a story text requires the reader to form a mental representation, or situation model, of that story (Kintsch, 1991). Situation models serve as mental simulations of events in a text. During construction of a situation model, there is a continual interaction between textual information and world knowledge (Kintsch, 1986).

Situation models have been studied extensively in literature, and from a cognitive perspective, can be characterised according to a set of conceptual dimensions or event indexes (Kintsch, 1991). Emerging from research on situation model production and reading comprehension, the five dimensions typically discussed are time, space, causation, motivation, and protagonist. Although these dimensions are not the only ones feasible, they have empirical support and can be adapted to fit other genres of text (Zwaan, Magliano, & Graesser, 1995).

Successful comprehension can be thought of as the ability to create and maintain a coherent and reasonably accurate situation model (Radvansky, 1999). Research conducted to date has supported the notion that mental visualisations support reading comprehension (Graesser, Singer, & Trabasso, 1994; Morrow, Bower, & Greenspan, 1989; Perfetti & Stafura, 2014).

2.4 Limitations in the development of situation models in children

In order to create an accurate representation of the situation described in a text, the relevant background information has to be available and active (Wassenburg, Beker, van den Broek, & van der Schoot, 2015). The ability to generate visual representations from texts becomes increasingly important as students move from richly illustrated story books to novels and longer narratives with relatively few illustrations.

Much research has explored the impact of insufficient prior knowledge on the reading comprehension of children. In studies undertaken by Lauren (1988), Schwartz (2007) and Kendeou (2007) children with poor background knowledge scored considerably lower on comprehension assessments (Panayiora Kendeou & Van den Broek, 2007; R & Lauren, 1988; Schwartz, Sears, & Chang, 2007). There is ample evidence to suggest that incorrect prior knowledge can result in flawed situation models, thus impacting negatively on the comprehension of the narrative in question. Several researchers have noted that mental representations of physical locations and phenomena often contain profound errors. Children's mental representations are based upon prior knowledge and experience, even though this information may be inaccurate, incorrect or inconsistent (Norman, 2014).

To concentrate specifically on the subject of this study, world knowledge is of significant importance when processing texts with many locational references intended to provide the reader with information about spatial configurations. Although understanding the spatial dimension of texts is critical for accurate comprehension, it is generally the aspect that readers find most difficult (Golledge, Smith, Pellegrino, Doherty, & Marshall, 1985; Hakala, 1999).

With reference to prior knowledge of spatial information in text, locational stereotypes are important in constructing a spatial mental model during text comprehension, because they will influence the understanding of spatial situations and interactions between characters and locations in the text.

Situation model scholars generally study cognitive processes undertaken when reading texts and do not necessarily focus on mental models as a representation of comprehension. Recent studies have tried to examine narrative comprehension within a situation model's theoretical context, but this theoretical approach remains relatively unexplored (Busselle & Bilandzic, 2009). This study aims to extend research on situation models by examining in-depth situation models constructed by individuals reading a story before and after they use VR as a comprehension support.

2.5 Attempts to enhance comprehension using visual electronic media

2.5.1 Television

Previous research has attempted to capitalise on the affordances of visual electronic media by exposing children to televised versions of fictional narratives in order to aid comprehension (Calvert, Huston, & C. Wright, 1987; H.-C. Chen & Graves, 1995; Neuman, Burden, & Holden, 1990; Sell, Ray, & Lovelace, 1995). Participants were exposed to a story presented by audiovisual means (television), and via an audio recording (radio). Results demonstrated that visual imagery generally had a positive impact on comprehension as it presented more information and an explicit mnemonic tool.

Research concluded that visual electronic media supports comprehension as children rely heavily on visualised actions and events when recalling narratives or generating visual representations of text (Flapan, 1968; Meringoff, 1980).

2.5.2 Multi-user Virtual Environments

Jenkins (2006) distinguishes between new media and old media through social participation. Old media involves 'passive media spectatorship' (Jenkins, 2006, p.5), while new media are participatory

in nature (Jenkins, 2006). In this sense, television belongs to old media, whereas virtual reality belongs to new media.

More recently, educational researchers and practitioners have paid considerable attention to the use of multi-user virtual environments (MUVEs) to support learning. MUVEs offer compelling visual and interactive components in a graphical virtual context. Educational MUVEs incorporate 2-D and 3-D virtual worlds in which learners control characters which represent them in the worlds (Ketelhut & Nelson, 2010; Mueller & Strohmeier, 2011). Through these 'characters', learners can explore immersive worlds, engage in collaborative learning activities and interact with objects.

Burgess' (2012) study into the effectiveness of MUVE exposure on reading comprehension deducted that participants who experienced reading and literacy instruction in a virtual environment showed increased reading achievement gains over a control group who underwent the same instruction and did not use a virtual environment (Burgess, Price, & Caverly, 2012).

Technologies currently used to improve visualisation

There are currently no educational technologies or applications available in Ireland with the sole intention of improving visualisation when reading. However, research suggests that educators make use of other technologies during visualisation instruction such as Google Images, Youtube videos and audiobooks (Dreyer & Nel, 2003).

2.6 The need for transformative learning experiences in literacy instruction

A recent study conducted by the National Council for Curriculum and Assessment unearthed that due to logistical and spatial constraints in classrooms, Irish teachers are less likely to employ constructivist and active methodologies than their European counterparts (NCCA, 2012). Although scholars maintain that reading comprehension must be an active process for learning to occur (Glenberg, Gutierrez, Levin, Japuntich, & Kaschak, 2004; Harris & Weiss, 2001), a 2005 report by the

Department of Education and Skills bemoans literacy teaching in Ireland, noting that children were not encouraged to take part in active instruction (DES, 2005).

First conceptualised by Dr. Ruben Puentedura, the SAMR model has four sequential stages: **S**ubstitution, **A**ugmentation, **M**odification, and **R**edefinition (Puentedura, 2013).

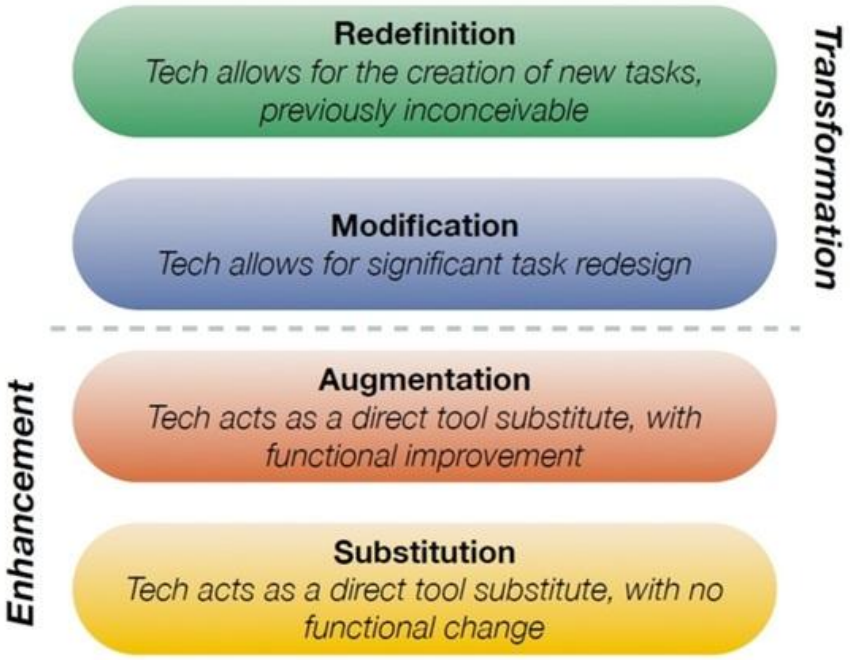

Figure 1 SAMR Model

The SAMR Model describes an ICT led pedagogy to be the use of technology as: a direct substitute tool with no change (Substitute), direct tool substitute with functional improvements (Augmentation), a tool for significant task re-design (Modification), or a tool for the creation of new tasks, previously inconceivable (Redefinition) (Muyinda, Annet, & Lubega, 2014).

Learning activities that fall within the substitution and augmentation classifications are said to *enhance* learning, while learning activities that fall within the modification and redefinition classifications are said to *transform* learning (Puentedura, 2013). Undoubtedly, the use of virtual reality as a support for reading comprehension exists at the Redefinition stage of the SAMR Model. In the context of this project, virtual reality enables learners to engage in a learning activity that would not be possible without a mobile device.

2.7 Virtual Reality

Virtual Reality (VR) enables the seamless connection of digital and physical domains, and is one of the newest technologies applied to education (Billinghurst & Dünser, 2012). VR is a live view of a real-world environment where the elements of the environment are augmented by software, such as audio or video.

Research to date has focused on using virtual reality in language learning. Research has concentrated on understanding prepositions (Hsieh, 2014), vocabulary acquisition (C.-P. Chen & Wang, 2015; Perry, 2015) and vocabulary retention (Ogawa, 2016). More recently, there are increasing numbers of cases of the research development of virtual reality books by international computer science laboratories. These studies however, focus solely on the technical aspects of VR books, and not the educational implications (Carmigniani et al., 2011; Cho, Jung, Lee, Lim, & Yang, 2011; Dünser, Walker, Horner, & Bentall, 2012). There are no current virtual reality aids to reading comprehension available in the primary classroom.

2.8 Potential affordances of Virtual Reality

Shelton (2003) suggests that VR facilitates constructive, intentional, and practical learning experiences (Brett E Shelton, 2002).

Virtual reality incorporates many features that may make it an excellent support for the development of situation models. One such affordance is the fidelity and accuracy to real world environments. As noted in Pirker & Gutl's (2015) study comparing representations in 2D and 3D, 3D virtual representations were reported to be more powerful in generating accurate and detailed mental visualisations (Pirker & Gutl, 2015).

Furthermore, AR has a greater capacity to promote kinaesthetic learning through physical movement through richly sensory spatial contexts.

2.8.1 Visual component

The visual component afforded by virtual reality supports Eitel & Scheiter's (2014) proposition that pictures help to facilitate the creation of a mental representation, as they clarify implicit or unclear relations in the text (Eitel & Scheiter, 2014). This so called 'visual effect' has especially been found in research with expository texts (Levie & Lentz, 1982; Peeck, 1993), but there has been little evidence in the case of narrative texts (Slough, Mctigue, Kim, & Jennings, 2010).

2.8.2 Acquisition of information

Significantly, in terms of visualisation and the development of mental models, VR-based learning reduces the acquisition of incorrect concepts and increases the understanding of complex content (B. E. Shelton & Hedley, 2002). As noted by Norman's (2014) investigation into the development of mental representations, inaccurate or skewed information can increase cognitive load and inhibit the development of accurate mental models; thus having a direct impact on comprehension. Therefore, the use of virtual reality diminishes the attainment of inaccurate ideas and supports authentic visualisation.

2.8.3 Interactivity

Studies undertaken suggest that interactive tools can support the development of mental models and representations (Rapp, 2005; Russell & Kozma, 2005). Crampton (2002, p. 88) defined interactivity in AR as 'a system that changes its visual data display in response to user input' (Crampton, 2002). Augmented reality offers interactivity by updating visual information based on user movement and responses.

2.8.4 Imagination

Virtual reality environments have the potential to stimulate creative imagination (Morgan, 2013). The Oxford English Dictionary defines imagination as 'the power or capacity to form internal images or ideas of objects and situations not actually present to the senses, including remembered objects and situations, and those constructed by mentally combining or projecting images of previously experienced qualities, objects, and situations'.

Research has noted the significance of creative imagination in the generation of situation models. Van Der Schoot et al.'s (2008) study emphasised the importance of imagination in relation to reading comprehension. The study observes that the reader's creative imagination 'helps the reader to update the situation model and keep track of various narrative dimensions' (Van Der Schoot, Vasbinder, Horsley, & Van Lieshout, 2008, p. 818). Competent readers relied on their imaginary abilities to create coherent situation models. In this respect, augmented reality has the potential to support readers in the generation of accurate visual representations.

2.9 Theoretical Framework

2.9.1 ARCS Model of Motivation

The proposed learning experience incorporates Keller's ARCS Model of Instructional Design (J. M. Keller, 1978). Keller's model outlines four specifications that must occur in order to promote and sustain motivation in the learning process. The four elements embrace attention (A), relevance (R), confidence (C), and satisfaction (S).

Figure 2 ARCS Model of Motivational Design

In order to stimulate the learner's attention, their motivation must be aroused by a novel, incongruous or surprising event (Keller, 2000). The use of virtual reality as an instructional support varies from conventional methods of improving reading comprehension.

To maintain motivation, it is imperative to use teaching materials that are relevant and of interest to the participant. The use of technology uncommon to the primary classroom setting, namely an iPod Touch and virtual reality headset, is relevant to the learner as it associates learning with authentic experiences.

The learner must perceive likelihood for successful achievement of learning objectives and targets to preserve motivation. As the proposed intervention utilises hardware and software that the learners are familiar with, participants are equipped with a sense of confidence that learning intentions will be achieved.

Learners must realise a sense of achievement or accomplishment in order to elicit satisfaction from the learning experience. Opportunities to communicate attainable learning targets to participants

are embedded in this intervention to provide learners with the chance to evaluate their knowledge and generate satisfaction from their contribution.

2.9.2 Schema Theory

Schema theory is based on the work of Jean Piaget and suggests an explanation for the facilitative effect of prior knowledge on reading comprehension (Afflerbach, 1990; Piaget, 1964). Readers with high prior knowledge of the content have well-developed schemata, into which they incorporate the information from a text. Information from the text is mapped onto the reader's existing knowledge structures, facilitating accurate comprehension and increased recall (Anderson & Pearson, 1998). The ease with which situation models are integrated depends on how many aspects of the dimensions are shared between prior knowledge and the iterations of the situation model that develop as the text is being read. Congruent information between dimensions results in more rapid updating into a situation model than incongruent information. Conflicting or incongruent information slows or even interrupts the integration process (Panayiota Kendeou, Van Den Broek, Helder, & Karlsson, 2014).

Figure 3 offers a graphic conceptualisation of situation model production. Using *Harry Potter* as an example, the figure explains what a reader might activate at the beginning of the reading process. As new information is obtained, the reader compares, evaluates and updates the representation into an integrated schema in long term memory (Griffiths, 2011).

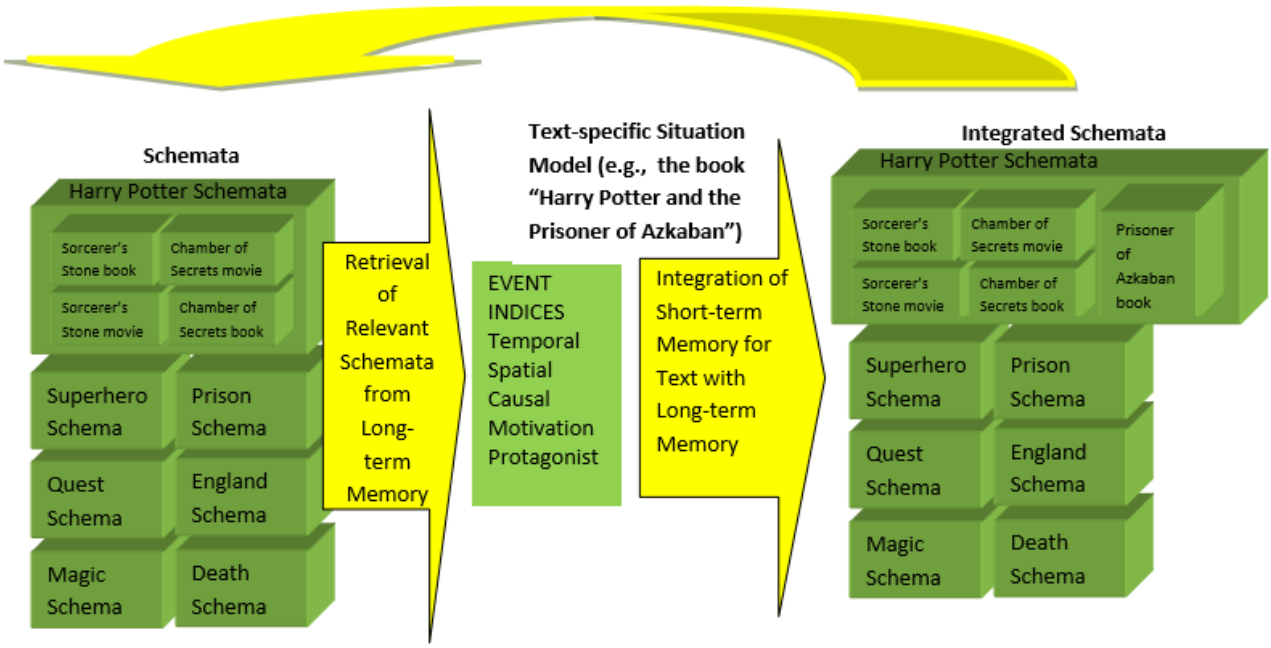

Figure 3 Construction of Situation Model

The construction of situation models happens over time while reading and leads to the updating of schemata stored in long-term memory (van den Broek, Kendeou, Lousberg, & Visser, 2011). As new information is obtained, the reader compares, and evaluates event indices, then ultimately integrates the updated representation into an integrated schema in long-term memory.

2.9.3 Constructivist Learning

Constructivist theory suggests that meaningful learning is a process of learning through engagement with and reflection on authentic experiences.

Furthermore, 'the influence of constructivist theory is evident in VR enhanced learning environments' (Wasko, 2013, p.18). From the constructivist outlook, VR emphasises the importance of the involvement of the learner actively in the learning process. There are several implications for the development of comprehension skills:

1) Creating authentic task based learning.

2) Connecting with learner's existing knowledge schemas.

3) Presenting both verbal and visual information simultaneously.

4) Giving learners advance preparation (Joseph & Uther, 2009).

2.9.4 Experiential Learning Theory

The concept of experimental learning includes learning from a concrete experience, through reflective observation, to abstract conceptualization, and finally, to testing in new situations and new experience. This can be illustrated as a cyclical pattern, the Experimental Learning Model (Kolb, 1984). Learners build a deeper understanding by cycling through the four steps of the Kolb's Learning Model (Beard, Wilson, & Mccarter, 2007).

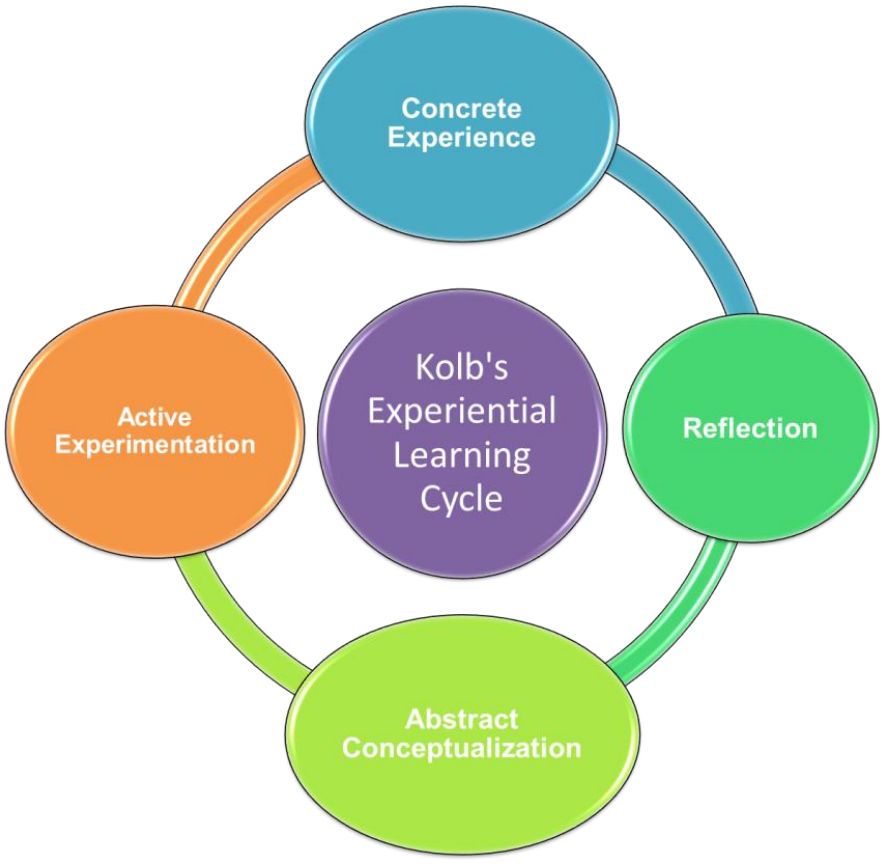

Figure 4 Kolb's Experiential Learning Cycle

A key idea of many scholars who have studied virtual reality in education is that the facilitation of total body involvement and promotion of sensorimotor learning enables experiential learning to

take place. The experiential learning model defines learning as an active and iterative process, which requires reflection of the learning content (Freitas & Neumann, 2009).

The research examining the general characteristics of virtual reality and its potential benefits for teaching and learning has found support for the effectiveness of virtual worlds. Elements such as immersion, interaction, manipulation, movement and active engagement have been found to foster experiential learning (Bishop, Ye, & Karadaglis, 2001; Dalgarno & Lee, 2010; Jarmon, Traphagan, Mayrath, & Trivedi, 2009).

As demonstrated by Boulos et al, educators often encounter difficulty implementing experiential learning during instruction (Boulos, Hetherington, & Wheeler, 2007). Diligent planning and consideration must be adopted when attempting to facilitate experiential learning in classrooms.

2.9.5 Optimal Experience Theory

On a somewhat smaller scale, this study is also reliant on Csikszentmihalyi's (1975) Optimal Experience Theory. Optimal experience is represents a 'holistic sensation that people feel when they act with total involvement'(Csikszentmihalyi, 1975, p.36). Csikszentmihalyi's theory encompasses three components: a) optimal experience requires a balance between the challenges the activity presents matched with the skills necessary to meet those challenges; b) optimal experience is a state of total immersion and absorption; and c) experiences are enjoyable and can lead to intrinsic motivation within the experience itself (Csikszentmihalyi, 2014a, 2014b).When examining this theory in relation to virtual reality environments, the educational significance becomes apparent. Virtual reality has the potential to link cognitive and effective affordances and induce optimal experience.

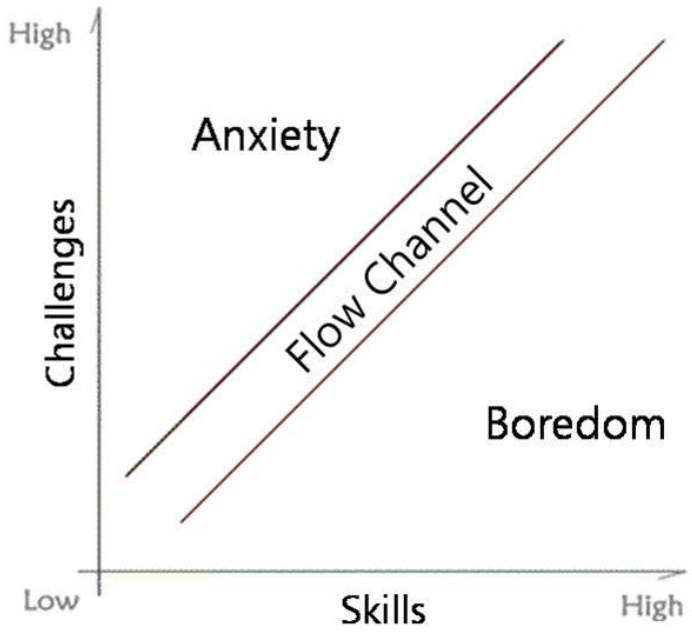

Figure 5 Optimal Experience Theory

2.10 Issues with the research and further directions

Most research and development practices relating to virtual reality educational supports were undertaken with a technological perspective focused solely on the field of computer engineering. Research which discussed VR i in terms of instructional design, teaching and learning theory and educational implications were extremely limited and difficult to source.

Chapter 3: Design

3.1 Introduction

The literature review has highlighted the need to improve the development of situation models to support reading comprehension. The researcher hypothesises that exploring augmented reality alongside narrative study can increase the accuracy of mental representations and therefore improve reading comprehension.

Firstly, the aim and objectives of the design will be expanded upon. The pedagogy underlying the design of the learning experience will be explained. Finally, an explanation of the implementation process will be provided.

Many factors affected the implementation of this intervention. Research noted that Irish educators blame time constraints (C.-P. Chen & Wang, 2015) and poor ICT infrastructure (McGarr & Kearney, 2009) for their inability to incorporate constructivist methodologies to their daily practice. In order for this concept to become commonplace, it is essential that can occur within existing structures.

3.2 Design Aim

The aim of this design is to assess the value of using virtual reality alongside formal literacy instruction in generating coherent, accurate situation models in primary school pupils.

3.3 Background and Context underlying Learning Experience

This learning experience was designed to support the formation of situation models and subsequently enhance reading comprehension in primary school pupils. In order to create a coherent representation of the described situation in a story, readers are required to monitor situational dimensions during reading. Various studies have outlined the difficulties that children encounter in generating and maintaining coherent mental representations while simultaneously

attempting to decode words (Mahapatra, Das, Stack-Cutler, & Parrila, 2010) and decipher phonemes (Shuker & Terreni, 2010).

Based on the cognitive theory of multimedia learning(Mayer, 2005a), with its underlying cognitive load theory (Sweller, 1999) and dual coding theory (Paivio, 1986), research has shown that visual information found in multimedia aid the creation of accurate, intact images which in turn allow for increased comprehension.

During this learning experience, participants will use virtual reality to explore real-world locations mentioned in two children's novels: Kensuke's Kingdom and Around the World in Eighty Days. Pupils will use the virtual reality function in Google Maps to virtually explore the settings alluded to in each narrative.

3.4 Description of Learning Experience

The intervention would take place daily over a eight week period. Members of the learning experience would be given the opportunity to manoeuvre virtual reality panoramas. Virtual reality will essentially afford readers the opportunity to position themselves in the location they are currently reading about.

Education is often viewed as a transformational experience for learners; however the role of technology in facilitating transformation receives much debate in literature (Donnelly, 2009; Milrad, Sharples, Kukulska-Hulme, Arnedillo-Sánchez, & Vavoula, 2009; Newman, 2012). With the increasing ubiquity of technological devices, the focus of current educational technology debate is how to capitalise upon the potential of mobile technology to transform education.

Transformational learning experiences take place at the Modification or Redefinition layer of the SAMR model (Puentedura, 2013). Mezirow suggests that transformational learning experiences allow for the most significant type of knowledge acquisition (Mezirow, 2003). This transformative

learning unit was designed to contrast traditional processes of assimilative learning in literacy education.

3.5 Phase 1

Actions	Influence on visualisation and reading comprehension	Influences
Outline of objectives	Motivation, Relevance	Keller's ARCS Model of Motivation (J. M. Keller, 1978)
Teacher modelling	Visualisation and reading comprehension	(Paquette, Fello, & Jalongo, 2007)
Introduction of technology	Integration of technology, Confidence, Satisfaction	Keller's ARCS Model of Motivation (J. M. Keller, 1978)
Open exploration	Problem-Centred Approach	Merrill's Principles of First Instruction (Merrill, 2002)

Table 1 Phase 1

3.5.1 Outline of objectives

In order to successfully measure the value of virtual reality as a tool to improve situation models, it was essential that learners were motivated to participate in the research project. In expectancy-value theory, 'effort' is identified as the major measurable motivational outcome. For 'effort' to occur, two necessary prerequisites are identified: 1) the participant must value the task and 2) the participant must believe that he or she can succeed at the task (J. M. Keller, 1978). Therefore, the learning experience would be presented in a way that was meaningful and engaging to the participant and promote positive expectations for the successful achievement of learning objectives.

Keller's ARCS Model of motivational design was utilised throughout the learning experience (J. M. Keller, 1978). The four components of Attention, Relevance, Confidence and Satisfaction were incorporated for the duration of the intervention.

In relation to the Relevance element, it was essential that expectations and prerequisites were communicated to learners in advance. This was achieved through discussion and modelling by the researcher.

3.5.2 Modelling

In order for the learners to fully comprehend the objectives and understand the task, a degree of modelling is beneficial. The researcher would demonstrate the use of the 'Talking Drawings' strategy (Paquette et al., 2007) to model the process of pictorially representing situation models. Within this stage, the researcher demonstrated the process of listening to a passage, highlighting key features and adjectives and verbally outlined the method of transferring a mental representation to a drawing. The researcher's verbalisations include a description of how central words in the narrative influence the formation of a situation model.

3.5.3 Introduction of Technology

The hardware and software necessary to implement the research project is introduced to participants. The learners are introduced to Google Cardboard Virtual Reality Headsets, iPod Touches and the Google Street View application.

Davis' Technology Acceptance Model (TAM) (Davis, 1993) is composed of five constructs including external variables, perceived ease of use, perceived usefulness, attitude and intention to use. Davis notes that the perceived ease of use of technology influences the user's attitude towards the technology (Davis, 1989).

3.5.4 Open Exploration

Merill's Principles of First Instruction were utilised when implementing the chosen technology initially. Merrill's Principles of First Instruction comprises of five elements: Problem Centred, Integration, Activation, Application, and Demonstration (Merrill, 2002). In relation to the Problem-

Centred component, it is necessary that learners are engaged in solving problems with the new technology, as recent research has adhered to the fact that students learn better when engaged in solving problems (Mayer, 1975). As a consequence, learners were presented with a problem and independently used technology to find a resolution. Merrill's model specifies that if learners receive initial independent experience, relevant information is activated and ready for use as a foundation for new knowledge (Merrill, 2002).

This phase is also consistent with the Satisfaction element of Keller's ARCS model (J. M. Keller, 1978). When learners perceive their effort is matching with their outcome, they will be proactive in engaging with continuous learning (Hung, Lee, Chao, & Chen, 2011). Keller recommended creating a scenario in which learners can immediately apply what they have learnt in order to create learning satisfaction (J. M. Keller, 1978). Learners used their newfound knowledge from the previous phase to engage in an informal problem-solving activity.

This phase also served to minimise the novelty factor of the technology, allowing for more accurate qualitative and quantitative data collection.

3.6 Phase 2

Actions	Influence on visualisation and reading comprehension	Influences
Introduction of texts	Generation of detailed, accurate situation models	(Vellutino, 2000)
Exploration of Virtual Reality	Integration of Technology	(Dede, Salzman, Loftin, & Ash, 2000)
Pictorial Representation of Situation Models	Representing individual mental representations pictorially	(Prior, Willson, & Martinez, 2012)
Individual Retelling of Pictorial Representation	Further analysis of individual situation models	(Yang, 2002)

Table 2 Phase 2

3.6.1 Introduction of texts

Vellutino's research on the construction of mental representations during reading stresses that the examination of multiple texts is preferred when assessing situation models. Reading multiple texts allows the reader to make connections between texts, and ultimately provides for more detailed, accurate situation models (Vellutino, 2000). In order to accurately assess the situation models of the participants, it was imperative to use a range of appropriate texts.

Texts chosen were unfamiliar texts that suited the average reading age of the learners involved. The participants read excerpts from three fiction texts over the course of the eight week intervention. The fiction texts chosen as part of this study were selected using the following criteria outlined in Table 3.

Criteria for selecting fiction texts
Appropriate text level for average reading age of participants
Rich, descriptive vocabulary
Main protagonist undertakes travel/a journey
References made to real-world locations

Table 3 Criteria for selecting texts

3.6.2 Exploration of Virtual Reality

Theory and empirical research in pedagogy and literacy education suggest that learning mode (the way in which information is presented to the learner) has a critical influence on learning outcomes. These literatures indicate that *didactic* learning through listening may not be suitable for this type of education, because developing an understanding of these concepts often requires building mental models of unfamiliar objects and locations. *Active learning*, in which learners are asked to construct their own knowledge through self-driven, interactive activities, has been suggested as a better educational approach for building mental models (Dede et al., 2000). These consequences were

considered during the design process and learners were encouraged to engage in autonomous, immersive and independent learning. The allocated exploration time afforded learners in the group an opportunity to investigate high-resolution panoramas and street-level images of real-world locations mentioned in the chosen texts.

The constructivist theory of constructing knowledge from experience, not from descriptions of experience, is applicable here. Immersion in VR allows for comparable interactions with objects that participants engage with in the real world. Affording learners the opportunity to construct their own knowledge for the duration of the learning experience adheres to the constructivist learning theory which was alluded to throughout.

Similarly, the use of VR tools as an instructional strategy reflects experiential learning (Dewey ref). Dewey (1938) promoted the benefits of experiential learning, explaining, 'there is an intimate and necessary relation between the processes of actual experience and education' (p.7). He maintained that experiential learning enables students to develop their own opinions of a concept based on their interaction with the information.

3.6.3 Assessment of Situation Models

Given the many requirements for the construction of a coherent situation model, assessment of learners' mental representations is complex and depends on a number of factors. Paquette et al. maintain that art is one of the most favourable tools in expressing knowledge in young children (Paquette et al., 2007). Furthermore, Zwaan maintains that a diagrammatic or pictorial representation is the most precise form of assessment (Zwaan, Langston, & Graesser, 1995). Consequently, in order to assess the accuracy of learners' mental representations, participants were asked to represent their situation models pictorially after each chapter studied. The students used A5 paper and had access to colouring pencils and crayons with a wide assortment of colours.

The pictorial representations of situation models were assessed using the following rubric:

Score	Description
0	No recognisable comprehension of locational information; entirely random. Images bear no relationship to text.
1	Beginnings of recognisable comprehension.
2	Some locational information accurately comprehended, the majority still inaccurate.
3	A balanced mixture of accurate and inaccurate spatial information.
4	Majority of spatial information accurately located, but some errors remain
5	Totally accurate comprehension of spatial information

Table 4 Scoring Rubric

It was important to communicate to participants throughout that drawings would not be assessed based on artistic ability or quality. Learners were continuously referred to the assessment rubric based on which their pictorial representations would be scored. By providing learners with a child-friendly version of the assessment rubric, reference was made to the Confidence element of the Keller's ARCS model of Instructional Design (J. M. Keller, 1978).

Measurable targets and objectives are important to elicit confidence from learners. Accordingly, by informing participants of performance requirements and assessment criteria, learners were given an opportunity to reflectively evaluate their work and instil a sense of self-assurance in their work.

3.6.4 Individual Retelling of Pictorial Representations

Kearney and Kaplin maintain that an imagistic and verbal approach must be combined for mental model elicitation. Combined oral- and visual-based procedures are theoretically supported by studies that suggest cognition is not solely language based, and that verbal and imagistic thoughts are carried out by two distinct systems (Kearney & Kaplan, 1997). Kearney & Kaplan support the notion that a retelling procedure can support the participant's cognitive ability to access more deeply held beliefs.

Therefore, in order to allow for thorough assessment, it was paramount that participants were afforded the opportunity to provide a verbal retelling of their pictorial representation. The learners

were encouraged to express verbally their comprehension and intended meaning in their own drawings. This allowed for the possibility that learners may have had insufficient time to complete their drawings or may not have possessed the artistic ability to include certain key elements of their situation models.

The individual retelling of pictorial representations took place after the drawings were created, and were transcribed by the researcher for analysis. The researcher used prompts to elicit responses based on the drawings (Appendix D).

3.7 Phase 3

Actions	Influence on visualisation and reading comprehension	Influences
Continuous Feedback	Reflection on Learning	Experiential Learning (Kolb, 1984)

Table 5 Phase 3

3.7.1 Continuous Feedback

Deci et al. argue that extrinsic rewards controls self-regulation and provides affirmative feedback (Deci, Koestner, & Ryan, 2001). Although the application used for the purpose of this research project lacked an inbuilt extrinsic reward capability, the continuous participation and completion of tasks were promoted through the class reward system.

Keller suggests that positive feedback should be provided to learners, regardless of performance (J. M. Keller, 1978). In order to fulfil Keller's element of Satisfaction, learners were afforded positive, constructive feedback from the researcher throughout the intervention. Review and reinforcement of comprehension strategies were included in lessons to allow participants to reflect on their advances in reading comprehension.

Section 4: Research Methodology

4.1 Introduction

This chapter will address the research questions raised in this project. A discussion of the research methodology and a description of the data collection and analysis will follow.

4.2 Methods

The purpose of this study was to determine whether exploring augmented reality alongside narrative reading could enhance the accuracy of situation models and therefore support reading comprehension. The study documented their mental representations through verbal and pictorial drawings and retellings.

4.3 Research Questions

This research project aims to address the following research question:

Is virtual reality an effective tool in improving reading comprehension in primary school students?

Sub-questions to be considered:

Can virtual reality improve visualisation skills in primary school students?

Is it feasible for the proposed framework to be suitably adopted in a regular primary school environment?

4.4.1 An Exploratory Case Study

In the field of education, case studies allow researchers to explore important issues and emerging themes in our ever changing society. Therefore, an exploratory case study approach was applied in this study to assess whether virtual reality influenced primary school students' reading comprehension. Bogdan and Biklen (2003) described a case study as a detailed examination of a

setting, or a single subject, a single set of documents or one particular event (Bogdan & Biklen, 2003). The case study method allows the researcher to understand the *how* and *why* of contemporary events, problems and situations (Yin, 2009).

4.4.2 Justification for mixed methods

Mixed methods were chosen for use with this exploratory case study. Mixed methods means that both qualitative and quantitative data will be collected, analysed and interpreted (Sharp et al., 2012).

Utilising a mixed methods approach has received some criticism in literature. Much of the arguments raised against mixed-methods research maintain that data sourced using mixed methods methodologies is vulnerable to collinearity (Roberts, 2000), and data may not have enough statistical power to support the research undertaken (Driscoll, Appiah-yeboah, Salib, & Rupert, 2007).

Others suggest that researchers must strive towards a quantitative and qualitative 'hybrid', rejecting any distinctions between both methodologies (Bryman, 2006). Viewing mixed-methods as a third research paradigm, Creswell welcomes the discussion and advocates that researchers are enabled to employ new ideas, strategies and methods to their research, adding that it is best able to capture the complexity of some educational issues (J W Creswell, 2003).

Having considered the advantages and disadvantages to mixed methods methodologies, the researcher concludes that a range of data collection methods will add strength and viability to the research conducted, and may highlight data that may have otherwise have escaped attention (Ågerfalk, 2013). It is important to note, that as a small-scale study with time and curricular constraints, the insights that the research project provide may prove to be unreliable.

4.5 Participants

The participants used for this study were thirty Second and Third Class pupils from a primary school in County Monaghan. The sample consisted of 16 females and 14 males ranging in age from seven years to nine years. All participants undertook daily English lessons of 30-40 minute duration. The participants' reading levels were assessed before the study. The average reading age of the cohort was 8 years and 7 months. The participants had previously studied a range of fiction and non-fiction texts but were not familiar with the texts chosen for this study.

Figure 6 Urbleshanny National School, Co. Monaghan

As the research was conducted as part of structured school lessons, participants did not endure a greater sense of pressure to succeed during the process of this intervention.

4.6 Researcher Bias

Due to the nature of the researcher's position as teacher of the participants, a conflict of interest arises. Bias may jeopardise the validity of a study or question the integrity of the instrumentation being examined (Chenail, 2011). The researcher's previous knowledge of the abilities and capabilities of the participants can unintentionally lead to bias where information is judged based on preconceived ideas. In order to address this, drawings and reflective passages were submitted anonymously. It was also emphasised repeatedly that impartial, unbiased work is encouraged.

4.7 Procedure of the Learning Experience and Data Collection

Research Question	Data Collection	Data Analysis
Is virtual reality an effective tool in improving reading comprehension in primary school students?	Pictorial Drawings of Situation Models Reading Assessment	Score pictorial representations Initial and final reading assessments compared
Can virtual reality improve visualisation skills in primary school students?	Verbal Retellings Pictorial Drawings of Situation Models	Review and transcribe verbal retellings Score pictorial representations
Is it feasible for the proposed framework to be suitably adopted in a regular primary school environment?	Class Discussions Reflective passages Researcher Observation	Review and transcribe discussions Code reflective passages Observation notes analysed

Figure 7 Data Collection and Analysis

The learners engaged in Shared Reading activities using the fiction texts chosen for this study. After reading each chapter, participants were asked to draw a pictorial representation of their situation model. Learners then explored the real-world locations referred to in the chapter in virtual reality. The learners generated an updated pictorial representation of their situation model. Both drawings were scored using a scoring rubric, analysed and compared.

iPod Touches were inserted into Google Cardboard virtual reality headsets and real-world locations were explored using the Google Street View app. It was decided to use iPod Touches as participants were proficient in using such technology already. The technology is innovative and requires minimal instruction in its use. The Google Street View app was chosen as it possesses an inbuilt 'Google

Cardboard' feature making it compatible with the virtual reality headset. The virtual reality headset and Google Street View technology support the implementation of experiential learning.

Figure 8 iPod Touch Handset

Figure 9 Google Cardboard Viewer

This learning experience took place over an eight week period. In order to increase the validity of the results, a number of different datasets were collected. Both qualitative and quantitative data were included.

Unless the intervention was deemed to be realistic and feasible within the confines of a classroom environment, utilising the technology available, it would not be as beneficial as a possible intervention to support reading comprehension. The learning experience took place as part of a Station Teaching Model, where the classroom is split into various teaching centres. Assessments were carried out to ensure that the station groups were mixed-ability. Students were divided into small groups based on assessment results and rotated between each teaching centre. Participants were split into groups of six and explored virtual reality as part of a 'Comprehension' station.

Procedure
All participants undertake reading instruction and comprehension tasks as part of curricular requirements. Texts are presented to learners. (Texts chosen for this study are based on the criteria outlined in Table 3.
Participants read texts individually.
Participants pictorially represent their understanding of the story.
Learners are given the opportunity to explore real-world locations mentioned in the texts in virtual reality headsets.
Participants are asked to present their updated situation models in drawing form.
Participants verbally retell their situation model drawings to researcher.
Participants update their reflective Padlet after each lesson.
Participants partake in a post-intervention interview to reflect on their experience.

Table 6 Procedure

Data collection comprised of both qualitative and quantitative approaches. Data collection comprised of:

- PM Benchmark Reading Assessment
- Researcher observation and informal questioning
- Individual representations of situation models

- Individual reflective passages
- Post-intervention group interviews

PM Benchmark Reading Assessment

Figure 10 PM Benchmark Reading Assessment Resource

The PM Benchmark Reading Assessment was administered before and after the intervention took place. The reading assessment is designed to assess students' independent reading and comprehension levels using unseen texts. The assessment kit requires learners to independently read a series of fiction and non-fiction texts and subsequently answer a series of lower order and higher order questions. An average reading age is then provided based on the results of the test.

A pre and post test was administered to identify potential gains in the comprehension level of the students. The learners were split into five mixed-ability groups of six based on the results of the pre-test. This form of quantitative data collection was significant in assessing the usefulness of VR as a tool to support reading comprehension.

Figure 11 Sample Reading Assessment

Researcher observation and informal questioning:

Iacono et al. conclude that the knowledge acquired through researcher observation is more valid and relevant than data collected using other research methods (Iacono, Brown, & Holtham, 2009). As the researcher has previous experience with the cohort of participants partaking in the study, informal observation is a fundamental element in this investigation. The researcher can make use of observation much more precisely than others with no previous experience with the group. However, it is imperative that bias does not influence the results.

The researcher observed the participants as they conversed and worked throughout this 8-week study. Lower and higher order questions were asked to assess participants' engagement with the learning experience and comprehension of the chosen texts. Notes and observations were recorded based on the participants' responses. Notes and observations were recorded as soon as possible after each lesson concluded.

Individual representations of situation models

Children are individuals with unique, complex and rich thoughts and feelings, and their drawings may provide us with insights into their cognitive, affective and social development. More recently, educators have been concerned with the ways in which children can represent their thoughts and understanding of topics. Vygotsky (1971) argues that not only are art and thinking closely connected but art can also be an advanced way of thinking (Vygotsky, 1971).

White and Gunstone (2000) found that using drawings to probe understandings was a useful approach in researching children's learning. Drawings enabled them to visualize and reveal to the child and teacher 'qualities of understanding' that can be hidden through other research procedures (White & Gunstone, 1992).

Scoring systems from Harwood et al.'s guide to assessing children's visualisation skills were modified to align with the research project (Harwood & Usher, 1999). Participants' drawings depicting their spatial situation models were scored based on their similarity to the real-world location in question.

Individual reflective passages

Participants were asked to complete an individual reflective paragraph upon conclusion of the intervention to reflect on their experiences of the project. The reflective passages were submitted anonymously using the Padlet platform.

Post-intervention group interviews

An interview protocol (John W Creswell, 2015) was designed using a series of general questions to guide the interview. Participants were asked about their experience of the intervention and whether they perceived that the use of virtual reality assisted them in creating more accurate situation models. They were also asked to reflect upon their experience of using virtual reality and whether they could identify potential advantages or disadvantages to using the technology alongside reading instruction.

One-to-one interviews were conducted between one and two weeks after the participants had used virtual reality as part of the intervention. The interviews were face-to-face, lasted approximately ten minutes and were audio recorded. Recordings were subsequently transcribed for analysis.

Question	Rationale
How would you describe your experience of using virtual reality?	Encouraging participants to reflect on the process undergone
Was virtual reality useful in helping you to create pictures in your head when reading stories?	Asking participants to comment on how useful or otherwise the virtual reality experience
Do you think you would use virtual reality when reading books again?	
Did virtual reality help you to understand the stories better?	
Do you prefer using your own imagination or virtual reality to create pictures in your head?	Identifying potential benefits and drawbacks of the technology
Can you think of any good or bad outcomes of using virtual reality when reading?	

Table 7 Interview Rationale

4.8 Data Analysis Report

4.8.1 Quantitative Measurement

Participants' drawings of their mental representations were assigned a score using the rubric in Table **.** To prevent researcher bias, the scores were administered by two teachers in the school based on their accuracy and similarity to the location in question. The scores were assessed and recorded.

4.8.2 Qualitative Measurement

A considerable amount of qualitative data was generated through informal observation, pictorial retellings, questioning, reflective paragraphs and the post-intervention questionnaire. Assessment and analysis of participants' drawings also allowed for further analysis to occur after the initial endeavour.

4.9 Ethical Considerations

As the participants were under eighteen years old, the consent of parents or guardians, as well as the learners themselves was sought before undertaking this study (Appendices A, B). The permission of the Board of Management and principal was required owing to the fact that the intervention took place in a primary school (Appendix C). All of the individuals received detailed and age appropriate information sheets and consent forms. Only learners with parental permission and completed consent forms took part in this study.

Legislation that is applicable to this study include the Data Protection Act 1988 and the Department of Education Child Protection Procedures for Primary and Post-Primary Schools (Department of Education, 2011).

4.10 Summary

This learning experience was designed to evaluate whether virtual reality is a useful tool in enhancing the visualisation abilities and subsequently, the reading comprehension abilities of primary school children. By administering a mixed-methods exploratory case study, a range of qualitative and quantitative data was collected to address the research question and sub-questions. The following chapter analyses the findings of the data collected.

Section 5: Data Analysis and Findings

5.1 Introduction

The focus of this study was to evaluate whether primary school students who use virtual reality as a support for reading comprehension would demonstrate improved comprehension of text.

The following chapter interprets and analyses the data that was collected as part of this investigation. The influence of virtual reality on reading comprehension will be examined through the research question that afforded the foundation for this study. The research question devised for this study, *'Is virtual reality an effective tool in improving reading comprehension in primary school students?'* will be assessed.

5.2 Quantitative Data Analysis

5.2.1. PM Benchmark Reading Assessment (Pre & Post) Test

The PM Benchmark Reading Assessment was administered to members of the group before and after the learning experience. The tests were administered by the researcher with the assistance of a Learning Support Teacher.

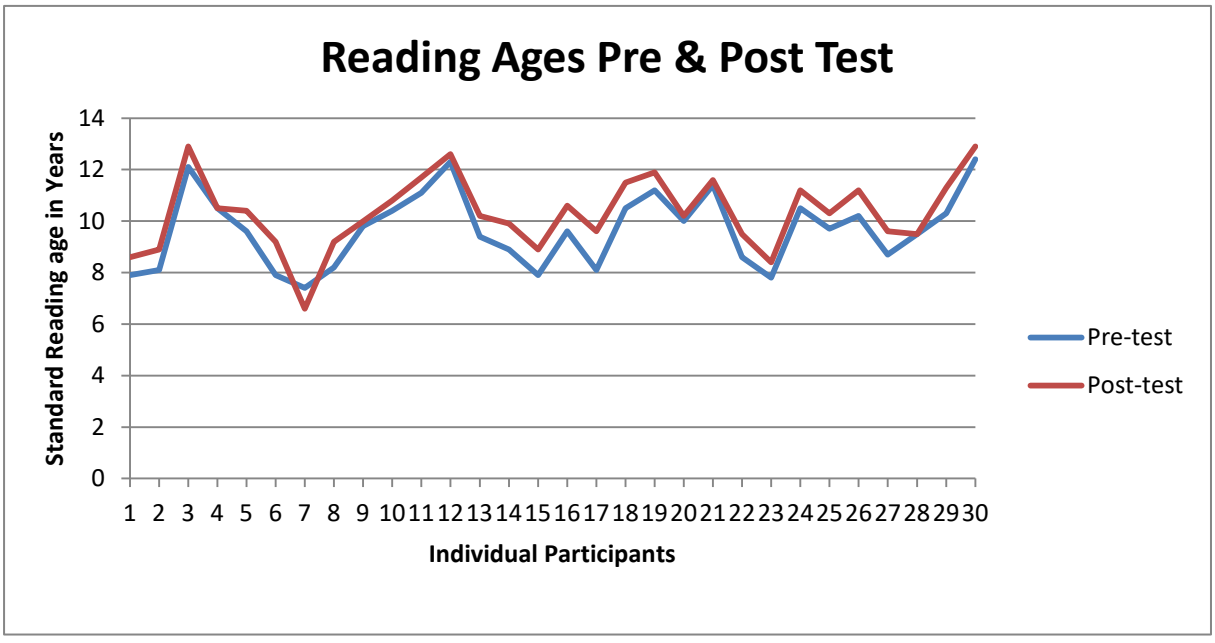

Figure 12 Reading Ages Pre & Post Test

Almost all participants (N=29, 97%) had improved reading ages upon completion of the learning experience. Figure 11 displays individual reading ages at pre and post test. Four participants (8, 14,

18 and 26 in Figure 11) showed increases of 12 months from their initial reading assessment. The average reading age of the cohort increased from 9 years and 6 months to 10 years and 3 months.

One participant (7 in Figure 11) showed a decrease on their initial score. As participants were presented with different texts at pre-test and post-test, it is possible that the participant was less familiar with the texts presented at post-test. Furthermore, texts chosen as part of this study were fiction texts. The assessment packs contained both fiction and non-fiction texts which may have unnerved the participant.

It is difficult to ascertain whether the increases in reading age are as a direct result of participants engaging in the learning experience. The primary school undertaking this study placed a whole-school focus on improving reading comprehension as part of a School Improvement Plan. Individualised, levelled reading books were introduced during the study on a whole-school basis. It must be considered that this school-wide intervention may have contributed to an improvement in individual reading ages.

5.2.2 Analysis of Rubric Results

Learners in the study represented their interpretation of situation models pictorially. The researcher and a Learning Support Teacher, who are both familiar with the chosen texts, scored the maps using the rubric in Table 4. When assessing the accuracy of learners' mental representations, participants' drawings were scored on a scale of 0 to 5 based on the accurate comprehension of spatial information provided in the text and their resemblance to the real-world location in question.

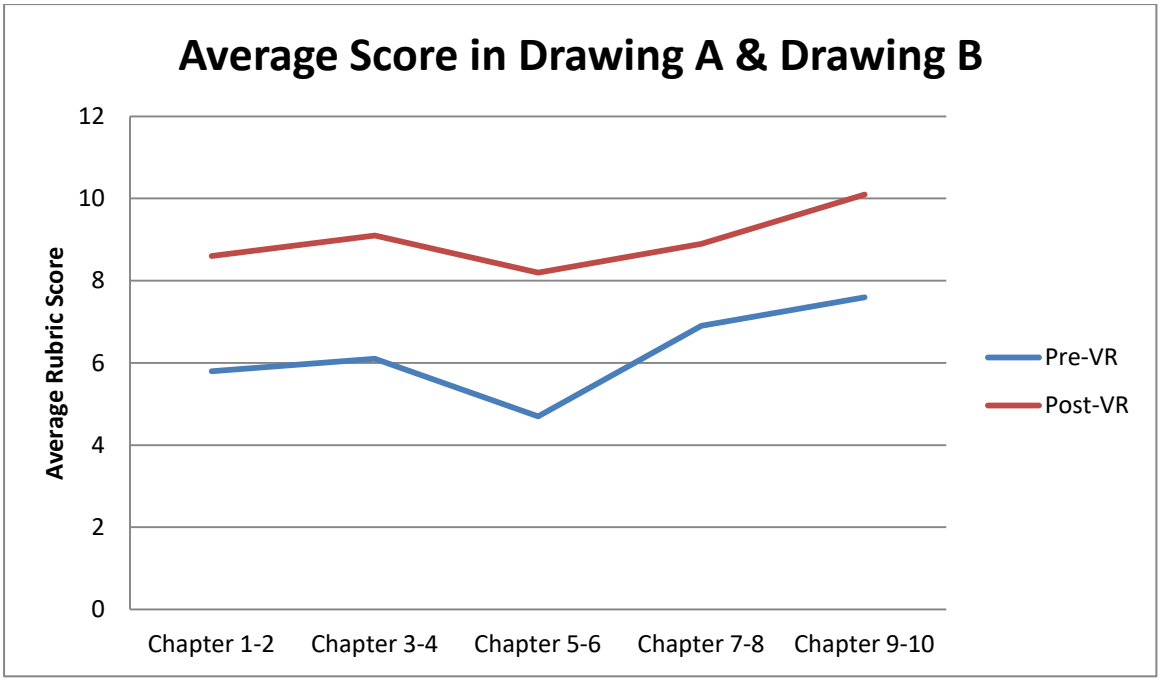

Figure 13 Drawing Scores Pre- & Post- VR

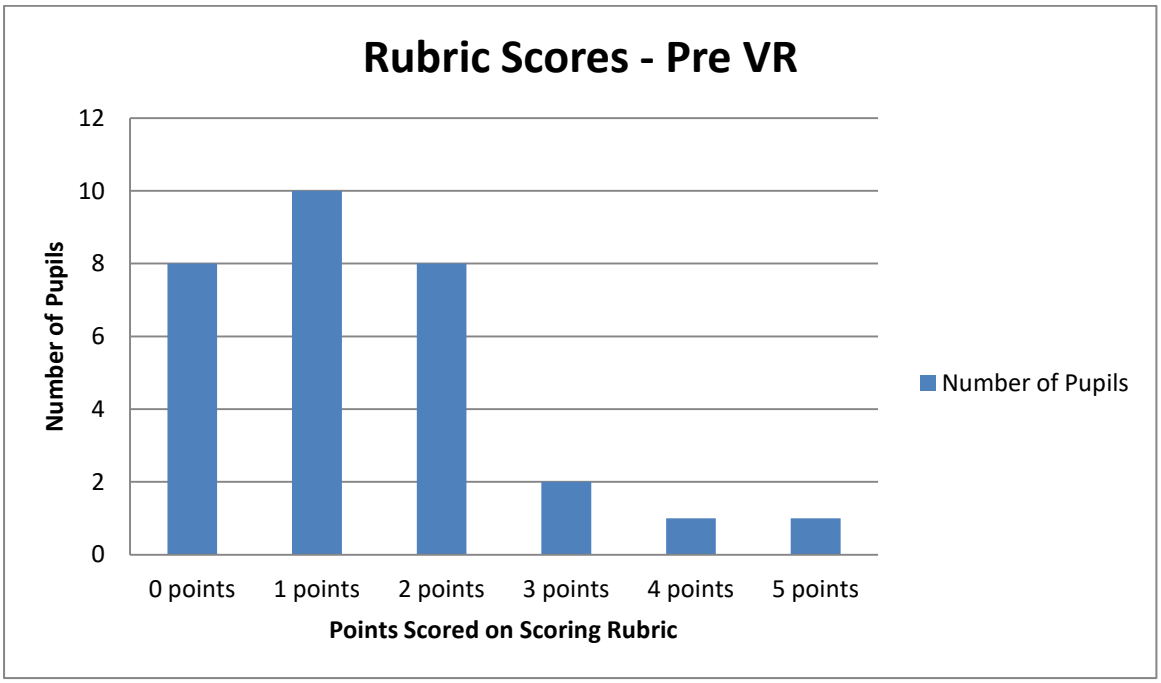

Figure 14 Rubric Scores - Pre VR

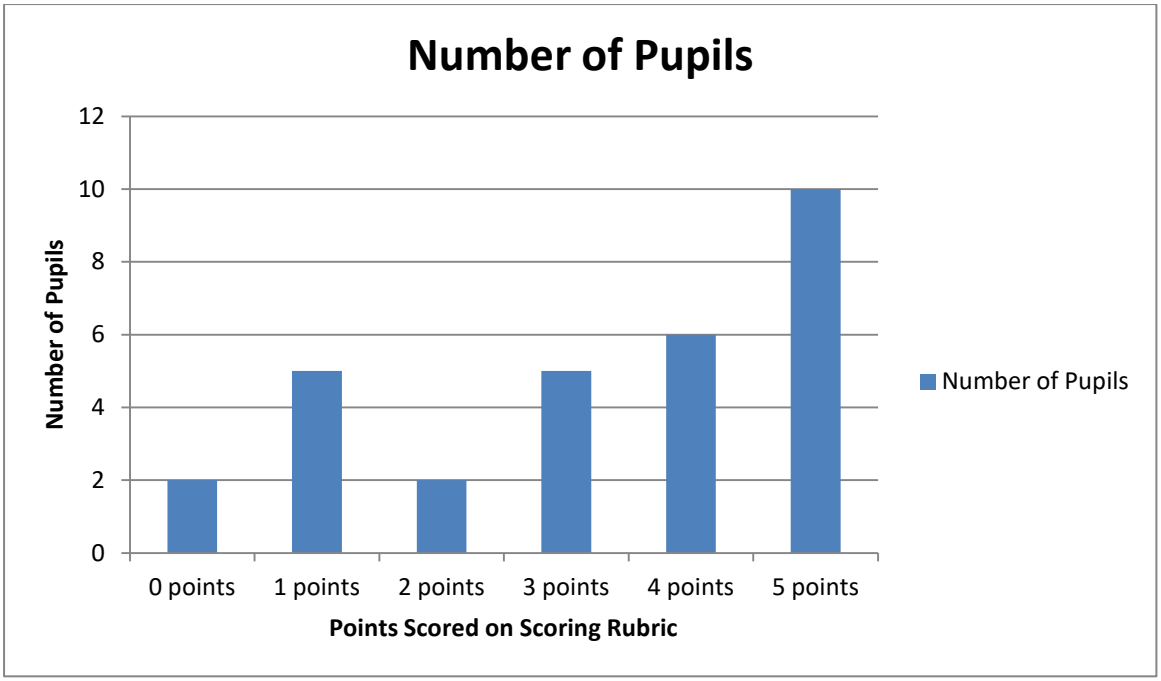

Figure 15 Rubric Scores - Post VR

Overall, there were positive gains from the research project. Figure 12 compares the scores of the pictorial representations using the rubric in Table 4.

Drawings were assessed after each chapter learners read. The drawings assessed after immersion in VR showed a significant statistical increase than those analysed before the VR intervention. The mean change from Drawing A to Drawing B was 3.57. The post-VR drawings showed an increase in breadth of understanding and improved comprehension.

5.3 Qualitative Data Analysis

Thematic analysis was conducted on data collected from the post-intervention interviews and participants' reflective passages using the six-step process outlined in Braun and Clarke Primary (Braun & Clarke, 2006). This included familiarisation with the data, generating initial codes, searching for themes, reviewing themes, defining/naming themes and producing the results.

The major themes and related subthemes that emerged from this analysis are outlined below.

5.3.1 Post-Intervention Group Interviews

The post-intervention group interviews where profoundly positive in nature.

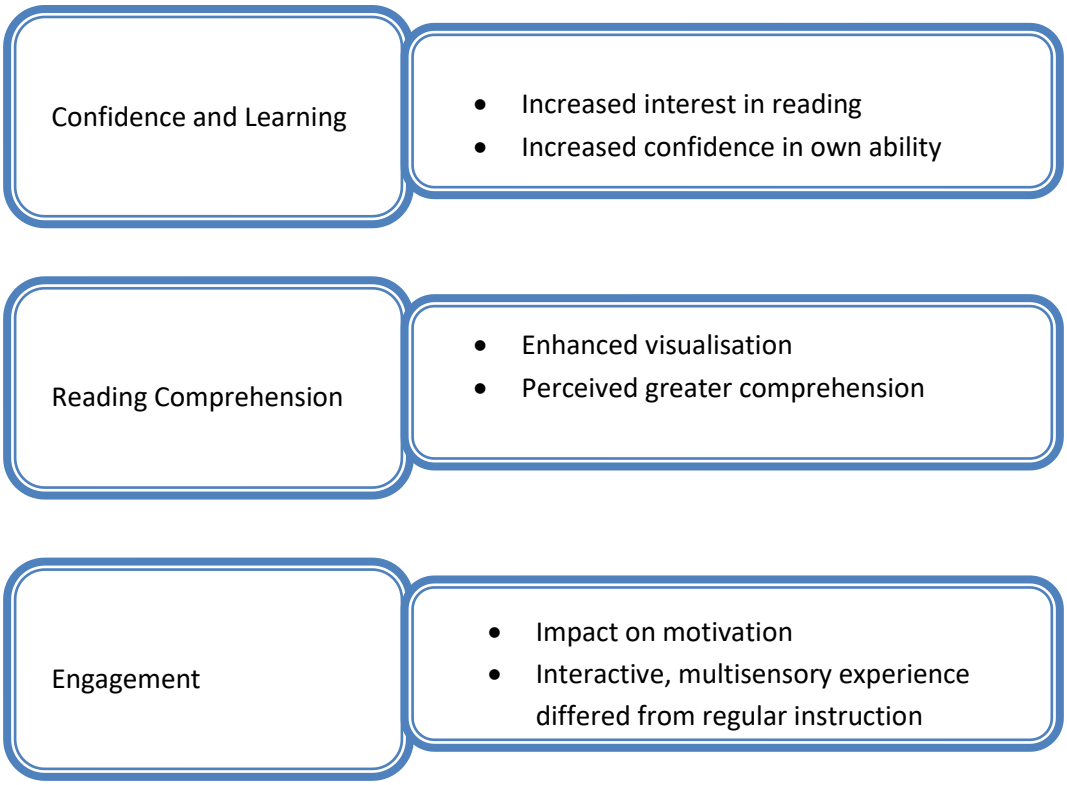

Figure 16 Emerging Themes

Confidence and Learning

Participants commented on how the intervention increased their interest in reading and confidence in their own ability.

> *'It [virtual reality] makes me want to read lots more books and travel to all the places in my head'.*
>
> *'I think it helped me to be a better reader because it made the movies in my head [situation models] clearer'.*
>
> *'I didn't like reading but I think using it [virtual reality] helps me to be a better reader. I'm going to use it to help me with my homework'.*

Reading Comprehension

Learners' responses indicated a perceived improvement in comprehension and visualisation, citing clearer mental models and an enhanced understanding.

> *'I could see everything really clearly in my head'.*
>
> *'I think it [virtual reality] helped me understand it [the story] better. I didn't know where some of the places in the book were before this.'*
>
> *'It helped me see in my head the places the characters were visiting in the book because I hadn't been to them before [locations in story] and I didn't know what they looked like'.*

Engagement

The levels of attention and engagement throughout the intervention rarely diminished and this was reflected in participants' responses. It became apparent that the technology had a positive impact on participants' motivation and desire to learn. Participants became keen to integrate virtual reality with other curricular areas. As the intervention progressed, learners would regularly ask to use virtual reality when studying other areas as part of Geography or History lessons.

It was evident throughout that the participants enjoyed engaging with the technology. Learners commented that the interactive lessons were a welcome change from regular literacy instruction.

> *'I think this makes reading more fun. I really felt like I was in the book sometimes'.*
>
> *'It made the book come alive'.*
>
> *'I hope we can do this [explore virtual reality] for every book we read'.*

5.3.2 Pictorial Representations of Situation Models

Participants were asked to pictorially represent their situation models before and after immersion in virtual reality. Picture A represents those drawn before using VR and Picture B represents those drawn after using VR. Samples of the drawings are recorded below.

A key difference between pictures A and B is the breadth of understanding and significant improvement in visualisations. Generally, the drawings recorded before immersion in VR show a vague, stereotypical understanding of the location in question. Drawings recorded after VR exploration showed a noteworthy improvement in the accuracy and detail of drawings.

Ayers Rock

Figure 17 Ayers Rock in Virtual Reality

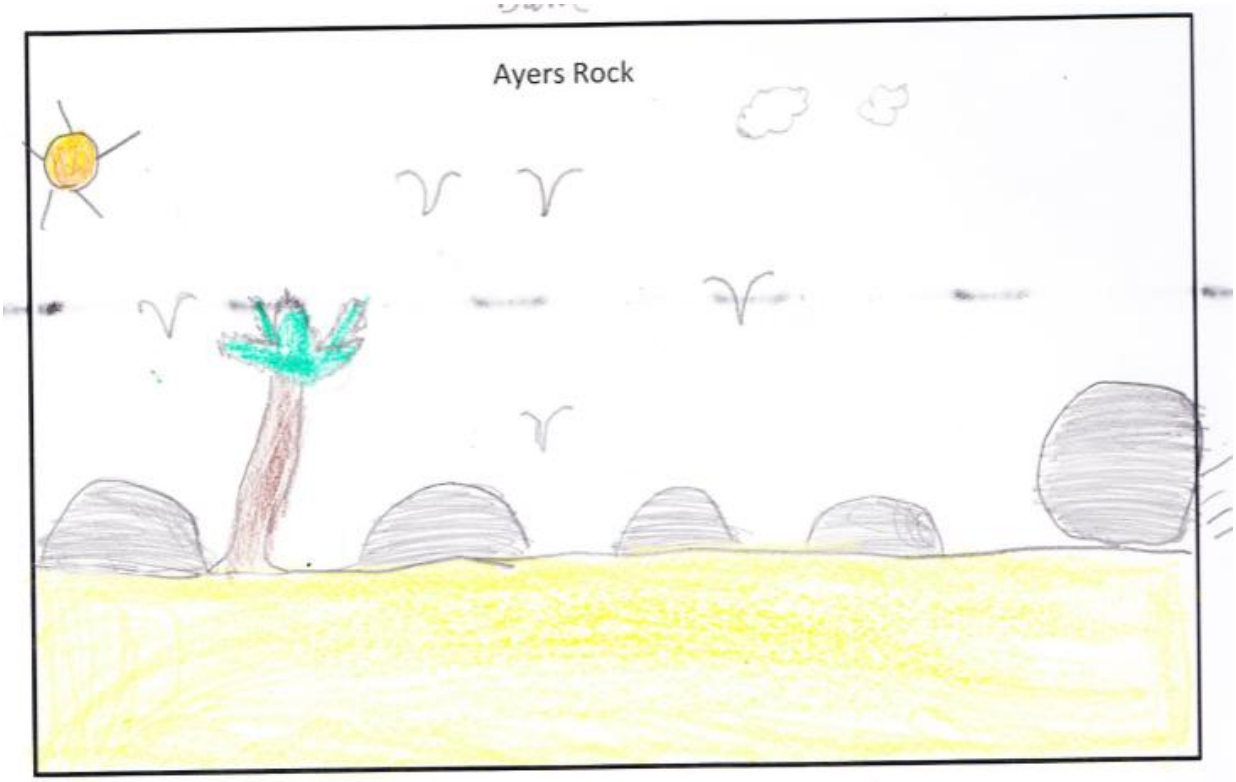

Figure 18 Participant 8 - Ayers Rock Pre VR

Figure 19 Participant 8 - Ayers Rock Post VR

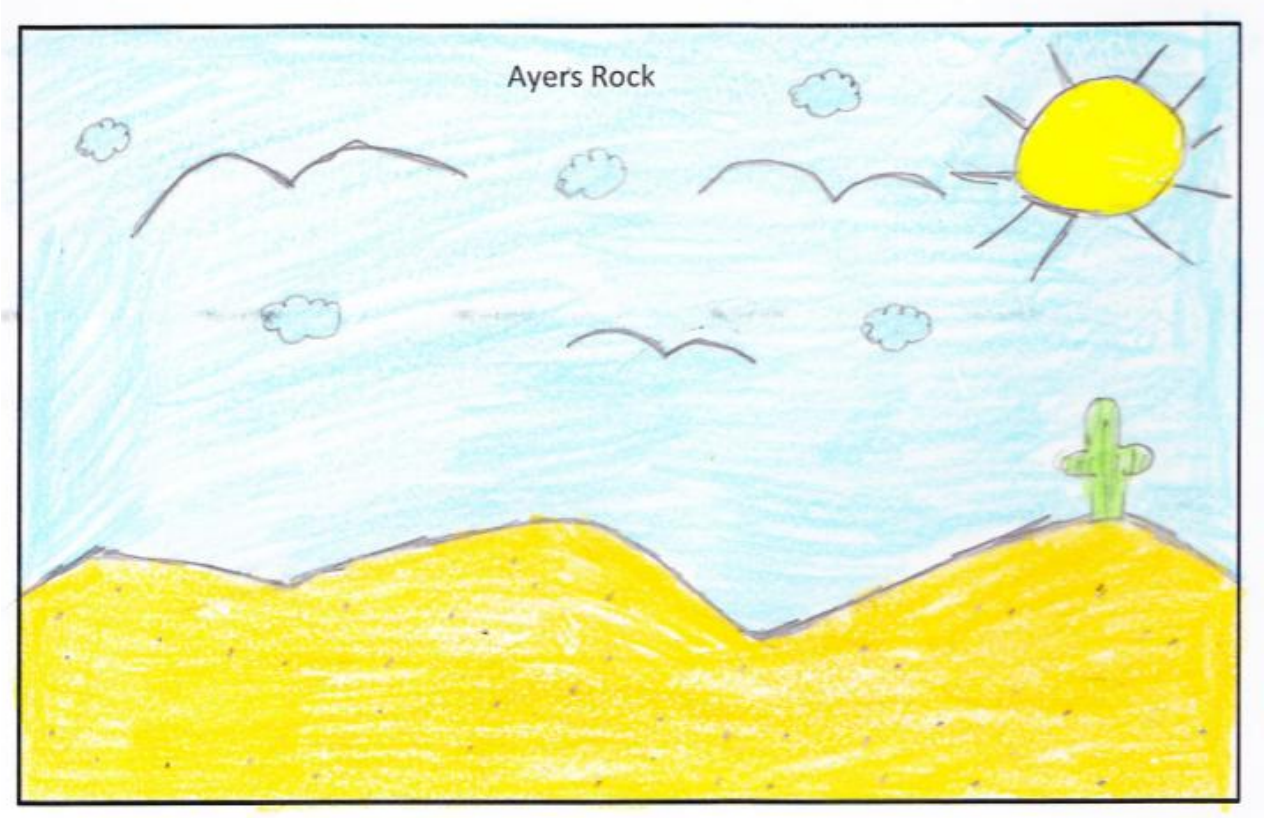

Figure 20 Participant 18 - Ayers Rock Pre VR

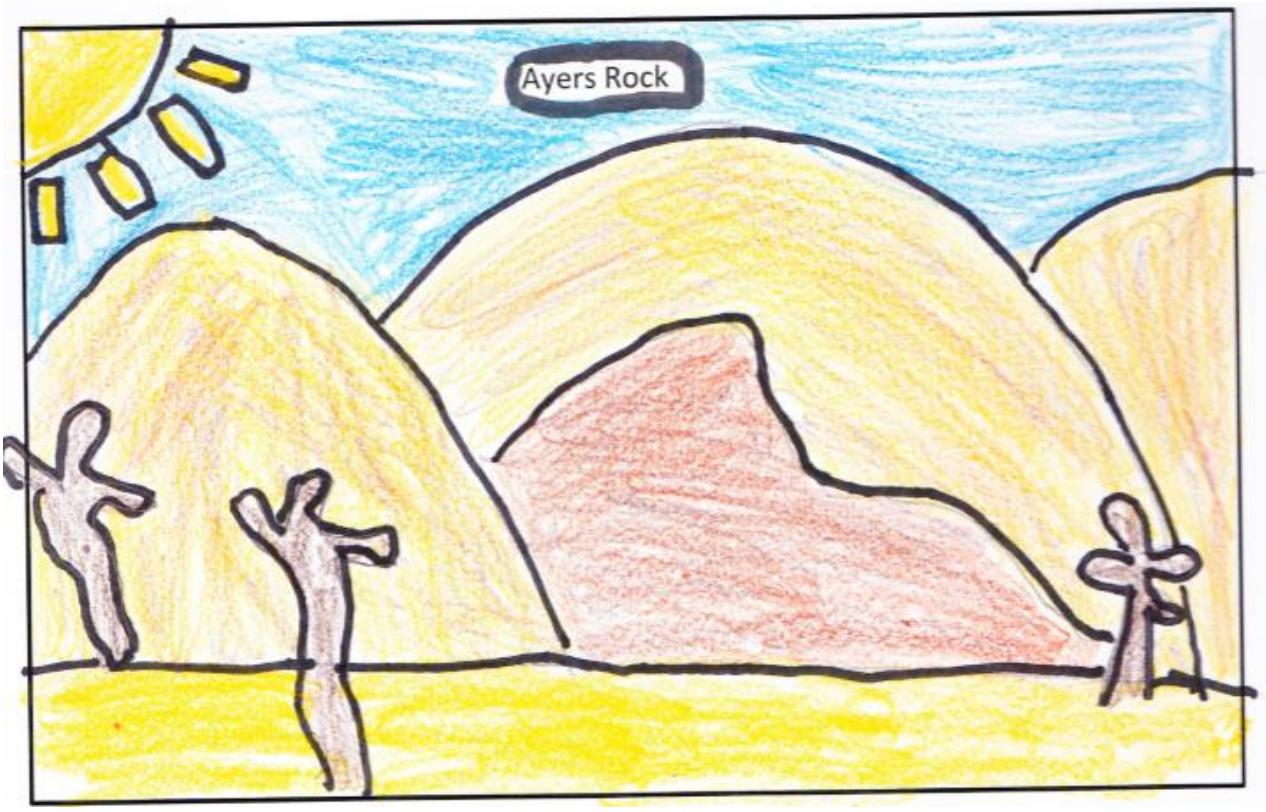

Figure 21 Participant 18 - Ayers Rock Post VR

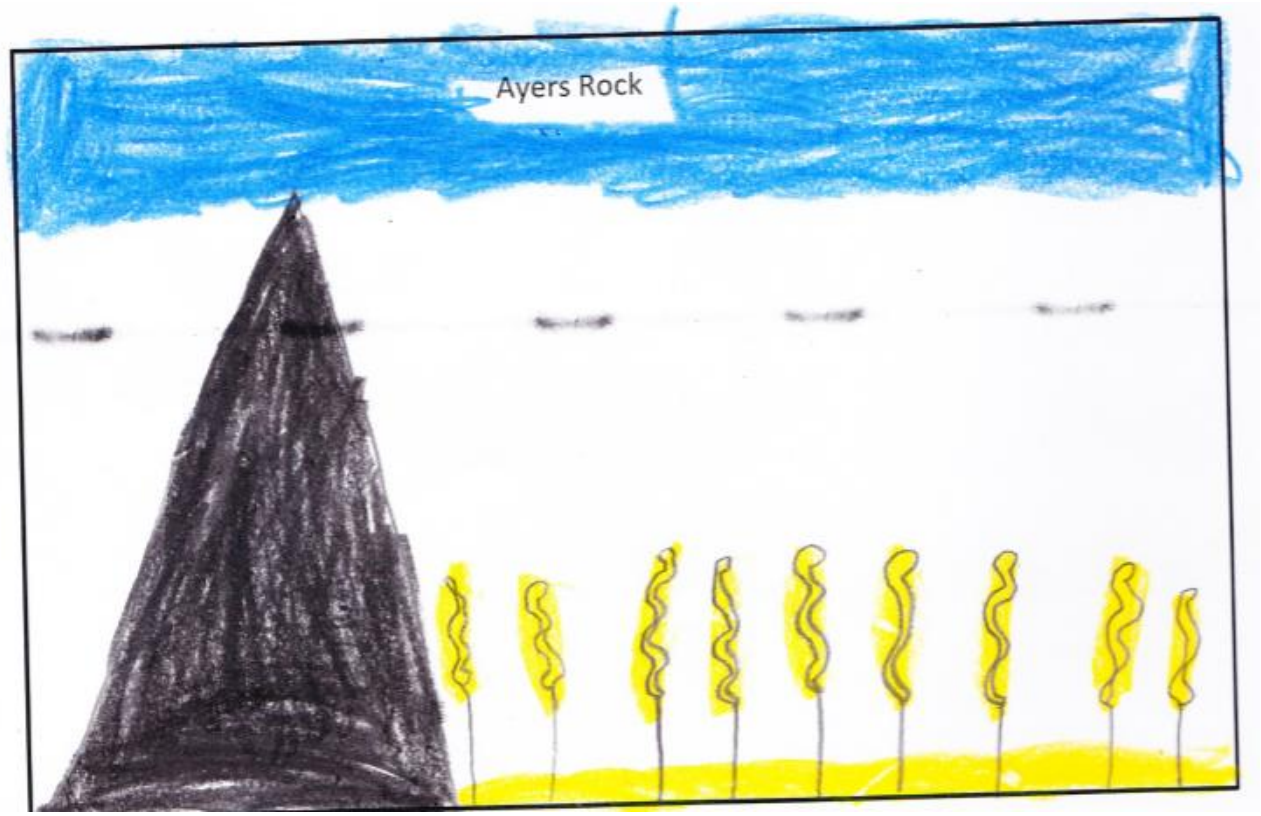

Figure 22 Participant 26 - Ayers Rock Pre VR

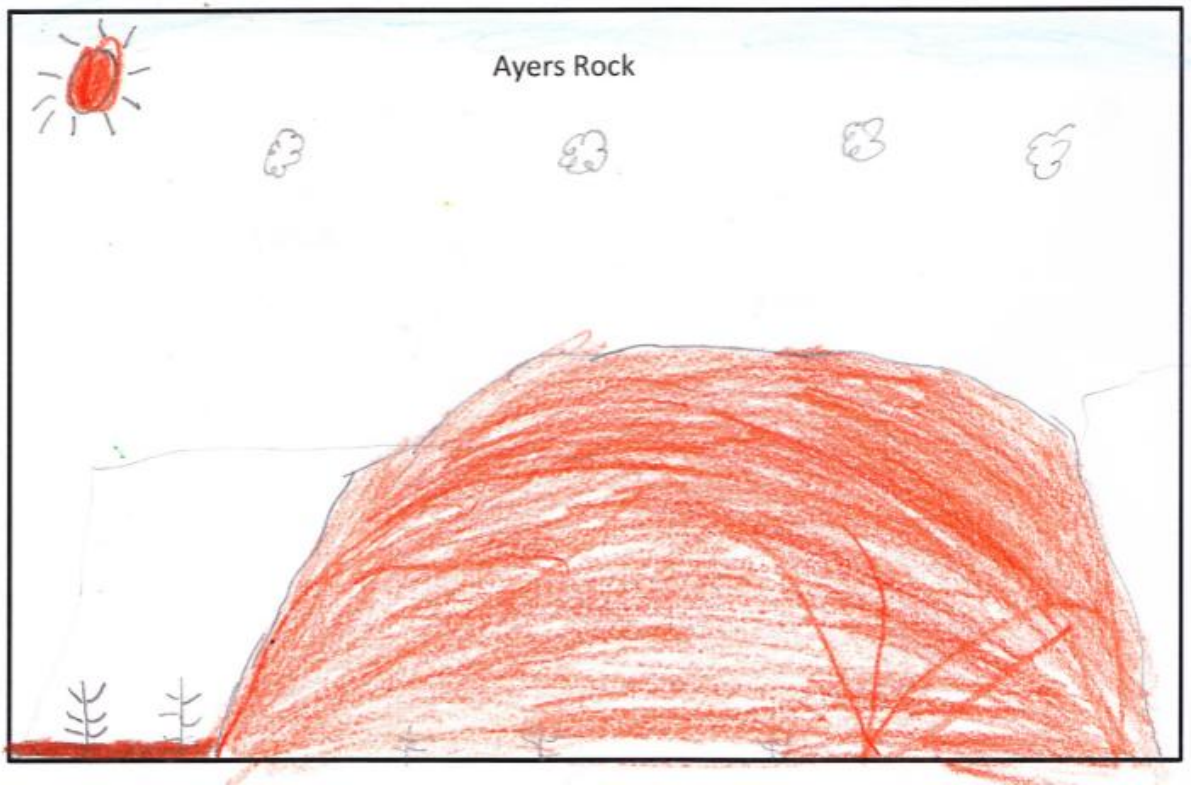

Figure 23 Participant 26 - Ayers Rock Post VR

The Great Barrier Reef

Figure 24 The Great Barrier Reef in Virtual Reality

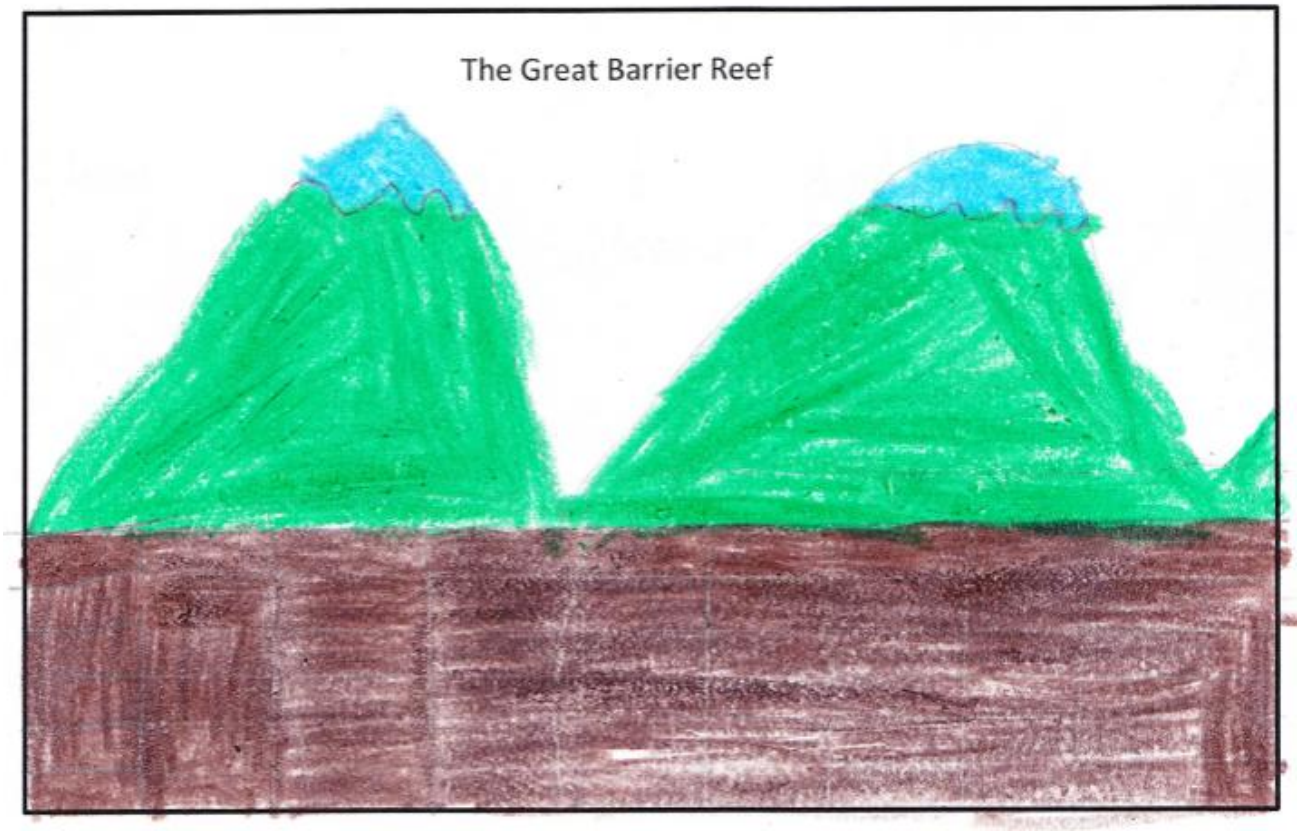

Figure 25 Participant 4 - Great Barrier Reef Pre VR

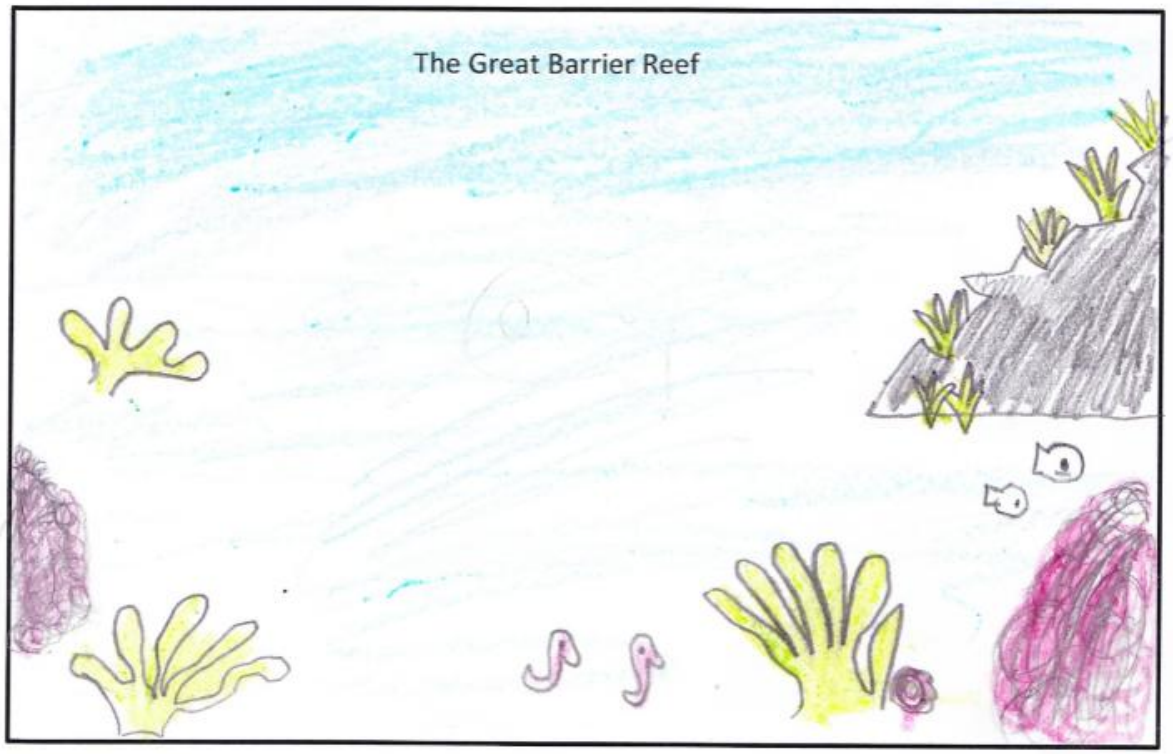

Figure 26 Participant 4 - Great Barrier Reef Post VR

Figure 27 Participant 20 - Great Barrier Reef Pre VR

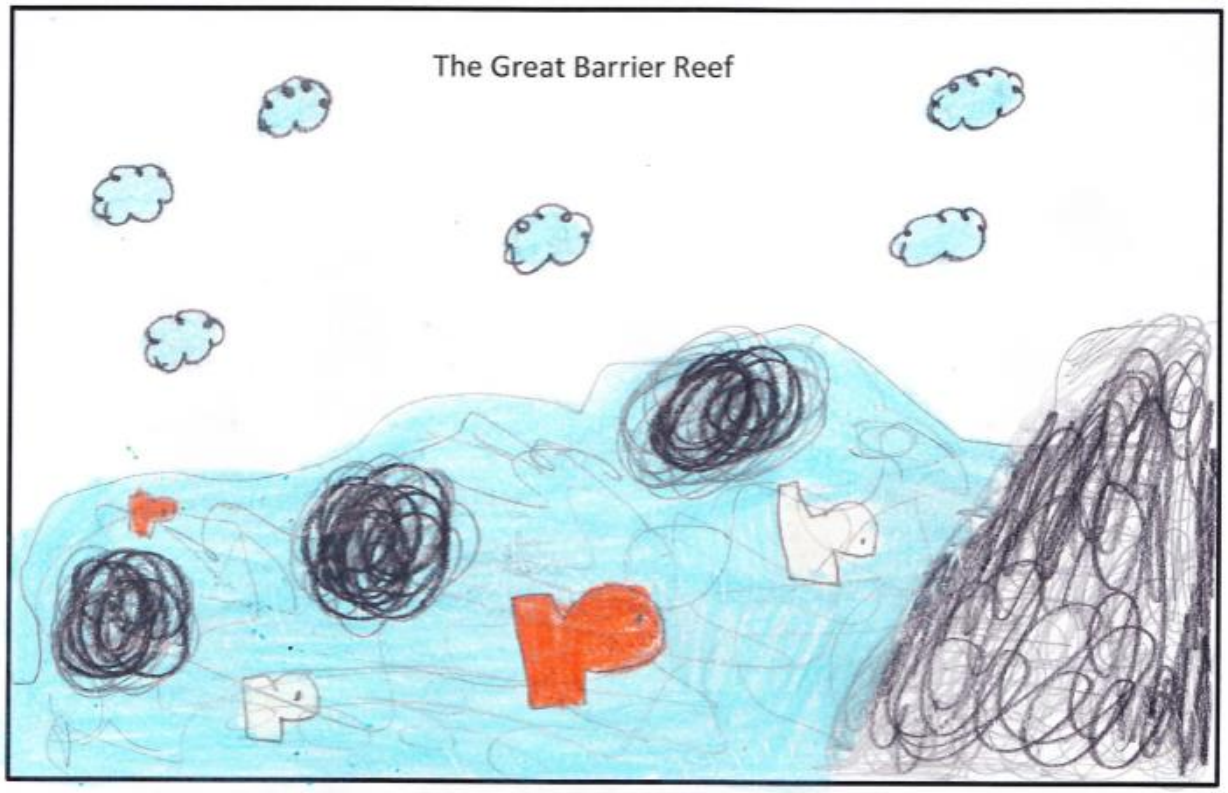

Figure 28 Participant 20 - Great Barrier Reef Post VR

Figure 29 Participant 29 - Great Barrier Reef Pre VR

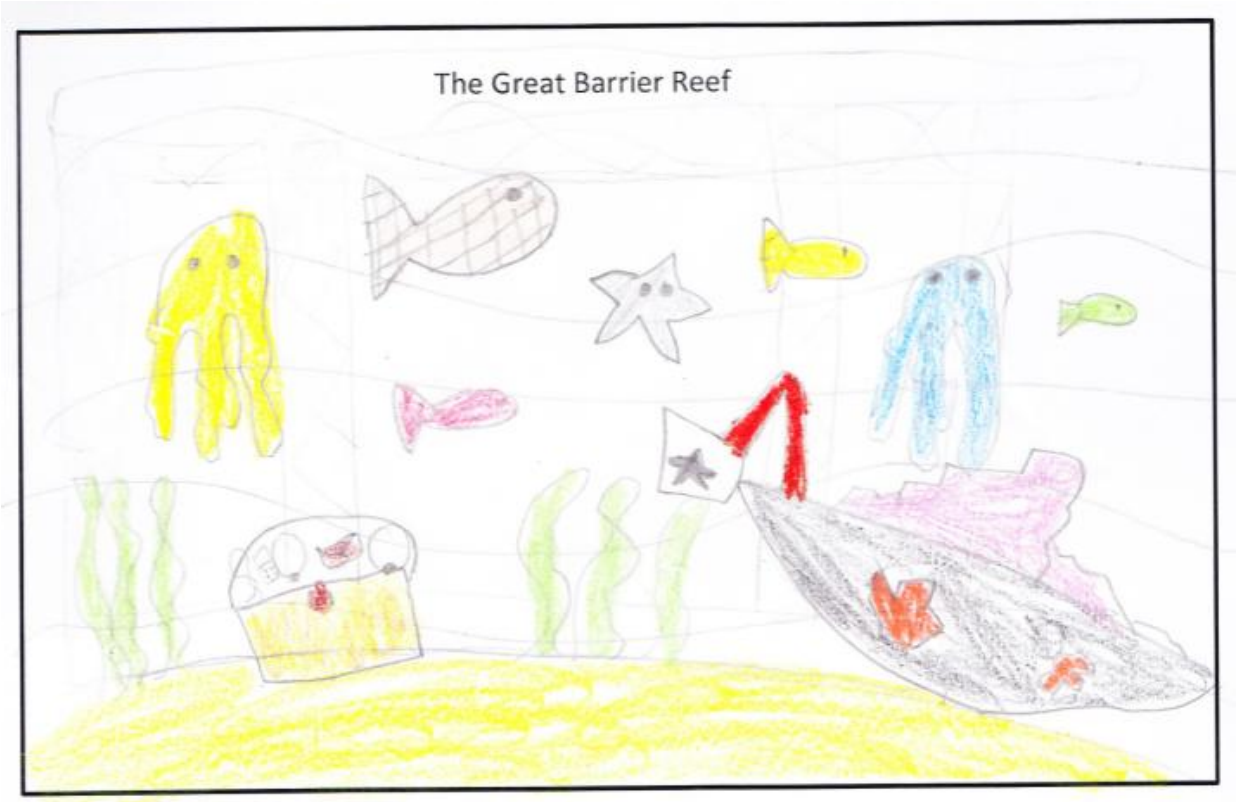

Figure 30 Participant 29 - Great Barrier Reef Post Vr

5.3.3 Researcher Observations and Informal Questioning

Throughout the intervention, it was clear by extensive observation that the learning experience was immensely enjoyable for participants. By implementing Keller's ARCS model (J. M. Keller, 1978), learners exuded a high level of engagement for the eight week duration.

5.3.4 Individual Reflective Passages

A word frequency cloud was generated using the responses participants posted on a Padlet wall.

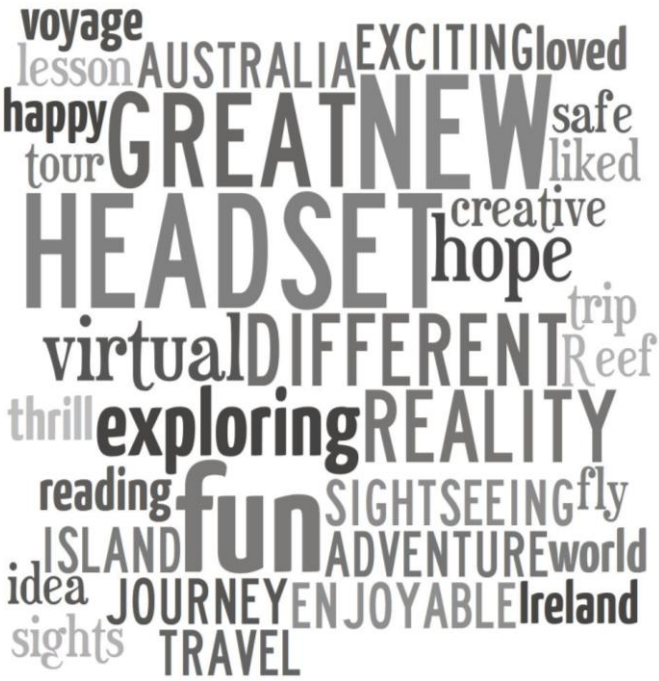

Figure 31 Word Cloud: Post Intervention Reflection

The feedback from participants was overwhelmingly positive. The most common feedback cited a newfound enjoyment and desire to read books. One participant responded:

> *'I love the way I felt that I was inside the story walking around with the characters. I definitely want to read more books and do it all over again'.*

Two participants relayed their disappointment that they did not have the hardware to utilise the technology at home.

> *'I would love to use this to help with my homework but I don't have the headset in my house'.*

In line with Kolb's Experiential Learning Cycle, this stage also offered learners the opportunity to reflect on the learning experience. One learner remarked that they would use their conceptualisations from this learning experience to inform their future learning:

> *'I think the last few weeks [of the learning experience] helped me to see that pictures and videos of things help me to learn better. I feel like I understood the book better than if I read it without virtual reality'.*

Words from the word frequency cloud such as 'fun', 'exciting' and 'great' highlight the level of engagement participants had with the experience, suggesting that the design elements of the intervention were successful. The words 'new' and 'different' however suggest that learners' engagement may have stemmed from the novelty of using the new technology.

5.4 Threats to Validity

There are many notable circumstances that may pose a threat to this study's validity. These threats include the scoring rubric, maturation and reading passages. In regards to internal validity, it is possible that there may be issues surrounding the scoring rubric as it is teacher generated, although it taps into critical elements of situation model assessment.

Some participants were absent for lessons in which a situation model assessment took place, therefore they had to complete their pictorial representation at a later date and missed instruction, which could pose a threat to internal historical validity.

As mentioned, the primary school in question had resolved at the commencement of the school year to implement measures to improve reading attainment as part of a School Improvement Plan. Consequently, the learning experience cannot claim full accountability for any favourable results.

Section 6: Discussion and Conclusions

6.1 Introduction

This chapter presents a discussion and conclusion on findings from the intervention.

The research question and sub-questions are restated and a comparison with previous research in this field is made. Significant points and implications emerging from this study are discussed. As a result of this relatively small-scale study, limitations are analysed and recommendations for future research are made.

6.2 Research Question and sub-questions

Is virtual reality an effective tool in improving reading comprehension in primary school students?

Sub-questions for consideration:

Can virtual reality improve visualisation skills in primary school students?

Is it feasible for the proposed framework to be suitably adopted in a regular primary school environment?

The primary conclusion from this study is that the use of virtual reality alongside narrative instruction supports the development of accurate situation models and improves reading comprehension. Literature suggested that the use of visual supports improve the creation of accurate situation models (Gunawan, 2014; Slough et al., 2010; Smith, Majchrzak, Hayes, & Drobisz, 2011). This notion proved similar to the findings in the study. An analysis of the pictorial representations of situation models submitted by participants before and after immersion in virtual reality showed accurate, detailed and precise situation models when reinforced by virtual reality.

Similarly, literature advocated the use of interactive tools to improve visuospatial awareness and support the development of situation models (Rapp, 2005; Russell & Kozma, 2005). This hypothesis was confirmed through analysis of the quantitative and qualitative data collected. Participants acknowledged that the interactive element made the intervention enjoyable, exciting and stimulating, noting it was a welcome change from traditional comprehension instruction.

6.2.1 Can virtual reality improve visualisation skills in primary school students?

There was an element of free choice around the boundaries of this task, which allowed the children to learn in an informal manner (Falk & Dierking, 2000). Although the learning experience was multisensory, the predominant sense used to fulfil the task was visual. The new knowledge constructed by their experiences is illustrated in the pictorial representations after exploring virtual reality.

A key difference between the first and second set of drawings was the differences in characteristics and features represented. Generally, the first set of drawings represented a vague understanding of the location in question with stereotypical representations. In contrast, the second set of drawings included specific features and distinctive attributes that expressed a significant improvement in comprehension. In addition, the accuracy and detail of the drawings improved considerably.

The interviews with participants revealed that in many cases learners could recall and describe the locations they had explored in great detail. Explaining his understanding of The Great Barrier Reef, Participant 8 recalled,

> '*The Great Barrier Reef we looked at in the headset was near Queensland in Australia. I learned that reefs can only be made in shallow water near the equator. You could see a lot of different fish - I think I saw lobsters, shrimp and some starfish there. It was so colourful and beautiful.'*

The study has also demonstrated that given the opportunity, children can represent their understandings through drawings. This was shown in the differences observed between the pre-virtual reality and post-virtual reality pictures.

Three participants in this study receive additional literacy support daily. Two of the three participants showed significant ability to represent their situation models pictorially, with their post-virtual reality drawings scoring above the class average. It may be that children with low literacy levels were able to express their new perceptions more clearly through drawing than through writing. This finding supports the work of Rennie and Jarvis (Rennie & Jarvis, 1995).

6.2.2 Is it feasible for the proposed framework to be suitably adopted in a regular primary school environment?

This hardware used to implement this study was virtual reality headsets and Apple iPod Touch handsets. The hardware was acquired on a loan basis for use in this study.

In order to adopt this framework in a regular primary school environment, a primary school would need to acquire a minimum of 6 headsets and iPod Touch handsets per class of 30 pupils. Instructions to make cardboard virtual reality viewers are readily available online.

Recent research has noted that many schools and educational institutions are devising and implementing Bring Your Own Device (BYOD) policies (Bruder, 2014). Given the popularity of iPod Touch handsets, it may be feasible to allow pupils to utilise their own device in order to implement the intervention. The Google Street View Application is free of charge.

By adopting the recommendations given above, it is feasible to adopt this framework in a regular primary school environment.

6.3 Implications

This study can provide teachers with important information in order to guide future instruction. The study supports previous research, that interactive and visual supports promote the development of accurate situation models. This suggests that virtual reality exploration alongside narrative study may support the generation of mental representations and therefore improve reading comprehension. However, the scores are not statistically significant so improved comprehension is not an assurance.

6.4 Limitations

One of the principal limitations of this research project was the challenge of successfully eliciting participants' mental models. The difficulty with obtaining mental models is that mental models are generated in the mind, and thus are not available for direct inspection or measurement (Jones, Ross, Lynam, & Perez, 2014). Given that we assume mental models actually occur when reading a text, we do not know whether the drawings represented actual mental models that existed having completed the story or mental models of something particularly salient during reading. Participants' varying abilities to draw may be another limitation of this study.

A further limitation in relation to this intervention was a limitation of time. Literature recognises that the process of learning to read and comprehend texts successfully takes many years; this research study was limited in timescale and took place over a eight week period. Similarly, reading attitudes are shaped over extended periods of time, and although an intervention can generate excitement and enhanced attitudes towards learning, longer term effects and trends cannot be examined. This study was designed as a probe for future studies and to investigate whether there may be potential for a longitudinal study to measure the long term impacts of such an intervention. As a time limitation applies, so does the issue of capturing a true mental model that's truly meaningful, as a reader might generate many mental models while reading such a story.

As the research was conducted with one class, and there was no control group to act as a reference point, it is difficult to ascertain the reasoning behind the gains in reading ability and positive improvement on learners' attitudes. It may be possible that a whole-school literacy improvement plan running concurrently affected the results.

Another limitation which must be considered is the 'Hawthorne Effect'. This states that individuals who are subject to a social examination may alter their behaviour as a result of being investigated, rather than due to the quality of any intervention introduced by the researcher (Macefield, 2007).

The conflict of interest, with the researcher being the class teacher, is another element for consideration when acknowledging limitations of the study.

6.5 Recommendations for Future Research

Previous research has proven that when children are confronted with expository texts, such as science texts; their ability to comprehend what they read is greatly influenced by prior knowledge and experience (Best, Floyd, & Mcnamara, 2004). However, literature focusing on the use of virtual reality to support the comprehension of other genres is scarce. This study focused solely on fiction texts with a reading age of 8-10 years. Future research could undertake to investigate different genres other than fiction that may be suitable for a similar intervention such as non-fiction, poetry, historical fiction, folktales and drama.

As studies with young adult readers have shown, young children with less prior knowledge will struggle to generate a coherent situation model when reading non-fiction texts as they are not able to generate the necessary inferences (Best et al., 2004). The basis for this study was reading ability. Further research could use prior knowledge as a basis for exploration.

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Appendix

Appendix A: Participants Consent Form and Information Sheet

Student Participant Consent Form

DECLARATION:

- I am under 18 years old and my parent/guardian has given permission for me to take part in this study.

- I have read, or had read to me, the attached *Participant Information Leaflet* for this study.

- I understand that no personal information about me will be recorded.

- I understand that it is a staff member of S.N. Iorball Sionnaigh running this study but that no data in this study will be used to identify me.

- I have had the chance to ask questions and all my questions have been answered. I understand the description of the project that has been given to me.

- I agree to my data being given as part of the project work for the MSc in Technology and Learning in a way that does not share my information.

- I understand that I may refuse to answer any question and that I may quit at any time without penalty.

- I agree to being watched by the researcher through note-taking, while doing tasks as part of this project.

- I understand that in the rare event that wrongful activities become known over the course of this project, these will be shared with parents and/or school prinicpal.

- I understand that audio may be recorded as part of this project. I understand that recording can be stopped at any time, and no audio recordings will be shared with anyone other than the researcher and supervision team, nor will any recordings be replayed in public.

- I understand that my data will be stored securely and deleted when study is completed.

- I understand that the study involves viewing a computer screen and that if I or anyone in my family has a history of epilepsy then I am taking part at my own risk.

- I have received a copy of this agreement.

I _____consent to taking part in this research project.

Signature of Participant: _____
Date:_____

Signature of project leader (TCD): _____ Date: _____

Statement of investigator's responsibility:
I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent. I undertake to act in accordance with the information supplied.
RESEARCHER CONTACT DETAILS: dalyc15@tcd.ie

A copy of the final project may be obtained by contacting the researcher at the e-mail address above after May 17th.

Student Participant Information Sheet

Title of Project: An investigation into the impact of an virtual reality software on reading comprehension.

Lead Researcher: Claire Daly

Background to Research:

This research project examines the impact (if any) of using virtual reality software to support the generation of mental imagery and therefore improve reading comprehension. Students will embark on a 'virtual tour' of a chosen novel by exploring key locations using the Google Street View application. The research seeks to find out if such an intervention can help students improve their comprehension skills and the generation of mental imagery when reading.

Procedures of this study:

As part of this study, students will be asked to:

- Complete a paper based, one page in length, English comprehension task before and after the intervention.
- Use virtual reality software (Google Street View application) to map the locations in Michael Morpurgo's novel 'Kensucke's Kingdom'.
- Participate in a post-intervention interview to assess experience of intervention.

The researcher will:

- Provide unbiased observations of the above tasks, carried out by your students, to in written format. An observation sheet will be provided.

Participation:

Participation in this study is voluntary. Participants in the study may withdraw at any time without penalisation. The study is expected to last 4-6 weeks. Participants are not required to register with Google to participate in the study.

The novel in question is part of the English curriculum and therefore will be studied by all pupils. This project has been designed as a supplementary activity to enhance comprehension. Any student unable or unwilling to take part will continue to engage in comprehension activities with another teacher. Each class will last for approximately 40 minutes.

Illicit Activity:

In the unlikely event that illicit activities become known over the course of the research, these will be reported to the relevant authorities.

Data Recording:

Samples of participants' drawings, interactive map excerpts, reflective passages and interview responses will be collected. Data collected will be separated from personal identity information as soon as possible after collection. Codes will be used to identify cases. The key linking codes to personal information will be password protected and stored securely, separate to the dataset. No audio recordings will be made available to anyone other than the researcher and supervision team, nor will any recordings be replayed in any public forum or presentation of the research. Recording may be stopped at any time throughout the project. Data will be destroyed upon submission of the project, no later than May 17th. The data will be password protected and stored securely on the school server.

Conflict of Interest:

Participants include students in the school where I am currently employed. The study contributes to the researcher's MSc in Technology and Learning within the School of Computer Science and Statistics of Trinity College Dublin.

Publication:

The results of this study will be presented as part of the project work for a postgraduate degree in Technology and Learning.

Researcher Contact Details:

Dalyc15@tcd.ie

Appendix B: Parent/Guardian Consent Form and Information Sheet

Parent(s)/Guardian(s) Consent Form

DECLARATION:

- I am 18 years or over and competent to provide consent.
- I have read, or had read to me, an information form providing information about this research (as detailed in the information sheet) and this consent form.
- I understand that my child's participation is fully anonymous and that no personal details about her will be recorded.
- I understand that it is a staff member of S. N. Iorball Sionnaigh running this study but that no information in this study will be used to identify my child.
- I have had the opportunity to ask questions and all my questions have been answered to my satisfaction. I understand the description of the research that is being provided to me.
- I agree to my child's data being presented as part of the project work for the MSc in Technology and Learning (TCD) in a way that does not reveal his/her identity.
- I freely and voluntarily agree to my child being part of this research study, though without prejudice to his/her legal and ethical rights.
- I understand that he/she may refuse to answer any question and that he/she may withdraw at any time without penalty.
- I consent to him/her being observed, by the researcher through note-taking, while completing the tasks associated with this project.
- I understand that in the unlikely event that illicit activities become known over the course of this research, these will be reported to appropriate authorities.
- I understand that audio recordings of my child may be documented as part of this project. I understand that the recordings may be stopped at any time, and no audio recordings will be made available to anyone other than the researcher and supervision team, nor will any recordings be replayed in any public forum or presentation of the research.

- I understand that her data will be stored securely and deleted on completion of the study.

- I understand that the study involves viewing a computer screen and that if my child or anyone in his/her family has a history of epilepsy then he/she is proceeding at his/her own risk.

- I have received a copy of this agreement.

I _____consent to my child_____ taking part in this research project.

Signature of Parent/Guardian: _____ Date: _____

Signature of project leader (TCD): _____ Date: _____

Statement of investigator's responsibility:
I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent. I undertake to act in accordance with the information supplied.
RESEARCHER CONTACT DETAILS: dalyc15@tcd.ie

A copy of the final project may be obtained by contacting the researcher at the e-mail address above after May 17th.

Parent(s)/Guardian(s) Information Sheet

Title of Project: An investigation into the impact of virtual reality on reading comprehension.

Lead Researcher: Claire Daly

Background to Research:

This research project examines the impact (if any) of using virtual reality software to support the generation of mental imagery and therefore improve reading comprehension. Students will embark on a 'virtual tour' of a chosen novel by exploring key locations using the Google Street View application. The research seeks to find out if such an intervention can help students improve their comprehension skills and the generation of mental imagery when reading.

Procedures of this study:

As part of this study, students will be asked to:

- Complete a paper based, one page in length, English comprehension task before and after the intervention.
- Use virtual reality software (Google Street View application) to explore the locations in Michael Morpurgo's novel 'Kensucke's Kingdom'.
- Participate in a post-intervention interview to assess experience of intervention.

The researcher will:

- Provide unbiased observations of the above tasks, carried out by your students, in written format. An observation sheet will be provided.

Participation:

Participation in this study is voluntary. Participants in the study may withdraw at any time without penalisation. The study is expected to last 4-6 weeks. Participants are not required to register with Google to participate in the study.

The novel in question is part of the English curriculum and therefore will be studied by all pupils. This project has been designed as a supplementary activity to enhance comprehension. Any student unable or unwilling to take part will continue to engage in comprehension activities with another teacher. Each class will last for approximately 40 minutes.

Illicit Activity:

In the unlikely event that illicit activities become known over the course of the research, these will be reported to the relevant authorities.

Data Recording:

Samples of participants' drawings, interactive map excerpts, reflective passages and interview responses will be collected. Data collected will be separated from personal identity information as soon as possible after collection. Codes will be used to identify cases. The key linking codes to personal information will be password protected and stored securely, separate to the dataset. No audio recordings will be made available to anyone other than the researcher and supervision team, nor will any recordings be replayed in any public forum or presentation of the research. Recording may be stopped at any time throughout the project. Data will be destroyed upon submission of the project, no later than May 17th. The data will be password protected and stored securely on the school server.

Conflict of Interest:

Participants include students in the school where I am currently employed. The study contributes to the researcher's MSc in Technology and Learning within the School of Computer Science and Statistics of Trinity College Dublin.

Publication:

The results of this study will be presented as part of the project work for a postgraduate degree in Technology and Learning.

Researcher Contact Details:

Dalyc15@tcd.ie

Appendix C: Board of Management Consent Form and Information Sheet

Board of Management Consent Form

DECLARATION:

- I am over 18 years old and I am competent to provide consent.
- I am the Principal/Secretary to the Board of Management of the school in which this research will be carried out (S.N. Iorball Sionnaigh, An Bhoth).
- I understand that the students involved are under 18 years old and not competent to provide consent and as result will have parent(s)/guardian(s) provide consent. Both parent/guardian and student must agree to participate or they cannot proceed.
- I have read, or had read to me, an information form providing information about this research (as detailed in the information sheet) and this consent form.
- I understand that the teacher's and students' participation is fully anonymous and that no personal details about them will be recorded.
- I understand that it is a staff member of S.N. Iorball Sionnaigh running this study.
- I have had the opportunity to ask questions and all my questions have been answered to my satisfaction. I understand the description of the research that is being provided to me.
- I agree to student data being presented as part of the project work for the MSc in Technology and Learning in a way that does not reveal students' identity.
- I freely and voluntarily agree to the school (S.N. Iorball Sionnaigh) being part of this research study, though without prejudice to the school's legal and ethical rights.
- I understand that the school may withdraw at any time without penalty.
- I understand that audio recordings of participants may be documented as part of this project. I understand that the recordings may be stopped at any time, and no audio recordings will be made available to anyone other than the researcher and supervision team, nor will any recordings be replayed in any public forum or presentation of the research.

- I understand that in the unlikely event that illicit activities become known over the course of this research, these will be reported to appropriate authorities.

- I understand that student data will be stored securely and deleted on completion of the study.

- I understand that the study involves viewing a computer screen and that if a student or anyone in her family has a history of epilepsy then she is proceeding at her own risk.

- I have received a copy of this agreement.

I _____consent to taking part in this research project.

Signature of Principal/Secretary to the Board of Management:
_____

S.N. Iorball Sionnaigh, An Bhoth
Date:_____

Signature of project leader (TCD): _____ Date:
_____

Statement of investigator's responsibility:
I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent. I undertake to act in accordance with the information supplied.
RESEARCHER CONTACT DETAILS: dalyc15@tcd.ie

A copy of the final project may be obtained by contacting the researcher at the e-mail address above after May 17th.

Board of Management Information Sheet

Title of Project: An investigation into the impact of virtual reality on reading comprehension.

Lead Researcher: Claire Daly

Background to Research:

This research project examines the impact (if any) of using virtual reality software to support the generation of mental imagery and therefore improve reading comprehension. Students will embark on a 'virtual tour' of a chosen novel by exploring key locations using the Google Street View application. The research seeks to find out if such an intervention can help students improve their comprehension skills and the generation of mental imagery when reading.

Procedures of this study:

As part of this study, students will be asked to:

- Complete a paper based, one page in length, English comprehension task before and after the intervention.
- Use virtual reality software (Google Street View application) to map the locations in Michael Morpurgo's novel 'Kensucke's Kingdom'.
- Participate in a post-intervention interview to assess experience of intervention.

The researcher and teacher will:

- Provide unbiased observations of the above tasks, carried out by your students, to the researcher in written format. An observation sheet will be provided.

Participation:

Participation in this study is voluntary. The school may withdraw at any time without penalisation. The study is expected to last 4-6 weeks.

The novel in question is part of the English curriculum and therefore will be studied by all pupils. This project has been designed as a supplementary activity to enhance comprehension. Any student unable or unwilling to take part will continue to engage in comprehension activities with another teacher. Each class will last for approximately 40 minutes.

Illicit Activity:

In the unlikely event that illicit activities become known over the course of the research, these will be reported to the relevant authorities.

Data Recording:

Samples of participants' drawings, map excerpts, reflective passages and interview responses will be collected. Data collected will be separated from personal identity information as soon as possible after collection. Codes will be used to identify cases. The key linking codes to personal information will be password protected and stored securely, separate to the dataset. No audio recordings will be made available to anyone other than the researcher and supervision team, nor will any recordings be replayed in any public forum or presentation of the research. Recording may be stopped at any time throughout the project. Data will be destroyed upon submission of the project, no later than May 17th. The data will be password protected and stored securely on the school server.

Conflict of Interest:

Participants include students in the school where I am currently employed. The study contributes to the researcher's MSc in Technology and Learning within the School of Computer Science and Statistics of Trinity College Dublin.

Publication:

The results of this study will be presented as part of the project work for a postgraduate degree in Technology and Learning.

Researcher Contact Details:

Dalyc15@tcd.ie

Appendix D: Pictorial Retellings Prompts

1. Tell me about your drawing.

2. What did you think as you made your drawing?

3. Can you tell me about X? (Included if a physical feature needs explanation or clarification).

Appendix E: Excerpt of Interviews: Coding Feedback

Participant: I usually don't like reading books. I hate them. The words are too big sometimes and I can't understand them so they're too hard. I thought this [learning experience] was good because it helped me to make a video in my head even though I couldn't understand some words. I wish we could use it every single day. (**Confidence and Learning)**

Participant: It made the books easier to understand because some of the places I hadn't heard of before and I didn't know what they looked like so it made the picture in my head wrong I think. The virtual reality game helped me to understand what it looked like properly. I loved it. **(Reading Comprehension)**

Participant: Usually when we read stories we have to answer questions and it's so boring I hate it. This made it really fun and different. **(Engagement)**

Appendix F: Post-Interview Questions

1. Did you find it hard to make pictures in your head of places you haven't heard of before?

2. Did seeing the place in virtual reality help you to understand the setting better?

3. What was your favourite part of the experience?

4. Were there any parts you didn't like?

5. Did virtual reality make reading more exciting or interesting?

6. Would you like to use virtual reality again when reading?

Appendix G: Example of Observational Notes

March 23rd 2017

In today's chapter, the protagonist made reference to Ayers Rock. We discussed where Ayers Rock might be and learners suggested it might be a rocky area like a quarry. Others thought it might be a standing stone. Participants were invited to draw their understanding of Ayers Rock.

Next, each station explored Ayers Rock in the headsets. Most pupils were unfamiliar with the location and tried to hypothesise why the rock was a red colour. Some divulged that it must be a hot area as Mars has red rocks. We then looked at Ayers Rock in an atlas and discovered it was in Australia. Several pupils had read stories or watched programs about Australia and shared their experiences.

Finally, participants were invited to pictorially represent their situation models again. Having examined them briefly, their second drawings seem much more accurate compared to their first attempts.