School of Education

Exploring English as an Additional Language Students' Perceived Engagement in and Experience of Content Vocabulary Acquisition and Retention Through Immersive Virtual Reality Games

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Declaration

To the best of my knowledge and belief, this thesis contains no material previously published by any other person, except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee, Approval Number (HRE2018-0253).

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Abstract

Acquiring target vocabulary requires learners to establish a strong connection between meaning and words and a thorough comprehension of the context is integral to understanding the meaning of unknown vocabulary. Language learners often find it difficult to link lexis to their meaning, and struggle to learn vocabulary related to a specific subject area. This challenge where English as an additional language (EAL) students struggle to acquire subject specific lexis to learn mainstream school subjects (Humanities and Social Sciences, Science, and The Arts) due to the lack of adequate content-specific vocabulary support was particularly the case at an independent school in Western Australia (WA), where this research took place. The main research intent of this thesis was to address this pedagogical concern by exploring whether headset-mounted display virtual reality (HMD VR) games could serve as an innovative approach to enhance content vocabulary learning and foster subject content knowledge of Years 7 and 8 Middle Eastern students. Specifically, it aimed to measure EAL students' content-specific vocabulary acquisition and retention, examine their perceptions of and attitudes towards VR game-based learning, and offer best practices for educational institutions that support culturally and linguistically diverse (CALD) learners. The research motivation was also driven by the fact that research investigating the perceptions of Middle Eastern middle school EAL learners experiencing HMD VR games in mainstream classrooms and its effectiveness in vocabulary acquisition and retention is still scarce.

The investigation entailed a pragmatic concurrent mixed methods design to collect and analyse both quantitative and qualitative data in order to answer the research questions. A total of Years 7 and 8 Middle Eastern students from an independent school in WA were selected to participate in this study. The treatment and control groups were formed through manual random sampling from each year level: The treatment group consisted of seven randomly selected students from Year 7 and seven randomly selected students from Year 8. This sampling procedure was the same for the control group. Hence, each group consisted of 14 students in total. A Google Cardboard headset was utilised to immerse treatment group players in a 3D environment, enabling them to acquire target vocabulary while exploring the content in nine different VR games related to Humanities and Social Sciences, Science, and The Arts. The control group students participated in traditional methods, that is researching the meaning of the same target words via a dictionary after locating them in a reading passage.

Qualitative data was collected through multiple data sources which comprised the following: game survey (open-ended survey questions), semi-structured focus group interviews, exit slips, observation notes, and researcher's journal. A thematic analysis approach was employed to interpret their experiences and provide in-depth descriptions, supported by triangulated data sources that tapped into the introspective (exit slips and semi-structured group interviews) experiences of students. A software program, Computer Assisted Qualitative Data Analysis Software (CAQDAS) was used to organise data. A pilot study was adopted to test the qualitative data collection instruments. Two thematic categories emerged as a result of the thematic analysis process: EAL learners' perceptions and attitudes towards headset-enabled 3D educational VR games, and the effects of those games on vocabulary acquisition and retention. Findings indicated that, despite technical issues encountered and the lack of adequate educational features, the VR games provided a fun element that not only enhanced students' engagement but also reinvigorated content and vocabulary learning.

Next, the quantitative data collection instruments measured the levels of students' acquisition and retention of target vocabulary items which included the following: pre-game survey (closed-ended survey questions), (to screen pre-existing vocabulary knowledge), post-test (to measure vocabulary acquisition via VR games) and delayed post-test (to measure vocabulary retention), and post-game survey. Quantitative data was analysed by giving each student a unique code. The scores from the tests were entered into the SPSS a software package (version 25) for statistical data analysis. The non-parametric Friedman test was used as an alternative to repeated-measures ANCOVA to compare the language gains across the three tests. In order to find where the significant difference occurred, whether there was a statistically significant difference between pre and post-test, or whether the HMD VR content-based games had an effect on vocabulary retention (delayed post-test), the Wilcoxon test was selected as a post hoc test of power. The comparison of the student responses in the pre-game survey, and the same eight questions listed in the post-game survey, were analysed by adopting a paired samples Wilcoxon test. Utilising headsets in a VR environment to learn new lexicon was rated positively ($M = 3.25 > M = 2.50$) by the majority of these EAL players ($N = 7$). With respect to treatment group students, a marked difference was found between pre- and post-tests ($p = .001$) and no difference between post- and delayed post-tests ($p = .018$), suggesting that the highly immersive VR environment can stimulate content-based vocabulary acquisition and enhance its retention. However, although control group learners also enhanced their vocabulary knowledge (p = .003) the post-hoc test on word retention showed that there was no statistically significant difference between pre- and post-tests (p = .877), suggesting that they failed to retain the words they acquired. This 3D approach to vocabulary learning implicates the pedagogical benefits of VR games for struggling EAL learners.

Nevertheless, it is important that the limitations and problems with HMD VR games in mainstream classrooms, as identified in this thesis, are addressed, in order to fully exploit its benefits. Although the findings of this research suggested that EAL learners favoured the presentation of content information alongside the visualised target words, future research could consider the educational factors, such as detailed written or verbal explanation of the subject content presented in the immersive games, that may moderate the efficacy of using headset-configured 3D environments in conventional classrooms. The findings in this study are a step towards understanding the effects of learning through highly immersive games and how VR environments can foster vocabulary acquisition, retention, and content learning of EAL students, particularly those who are struggling with mainstream subjects.

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Chapter 1: Introduction

1.1 Chapter Overview

Chapter One presents an overview of the study. The context of the study is reported in Section 1.2. Subsequently, the theoretical underpinnings and the rationale of this study are described in Sections 1.3 and 1.4 respectively. The aims and objectives are explained in Section 1.4.1. The research questions (RQ) are presented in Section 1.5. Section 1.6 discusses the significance of this research. Next, a description of the thesis structure and overview is presented in Section 1.7. The methods used to collect and analyse the qualitative and quantitative data are reported in Section 1.8. Key terms used throughout the thesis are defined in Section 1.9. Finally, the chapter concludes with a summary in Section 1.10.

1.2 Context of the Study

Acquiring target vocabulary requires learners to establish a strong connection between meaning and words (Tokowicz & Degani, 2015), and a thorough comprehension of the context is integral to understanding the meaning of unknown vocabulary (Gass et al., 2020; Groot, 2000). As such, language learners often find it difficult to link lexis to their meaning, and struggle to learn vocabulary related to a specific subject area (Alfadil, 2020). Research has suggested that teachers need to give English as an additional language (EAL) students 'subject-specific language support so they can succeed at school like everyone else' (Ollerhead 2022, para. 22). Therefore, discovering and developing effective approaches to teach content-based vocabulary may lead to academic success for EAL students, as retaining content-based vocabulary can facilitate students acquisition of new knowledge across subjects in mainstream schooling (Kohnke & Ting, 2021). This challenge where EAL students struggle to learn subject specific vocabulary is particularly the case in an independent school in Western Australia (WA) where this research took place. It investigates an immersive virtual reality (VR) application for vocabulary learning for EAL learners at an independent school in Perth, WA. The study was conducted in 2018, where 247 students were enrolled in the school. The majority of them migrated from the Middle East during their early childhood years and predominantly speak their mother tongue at home.

In 2018, the school reported to the Australian Curriculum, Assessment and Reporting Authority (ACARA, 2018) that 91% of the students' language background were other than English. Despite the culturally and linguistically diverse (CALD) backgrounds of the student population, the school did not modify the WA curriculum according to the English proficiency levels of those EAL learners. According to the WA School Curriculum and Standards Authority (SCSA, 2022), all public (government schools), independent (non-government schools unaffiliated with an agency or church and private schools (independent schools and schools affiliated with an agency or church) in WA have to meet 'judging standards'. These standards test student achievements in mainstream subjects, including their literacy skills. For example, the Year 8 Science sample assessment activity related to Earth and Space Sciences requires the students to use content-specific vocabulary items to identify the type of particles in a rock (SCSA, 2017). Another example is related to The Arts curriculum, where students must use art-related terminology to describe an artwork (SCSA, 2022). In Humanities and Social Sciences (HASS), one of the achievement standards related to Geography is to narrate the content related to landscapes (SCSA, 2017).

The English proficiency levels of the Middle Eastern EAL students in the independent school are generally low, and most fail to meet the judging standards. These at-risk students struggle in mainstream subjects such as English, Science, HASS, The Arts, and Math and need to improve their content-specific vocabulary knowledge in order to better understand those subjects and meet the academic demands. Whilst the mainstream subject teachers attribute the achievement gap to students' limited vocabulary, these teachers lack training in teaching English to speakers of other languages (ESOL) to develop proper strategies to support their EAL learners. Teachers' lack of training and adequate strategies to support EAL students in Australian mainstream classrooms has also been reported in previous research (Ollerhead, 2022). In this study context, mainstream teachers rely only on the sole ESOL teacher in the school to cover the vocabulary items related to the main subject. For example, the Science teacher frequently asks the ESOL teacher to add science vocabulary items to the students' weekly target word lists because the students have insufficient vocabulary knowledge to carry out Science-related tasks. However, the ESOL teacher tended to use traditional methods of teaching Science vocabulary, such as asking students to look up new words in an English-only dictionary or simply memorising them. Hence, these EAL students still struggle to complete their tasks in class, which consequently impacts their academic performance in both school and national assessments.

The situation is particularly high-stakes in the end-of-semester assessments when students are required to receive a scaled mark of 50 or above in order to meet subject competency requirements mandated by the Australian Curriculum (ACARA, 2016a). Whilst working as a specialist teacher in the case study school from 2016 to 2021, I attended staff meetings, directed by the Curriculum Coordinator, to discuss the strategies that could be implemented to overcome this challenge and increase EAL students' subject specific vocabulary knowledge. To transform the status quo, the researcher proposed an approach to teach content vocabulary via playing VR games related to Science, The Arts, and Humanities and Social Sciences as a post-reading activity in class. This new strategy was accepted by the Curriculum Coordinator of the independent school. This new approach was applied in the case study school in 2018. As an ESOL teacher and researcher, this study is personally meaningful to myself, as it intends to support EAL learners in the case study school to access the curriculum equitably.

1.3 Theoretical Underpinnings

Although content-specific vocabulary was considered an important aspect to better understand the subject matter, English vocabulary was still taught in traditional, structural, and explicit ways to the CALD students in this case study school. This intentional vocabulary learning strategy refers to learners' deliberate attempts to acquire an unknown vocabulary item through strategies such as using dictionaries, memorising word lists, or learning from personalised approaches (Barcroft, 2009; Fukkink et al., 2005; González-Fernández & N. Schmitt, 2020). Deliberate vocabulary teaching was considered useful as it was found to raise learners' consciousness (i.e., noticing) of target words (Alamri & Rogers, 2018; Pellicer-Sánchez et al., 2021; Sökmen, 1997) on multiple occasions. However, these EAL students still struggled to understand the subject matter even after following this approach to vocabulary learning. Therefore, incidental vocabulary learning (Schmitt, 2001) was trialled in this study to allow language learners to acquire lexis whilst enjoying a task without the intention and conscious operations to learn new vocabulary (C. Chen & Truscott, 2010; R. Ellis, 2015; Ender, 2016; Gass, 1999; Hulstijn, 2013). From the perspective of second language acquisition, Krashen (1989) argued that learners acquire more words when reading or guessing the meaning of unknown words through comprehensible input, where language learners 'pick up' a target language by understanding the input via contextual cues. Moreover, learning vocabulary in context is particularly significant when language learners aim to acquire academic terminology to learn about content in the target language (Stenberg & Powell, 1983; Van de Craen et al., 2007).

The cognitive constructivist theory proposed by Piaget (1953) also explained how knowledge is retained through contextual cues (Xanthou, 2011). As language learners are introduced to a new topic, the related schemata in one's mind are activated (Xanthou, 2011). Schema is identified as a mental representation of knowledge which is categorised into systems of thoughts (Kalina & Powell, 2009). When a language learner interacts with new information related to a familiar topic, such as new vocabulary items, the activated schemata assist the language learner to clarify the meaning with the additional support of contextual cues (Moghadam & Fatemipour, 2014). Contextual cues could help students to fill in knowledge gaps, clarify meaning of unknown words, and interpret meaning out of context (Goodman, 1984; Rumelhart, 1977).

According to the cognitive theory of multimedia learning (Mayer, 2005, 2014), learners actively construct new knowledge by using visuals and textual forms (pictures, written text, animations, and videos) of unfamiliar words. Images of words get coded twice, first visually, then verbally, in our brains (Kanellopoulou et al., 2019). Therefore, presenting visuals alongside written words are more likely to contribute to better word recall and incidental vocabulary acquisition (Artman, 2020; Ramezanali & Faez, 2019). The present study on immersive game-based learning aligns with the cognitive theory of multimedia learning because the VR games present the target words via 3D visualisations with audio descriptions. However, visuals in this study were not limited to animations or videos. Instead, visuals could be manipulated by players in the virtual simulation.

This study aimed to immerse language learners in an input-rich context through 3D simulations, which spontaneously enhances foreign language acquisition (Y.C. Shih & Yang, 2008). Situated learning, or "context-aware learning" (Naismith et al., 2004, p. 14), enables language learners to focus on the context, and stimulates language learners to form their own representation of knowledge by immersing players in the subject topic (Comas-Quinn et al., 2009).

Situated learning environments provide language learners situations where they can construct lexical knowledge through interaction (Nikbakht & Boshrabadi, 2015), participation (Piirainen-Marsh & Tainio, 2009), and experience (Palaigeorgiou et al., 2017).

The real-life full immersion, where language learners are in the natural language environment interacting in situations with fluent speakers of the target language, is considered to be an effective method for learning a foreign language (Kaplan-Rakowski & Wojdynski, 2018). However, this is not a viable or accessible option, as travelling to another country to visit a museum to engage with the target language is not possible in the classroom. Thus, head mounted display (HMD) VR, a digital game-based learning environment, offers an alternative approach to immersing language learners in realistic situations, without physically dislocating learners, that cannot be directly experienced by humans (such as visiting the sun) (Legault et al., 2019). Moreover, previous research indicates that digital games are conducive to situated learning in that learners are able to acquire the target vocabulary while being immersed in topic-related game scenarios (J. C. Chen, 2016). Second language acquisition (SLA) researchers have been adopting games to teach a foreign language as even games developed for commercial purposes could foster language learning and present lexis in various subjects. Interactive games enable learners to interact with the target words, and foster students to develop their individual experience to construct their language knowledge (Berns & Reyes-Sánchez, 2021; Frazier et al., 2021; Sykes, 2018).

Given the focus of this study on contextualising vocabulary items, interaction, learning authentic language, and experience, incorporating immersive VR games to enhance learners' content-specific vocabulary acquisition and retention aligns with situated language learning theory. That is, the target vocabulary items are situated in the context related to mainstream school subjects in HASS, Science, and The Arts. The digital games are purposefully selected to enable students to experience first-hand situations that simulate these subject matters in the virtual world beyond physical boundaries; hence, highly immersive games offer a fruitful basis to integrate educational methods to gaming (Karageorgakis & Nisiforou, 2018; Singh et al., 2020). Thus, the aim of this study is to demonstrate Middle Eastern EAL learners' perceptions of and attitudes towards adopting an HMD VR game-based approach to learn content-specific vocabulary items situated in the context of games. Additionally, this research also intends to investigate and assess how the digital game-based learning intervention makes a difference to Middle Eastern EAL learners' SLA in vocabulary learning and whether it can be retained.

1.4 Rationale of the Study

Although there are varied approaches to teaching vocabulary (Nam, 2010; Nation, 2001; Urun et al., 2017), its acquisition and retention is generally perceived as a learning obstacle by language learners, researchers, and teachers (David, 2008; Yousefi & Biria, 2016). Learning content-based vocabulary has the potential to improve EAL students' academic success, as it helps them acquire new knowledge across subjects (McCollin et al., 2009; Scott et al., 2008; Spencer & Guillaume, 2006). This study aims to optimise vocabulary learning and teaching through innovative approaches, one of which is headset-enabled VR games. Research has shown that VR technologies can play a significant role in language learning (Dawley & Dede, 2014; Monteiro & Ribeiro, 2020; Parmaxi, 2020). For example, VR environments render viable contexts for learning by enabling learners to interact with realistic three-dimensional (3D) objects (Parong & Mayer, 2018; Shaffer et al., 2005), and to immerse themselves into situations and VR worlds that are not possible to experience or explore in the classroom (Alfadil, 2020; Pigatt & Braman, 2016). Through environments that mimic real-world scenarios; VR fosters experiential learning, encourages learners to make meaningful connections between visuals and content, stimulates creativity, and promotes interactive active learning (Akhunova, 2021; J. C. Chen, 2016). Thus, VR helps learners to discover knowledge with respect to 3D objects.

Because the use of highly immersive environments in vocabulary learning remains in its infancy (Tai et al., 2020; Trunfio et al., 2020; Wu et al., 2020), this under researched area allows this current study to bridge multiple gaps in the literature. First, analysing the appropriateness of HMD VR and its effects on EAL learners' vocabulary learning deserves research attention (Radianti et al., 2020; Tai et al., 2020). Thus, researchers have been calling for further studies to validate highly immersive environments effectiveness in Kindergarten to 12 (K-12) language education (Alfadil, 2020; Dhimolea et al., 2022; T.J. Lin & Lan, 2015; Qiu et al., 2021; Radianti et al., 2020). Next, there is a scarcity of research on vocabulary acquisition and retention via headset-enabled VR enabled games (Alfadil, 2020; Godwin-Jones, 2016), and this study will investigate the effects of HMD VR on content-specific vocabulary acquisition and exploring Middle Eastern language learners' perceptions to better understand the underlying factors that influence game-based VR learning.

1.4.1 Aims and Objectives

This thesis explores whether headset-enabled VR games could serve as an innovative approach to enhance content vocabulary learning and foster subject content knowledge of EAL students. Specifically, it aims to (1) measure EAL students' content-specific vocabulary acquisition and retention, (2) examine their perceptions of and attitudes towards VR game-based learning, and (3) offer best practices for educational institutions that support CALD learners. The research motivation is also driven by the fact that research investigating the perceptions of Middle Eastern middle school EAL learners experiencing HMD VR games in mainstream classrooms and its effectiveness in vocabulary acquisition and retention is still scarce (Alfadil, 2020; Dhimolea et al., 2022).

1.5 Research Questions

There are three research questions in this study raised to guide the research design and process:

- RQ 1. How do EAL learners perceive their first-hand experience of using headset-enabled, educational VR games to engage with the content-specific vocabulary items?

The first question intends to provide empirical evidence on how EAL students perceive engaging with the mainstream subject matters through HMD, VR game-based learning. It also investigates students' experiences of and attitudes towards a highly immersive VR learning environment. The qualitative data from interviews, exit slips and notes taken during observations and quantitative data from pre- and post-game survey helps to answer RQ 1.

- RQ 2. What are the aspects of a headset-enabled, VR game-based learning environment that can facilitate or hinder content-specific vocabulary learning?

This question is focused on how students discern the facets of VR games to learn target vocabulary. It aims to explore students' perspectives of the aspects of VR games that can facilitate or hinder vocabulary acquisition. The qualitative data from interviews, exit slips and notes taken during observations helps to answer RQ 2.

- RQ 3. To what extent does a VR game based, headset-enabled approach's effects differ from a traditional textbook-based approach in EAL learners' acquisition and retention of content-specific vocabulary?

The final research question intends to measure whether the HMD VR game-based approach enhances vocabulary acquisition and improves retention compared to the traditional method which is using a dictionary. Conversely, the HMD VR game-based approach allows learners to interact with the visualised target words in a highly immersive learning environment. To answer this question, quantitative data is drawn from the pre-test, post-test and delayed post-test results from both control and experimental groups.

1.6 Significance

This study is significant because it is driven by the current development of research trends in adopting HMD VR games to teach content-specific vocabulary whilst addressing the theoretical and practical gaps in the current literature.

Research about game-based situated theory was limited in previous studies and theories were often disconnected to the research in that researchers linked theory to the features of the games or applications rather than the learning outcomes (Cook et al., 2019; Radianti et al., 2020). This was found to be an indicator of the VR low maturity level, which demands further research to identify outcomes with respect to theory so that it could be adopted in everyday teaching activities (Godwin-Jones, 2016; Wu et al., 2020). As it is crucial to examine the theoretical basis for technology-enhanced vocabulary learning (Gao, 2021; Klimova, 2018), this investigation renders significance in providing direction for optimising HMD VR for improvement of content-specific lexical learning in mainstream classrooms. Furthermore, a useful contribution and impact can be expected from this research as it is grounded in sound learning theories which are situated language learning theory and digital game-based learning careful selection of VR games linked to the Australian curriculum, and the research explicitly describes the selection of the games and how they were implemented in the classroom environment. Testing the theory, the findings will also be beneficial for a better understanding of content-specific vocabulary acquisition and retention, thus advancing future research directions.

Unlike some previous research that do not link learner outcomes to theories, this study may benefit researchers who conduct meta-analyses to research the impacts of HMD VR games from a theoretical lens. This thesis is one of the few research projects that has grounded the investigation in explicit theoretical foundations as learning outcomes are evaluated with reference to theory. Particularly, student perceptions reported in this research could shed light on how haptic information affects students' subject-specific lexis acquisition.

Guided by situated learning theory, this study may also demonstrate the adoption of HMD VR games in schools that follow the Australian curriculum to teach EAL students in order to meet the curriculum standards. This task design was considered to be effective by allowing students to play these games as a post-reading activity, rather than being the central method of instruction. Not only will it show that learning words related to the subject matter is important to comprehend complex concepts, but it will further emphasise that students can make realistic progress. Moreover, it will demonstrate that highly immersive games could realistically fit into lessons related to mainstream subjects. The method in this thesis will detail how both mainstream and language teachers could incorporate this new approach into lesson planning without eliminating the reading activities from their subject textbooks.

This study could assist educational institutions and teachers who support EAL students in their classrooms who aim to adopt immersive games to teach vocabulary. The findings may promote the use of game-based approaches in the classroom and ascertain its effectiveness regarding lexical learning with reference to mainstream subjects. The effects of HMD VR games on student learning and EAL students' perceptions could provide evidenced-based implications for educational institutions that support EAL learners.

1.7 Research Methodology

To address the research questions, a pragmatic, concurrent mixed-methods design was utilised to collect and analyse both quantitative and qualitative data. Mixed-methods research design was chosen due to the complex phenomena that have different layers that need to be observed in relation to student perceptions and attitudes and measured linked to students' acquisition and retention of words (Almalki, 2016; Feilzer, 2010). The collected data aimed to 1) determine whether the students acquired and retained the target words after playing these immersive VR games; and 2) elicit the student perspectives to better understand what worked or did not work in using highly immersive subject-based games. This was made possible through corroboration of both qualitative and quantitative research approaches (Almalki, 2016; Creswell, 2013).

To answer both Research Questions 1 and 2, multiple qualitative data sources were gathered: pre-game survey (open-ended survey item responses), semi-structured focus group interviews, exit slips, observation notes, and the researcher's journal. Qualitative data was triangulated to explore students' experiences of and attitudes towards a highly immersive VR learning environment, and the aspects of VR games that can facilitate or hinder vocabulary acquisition. This enabled the researcher to gather data from the insider perspectives of these EAL students (Bryman, 2006; Grbich, 2012), in order to better understand the nuanced factors that influence VR-based vocabulary learning. Triangulation also strengthens the trustworthiness of this research by providing a holistic picture of the phenomenon and elaborating on the quantitative results (Abdalla et al., 2018; Mc Kim, 2017).

To answer Research Questions 1 and 3, the quantitative data instruments measured the levels of students' acquisition and retention of target vocabulary and whether their perceptions changed towards a HMD VR approach as follows: pre- and post-game surveys (closed-ended survey item responses), pre-, post-, and delayed post-vocabulary tests. The quantitative data may have improved the reliability of this research, by using a statistical technique to provide an objective result of whether HMD VR games facilitated EAL students' vocabulary acquisition and retention. In addition, the measured test results may provide evidence for SLA and language assessment and contributes to students' meeting the curriculum demands via their assessment results at school.

Moreover, using mixed methods enabled the researcher to verify whether qualitative evidence that participants' perceptions of using HMD VR to learn subject specific vocabulary corroborate their vocabulary test results. Simply put, the textualised data explained, defined, and suggested why VR games worked well or failed to enhance their vocabulary acquisition as shown in the statistical results. Further incorporating a qualitative design augmented the outcome of the quantitative statistics (Kivunja & Kuyini, 2017; Mc Kim, 2017). Mixed methods research design was chosen in order to answer all research questions in a singular investigation (Johnson & Onwuegbuzie, 2004; Kivunja & Kuyini, 2017). Consequently, the employment of the mixed methods research design offers a more robust analytical framework to harness the strengths of both approaches (Almalki, 2016; Greene, 2005). A pilot study was also conducted to trial the suitability and effectiveness of the selected VR games, thus ensuring the validity of data collection instruments (see Chapter 3, Section 3.10).

1.8 Thesis Overview

The thesis is structured as follows: Chapter 1 presents the introduction to the study and presents the backbone of this research. Chapter 2 provides a review of the literature regarding vocabulary acquisition and retention theories, and the connections of these theories to immersive game-based learning environments via HMD VR. In Chapter 3, the research design and procedures employed to address the research questions are outlined, with both quantitative and qualitative methods being selected to investigate the effectiveness of HMD VR game-based content-specific vocabulary learning environments. The characteristics of the games employed in this research are also detailed in Chapter 3. Chapter 4 presents the qualitative and quantitative findings respectively, followed by Chapter 5 that provides the integration of findings to address each research question. It also discusses both theoretical and practical implications of applying HMD VR game-based learning to educational environments, whilst highlighting the impact of this innovative approach on the vocabulary acquisition and retention of Middle Eastern EAL learners in mainstream classrooms. Finally, Chapter 6 concludes the thesis with the implications, limitations, and future directions derived from the results of this investigation.

1.9 Key Terms and Definitions

This section summarises the main concepts that reflect the RQs and provide the framework for investigating the impacts of VR games supported by HMD in learning English vocabulary in a mainstream classroom of Years 7 and 8 Middle Eastern language learners. The main concepts adopted in this thesis are defined in Table 1.1. With reference to the definitions below, *vocabulary*, *content/subject-specific vocabulary*, *lexis*, and *word* are used interchangeably in this thesis. Furthermore, in the discussion in Chapter 2 (Section 2.5) and considering the study context, VR applications are referred to as *VR games, HMD VR environments, headset-enabled VR, highly immersive VR environments/games, and 3D VR environments, game-based simulations* synonymously. As the selection of the VR applications was based on the content of the WA curriculum (see Chapter 3, Section 3.7.1), VR environments are also referred to as *content-based VR games*. According to the definitions in Table 1.1, as the participants in this research are not only *CALD* learners but also *English as an additional language (EAL)* learners, these two terms are used interchangeably.

Table 1.1

Definition of Main Concepts Presented Throughout the Thesis

Concepts	**Definitions**
Vocabulary	"Words are the basic building blocks of language, the units of meaning from which larger structures such as sentences, paragraphs and whole texts are formed" (Read, 2000, p. 1). Words could consist of a verb, noun, or a meaning represented by multiple words such as a phrasal verb (Schmitt &Schmitt, 2020).
Lexis	"The term lexis, from the ancient Greek for 'word', refers to all the words in a language, the entire vocabulary of a language" (Caro & Mendinueta, 2017, p. 206).
Content/subject-specific Vocabulary	"A specific register of English that has distinctive lexical, morphological, syntactic, and stylistic features, that students are expected to use in school subjects" (Ehlers-Zavala, 2008, p. 76). Hence, content-specific vocabulary consists of items that are directly concerned with the particular subject area (Nation & Meara, 2013).
Explicit Vocabulary Learning	Explicit vocabulary learning refers to learners' deliberate attempt to acquire an unknown vocabulary item through strategies such as using dictionaries, memorising word lists, or learning from personalised approaches (Barcroft, 2009; Fukkink et al., 2005; González-Fernández & N. Schmitt, 2020).
Incidental Vocabulary Acquisition	Incidental vocabulary learning (Schmitt, 2001) refers to language learners acquiring lexis whilst enjoying a task or reading a passage without the intention or effort of learning new words (C. Chen & Truscott, 2010; Ender, 2016; Gass, 1999; Hulstijn, 2013).
Situated Vocabulary Learning	"Learning viewed as situated activity has as its central defining characteristic a process that we call legitimate peripheral participation. …learners inevitably participate in communities of practitioners and that the mastery of knowledge and skill requires newcomers to move toward full participation in the sociocultural practices of a community" (Lave & Wenger, 1991, p. 29). In other words, a procedure of acquiring vocabulary which cannot be dissociated from the situated, contextual, and social engagement with authentic materials (Fox, 1997).
Digital Games	Digital games refer to playful environments enabling computers (electronic devices) and learners to interact in virtual environments based on a set of rules to reach the educational objectives (H. Hung et al., 2018). Giryakova (2014) also suggests that the general term used for simulations that have been gamified or game inspired are referred to as games.
Gamification	"An integration of game elements and game thinking in activities that are not games" (Kiryakova et al., 2014, p. 1).

3D Environment	The terms virtual reality and 3D VR environments are used interchangeably as 3D environments are defined as "Capitalizes upon natural aspects of human perception by extending visual information in three spatial dimensions and may supplement this information with other stimuli and temporal changes" and that "a virtual environment enables the user to interact with the displayed data" (Wann & Mon-Williams, 1996, p.833).
Virtual Reality	"An immersive environment in which a participant's avatar, a representation of the self in some form, interacts with digital agents and contexts" (Dawley & Dede, 2014, p. 724). Virtual Reality is also commonly referred to as simulations which a perceiver experiences telepresence (Kilmon et al., 2010, p. 315; Steuer, 1992, p.75).
Virtual Worlds	"The persistent online social spaces; that is, virtual environments that people experience as ongoing over time and that have large populations which they experience together with others as a world for social interaction" (Schroeder, 2008, p. 2).
Telepresence	Telepresence is the extent to which one feels physically present in computer-generated spaces (Albayrak et al., 2022; Schroeder, 2010; Steuer, 1992, p. 6).
Head Mounted Displays	"Image display units that are mounted on the head. A unit consists of a helmet and small CRTs or liquid-crystal displays (LCDs) in a pair of goggles. The field vision on the display screens is expanded by the optical system producing an imaginary screen that appears to be positioned several meters in front of the viewer" (Shibata, 2002, p. 57)
Headset-enabled Virtual Reality	Headsets include smart glasses to block the real environment from the learner and increase the sense of telepresence (Godwin-Jones, 2016). Headset enables the user to walk through a virtual reality environment (or stereo images of real places, such as museums) as the smartphone accelerometers and gyroscopes track head motions to modify the images (Maclsaak, 2015).
Immersion	"Immersion describes the involvement of a user in a virtual environment during which his or her awareness of time and the real world often becomes disconnected, thus providing a sense of 'being' in the task environment instead" (Radianti et al., 2020, p. 2). In this study, immersion refers to the perception of feeling present 'in a non-physical world' via the simulation reflected through the VR system that provides the user with visuals, sound, or texts (Freina & Ott, 2015, p. 133).
Highly Immersive Virtual Reality	Highly immersive virtual reality refers to "experiences where a person can exercise a significant degree of agency in the virtual environment through interaction, manipulation, navigation, play and creativity" (Southgate et al., 2018, p. 131).
Culturally and Linguistically Diverse (CALD)	The Australian Bureau Statistics (1999) has suggested a standard set of cultural and language diversity measures to be used to identify CALD people who live in Australia. The set includes four primary indicators: 'Country of Birth', 'Main Language Other than English Spoken at Home' (herein referred to as "language spoken at home"),

	'Proficiency in Spoken English', and 'Indigenous Status'. This is the minimum core set that needs to be collected to determine an individual's CALD status" (Pham et al., 2021, p. 2). According to these measures above, there are over 7 million people out of 25 million who are CALD, including those who are migrants or from an Indigenous background (Pham et al., 2021).
English as an Additional Language (EAL)	English as an additional language applies to English language learners whose English is not their first language; however, English is ordinarily spoken by people in their host country (Judd et al., 2001).

1.10 Chapter Summary

This chapter presents an overview of this thesis. Following the summary, information regarding the background to the problem was detailed. Theoretical underpinnings guiding this research were outlined and the rationale of this investigation was reported, including the aims and objectives. Subsequently, the main concepts were defined that reflected the research questions and provided the framework for investigating the effects of HMD VR learning on content-specific vocabulary acquisition of Middle Eastern language learners in mainstream classrooms. Next, the significance of the study was put forth. Following this, a description of the thesis structure and overview was provided, and the methods used to collect and analyse the qualitative and quantitative data were elaborated. Finally, key terms and definitions were presented in the final section.

Chapter 2 presents the review of the literature regarding vocabulary acquisition and retention theories in detail.

Chapter 2: Review of the Literature

2.1 Chapter Overview

The previous chapter provided an introduction to the study by presenting the background of the problem and discussing the RQs arising from the problem. Chapter one also provided an overview of the study by summarising the content related to each chapter.

This chapter presents the review of the literature related to the research problem. As the study aims to explore English as an additional language (EAL) learners' perception of and attitudes towards head mounted device virtual reality (HMD VR) games to acquire content-specific vocabulary, the chapter is organised to first review the theories related to vocabulary acquisition processes. This is followed by the integration of these theories into game-based learning. Finally, there is a focus on studies related to HMD VR game-based vocabulary learning. The following section outlines this chapter in greater detail.

The review of the definition of vocabulary is reported in Section 2.2. It includes details relating to vocabulary learning in foreign language education (Section 2.2.1). As this current research is concerned with learning content-specific words (lexis) (see Chapter 1, Section 1.1), the next section provides an insight into the definition and importance of learning content-specific items (see Section 2.2.2).

Subsequently, vocabulary acquisition processes are described in Section 2.3, in relation to intentional vocabulary acquisition (Section 2.3.1) and incidental vocabulary acquisition (Section 2.3.2). The section concludes with the theoretical debate of whether vocabulary acquisition is incidental or intentional (Section 2.3.3).

The vocabulary learning theories are detailed in Section 2.4: (a) Section 2.4.1 explains the cognitive constructivist theory and (b) Section 2.4.2 presents the cognitive theory of multimedia learning. Finally, (c) the situated learning theory is described in Section 2.4.3.

Next, Section 2.5 presents a review of the literature with respect to digital games; particularly reporting the theoretical underpinnings of this dissertation (Section 2.5.1), and digital game-based language learning (Section 2.5.2).

Section 2.6 reports on the definition of VR, explaining literature related to the role VR plays in education in Section 2.6.1. Section 2.6.2 particularly reviews literature regarding the interrelationship between VR and language learningin. Sections 2.6.3 and 2.6.4 present headset-enabled VR and conclude with detailed research results of headset-enabled VR in vocabulary acquisition. This is a central aspect of this thesis. Accordingly, the gap in previous studies is addressed in Section 2.7, and the hypothesis of this research is presented in Section 2.8. This chapter ends with a summary in Section 2.9.

2.2 Vocabulary

Vocabulary is a core element in second language acquisition (SLA) (Urun et al., 2017; Willis & Ohashi, 2012), and the building block for the development and construction of language skills such as reading, writing, speaking, and listening in a target language (González-Fernández & Schmitt, 2017; Laufer & Nation, 2012; Nam, 2010; Nation, 2001). According to Read (2000, p. 1), "words are the basic building blocks of language, the units of meaning from which larger structures such as sentences, paragraphs and whole texts are formed". However, Schmitt and Schmitt (2020) argued that identifying vocabulary solely as a word is considered as a formulation not fully capturing the meaning. Chomsky (1981) claimed that representation of lexemes was not concrete, but abstract, thus learners linked phonological and orthographic elements to meaning which resulted in the mental presentation of concepts. Crystal (1995, p. 138) defines lexeme or lexical item as "a unit of lexical meaning, which exists regardless of any inflectional endings it may have or a number of words it may contain". Schmitt and Schmitt (2020) stressed that the terms *lexical items* and *lexical unit,* were coined to identify the interchangeable nature of vocabulary. For example, a lexical item could consist of a verb, noun, or a meaning represented by multiple words such as a phrasal verb. Words that are closely related (lexical unit) in meaning, such as 'wrote', 'writing', and 'writes' refer to the inflections of the root word 'write', and although they are spelt differently, they are closely related in meaning belonging to the same word family (Schmitt & Schmitt, 2020).

2.2.1 Vocabulary Learning in Foreign Language Education

As those who speak English as their mother tongue have an approximate vocabulary knowledge of 20,000 word families, linguists concurred that language learners also needed to have an adequate word bank in order to function well in a target language (Schmitt & Schmitt, 2014, 2020). Lacking the knowledge of word meaning (the morphological, syntactic and discourse information of a word in a given text) results in no comprehension or misuse of words in context (Faraj, 2015; Fukkink et al., 2005; Hunt & Beglar, 2005). Moreover, language learners could not comprehend or communicate in the target language without acquiring the meaning of the lexis (Guaqueta & Castro-Garces, 2018; Touti & Maleki, 2016). McCarthy (1990) confirmed this notion by stating, "no matter how well the students learn grammar…without words to express a wide range of meanings, communication in an L2 [second language] just cannot happen in any meaningful way" (viii). In fact, language learners would have difficulty watching a movie, reading a novel or a newspaper, writing a letter, or communicating in the target language without the sufficient word knowledge of at least 8,000 to 9,000 word families (including proper nouns)

(Nation, 2006). Further, Schmitt and Schmitt (2020) conclude that a poor vocabulary size limited the sorts of texts that a language learner could read independently. Consequently, in English, there is a direct connection between a learner's vocabulary knowledge, as measured by standard vocabulary tests, and how well the language learner performs on English proficiency tests (Nation & Meara, 2013). Given the pivotal role vocabulary learning plays in foreign language education, vocabulary learning pedagogy and research have increasingly been prioritised by researchers, language instructors, and learners (Helman et al., 2019; Laufer, 2012).

In the 1970s, vocabulary teaching did not receive much attention from researchers, and was sidelined in language learning activities because it was considered a minor aspect of language learning (Marton, 1977). Applied linguists and SLA researchers had concentrated instead on grammar (Coady, 1997; Hatch & Brown, 1995; R. Ellis, 1999; Huckin et al., 1993). However, in Meara's (1980) study, language learners expressed their inexperience with vocabulary as their main problem in learning the target language. Research findings reported over the past decade (Gan, 2012; R.M.I. Khan et al., 2018; Macis & Schmitt, 2017; Nation & Meara, 2013) verified that language learners' lack of vocabulary knowledge led to their difficulties in understanding and using the target language. For example, Smith et al. (2013) investigated how Chinese students studying English as a foreign language learned new vocabulary via inference-based computer games embedded in ebooks. Learners in this study also identified vocabulary learning as a daunting task, a sentiment echoed in other studies (David, 2008; Qasem & Zayid, 2019; Yousefi & Biria, 2016).

Given that vocabulary acquisition is integral to foreign language learning (Rasouli & Jafari, 2016; Willis & Ohashi, 2012), the opposite belief that vocabulary learning is of little significance has negatively affected foreign language learners in the past (Twadell, 1973). The English language makes more extensive use of core vocabulary items in comparison to most languages (Nation & Meara, 2013). In English, achievement in using the target language skills was directly determined by the extent of one's vocabulary knowledge (Nation & Meara, 2013; Suggate et al., 2018). Moreover, English has a variety of vocabulary registers across genres such as legal terminology, scientific usage, business English and in academia (Coxhead, 2019; Dang, 2018; Nation & Meara, 2013).

Content-specific vocabulary in academic use forms the building blocks for understanding mainstream subjects (Castellano-Risco et al., 2020; Uchihara & Harada, 2018). These content words are highly salient and topic-focused, leading to the comprehension of the subject content (Alfadil, 2020; Donley & Reppen, 2001). According to Snow and Uccelli (2009), academic language could include multiple vocabulary types, however there was no standard definition. For example, Ehlers-Zavala (2008) defined academic language as "a specific register...that students are expected to use in school subjects" (p. 76), whilst Scott et al. (2008) described academic vocabulary as "a register of English that has distinctive lexical, morphological, syntactic, and stylistic features" (pp. 184–185). The term academic vocabulary also correlated to a variety of different forms referred to as; content-specific vocabulary (Hiebert & Lubliner, 2008), subject-specific vocabulary (Rieder-Bünemann et al., 2022), technical vocabulary (Fisher et al., 2008), technical terms (Bieri, 2018), and Tier 3 words (also known as low frequency words that occur in specific domains) (Beck et al., 2013). Content-specific vocabulary, which consists of items that are directly concerned with the particular subject area, such as science, could include words like 'xiphoid', 'vascular', 'neck', and 'chest' that is related to anatomy (Nation & Meara, 2013). Thus, developing content-specific vocabulary knowledge in subject areas is crucial for language learners participating in mainstream classrooms (Castellano-Risco et al., 2020; Kalay, 2021; Merikivi &

Pietilä, 2014). If students lack the vocabulary needed to understand subject matter, they will not be able to make a connection to the concepts being taught and, as a result, fail to meet academic demands (Donley & Reppen, 2001; Kohnke et al., 2021; Marzano & Pickering, 2005; St. John & Vance, 2014).

In texts related to subject matter, content-specific vocabulary makes up about 20–30 per cent of the running words in the reading passage (Chung & Nation, 2003). Miller (1993), for example, highlighted the role of content-specific vocabulary knowledge related to mathematics: “Without an understanding of the vocabulary that is used routinely in mathematics instruction, textbooks, and word problems, students are handicapped in their efforts to learn mathematics” (p. 132). Bicer et al.’s (2015) research supported this notion, as students who lacked the knowledge of basic science vocabulary items, such as ‘evaporation’, failed to synthesise multiple content-specific words to understand the complex system of the water cycle.

Given the importance of content-specific vocabulary knowledge, the word learning process needed to receive deliberate attention (Gu, 2019; Helman et al., 2019; Możejko, 2020) and the opportunity to learn it using language knowledge (Nation & Meara, 2013). Cummins (1980) provided theoretical impetus for content and language integrated learning (CLIL). According to Cummins, CLIL could be cognitively demanding as learners were expected to acquire content-specific language alongside learning knowledge about the subject matter. To reduce the cognitive load, CLIL instructors could design tasks in context (Barrios & Acosta-Manzano, 2020; McDougald, 2018; Sidorenko & Kudryashova, 2021). That is, the meaning of vocabulary items could be clarified and solidified through communication (Yanguas, 2012), visuals (Yun, 2011), or other contextual cues (Castellano-Risco et al., 2020). For example, if language learners were studying shapes related to geometry, they could resort to the images provided to them to help clarify the meaning of the abstract terminology. By using the academic terms, they have learnt, learners could then access advanced topics and engage with the content (Snow et al., 1989; Van de Craen et al., 2007).

Overall, language learners have often struggled to learn lexis whilst learning academic subjects (Huckin & Coady, 1999; Meara, 2002). This struggle was intensified when trying to learn vocabulary, or terminology, concerning a specific field of study such as science (Alfadil, 2020; Kovacikova, 2019). EAL students grappling to meet their subject demands due to their limited content-specific vocabulary knowledge have also been the main issue in this research. This study seeks to address this problem via theoretical guidance. Applied linguistics and SLA researchers have developed multiple theories to explain the vocabulary acquisition process (Channell, 1988; Dakhi & Fitria, 2019; X. Yang et al., 2021); a selection of these theories is explained in the next section.

2.3 Vocabulary Acquisition Processes

As presented in the previous sections of this chapter, vocabulary acquisition is of paramount importance in learning a foreign language (Lessard-Clouston, 2013; Rasouli & Jafari, 2016; Schmitt, 2019). Researchers have endeavoured to develop hypotheses, theories, and principles in order to better understand the cognitive processing involved in intentional or incidental vocabulary learning (Alemi & Tayebi, 2011; Choo et al., 2012; Ender, 2016). In the following sections, a definition and explanation of intentional vocabulary learning is provided in Section 2.3.1, followed by the identification and elaboration of the incidental vocabulary acquisition process in Section 2.3.2. This section concludes by presenting a critical discussion of whether vocabulary is acquired intentionally or incidentally in Section 2.3.3.

2.3.1 Intentional Vocabulary Learning

Intentional vocabulary learning refers to learners' deliberate attempt to acquire an unknown vocabulary item through strategies such as using dictionaries, memorising word lists, or learning from personalised approaches (Barcroft, 2009; González-Fernández & N. Schmitt, 2020; Fukkink et al., 2005). Explicit language teaching enables language learners to become aware of the pedagogical grammar rules, such as focusing on language forms (N.C. Ellis, 1994). These intentional strategies were underpinned by the notion that consciousness of foreign language forms proceeded their use (N.C. Ellis, 1994; Harris, 2009). Graves (2006) suggested that any intentional approach to vocabulary instruction should include the explicit teaching of new words by using simple definitions first in order to clarify meaning. It has also been suggested that language learners could receive explicit vocabulary instruction on: spelling and pronunciation (Sparks et al., 2008), word parts and meaning (Cohen, 2008), collocations (Beck et al., 2013), grammatical patterns (Scheffler & Cinciała, 2011), contexts of use (Schleppegrell & O'Hallaron, 2011), and sufficient time to learn each word (Beck et al., 2013).

Intentional vocabulary teaching was considered useful as it was found to raise learners' consciousness of target words (Pellicer-Sánchez et al., 2021; Sökmen, 1997) so that words were noticed on multiple occasions (Alamri & Rogers, 2018). Furthermore, explicit lexis instruction was praised for promoting EAL learners to elaborate on the systematic knowledge of word parts such as prefixes (Afshar, 2021), stems and suffixes (Miguel, 2020; N. Schmitt, 2019), underlying concepts and meaning extensions (Schmidt-Unterberger, 2018), collocational patterns (Khonamri et al., 2020) and types of associations (Miller & Fellbaum, 1991). However, according to Krashen's Input Hypothesis (Krashen, 1989), the target words language learners intentionally learned required them to think to make the right choice before using those words in context.

Therefore, intentional vocabulary learning was claimed to hinder foreign language learner's fluency in speaking (N.C. Ellis, 1994; R. Ellis, 2009, 2015).

2.3.2 Incidental Vocabulary Acquisition

Incidental vocabulary learning (R. Schmidt, 1994) refers to language learners acquiring lexis whilst enjoying a task or reading a passage without the intention or effort of learning new words (C. Chen & Truscott, 2010; Ender, 2016; Gass, 1999; Hulstijn, 2013). In other words, students acquired vocabulary items without awareness and conscious operations to learn new vocabulary (R. Ellis, 2015). The benefits of incidental vocabulary acquisition have been explained by Krashen's Input Hypothesis (1989): "When the LAD [language acquisition device] is involved, language is subconsciously acquired - while you are acquiring, you don't know you are acquiring; your conscious focus is on the message, not form…" (p. 440). Krashen (1989) found that learners acquired more words when reading or guessing the meaning of unknown words through comprehensible input. Comprehensible input could be explained by Krashen's Input Hypothesis (Krashen, 1985, 1989, 1992) that language learners 'pick up' a target language by understanding the input slightly above their current level, through contextual cues, which leads to output, that is speaking in the target language.

2.3.3 The Debate: Is Vocabulary Acquisition Intentional or Incidental?

Krashen and Terrel (1983) argued that intentional vocabulary learning builds the knowledge about the accuracy in language forms rather than fluency in using the language. Hence, they considered incidental learning more effective as subconscious SLA has an effect on language performance. However, Krashen's stance on input hypothesis is an extreme non-interface position (also known as non-interventionist) (N. Ellis, 1994) in that explicit and implicit language knowledge stored in the schemata could not be transferable (Krashen & Scarcella, 1978; Krashen

& Terrel, 1983). This hypothesis was linked to the finding in psychology regarding dissociation of explicit and implicit memory systems in the brain (N.C. Ellis, 2008). Following input hypothesis, conscious '*learning'* could not be converted to language '*acquisition'*, the latter of which was the catalyst for fluency (R. Ellis, 2008). The notion of acquisition was further explained by how implicit learning manifested language learners to use foreign language fluently. This fluency could be explained by elaborating that this acquisition process was similar to how a person learnt and spoke their mother tongue, which empowered language learners to automatically use words in context (Krashen, 1985; N.C. Ellis, 1994; R. Ellis, 2009, 2015).

Long (2015) also argued that as people got older, they lose the ability to emulate the acquisition process they used when learning their mother tongue for the first time. However, De Keyser (2007) supported a strong interface stance in that intentionally gained knowledge (explicit knowledge) could be converted into implicit knowledge. That is, when a language learner engaged in excessive practice of a target language, they were able to automise the explicit knowledge and gear it towards the implicit knowledge (i.e., incidental learning).

In response to the strong interface position, other researchers (N.C. Ellis, 2005; Shintani, 2013; Skehan, 2014) argued that although there was a link between explicit and implicit language knowledge, there was no direct connection. Language learners would need to foster the development of implicit knowledge after being explicitly exposed to the target language (N.C. Ellis, 2005; Schmidt, 1993; Shintani, 2013; Skehan, 2014). Thus, learners needed to be aware of the intentional language learning process and notice the gap in their interlanguage system (De Vos et al., 2019). Hence, being exposed to more comprehensible input allowed incidental vocabulary acquisition to take place (Mushait & Mohsen, 2019), and presented opportunities for developing implicit knowledge in language production (Shintani, 2013). The effects of comprehension on vocabulary acquisition was reported by Rashidi and Adivi (2010) on 40 Iranian EFL students divided into two random groups. Findings showed that students in the treatment group acquired more target words by reading the same five short stories in comparison to their counterparts in the control group, who were explicitly taught to the target words (Rashidi & Adivi, 2010). The positive effects of incidental vocabulary acquisition were also reported by Karami and Bowles (2019) where the participants consisted of 78 EFL adolescent learners. Whilst the control group received the synonyms, antonyms, translations, and English definitions for the target English vocabulary, the treatment group read the words from texts about the content (Karami & Bowles, 2019). Consequently, students who received instruction through the incidental approach gained more vocabulary knowledge than the control group (Karami & Bowles, 2019).

Incidental vocabulary acquisition is more effective than the intentional one based on the trends in the literature review on this area. Therefore, the students mentioned in this thesis, who were in the treatment group, received implicit instructions whilst the control group researched the target words' meanings from the dictionary (see Chapter 3).

2.4 Vocabulary Learning Theories

This section examines theories with respect to vocabulary acquisition and retention. It starts by explaining vocabulary acquisition through the cognitive constructivist theory and the cognitive theory of multimedia learning. Finally, the situated learning theory regarding vocabulary acquisition and retention is explained in detail, as a focus of this dissertation.

2.4.1 Cognitive Constructivist Theory

In order to pedagogically inform the design of effective methods, how language learners learn has been a subject of interest to many researchers (Coady, 1997; Kanellopoulou et al., 2019; Y. Kim, 2008; Moody et al., 2018). Piaget (1953) has proposed the cognitive constructivist theory where learners used their cognitive structures called schemas or schemata, in order to understand their environment by processing information that enhanced comprehension, learning or retention of knowledge (Wadsworth, 1996).

Schema is identified as a mental representation of knowledge which is categorised into systems of thoughts (Kalina & Powell, 2009). Schemas, which are formed by the categories of knowledge, assisted language learners to understand their environment (Giridharan, 2010). If the new information could fit directly into the language learners' schema related to their background knowledge, this was identified as *assimilation* (Kalina & Powell, 2009). In contrast, *accommodation* refers to the condition where new information does not fit into the existing schema, thus reconstruction of the schema is required (Bettencourt, 1989). In other words, learners used their existing knowledge (schemas) to process and understand the new information (Zimmerman, 2013). Therefore, language learners constructed new knowledge via assimilating or accommodating new information through their existing knowledge, which would expand their current schema (O'Malley et al., 1990). As a result of this assimilation or accommodation, learners' cognitive structures were modified, and this continual process was an ongoing interaction between the schema and the environment (Chun & Plass, 1997).

Importantly, this theory also explained how knowledge was retained (Xanthou, 2011). As language learners were introduced to a new topic, the related schemata in one's mind activates (Xanthou, 2011). When a language learner interacted with new information related to a familiar topic, such as new vocabulary items, the activated schemata assisted the language learner to clarify the meaning with the assistance of contextual cues (Moghadam & Fatemipour, 2014). Contextual cues could help students to fill in knowledge gaps, clarify meaning of unknown words, and interpret meaning out of context (Goodman, 1984; Rumelhart, 1977). Meaningful contexts were a prerequisite to establish strong connections between meanings and the vocabulary items (Sert, 2017; Xanthou, 2011). Liebscher and Groppe (2003), predicted that, regardless of the presentation of abstract (harder to convey meaning) or concrete (easier to convey meaning) nouns, contextual cues would assist language learners to acquire equivalent comprehension (Schwanenflugel et al., 1992). Previous research provided evidence through offering relevant contextual information, that tapped into learner prior knowledge, EAL learners could increase their vocabulary (Ramos & Dario, 2015; Schwanenflugel & Shoben, 1983; Wattenmaker & Shoben, 1987).

Furthermore, studies showed that most vocabulary was learnt in context, as the context supported the clarification of information presented (Arvizu, 2020; Paribakht & Wesche, 1996). The nuanced factors of offering relevant contextual information to support the acquisition process was further elaborated by Sternberg and Powell (1983), who identified the following contextual cues that could have assisted the clarification of the meaning of an unknown word:

(1) *Stative descriptive cues*: information concerning the property, such as the size, shape, colour, or odour of the target vocabulary item;

(2) *Functional descriptive cues*: information about the possible purposes, action, performance or potential use of a lexis;

(3) *Causal enablement cues*: information concerning possible causes of or enabling conditions of the target word;

(4) *Class membership cues*: cues regarding one or more classes to which word belongs, or other members of one or more classes of which the target vocabulary item is a member; and

(5) *Equivalence cues*: information related to the meaning of a lexical item, or contrasts to the meaning of the target word (Sternberg & Powell, 1983).

Through these cues offered in context, the unknown vocabulary items were explained for better understanding (Groot, 2000). Besides, with the inclusion of the above cues, learning vocabulary in context was particularly significant when language learners aimed to gain skills and knowledge through the target language, such as the essential need to acquire academic terminology to learn about content (Stenberg, 1987; Van de Craen et al., 2007). In this study, the HMD VR presented learners with contextual cues of the target words in topic-related games.

Consequently, Piaget suggested that the concept of schemata formed through contextual cues varied according to the topics or themes whether by grammatical forms, meanings, or associations (R. Ellis, 1999, 2015). For example, the first time a child encountered the real animal pony, it may have been classified under the schema for dog due to their physical similarities. However, after the child realised that some horses can be large whilst others could be small, the child modified their schema of a horse based on this experience (Mandler, 2014). Thus, vocabulary was categorised in concepts which differed from one schemata to another (Chan & Kwan, 2021).

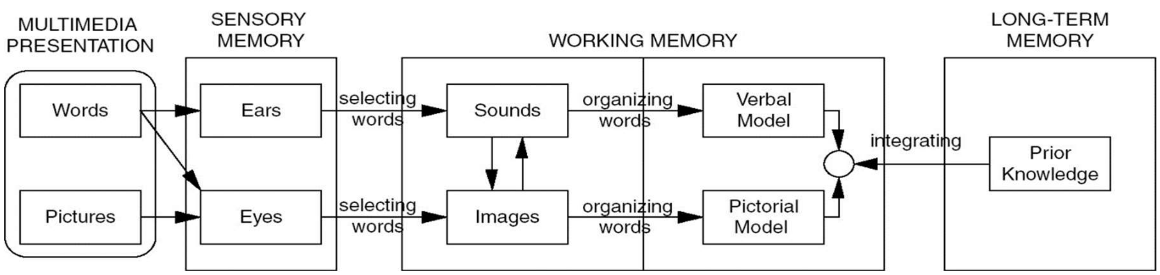
2.4.2 Cognitive Theory of Multimedia Learning

Mayer (2005, 2014) suggested the cognitive theory of multimedia learning to explain the cognitive process of foreign language learning. According to the cognitive theory of multimedia learning, learners actively constructed new knowledge by using visuals and textual forms of unfamiliar words.

As shown in Figure 2.1, Mayer (2005, 2014) claimed that when information came to sensory memory through ears or eyes, learners selected verbal and visual language items presented via the multimodal material. However, Mayer (2005) warned about the limited capacity assumption, suggesting that learners could only hold a few visuals and words in the working memory capacity at a time, as the sensory memory had a lifespan of a few seconds. Then, language learners organised these selected items in verbal or visual modes, where a link was constructed between the two systems in the working memory, which can last up to a few minutes (Mayer, 2005). Despite its relatively short duration and limited capacity, working memory actively holds new information gained through sensory memory and is readily available during vocabulary learning due to its active and direct engagement with the learning environment (Amiryousefi & Ketabi, 2011; Baddeley, 2002; Ramezanali & Faez, 2017).

Figure 2.1

Cognitive Theory of Multimedia Learning (Mayer, 2014, p. 37)



When the verbal and pictural model in the working memory connected new information, it enhanced vocabulary retainment by integrating new information with prior knowledge which was stored in the long-term memory (Ramezanali & Faez, 2017; Sweller & Chandler, 1994; J. Zhang, 2004). One had to establish a link in form and meaning between newly acquired knowledge and background knowledge in order to retain the target lexis (Amiryousefi & Ketabi, 2011; Mayer, 2014). Vocabulary retention occurred when information stored in working memory had been transferred to the long-term memory (N. Ellis, 1997).

Mayer (2014) further postulated that retention of knowledge could be achieved through meaningful engagement and sufficient interaction with target words. For example, Reynolds et al. (2015) found that only encountering the target word three times, whilst reading a text, was sufficient to learn the target vocabulary item. However, whilst listening in the target language, one needed to be exposed to the target lexis more than 15 times to acquire the target lexis (Van Zeeland

& Schmitt, 2013). Thus, research suggested that multiple encounters with a target vocabulary item was integral to linking form to meaning (González-Fernández & Schmitt, 2020). In addition to the number of encounters, Underwood (1989) implied that a picture was worth a thousand words: “We remember images better than words; hence we remember words better if they are strongly associated with images” (p. 19). This finding was also echoed in other studies (Duquette & Painchaud, 1996; Kost et al., 1999), where language learners who viewed pictures received higher scores and claimed that participants in their study were able to acquire the meaning of unknown vocabulary items through visual aids. Research (Teng & Zhang, 2021; Z. Wang et al., 2020) also suggested that images left stronger traces in our brain, leading us to remember the target language. Despite written and spoken words being coded once, images of words got coded twice, first visually, then verbally, in our brains (Kanellopoulou et al., 2019). Therefore, presenting visuals alongside written words were more likely to contribute to better word recall and incidental vocabulary acquisition (Artman, 2020; Ramezanali & Faez, 2019). The present study on highly immersive VR learning environment aligned with the Cognitive theory of multimedia learning since the VR games presented the target subject words via 3D visualisations with audio descriptions. However, presenting visuals in this study was not limited to pictures, but instead they could be manipulated by players in the virtual simulation.

2.4.3 Situated Learning Theory

Lave (1993) defined situated learning as “…a theory that encompasses mind and lived-in-world, treating relations among person, activity, and situation, as they are given in social practice, itself viewed as a single encompassing theoretical entity” (p. 7). In other words, situated learning theory viewed foreign language learning as a procedure of gainingknowledge (which could not be dissociated from the contextual and social engagement) in authentic settings using real materials with their teachers and peers (Fox, 1997). Buendgens-Kosten (2013) identified authenticity as "not an objective feature of an object, text, person, or activity, but that authenticity reflects the way people frame this object, text, person, or activity" (p. 272). Buendgens-Kosten (2013) suggested that the authenticity of materials depended on the realness originates from, with reference to the objective features that are considered to be at the basis of the negotiation of authenticity.. Lave and Wenger (1991) further elaborated on the situated learning theory by arguing that practicing language in context was the fundamental principle of situated language learning, where learners were immersed in authentic contexts which lead to deep understanding and meaningful learning. Dornyei's (2019) research found that in an environment immersed in an authentic setting, language learners were encouraged to think, speak, and write in the target language. Y.C. Shih and Yang (2008) echoed these findings by stating thatlanguage learners were immersed in an input-rich context which spontaneously enhanced foreign language acquisition. Moreover, Naismith et al.'s (2004, p. 14) and Comas-Quinn et al.'s (2009) studies concluded that situated learning, or 'context-aware learning', enabled language learners to focus on the context, and stimulated them to form their own representation of knowledge by immersing them in the context. Another point was made by researchers, who stated that situated learning concentrated on presenting authentic activities and contexts which were incorporated to connect learners' life experiences with their language learning experience to engage students with the subject matter (Gonulal, 2019; Kuru Gönen, 2019; Y.F. Yang, 2011). As another example, Santos et al. (2016) designed a software program to teach vocabulary by displaying words and animations to teach new words that were relevant to the objects found within the environment. The results conveyed that situating target words in context reduced language learners' cognitive load, improved their attention, and increased satisfaction, which were also reported in previous studies (Hsu, 2019; Zhonggen et al., 2019). Similarly, systematic reviews (Acquah & Katz, 2020; Persson & Nouri, 2018) on situated language learning reported that situating language in context had a positive influence on language learners' interest and confidence in learning a foreign language.

Lave and Wenger (1991) stated that resources developed by foreign language instructors could be grounded in socially situated contexts for students to transfer and use their language knowledge in real life (Lave & Wenger, 1991). This could be achieved through students bringing their own needs, skills, prior knowledge, and learning styles to engage in context-based experiential learning tasks (Felix, 2002). As a result of students being immersed into situated learning environments, students to gain experience through actively accomplishing a real-life task (McNeil, 2013). Using language in real life motivated language learners to learn vocabulary (Mills, 2011). Otherwise, Stenberg (1987) stated that such language teaching programs could not be successful.

Indeed, one of the benefits of situated learning was the experiential learning opportunity it offered for language learners (Dawley & Dede, 2014). According to Kolb's (1984) Experiential Learning Cycle and Dawley and Dede (2014), knowledge creation was the conversion of experience where the concrete experience was followed by the reflective observations about the experience. For example, a learner went through experiences regarding a situation by participating in fieldwork, and then reflecting on the experience conceptualising even abstract concepts based on concrete experiences (Dawley & Dede, 2014). Morris (2020) defined concrete experiences as situations where:

> "Learners are involved, active, participants; knowledge is situated in place and time; learners are exposed to novel experiences, which involves risk; learning demands inquiry to specific real-world problems; and critical reflection acts as a mediator of meaningful learning" (p. 1064). Then, learners conceptualised and drew conclusions about their experience and applied these conclusions into new experiences (Kolb, 1984).

Research has shown positive effects of situated learning on language acquisition (Eang & Na-Songkhla, 2020; Uz Bilgin & Tokel, 2019; D. Zhang et al., 2020). For example, Gee (2018) attributed the positive outcomes of situated learning to presenting words in contexts: “the meanings of words, phrases, and sentences are always situated, that is, customized to our actual contexts” (p. 138). However, Lave (1993) claimed that providing real-life scenarios, where language is situated for students to experience and practice at schools or language courses, were not always doable. It could be explained by the conventional theories of learning and schooling which appealed to the character of some knowledge and forms of knowledge transmission. In order to tackle this downside, situated language learning could optimise teaching-learning environments with the enhancement of new technologies (C.H. Chen et al., 2021; Kuru Gönen, 2019). For example, to overcome physical boundaries, software applications via a phone or computer were used to engage in online language learning communities to communicate by verbally chatting or texting to each other (Kessler, 2018). The aim of such communities was to encourage learners to interact with other language learners or native speakers of the target language to practice language or exchange ideas (Godwin-Jones, 2018). Importantly, highly immersive virtual environments could immerse learners in software applications such as Second Life (Blyth, 2018), where learners extended themselves in the games through avatars (Gee, 2012), to communicate in the target language and interacted with situated vocabulary items whilst being immersed in real-life task scenarios (Cooke-Plagwitz, 2008; Jabbari & Eslami, 2019).

Overall, situated language learning with reference to multimedia computer assisted language learning and HMD virtual environments could have: (a) enhanced meaningful language and vocabulary learning (J. C. Chen, 2016); (b) fostered interactivity with others and digital objects, thus increased learner attention (Alfadil, 2020); (c) offered experiential learning experience using authentic language (Lee et al., 2017); (d) immersed language learners deeply in the context where rich contextual cues foster their understanding of the target lexis (D. Zhang et al., 2020); (e) enabled learners to reflect on what they have learnt and how they have gained knowledge, thus promoted learner agency (C.P. Wang et al., 2020); and (f) motivated learners by offering a fun environment (Hadid et al., 2019).

This study, focusing on presenting immersive VR games to enhance language learners' content-specific vocabulary acquisition and retention aligned with situated language learning theory. The focus of this research is on contextualising vocabulary items, interaction, learning authentic language, and experience. In other words, the target vocabulary items in this research are situated in the context of topics related to Humanities and Social Sciences (HASS), Science, and Arts for students to learn (see Chapter 3, Section 3.7.1). Moreover, the realistic tasks embedded in these games were considered according to Gee's (2005) description of "good game". Gee's good games' principles that identify the characteristics of good educational games are discussed below.

2.5 Digital Games

Gaming is characteristic of human nature as humans evolved and developed the mental capacity to play games by using their imagination (Baltra, 1990; Demirbilek et al., 2010). Gee (2014) stated that games are now externalised in simulations, where humans could play digital games in a digital game by actively manipulating objects (Gee, 2014). Vogel et al. (2006, p.231) defined computer games as "activities that are interactive, provides feedbacks such as rewards, and has goals". Manesis (2020) suggested that computer games are synonymous to digital games, electronic games, and video games. He further states that a game can also be identified based on the elements of interaction, the rules and aims of the game, and whether it has a plot or provides feedback to the user (Manesis, 2020). Since gamification is conceptualised as "an integration of game elements and game thinking in activities that are not games" (Kiryakova et al., 2014, p. 1), simulations can be gamified (Bonde et al., 2014; Wiggins, 2016). Simulation was described as "a method or technique that is employed to produce an experience without going through the real event" (So et al., 2019, p. 52). Although the definitions of digital games and simulations seem closely related, Gee (2014) makes further distinctions between digital games and simulations in that, "One is that most (but not all) video games have a win state, and the other is that gamers don't just run a simulation, they micro control elements inside the simulation" (Gee, 2008, p. 31). Additionally, Giryakova et al. (2014) claimed that simulations that have been gamified, or game inspired should also be called games. Becker (2021) also used 'games' as an umbrella term to make the distinction between the types of teaching and learning through games, including 'gamification' Thus, in this thesis, simulation games carried out in VR environments using headsets are referred to as 'games', as the applications are either games or gamified and the game-based, simulated nature of the applications align with Gee's 'good games' principles (see Chapter 3, Section 3.7.1).

The digital age has influenced young adults radically, as they now increasingly invested in online computer games outside of school (Alfadil, 2020; Rhodes, 2017). Video game sales in Australia increased by 15 per cent between 2013 and 2018 (Brand et al., 2019). The figures in their study collected from 3,228 individuals of all ages in 1,210 households indicated that over 91 per cent of households owned a video game device, with 21 per cent of them having a VR headset device. Of the participants, 70 per cent used mobile phones to play games whereas 65 per cent used consoles. The daily total play time of all ages was 81 minutes, with children playing on average 100 minutes a day. This comprehensive report found that half of the parents stated that their children's schools used video games for education and that these games could be an effective source to learn Science, Technology, Engineering and Mathematics (STEM skills) whilst promoting creativity (Brand et al., 2019).

During the COVID-19 pandemic, over 75 per cent of Australians connected with others through playing digital games, and 77 per cent of them claimed that collaboration through video games safeguarded their emotional wellbeing, whilst 70 per cent claimed that it helped their social wellbeing and suggested that playing video games helped to keep their minds active (Brand & Jervis, 2021).

Given the increased time young adults were investing in playing digital games, researchers and instructors in education were actively incorporating digital games and simulations to the classroom (Radianti et al., 2020). As theoretical guidance is crucial whilst integrating digital games and simulations to language learning environments, the following section presents an integration of game theory.

2.5.1 Theoretical Underpinnings

2.5.1.1 Digital Gamesand Situated Learning

Situated learning environments provided language learners situations where they could construct lexical knowledge through interaction (Nikbakht & Boshrabadi, 2015), participation (Piirainen-Marsh & Tainio, 2009), and experience (Palaigeorgiou et al., 2017). Previous research indicated that digital games were conducive to situated learning as they enable learners to acquire the target vocabulary while being immersed in topic-related game scenarios (J. C. Chen, 2016). The pedagogical approach of adopting digital games to incorporate game features into teaching the content is defined as digital game-based learning (DGBL) (Liao et al., 2019). Researchers (Y.H. Chang et al., 2020; Hwang & Wang, 2016; Sundqvist & Sylvén, 2012) suggested that situated learning environments could be instantiated within digital game-based learning where learners could acquire target lexis through assimilating or accommodating new words into their schemas (van Eck, 2007). To illustrate, the situations in digital games, also known as narratives, described a sequence of fictional or non-fictional events based on the setting, characters, and action (Kiili, 2005). The use of stories was important whilst developing digital games (Rollings & Adams, 2003). As digital games were also adopted by instructors in the classrooms, the stories of games also had an effect on how learners viewed the storyline (i.e., the narrative aspect of each game) and this was determined by their decisions and interactions with these elements in the game (Kiili, 2005). In order to increase interactions and promote the decision making process, the game narratives requested learners to solve a problem or complete the objective of the game (Gee, 2005; Kiili, 2005). Thus, according to previous research (Gros, 2007; Kiili, 2005) DGBL environments enabled students to explore or manipulate objects, leading to better discovery of new rules and ideas in the game in order to reach the goal. Discovery learning also allowed students to experience the game world by actively constructing their knowledge through situations in simulations (Hsieh et al., 2015; Kiili et al., 2012).

Given all games have some sort of story embedded in them, when a language learner entered the learning simulation, they constantly made decisions, experimentation, and refinement in the situated learning environment (Gök & İnan, 2021; Kiili et al., 2012). For example, in the *Titans of Space Plus* game learners took the role of an astronaut to travel into our solar system to explore precise knowledge concerning the largest known stars (Alfadil, 2020; Mintz et al., 2001). Such games with stories have the potential to situate the meaning of vocabulary within this context (Alfadil, 2020; Hickman & Akdere, 2018; Mills et al., 2020). These digital games could be powerful learning tools via presenting topics (Martinez-Garza et al., 2013; Xie et al., 2019) and enhance experiential learning by allowing players to assume a different identity (Gee, 2005).

Similarly, the current study also proposed the use of VR games where the meaning of target words was situated in context (see Chapter 3, Section 3.7.1). In addition, the storylines of these games enabled players to adopt an identity, such as taking the role of a diver or astronaut, allowing EAL learners to discover precise information related to the subject matter.

As digital games enabled students to experience situations in the virtual environment beyond physical boundaries, digital game-based learning offered a fruitful basis to integrate educational methods to digital games (Karageorgakis & Nisiforou, 2018; Singh et al., 2020). For example, challenges presented in games encouraged players to solve problems by first generating initial ideas (S.Y. Huang et al., 2020; Papadakis, 2018). These initial ideas were referred to as primary creativity which could lead to innovative solutions (Kiili, 2005; Parmaxi, 2020). Then, as players considered their constraints and available recourses of the game world, these initial ideas develop to idea generation, which could be more fruitful if the idea generation process was performed in groups (Gros, 2015; Khatoony, 2019; Kiili, 2005). After generating ideas, players tested their ideas where they reflected on their experiences and viewed the results of their actions. This reflection enabled the construction of schemata to discover new solutions to the problem. As learners tested the solutions, their skill level increased, which resulted in understanding the knowledge related to the game and the subject matter (Kiili, 2005; Q. Li, 2010).

Testing various solutions to gain knowledge about the content was considered important in playing these digital games (Arnab et al., 2019). However, if the storyline only required one solution, then this may have decreased learner motivation as challenges were considered crucial to experiential game-based learning (Kiili, 2005). To sum up, real or imaginary contexts where players complete missions embedded in storylines enabled learners to continuously practice the target language whilst acquiring content knowledge (C.I. Cheng et al., 2018; Zou et al., 2021).

2.5.1.2 Characteristics of 'Good Games'

Gee (2005) developed the following seven principles to identify the characteristics of effective educational games and identified such games as 'good games'. Gee's (2005) good games' principles for learning had set the basis for carefully selecting HMD VR games online adopted in this research. The good games' principles are presented in detail below.

Games developed for the purpose of education were sometimes referred to as serious games in the literature. The term 'serious games' was first coined by Abt (1975) as follows: "We are concerned with serious games in the sense that these games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement" (p .9). However, Gee (2005) did not make such a distinction; instead, he argued that commercially developed games could be as effective to teach content in learning environments depending on the games' characteristics, as confirmed by other research Bawa et al., 2018; Lacasa et al., 2008). In the first guiding principle, Gee (2005) posited that 'good' educational games enabled the players to interact with the game as active agents. According to multiple research, interaction was also found to be an important feature as it allowed learners to make their own decisions that contribute to the active learning experience (Graesser et al., 2008; Tisue & Wilensky, 2004). Gee (2005) also argued that players co-designing the game whilst playing through interaction increased learner engagement which was central to motivation (Cornillie et al., 2012; Reinhardt & Thorne, 2016).

The second principle identified by Gee (2005) was games offering players the opportunity to customise settings according to their learning styles by requiring players to keep game plan logs to accomplish the mission. Reflecting on one's preferred learning style and how they learn has been beneficial to language learning as evidenced in multiple studies (Cuthbert et al., 2019; Márkus et al., 2018; Whitton & Hollins, 2008). This reflection process was considered crucial to retain information as learners would be thinking about their experience of using words in situations which could enable the information stored in working memory to be transferred to the long-term memory (B. Chang, 2019; von Glasersfleld, 1982). Furthermore, good games offered players a new identity (Gee, 2005), such as being an astronaut in the *Titans of Space Plus* game (Alfadil, 2020) which triggered discovery on the part of the player (Voulgari et al., 2014). Moreover, whilst discovering, learners could form an understanding of how it felt to travel to space, by taking on a certain identity to complete their mission (Gee, 2005). Cognitive research indicated that as humans, perceptions and actions were connected (Barsalou, 1999; A. Clark, 1997; Glenberg, 1997; Glenberg & Robertson, 1999). Thus Gee (2005) stated that when players could easily manipulate characters or objects in the game, they felt as if their bodies and minds were extended into the game, which was also evidenced in other studes (Hannafin & Land, 1997; Kesim & Ozarslan, 2012). This could have fostered learners' experiences of authentic situations to practice the target language, as they felt like they were really in the simulation (Sykes, 2018; Q.F. Yang et al., 2020).

A high immersion could have decreased the cognitive load of learners (Liao et al., 2019). As digital games effectively presented multimedia learning materials (Plass et al., 2020b), the working memory capacity of learners could have been easily overloaded due to presenting a variety of information in visual and verbal modes all at once (Kiili, 2004). Mayer's (2005) cognitive theory of multimedia learning, which assumed working memory included limited channels for both visual and auditory (verbal) processing, also supported this notion (Kanellopoulou et al., 2019; Killi, 2005). However, the promise that working capacity may be increased by the visual, auditory, and haptic information presented to the player simultaneously through digital games could overcome this issue (Killi, 2005). Thus, digital games played with haptic information presented via VR headsets that support immersion could reduce the cognitive load by presenting educational materials more realistically (Bahari, 2022; C.L. Huang et al., 2020). Sato et al. (2009) defined haptic information as “information of the position and the force of human motion” (p. 1651).

Importantly, the ‘Information on Demand’ and ‘Just in Time’ (Gee, 2005) principles indicated that good games provide verbal information about the subject matter just in time, or when learners request to hear the information (Aleven et al., 2010; Gee, 2005; Klopfer, 2017). Hearing the information or words just in time may have helped learners relate the meaning of the word to the action image in the working memory, as explained by the cognitive theory of multimedia learning (Mayer, 2005, 2014). This could also have empowered language learners to situate meaning of words and use them according to the situation (Lave & Wenger, 1991).

Gee’s (2005) ‘The Fish Tanks and the Sandboxes’ principles related to simplifying the first two levels of the game and ensuring not much can go wrong in the game to help players to understand the storyline and requirements of the game (Becker, 2013; Coleman & Money, 2020). Otherwise, players may not have learnt in an environment where they felt the pressure of failure (Reinhardt & Thorne, 2016; A.I. Wang & Tahir, 2020). Good games offered sandboxes in the beginning that make the player feel competent even if they are not (Lukosch et al., 2013). Then, they put a moratorium on any failures that could have hindered the fun, risk taking, hypothesising, and learning. Moreover, good games made failure a part of the fun factor which was crucial to learning (Buday et al., 2012; Gee, 2005).

Another principle identified by Gee (2005) was related to good games motivating players to practise and apply their language skills and knowledge as a strategy in order to have achieved the goals in the games (Prensky, 2001; Ranalli, 2008). This characteristic of a game could have enabled learners to practice language or target vocabulary in a situated and meaningful environment (Alfadil, 2020; Gee, 2005; Reinhardt & Thorne, 2016). Moreover, good games motivated learners to view how each element in the game fit into the overall system (Chu & Fowler, 2020). This will not only promote understanding of how things work in the chosen game world, but it will also encourage learners to consider how the purpose of their action in the moment contributes to the game (Gee, 2005; F. Y. Li et al., 2021). This reflection could enhance the adoption of new information into their mental schemata as explained by the dual coding theory (Paivio, 1990).

Last but not least, the 'Meaning as Action Image' principle concerns humans learning through experience. Learners think through experiences (Gee, 2005). For example, rather than thinking of a wedding through general definitions, a person thinks of imaginative reconstructions of weddings based on their experiences about the weddings they have attended. Thus, it is the experience that attributes a meaning to the word wedding (Gee, 2005). Therefore, if a learner's sole source is dictionary-like information, then they cannot understand what they are reading or hearing as humans need to reflect on experience and run the models in their heads (Beavis et al., 2015; C.Y. Hung et al., 2015). As a result, Gee (2005) claims that the ultimate reason video games work is that the human mind works similar to how video games work.

Overall, the use of technology alone does not motivate students and careful consideration should be given to theoretical guidance whilst utilising digital games for language learning (Mayer & Johnson, 2010; Plass et al., 2020a). Learning situations and methods that engage learners must be created considering how students process information to acquire a foreign language and the principles of good games that could effectively merge the content of learning and the motivation of games (Kafai & Burke, 2015; Prensky, 2001).

2.5.2 Digital game-based language learning

Digital games could be used to set educational goals to stimulate students to gain knowledge

(Debabi & Bensebaa, 2016) and have the potential to promote students' interest and increase their motivation (Anastasiadis et al., 2018; Prensky, 2003; Wichadee & Pattanapichet, 2018). As such, according to Ravenscroft (2007), although students' attention and motivation was significantly reduced after about 20 minutes in a classroom, digital games increased learners' attention span to over 30 minutes. Due to the nature of well-designed games (Gee, 2005), digital-game based learning environments offer a student-centred learning approach (Anastasiadis et al., 2018).

Prior research on game-based learning also shows that using digital games in language education promotes the progress of communicative fluency (Grimshaw & Cardoso, 2018) and stimulates meaningful discovery learning (Baltra, 1990; Tokarieva et al., 2019) which motivates learners (Paraskeva et al., 2010 Roblyer & Doering, 2010; Tüzün et al., 2019; J. C. Yang et al., 2022). Moreover, digital games provide an enjoyable learning atmosphere where learning anxiety may be decreased (Aghlara & Tamjid, 2011; J. C. Yang et al., 2022), and facilitate learning by fostering learners' cognitive, behavioural, affective, and sociocultural engagement with the subject matter (Plass et al., 2015). Also, when digital games include content information related to the subject matter, it could enhance learners' acquisition of new concepts and skills (Alfadil, 2020; Devlin et al., 2014). These concepts in education could relate to the teaching of many subjects such as science, English, and mathematics (Hwang et al., 2012; L. H. Wang et al., 2022). For example, massively multiplayer online games (MMOG) such as *Minecraft* (with new mechanics designed and incorporated) encourages leaners to interact with each other to promote better communication and collaborative learning whilst cognitively engaging in subjects such as STEM to meaningfully discover the content (Mavoa et al., 2018).

One of the areas in education where digital games have been incorporated, researched, and actively used is foreign language education (Chapelle, 2003; Chilingaryana & Zverevab, 2017;

Peterson et al., 2022). Students' passion for digital games can motivate language teachers to incorporate these tools in their classrooms (Reinhardt, 2018), as carefully selected games are applicable to language learning (Ibrahim, 2018). For example, teachers adopting games in foreign language teaching in Yolageldi and Arikan's (2011) and Castillo-Cuesta's (2020) studies emphasised that students more effectively learned grammar in the context of games, compared with peers taught using traditional methods (which is further explained in Section 3.8).

Shih's (2008) research revealed that applying digital games to language learning fosters learners' language development of their listening, speaking, reading, and writing skills in the target language. Observation and interview results indicate that students liked the opening stories and role plays in the games, which motivated them to improve speaking and reading skills, which was also echoed in other studies (Casañ-Pitarch, 2018; Nikolopoulou et al., 2019). The goal-based scenarios encouraged learners to use communication strategies, which also developed speaking and writing skills (Shih, 2008). In addition to enhancing foreign language skills, digital game-based learning was also found to allow learners to construct their own knowledge in the target language (Wichadee & Pattanapichet, 2018), by developing their own social identity (Shadiev & M. Yang, 2020) and building language skills to complete games (Holden & Sykes, 2012). A similar study was conducted by Ibáñez et al. (2011), where foreign language students had a goal, such as visiting a target location, to accomplish in the 3D virtual world. Learners improved their listening skills by approaching an object and listening to necessary details, while writing skills were promoted via 'chatbot' where learners asked and gave information to different characters in the game about how to find the target location. Dixon et al.'s (2022) meta-analysis results from 26 research studies published between 2008 and 2020 echo the findings above, in particular that digital games developed for entertainment were effective for foreign language acquisition.

Importantly, the meta-analysis showed that research incorporating supplementary learning material had distinct advantages over that which simply had learners playing a game without teacher intervention (Dixon et al., 2022). Another meta-analysis, conducted by Huang et al. (2018), reviewed research papers published between 2007 and 2016 on the effectiveness of digital games for language acquisition. They found that studies that adopted digital games in learning EAL generated positive outcomes regarding language acquisition. A further meta-analysis was conducted by Poole and Clarke-Midura (2020) by reviewing 49 studies published between 2012 and 2017, researching the effects of digital games on additional language learning. However, only 18 of those studies focused on second language vocabulary development. The results suggested that most studies reported higher vocabulary gains in students who were playing digital games to learn the target words due to the gaming environment providing contextual cues of unknown words (Poole & Clarke-Midura, 2020).

Although games are an ancient form of learning (Baltra, 1990), with humans starting to play games by using their imagination to form and play under different scenarios (Demirbilek et al., 2010), the digital age (Prensky, 2001) has enabled humans to simulate and play with their imaginations via digital games (Gee, 2014). Research indicates that digital games are continuously being developed in order to increase motivation and enhance meaningful learning in education (Merzifonluoğlu & Gonulal, 2018; Poole & Clarke-Midura, 2020) and foreign language learning (Aghlara & Tamjid, 2011; Chapelle, 2003; Chilingaryan & Zvereva, 2017; DeHaan et al., 2010; P. Li & Lan, 2022; Shih, 2008; Yolageldi & Arikan, 2011) through direct experiences with the game world providing possibilities for reflectively exploring content (Alfadil, 2020). Developments in digital games, now offering immersive simulations of HMD VR environments through desktop or goggles (Qiu et al., 2021), provide increasingly greater opportunities for language learners by providing visual support and authentic learning by immersing themselves in the context (W. Huang, et al., 2021). Furthermore, according to Rozinaj et al. (2018), VR technologies will soon replace not only traditional classrooms, but also the way computers are used, which will engender a major shift in education systems. Thus, there has been an increase in research in the field of education and language learning concerning VR (Bahari, 2022; L. Miller & Wu, 2022; Turgunova & Abduramanova, 2022), which will be discussed in the next sub-section.

2.6 VR

The advancement of digital technologies has enabled games to be played in VR environments, thereby providing unique opportunities to immerse EAL learners in engaging language learning activities (Dawley & Dede, 2014; Kaplan-Rakowski & Wojdynski, 2018). VR can be defined as "an immersive environment in which a participant's avatar, a representation of the self in some form, interacts with digital agents and contexts" (Dawley & Dede, 2014, p. 724). Schroeder used the term virtual environments and VR synonymously and defined both as "a computer-generated display that allows or compels the user (or users) to have a sense of being present in an environment other than the one they are actually in, and to interact with that environment" (Schroeder, 1996, p. 25). Steuer (1992, p. 7) defined VR "as a real or simulated environment in which a perceiver experiences telepresence". VR is also commonly referred to as simulations in which a perceiver experiences telepresence (Kilmon et al., 2010, p. 315). According to Torrejon et al. (2013), telepresence is the technology which allows users to interact and combine virtual objects in applications. Steuer (1992, p. 6) identifies telepresence as, "the extent to which one feels present in the mediated environment, rather than in the immediate physical environment", and the two technical dimensions enabling telepresence are identified as vividness and interactivity. Vividness refers to the nature of VR offering a sensorially rich mediated environment by presenting information to the senses, whilst interactivity is concerned with the degree to which players can manipulate the form or content of the virtual environment (J-H. Kim et al., 2021; Steuer, 1995). Thus, the main difference between digital games and VR is in relation to the high immersion and the feeling of telepresence offered by VR environments (Bouvier et al., 2008). Moreover, Schroeder (2008) suggests that virtual worlds are, "the persistent online social spaces; that is, virtual environments that people experience as ongoing over time and that have large populations which they experience together with others as a world for social interaction" (p. 2). Girvan (2018, pp. 1097–1098) further explains the relationship between a virtual world and virtual environment and VR as follows:

> A virtual environment is a component of a virtual world. Every world contains an environment for its inhabitants. In a virtual world, this is described as the virtual environment … VR is a technical system through which a user or multiple users can experience a simulated environment. One such environment is a virtual world.

Due to these dimensions, VR is frequently used in daily lives of many people through applications in computers, tablets, and smartphones to virtually navigate new places, or visit a heritage site (Alfadil, 2020; Ibáñez & Delgado-Kloos, 2018). This increase in adoption of VR technologies in games, software applications, and education has also attracted researchers, instructors, and administrators in education, and accordingly been actively incorporated to educational environments via a large variety of different applications (Radianti et al., 2020). Sykes and Thorne (2008) categorised these applications used in VR desktop environments based on the following features (a) open social virilities consisting of Second Life (SL) which allows users to immerse themselves in individual and collaborative group activities simultaneously through text messaging using the tools of the application or communicating through a computer microphone and headphone; (b) massively multiplayer online games (MMOGs) including World of Warcraft (WoW) that focus on role-playing facets where thousands of players could collaborate or compete with each other simultaneously; (c) synthetic immersive environments representing a high level of realism and integrating pedagogical principles whilst developing simulations.

With the development of VR headsets (discussed in Section 2.7), virtual environments are not limited to the use of desktop computers (Hu et al., 2016). Thus, desktop VR environments have recently been identified as ‘VR’, whilst headset-configured VR has been referred to as ‘immersive VR’ (Radianti et al., 2019). Slater and Wilbur (1997) identified immersion as the “extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding, and vivid illusion of reality” (p. 603), where the resolution or frame rate of a VR environment determined the degree of immersion (Radianti et al., 2020).

However, research findings adopting desktop VR to teach a foreign language (J.C. Chen, 2016; Qiu et al., 2021; Wehner et al., 2011) has set the basis of reporting immersion and proving pedagogical and theoretical guidance for those who adopted the head mounted device (HMD). Therefore, although this study adopted a HMD VR tool, a brief literature review on integrating desktop VR into education and language learning is presented in Section 2.6.1. It is followed by a review of literature concerning headset-configured VR and vocabulary acquisition in Section 2.6.2.

2.6.1 VR and Education

Digital games using VR can maximise immerse learning experiences as learners can interact with virtual objects in a virtual context to learn mainstream subjects, which may not be possible or difficult to carry out in a classroom (J.C. Chen, 2016; Curcio et al., 2016; Dawley & Dede, 2014; Feng et al., 2018; Shaffer et al., 2005). Through environments that mimic real-world scenarios and enable collaborative learning, VR fosters experiential learning, empower learners to make meaningful connections between visuals and content, facilitates creativity, and offers an interactive active learning opportunity (Akhunova, 2021; J.C. Chen, 2016).

Learners could immerse themselves in authentic experiences in gamified environments, such as travelling through a human body, which was otherwise generally not possible (Alfadil, 2020; Gregory et al., 2014). Furthermore, it immersed learners (to some degree) into situations that were not possible to experience or explore in the real world such as submarine exploration, travelling into the past or exploring museums in other countries, or visiting microscopic places, such as molecules (Johnston et al., 2018; Piovesan et al., 2012). For example, students could learn about how the solar system rotates by physically engaging in the 3D VR environment (Alfadil, 2020; W. Huang et al., 2021; Lai et al., 2020). According to Piovesan et al. (2012), physically engaging in an environment not possible in a traditional classroom could offer a fun learning environment that increased learner motivation and attention (T. Khan et al., 2019). Hence, VR helped learners to discover precise knowledge with respect to objects and micro and macro visualistions that were not possible to experience in real life with the naked eye (Alfadil, 2020; Schott & Marshall, 2018).

For instance, Parong and Mayer's (2018) research aiming to compare the instructional effectiveness of VR versus a desktop slideshow for teaching biology about the human body found that learners exposed to VR resulted in significantly better ratings for enjoyment, engagement, and motivation than the control group, which only viewed the slideshow. Dubovi et al. (2017) adopted a Pharmacology Inter-Leaved Learning Virtual Reality to teach nursing students' practical skills, which had positive outcomes as learners stated that the VR fostered telepresence positively developed their practical skills. In Passig et al.'s (2016) research, experimental group students using a Collaborative Virtual Reality Learning Environment to learn geometric problem solving of volume and surface area performed significantly better than the control group who read the chapter face-to-face and the summarised it in hand writing. Similarly, Alrehaili and Al Osman (2019) adopted a VR application to teach learners between 13 to 16 years old the role of honey bees from a scientific perspective. By testing players' knowledge on the subject before (pre-test) and after the application (post-test), results showed that students using VR gained significantly more knowledge in comparison to their pre-test results whilst reporting an increase in motivation and engagement in comparison to the traditional approach. Other studies confirmed that virtual environments presenting content information through a realistic 3D vision with visual, audio, and textual information increased learners' engagement, motivation, and content knowledge (Cai et al., 2017; Loureiro & Bettencourt, 2014; Pellas et al., 2019; Zinchenko et al., 2020).

Accordingly, VR may be a keystone to effectively provide instruction, motivate learners to engage with the content in learning environments by simulating environments not possible to interact with in real life (Alfadil, 2020). Moreover, these unique facets of VR have led SLA researchers and instructors to integrate VR with language learning tasks (Lan, 2020; Symonenko et al., 2020), which will be discussed in the next sub-section.

2.6.2 VR and Language Learning

VR can be a useful tool to teach and learn a foreign language as it introduces a new dimension to the realm of language education (T.J. Lin & Lan, 2015), resulting in enhanced language acquisition and increased engagement (Godwin-Jones, 2016; Lloyd et al., 2017; Zhao & Liu, 2022). The incorporation of VR into classrooms enabled language learners to engage in situations offering them to interact with the subject content through a novel approach, such as visiting space, otherwise inaccessible in the traditional classroom (H. Gao et al., 2021).

For example, Y. Chen et al. (2020) found that incorporating a Google Earth VR field trip for middle school English learners to reflect on whilst completing their expository English writing experiences resulted in a statistically significant increase in expository writing skills concerning description, cause-effect, and compare-contrast. Furthermore, through a descriptive survey, language learners in this study reported that using VR to improve writing skills in the target language was engaging (Abdel-Reheem Amin, 2020; Y. Chen et al., 2020). Besides improving writing skills, VR was found to develop English language learners' speaking proficiency, by reducing learner anxiety (Chien et al., 2020; Sun & Hsieh., 2018; York et al., 2021), whilst learners were interacting with problem solving tasks in real time collaboration through negotiating meaning (J. C. Chen, 2016; Park, 2018). Along with speaking skills, listening skills were also found to have been improved via virtual worlds in Levak and Son's (2017) study, where learners had the opportunity to engage in conversations via meeting random avatars in Second Life (SL), hear music, and hearing others' conversations. Learners improved their listening skills by having the opportunity to practice listening skills in situations such as how conversations might take place whilst shopping and changing their context via one click which made it easier in comparison to real time. The other feature that may have made listening easy was due transferring their listening skills to real life (Dolgunsöz et al., 2018; Levak & Son, 2017; Soto et al., 2020).

In addition, VR environments were found to improve language learners' vocabulary knowledge via desktop VR games presenting 3D visuals of target vocabulary items (T.J. Lin & Lan, 2015). These games leverage autonomous learning that allowed language learners to actively construct knowledge through situated experience (Aguayo et al., 2017; Gee, 2005; W.H. Huang et al., 2010), and stimulated educators and students to teach and learn "outside the box" (J.C. Chen, 2016, p. 168). In J.C. Chen's (2016) study, EAL students were exposed to multimodal 3D input in Second Life (SL). They acquired new English vocabulary as they interacted with other SL residents using voice/text chat or with 3D objects they built when exploring different SL islands. The findings also revealed that VR not only offered an open, immersive, and creative venue that enhanced the EAL students' communication skills and vocabulary acquisition, but above all, instilled the fun element in their English learning. Similarly, other studies (Berns et al., 2013; C.H. Chen et al., 2021; Dhimolea et al., 2022) found that 3D VR games made vocabulary learning easier as these games visualise and situate vocabulary in context and provide immediate feedback.

Through the development of headsets configured in VR environments, players experiencing high immersion could increase their interaction (Fuhrman et al., 2021), telepresence (Ebert et al., 2016) and thus language learning (Legault et al., 2019). Overall, the above literature review indicates that VR games augment authentic and situated learning experiences, such as travelling through a human body to explore the information, observe the visuals, and interact with vocabulary items associated with human body parts (Blyth, 2018; Lan, 2020; Philippe et al., 2020).

2.6.3 Headset Enabled VR

Although desktop VR environments were found optimal for vocabulary acquisition in comparison to the traditional methods adopting explicit teaching methods (Godwin-Jones, 2014; Jauregi et al., 2011; Rama et al., 2012), virtual environments can be augmented by headsets (also known as head mounted displays, HMDs) (Angelov et al., 2020). HMDs include smart glasses to block the real environment from the learner and increase the sense of telepresence (Godwin-Jones, 2016). According to Radianti et al. (2020) "Immersion describes the involvement of a user in a virtual environment during which his or her awareness of time and the real world often becomes disconnected, thus providing a sense of "being" in the task environment instead" (p. 2). Freina and Ott (2015) define immersion as "a perception of being physically present in a non-physical world by surrounding the user of the VR system created with images, sound, or other stimuli so that a participant feels he or she is actually there" (p. 133). Previous research (Di Natale et al., 2020; Kwon, 2019; Radianti et al., 2020) suggested that those users of HMD VR responded to mediated stimuli equivalent to their real-life counterparts, meaning that HMD VR offered players high immersion, almost indistinguishable from a real-life experience. Overall, highly immersive VR refers to a technological tool offering telepresence in the computer-generated world through a head mounted device which covers players eyes to block the actual surrounding with dual-display stereoscopy to simulate depth perception that is interactive to head movements (Botella et al., 2017; Freeman et al., 2017). 3D immersion enhanced by the sight and sound provided by the headsets offers an innovative approach (Butt et al., 2018; Freina & Ott, 2015).

Given recent technological developments, the HMDs, such as Google Cardboard, HTC Vive, Oculus Go, or Oculus Rift, offer players a high degree of immersion in contrast to desktop VR (Kaplan-Rakowski & Wojdynski, 2018). A low cost Google headset consists of carboard, lenses, a magnet and a washer pair to control switch to trip the gate magnetometer used as a compass in smartphones (Maclsaak, 2015). Due to its highly immersive nature, HMD VR has been used in many fields since 2000's, including language learning (Elmqaddem, 2019; Garcia et al., 2019). This study also makes use of low-cost Google's headset, to immerse learners in the topic-oriented 3D games. As the current research is concerned with using HMD headsets to learn English as a foreign language, the following section presents literature on HMD VR games used to acquire vocabulary.

2.6.4 Headset Enabled VR in Education

HMD VR has been incorporated to education with an effort to offer a fun learning environment that presents complex information by addressing multiple senses to ease the learning process (Carroll & Yildirim, 2021; Zhou et al., 2018). Meta-analysis of clinical trials found that

VR reduces anxiety and induce relaxation (Anderson et al., 2017; Annerstedt et al., 2013; Baños et al., 2009; Carl et al., 2019; Kenney & Milling, 2016; Malloy & Milling, 2010; Riva et al., 2007; Serrano et al., 2016; Valtchanov et al., 2010). HMD VR empowers learners to perceive information beyond the limitations of the classroom which brings a new perspective on how learners view and understand the world around them (Alfadil, 2020). Immersive VR enables students to interact with content or objects in a content-based environment (Dhimolea et al., 2022; Papachristos et al., 2017) to discover information and construct their knowledge by reflecting on their experience (Freina & Ott, 2015; Schott & Marshall, 2018).

2.6.4.1 Vocabulary Learning Via Immersive Games

Regardless of the initial intention of the developed applications, SLA researchers have been adopting games to teach a foreign language as even games developed for commercial purposes could foster situated language learning and present vocabulary items in the context, enable learners to interact with the target words, and foster students to develop their individual experience to construct their language knowledge (Berns & Reyes-Sánchez, 2021; Frazier et al., 2021; Sykes, 2018). The following VR game is an example of how immersive learning environments address multiple senses to learn content and how they could be integrated to acquire English as a foreign language. The reviewed games include those developed specifically for EAL or foreign language (FL) learners, applications designed for educational purposes to intentionally teach a specific content, and games developed for commercial purposes. Although discontinued since June 2021, this immersive VR application, *Google Expeditions,* enabled learners in the simulation to participate in virtual trips to a location the teacher decides. The teacher naturally could pose questions/instructions concerning practicing the target language coupled with the ability to discover the content (Craddock, 2018). For example, whilst visiting the historic centre of Rome, the teacher could ask learners to describe what the sections of the Colosseum are to practice the target vocabulary items which could be ‘dungeon’, ‘column’ etc., as the written form of these words are provided through text next to the Colosseum.

As headsets block the vision of real environments and increase the sense of telepresence in the VR world in unique settings related to the content of games (Y.L. Chen & C.C. Hsu, 2020; Dawley & Dede, 2014), these features make HMD VR a promising tool to teach and learn a foreign language by immersing learners in educational situations (Jensen & Konradsen, 2018). The unique properties of HMD VR games offer virtual opportunities to learn content words, such as interacting with other target language speakers and target 3D objects, listening to information of the content, constructing knowledge in highly immersive experiences, and receiving feedback (K. W. K. Lai & Chen, 2021; Palmeira et al., 2020). For example, in Alfadil’s (2020) study, receiving immediate feedback from the virtual characters in the Mondly HMD VR game was proven to facilitate 49 Year 7 EFL learners’ vocabulary acquisition. Middle Eastern EAL players (aged 12-15, $N = 64$) using a HMD in a language course to interact with a English-speaking teacher (‘Mr. Woo’, a raccoon character host) and discover new information associated with 3D objects presented. In the House of Languages game, Mr. Woo walked the players around the cartoon house to teach them English. When players interacted by gazing at 3D objects using the Samsung Galaxy Smartphone *Gear VR* the game presented the names of the objects with an audio feature that enabled learners to hear the pronunciation of the words. After discovering target objects, the game presented players mini games such as word guessing puzzles (Alfadil, 2020). As a result of this interaction, although the treatment and control group had similar vocabulary knowledge pre-treatment the students who played the VR game acquired more vocabulary than those instructed in the traditional method (VR group: $M = 81.47$ > control group: $M = 71.16$).

Similarly, Tai et al. (2020) adopted Mondly VR to teach English to two classes compromising of 49 seventh graders in Taiwan. Whilst one class used the HMD to play the application, the other students only watched a walkthrough of a recorded version of Mondly VR on a desktop. Although there was no pre-existing difference in language learners' vocabulary scores, learners using HMD retained more words than those watching desktop VR ($M = 14.58 > M = 8.68$, $p = .00$).

In Lai and Chen's (2021) study, 30 Year 12 EFL Chinese students' English proficiency levels were comparable prior to the treatment. The VR group adopted Oculus Go to play with Angels and Demigods, a game where humanity has fallen into civil war, allowing users to interact with the in-game characters by selecting dialogue choices which alter the paths of the game's storyline (K. W. K. Lai & Chen, 2021). The dialogues players read consisted of target vocabulary items. Although the desktop VR group also played the same game as the HMD supported condition, they did not experience the high immersion and visuals were not realistic. As a result of multiple vocabulary tests each consisting of 20 target words, the sense of immersion and telepresence afforded by HMD VR games may have led to a stronger and positive influence on the vocabulary gains of the 15 Year 12 EFL participants in comparison to the desktop computer gaming group (K. W. K. Lai & Chen, 2021).

Likewise, in Monteiro and Ribeiro's (2020) research, 25 undergraduate EFL from Brazil were immersed in a real life-like scenario where they visited the Frida Kahlo Museum in Mexico City. During this tour in the museum, text about the exhibits were provided and the 17 target vocabulary items were presented in capital letters within the context. Although learners were not provided with the translations or definitions, they were successful at acquiring the target lexis through the cues presented in text on the screen. The authors attributed vocabulary gains to

Mayer's (2005, 2014) cognitive theory of multimedia learning (see Section 2.4.2).

Due to the potential of highly immersive VR, Palmeira et al. (2020) conducted a meta-analysis concerning research regarding advantages and disadvantages of HMD VR in foreign language vocabulary acquisition. As a result of their research, they identified 26 studies that addressed vocabulary acquisition through HMD VR, and only nine of these were included in the analysis presenting data regarding the benefits and difficulties of using HMD VR in vocabulary acquisition. Ebert et al.'s (2016) and Vazquez et al.'s (2018) studies also reported that using HMD VR enhanced language learners' vocabulary retention. Retention was regarded as a significant advantage of highly immersive simulations since the goal of language learning is to store vocabulary into the long-term memory (Xie et al., 2019). Superior retention has been found to be one of the important benefits of using HMD compared to the traditional VR desktop condition (Krokos et al., 2019) In other words, high immersion assists to develop more memorable experiences to recall acquired knowledge. Krokos et al.'s (2019) findings showed that virtual memory palaces (a spatial mnemonic assisting to recall information associated with salient features in that environment) in the HMD condition produced a superior memory recall of information compared to the VR desktop condition. Similarly, Freina and Ott's (2015) study also suggested that HMDs enhance immersive learning and new knowledge retention. Importantly, language learners mentioned that interacting to manipulate visualised words increased the sense of immersion. Moreover, it was noted that high immersion led to greater engagement and involvement with the target vocabulary (Legault et al., 2019; A. Cheng et al., 2017; Kaplan-Rakowski & Wojdynski, 2018), through interaction, immersion, and engagement experiences in situated context (Christoforou et al., 2019; Pinto et al., 2019). The disadvantages reported were related to the discomfort of HMD, dizziness, poor visuals, or tired eyes (A. Cheng et al., 2017;

Ebert et al., 2016; Kaplan-Rakowski & Wojdynski, 2018).

Overall, the real-life full immersion where language learners are in the natural language environment interacting in situations with native speakers is considered to be an effective method for learning a foreign language (Kaplan-Rakowski & Wojdynski, 2018). However, this is not a viable or accessible option, thus HMD VR introduces an alternative approach immersing the language learner in situations or contexts that cannot be experienced by humans, such as visiting the sun, whilst in a classroom without physically dislocating learners (Legault et al., 2019).

VR headsets enable learners to immerse themselves in content-based games (e.g., InCell VR (Luden.io, 2017a) teaches cells in Science), where they can interact and explore the target vocabulary in a 3D fashion (Tai et al., 2020). Despite the benefits, further investigations are needed to gain better insights into EAL students' first-hand experiences and views regarding the impacts of HMD VR games on learning content vocabulary (Palmeira et al., 2020). Thus, the following section discusses the gap in research with respect to using headset-enabled VR games in mainstream classrooms to teach content-specific vocabulary items.

2.7 The Research Gap

Although prior research has reported on the effectiveness of learning vocabulary through HMD (Alfadil, 2020; Tai et al., 2020), most VR studies on English vocabulary learning only focused on desktop VR (A. Cheng et al., 2017; T.C. Lin & Lan, 2015; Liou & Lee, 2012), rather than on HMD VR. Thus, research on the use of highly immersive environments in vocabulary learning remains in its infancy (Tai et al., 2020), including analysing the application, practices, and appropriateness of HMD VR and its effects on ELL learners' vocabulary learning (Tai et al., 2020). Therefore, researchers have been calling for further studies to validate highly immersive environments usefulness in K-12 language education (Alfadil, 2020; Dhimolea et al., 2022; T.C.

Lin & Lan, 2015; Qiu et al., 2021; Radianti et al., 2020).

Correspondingly, Radianti et al. (2020) have conducted a meta-analysis of research adopting HMD VR for higher education, including language learning. They found that 68 per cent out of 590 studies are not framed by theory. Moreover, research based on game-based, contextual, and experiential learning consisted of only three per cent but situated theory was not mentioned and most articles' theories were disconnected to their research as researchers linked theory to the features of the games or applications rather than the learning outcomes (Radianti et al., 2020). As this was found to be an indicator of the VR maturity level, which hinders its adoption in day-to-day teaching activities (Radianti et al., 2020; Wu et al., 2020), it is crucial to examine the theoretical basis for technology-based vocabulary learning (Handley, 2014; Klimova, 2018). Thus, a high contribution and impact can be expected from research that is grounded on sound learning theories, careful selection of design elements, and research explicitly describing the design and development process (Hamilton et al., 2021; Radianti et al., 2020). Palmeira et al.'s (2020) meta-analysis focusing on foreign language vocabulary acquisition also demonstrated that there were only nine published articles by 2019 that not only reported the quantitative results of vocabulary tests, but also explained the effects of HMD VR on language learners. However, it should be noted that this meta-analysis was not limited to the English language.

Recent studies concerning English vocabulary acquisition researched the effect of one highly immersive application or game. Linking HMD configured VR to English lexical learning and theory was also found to be limited. After a comprehensive review of the literature, it appears that exploring the effects of adopting HMD VR to teach Middle Eastern English language learners' content-specific vocabulary has not been reported.

This being the case, the purpose of the current study is to address multiple gaps by investigating the effects of HMD VR on content-specific vocabulary acquisition and exploring Middle Eastern language learners' perceptions. In this research task, vocabulary acquisition is examined based on four different conditions. Unlike previous research, this study:

(1) adopted nine different games used in an HMD condition (see Chapter 3, Section 3.7.1);

(2) situated the nine different games in three mainstream subject areas (Science, Humanities and Social Sciences, and The Arts);

(3) recruited Middle Eastern EAL students in the mainstream classroom. This task design was considered to be effective through a different strategy than the previous studies by allowing students to play these games as a post-reading activity, rather than being the central method of instruction.

(4) grounded investigation in explicit theoretical foundations and learning outcomes will be evaluated with reference to theory in Chapter 5, where the discussion of the findings is presented.

Lexical learning was determined using a comparison of three vocabulary test results obtained before and after, and two weeks after the implementation of highly immersive VR (see Chapter 3, Section 3.4.2, Data analysis).

2.8 Hypothesis

Based on the theoretical and conceptual frameworks above, the study hypothesises that:

(1) There is a relationship between language learners' vocabulary test results and their use of HMD VR to learn subject specific vocabulary items.

(2) There is qualitative evidence that the results of participants' perception of using HMD VR to learn subject specific vocabulary items is significant to explaining the vocabulary test results.

2.9 Chapter Summary

This chapter started with an overview presenting the main constructs of this study in relation to vocabulary acquisition theories and headset-enabled VR in vocabulary acquisition. The review of the definition of vocabulary was reported by detailing vocabulary in foreign language and content-specific vocabulary in foreign language. Vocabulary acquisition processes were described in relation to intentional and incidental vocabulary acquisition. This chapter also included a discussion of whether vocabulary acquisition is incidental or intentional.

Vocabulary learning theories were detailed by explaining the cognitive theory of multimedia learning and situated learning theory. Next, a review of the literature with respect to digital games, particularly reporting the theoretical underpinnings of digital game-based learning addressing this dissertation, and digital game-based language learning were presented.

Subsequently, the definition of VR, explaining literature related to VR and education by reviewing literature regarding VR and language learning was reported. Further details about headset-enabled VR were provided in this chapter, by reviewing previous research results that adopted headset-enabled VR in vocabulary acquisition. Consequently, the gap in previous studies was identified and the hypothesis of this research was presented.

Chapter 3 presents the methods adopted in this research.

Chapter 3: Methods

3.1 Chapter Overview

The previous chapter provided a review of the literature of foreign language learners with limited vocabulary struggling to understand content related to a specific subject area. Findings of previous research indicated that digital games have the potential to motivate learners. As the literature review has shown, research to teach content-specific vocabulary items to Middle Eastern English as an additional language (EAL) students in Western Australia (WA) via head mounted display (HMD) virtual reality (VR) games is limited.

This chapter describes the methodology employed in the current study. It starts by elaborating on the research questions (RQ) in Section 3.2 and providing a description of the research design in Section 3.3. Next, the description of the setting and participants is provided in Sections 3.4 and 3.5 respectively. This is followed by a description of ethical considerations in Section 3.6.

The headset-enabled VR games and the relevant subject areas are presented in Section 3.7. This section also elaborates on the data collection tools used in this study.

The data collection procedures are then described in Section 3.8. The discussion of the pilot study results, the process of analysis, including the coding and data treatment, is also outlined in Section 3.8. The chapter concludes with a summary in Section 3.9.

3.2 Research Questions

This research aims to provide data to support better vocabulary retention, suggest pedagogical implications for educational institutions that support EAL learners and explore an innovative approach to optimising vocabulary learning and teaching. This chapter presents the methods used to investigate the following research questions on the effects of game-based HMD

VR learning environment on vocabulary acquisition and EAL students' perceptions and attitudes towards this environment, detailed in Chapter 1:

- RQ 1. How do EAL learners perceive their first-hand experience of using headset-enabled, educational VR games to engage with the content-specific vocabulary items?
- RQ 2. What are the aspects of a headset-enabled, VR game-based learning environment that can facilitate or hinder content-specific vocabulary learning?
- RQ 3. To what extent does a VR game based, headset-enabled approach's effects differ from a traditional textbook-based approach in EAL learners' acquisition and retention of content-specific vocabulary?

3.3 Research Design

A pragmatic, concurrent mixed methods design was utilised to collect and analyse both quantitative and qualitative data in order to answer the research questions (Feilzer, 2010). Yvonne Feilzer (2010) indicated that, mixed methods involved, "Pragmatism as a research paradigm that supports the use of a mix of different research methods as well as modes of analysis while being guided primarily by the researcher's desire to produce socially useful knowledge" (p. 6).

Pragmatism holds the view that providing an answer to the research question is more important than a philosophical stance or choosing only one method that supports a positivist or interpretivist stance (Klockner et al., 2021). Pragmatism enables the researcher to combine both methods to find the meaning and the truth in the consequences of actions and the effects of concepts (Shaw et al., 2010). This should not be confused with expedient as it requires in-depth knowledge of both methods to create good quality social research (Feilzer, 2010; Merriam & Tisdell, 2016). Pragmatism "offers an immediate and useful middle position philosophically and methodologically; a practical and outcome-oriented method of inquiry that is based on action and leads" (Johnson & Onwuegbuzie, 2004, p. 17).

Pragmatism is a philosophy which suits this research. It addresses the importance of context through discovering the observable practical consequences of playing immersive games to learn the target lexis. Pragmatism is also outcome oriented. The truth lies in discovering the process of what works best for these culturally and linguistically diverse students, according to their interpretation. It links to a reflective practitioner paradigm whereby students are asked to think critically about what they do and the effect of the VR game-based learning concept.

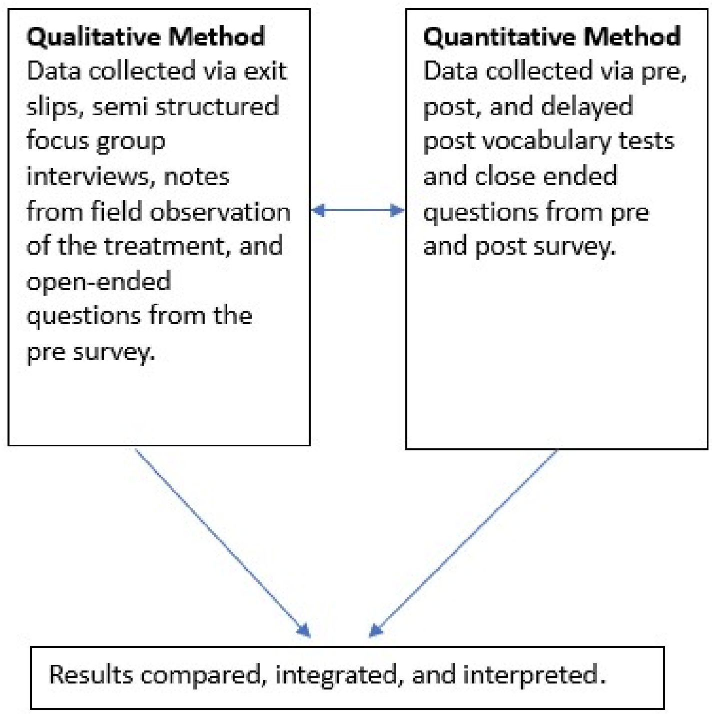
Utilising pragmatism also fosters consistency and coherence between the researcher's worldview and the findings (Kivunja & Kuyini, 2017). It intends to find 'what works?' regarding the VR games, and the knowledge produced from the findings of mixed methods results in answering 'what worked?' (Holloway & Todres, 2003). Solely presenting quantitative research results from the vocabulary tests would have lacked students' voices and attitudes towards HMD 3D VR environments. Only presenting qualitative research results of students' perceptions would have needed objectivity of whether students acquired content-specific vocabulary items via VR games. Therefore, a mixed methods design adds more value to this research than a single method.

In this study, a quantitative element to the design was included. It assisted to understand whether students have acquired or retained the target vocabulary in a highly immersive environment from a statistically valid lens. Quantitative data was collected to answer the first research question. This data was collected by pre-test, post-test, and delayed post-tests to measure the levels of students' acquisition and retention of target vocabulary items. Then, a qualitative design was also integrated to ensure this robust quantitative finding was grounded in the EAL learners' experience. The data reflected on the participants' point of view and gains on various perspectives of their encounter to learn new words related to the WA curriculum (see Section 3.7.2). The second and third research questions were addressed by multiple data sources. The following textualised qualitative data assisted to better understand nuanced factors that influence game-based VR and vocabulary learning supported by students' perceptions: the pre-game survey (open-ended survey questions), semi-structured focus group interviews, exit slips, observation notes, and the researcher's journal. This data provided in-depth evidence to corroborate the quantitative data and capture a holistic picture of the investigated phenomenon (Mackey & Gass, 2015; Tashakkori & Creswell, 2007).

This research design was chosen as the phenomena have different layers that needs to be observed and measured. Exploring the answers to these research questions was possible by combining the two methods (Feilzer, 2010) (see Figure 3.1). Further incorporating a qualitative design augmented the outcome of the quantitative statistics (Kivunja & Kuyini, 2017). This is in view of the fact that a qualitative design enabled the collection of comprehensive and insightful data from these players (Bryman, 2006). The textualised data explained, defined, and suggested why VR games worked well or failed to enhance their vocabulary acquisition. Hence, this may have improved the validity of this research by providing a better understanding of the results and presented a holistic picture of the phenomena (Mc Kim, 2017).

Figure 3.1

Visual Representation of a Mixed Methods Research Design



A concurrent mixed methods design was used to collect data combining the two research approaches (Creswell & Creswell, 2018). Concurrent design refers to "the quantitative and qualitative phases of the research study occurring at approximately the same point in time" (Leech & Onwuegbuzie, 2009, p. 268). Table 3.1 demonstrates the concurrently conducted mixed methods of this research study:

Table 3.1

Concurrent Mixed Method Design

Timeline	Instruments	Type of data	RQ
Week 1	Pre-test,	Quantitative	RQ 3
	Pre-game survey	Qualitative and Quantitative	RQ 1-2
Week 2-10	Field notes	Qualitative	RQ 1-2
	Observations of treatment		
	Exit slips		
Week 1, 5 & 10	Interview	Qualitative	RQ 1-2
Week 10	Post-test	Quantitative	RQ 3
	Post-game survey	Qualitative and Quantitative	RQ 1-2
		Quantitative	
Week 12	Delayed post-test	Quantitative	RQ 3

As described in Table 3.1, the pre-vocabulary test, one of the quantitative data collecting instruments measuring students' pre-vocabulary knowledge to answer Research Question 3, was conducted in Week 1. The pre-game survey collected background information of these culturally and linguistically diverse learners in Week 1. It also asked the students their preferred method of learning content-specific vocabulary before playing the 3D VR games to learn new words. The semi-structured focus group interviews, one of the qualitative data collecting instruments required to understand student perceptions prior to the treatment, took place in Week 1 to answer Research Questions 1 and 2. Students had their second interview in Week 5, to discuss about their opinions of the first four games they had played. To collect in-depth data of students' views on each VR game they played, students completed exit slips and the researcher took field and observation notes of treatment between Weeks 2 to10. The post-game survey conducted in Week 10 aimed to collect data on whether students' preferred methods of learning new words changed after using VR games. Students completed a post-vocabulary test in Week 10, after playing the VR games, to measure whether they have learnt the target words. In Week 10, it was essential for the students to participate in a semi-structured focus group interview to collect qualitative data providing insight to their opinions about playing VR games to learn content-based lexis. If the post-test and the focus group interview had not taken place in the same week after playing the immersive games, it may not have been possible to make the claim that any change in vocabulary acquisition or perception was directly caused by playing the VR games (Alfadil, 2020).

To answer Research Question 3, students completed a delayed post-test in Week 12 to determine whether they retained the target content-specific words. The delayed post-test was conducted two weeks after the post-test. This time frame was based on the rationale that applying a delayed post-test more than two weeks after the treatment may lead to maturation and the likelihood of participant attrition (Mackey & Gass, 2015).

Consequently, this type of mixed methods research design was chosen in order to answer all research questions in a single investigation (Almalki, 2016; Kivunja & Kuyini, 2017). Thus, this design provided the opportunity for deeper insight and interpretation of data from a variety of perspectives (Creswell & Creswell, 2018; Johnson & Onwuegbuzie, 2004). A pilot study was also conducted to test the VR games and the reliability of data collection instruments (see Section 3.10.3).

3.4 Setting

The research took place at an independent Kindergarten to 12 (K-12) school in WA in 2018. The school had one class for each year level. The participants were 14 Year 7 and 14 Year 8 (age 12-13) EAL students who were combined into one class. Students were familiar with combined classes, as Year 7 and Year 8 students had common subjects such as Languages Other Than English and Health.

Although the Year 7 and Year 8 curricula are not exactly the same, they both included revision and transition classes. For example, in Science cells are covered in Year 8, but could be a transition class for Year 7. Similarly, topics covered in Year 7 could be revision for Year 8. There was also flexibility for teachers in choosing content thus enabling them to expand the scope of the context or to embed cross-curriculum priorities into the content. For example, incorporating a topic related to sustainability into Science may have enabled students to understand chemical, biological, physical and Earth and space systems in a Year 8 Science context, and act towards a more sustainable future (SCSA, 2014a).

Technology was also a compulsory learning area of the WA curriculum (SCSA, 2014b). The curriculum coordinator in the school implemented an annual STEM festival; that is, each teacher produced cross-curricular STEM projects related to their subject areas and hosted other schools to display student projects. Therefore, the curriculum coordinator and subject teachers were eager for this research to take place as part of the school's cross-curricular event. The teachers were also required to allocate a few weeks each year to prepare for a STEM festival, thus supporting the time allocations to this research.

Note that the cross-curricular activities in which students participated were not assessed in the school (SCSA, 2014b). Therefore, students were aware that they would not receive a mark for participating in this study (see Section 3.6).

The researcher was previously working as a teacher in this school but was on leave at the time of the main study's data collection stage of this research. The researcher's role was the following: (a) obtain approval from the curriculum director and the students, (b) liaise with the specialist teachers to distribute the games in the timeline according to the sequence of the content, (c) organise seven headsets and seven smartphones, (d) assist the treatment group transfer to another classroom to play the VR games, (e) and instruct how to play the VR games to the students.

3.5. Sampling and Participants

Twenty-eight students with a Middle Eastern background from Years 7 and 8 took part in the study. All students who provided consent participated in the study. Students were organised into groups and played games that were related to the subject content covered in the curriculum, which is further explained in Section 3.5. The participants' English proficiency levels had been assessed by their English teacher as being in the lower band, which did not meet the 'satisfactory' standard, as explained in Section 1.3. Middle Eastern EAL students in this independent school struggled in mainstream STEM subjects and the teachers attributed the achievement gap to students' limited vocabulary. According to ACARA (2016b), developing content-specific vocabulary knowledge was identified as a required general capability for years K-10 regarding mainstream subjects.

Students were required to achieve the following: "develop strategies and skills for acquiring a wide topic vocabulary in the learning areas and the capacity to spell the relevant words accurately. In developing and acting with literacy, students: understand learning area vocabulary, use spelling knowledge" (ACARA, 2016b, Word section). The Year 8 Science sample assessment activity related to Earth and Space Sciences, for example, required the students to use content-specific vocabulary items to identify the type of particles in a rock. Another example was related to The Arts, where students must use art terminology to describe an artwork in order to meet the 'satisfactory' standard. In Humanities and Social Sciences (HASS), one of the achievement standards related to Geography is linked to how comprehensibly the content related to landscapes was narrated. Presenting a detailed description of landscapes using a variety of content-specific vocabulary items are awarded 8 marks. However, if students briefly described the landscape, they only collected one or two marks (ACARA, 2016c). These at-risk EAL students needed to improve their content-based vocabulary knowledge in order to understand their subjects and meet the academic requirements.

The treatment and control groups were selected through manual random sampling from each year level: The treatment group consisted of seven randomly selected students from Year 7 and seven randomly selected students from Year 8. This sampling procedure was the same for the control group. Hence, each group consisted of 14 students in total. Two Year 8 students did not give consent therefore did not participate in the research. They remained in class with the control group and completed the cross-curricular activities as part of the curriculum. Data from these two students, consisting of the vocabulary tests were not collected by the researcher.

A pre-game survey that elicited students' diverse linguistic and cultural backgrounds was administered a week before they commenced playing the VR games. Each student completed the survey that consisted of both close-ended and open-ended questions. Table 3.2 outlined the students' demographic information.

Table 3.2

Students' Linguistic and Cultural Backgrounds

Name	Gender	Country	Age	Age moved to Australia	Home language
Nur	Female	Syria	13	11	Arabic
Laila	Female	United Arab Emirates (Dubai)	13	10	Arabic
Lena	Female	Syria	13	11	Arabic
Yousef	Male	Iraq	12	8	Arabic
Zehra	Female	Turkey	13	5	Turkish
Ayten	Female	Turkey	13	6	Turkish
Salma	Female	Iraq	12	4	Arabic
Fatima	Female	Turkey	12	3	Turkish
Rawan	Female	Pakistan	12	5	Urdu
Sulafa	Female	United Arab Emirates	12	8	Arabic
Reem	Female	Jordan	12	5	Arabic

Rania	Female	Egypt	13	4	Arabic
Kareem	Male	Kuwait	12	5	Arabic
Hashem	Male	Libya	13	6	Arabic
Jamila	Female	Syria	13	11	Arabic
Sahar	Female	Syria	13	11	Arabic
Nadia	Female	Syria	12	11	Arabic
Farooq	Male	Turkey	13	3	Turkish
Nesrin	Female	Turkey	13	6	Turkish
Talia	Female	Iraq	12	5	Arabic
Lila	Female	Somalia	12	6	Somalian
Aaliyah	Female	United Arab Emirates	12	4	Arabic
Amir	Male	Libya	12	8	Arabic
Bayan	Female	Syria	13	11	Arabic
Ahmad	Male	Jordan	12	7	Arabic
Batool	Female	Egypt	13	2	Arabic
Hussein	Male	Egypt	13	4	Arabic
Alya	Female	Iraq	12	10	Turkish

3.6 Ethical considerations

Approval from Curtin University's Human Research Ethics Committee was obtained prior to the research (Curtin University, 2018) based on the following protocols:

- Informed Consent. Permission was first obtained from the school curriculum director. The purpose of the research was explained to students at an information session held by the researcher in class. Informed consent was sought from the students, and their guardians were informed and received a copy of the information sheet and a copy of the student's consent form. The consent form (see Appendix A) and the information statement (see Appendix B) provided information about who to contact if any questions arise regarding the research, and clearly stated procedures in a language that is understandable for students and their parents. The school office administrator, who speaks the parents'/guardians' native language, was available to translate any further information or questions raised by parents to ensure thorough understanding. The consent form emphasised the following: participation is voluntary, no extra points or higher grades were given for participation, no penalty applied for declining to participate, and participants can withdraw from the research at any time. No staff members had access to the instruments or consent forms.

- Confidentiality and Privacy. Because of the nature of English language learning in Australia, participants were likely to be drawn from a refugee and immigrant population that fears the disclosure of sensitive information (Mackey & Gass, 2015). De Costa et al. (2021) advised that "as a consequence, researchers sometimes need to take pre-emptive measures to protect and prepare their participants who might be unaware of potential dangers associated with their participation" (p. 61). Pseudonyms were adopted for all participants and the school where the research took place. The school and student names were coded, and only the researcher had access to the codes. Participants were not identified nor revealed in the thesis, or any publications related to the research. Specialist teachers read the transcribed quotations from the interviews to approve the anonymity of focus group students.
- Risks and Benefits. To eliminate any inequity between the treatment and the control group, the treatment method was applied to the control group after the data was collected. This application ensued at the STEM festival which was held 4 weeks after the research finished. The interviews took place with focus group students during their elective subjects, where each student worked at their own pace to complete their assigned projects. Approval was sought from the curriculum coordinator and subject teachers, to ensure students were not disadvantaged. The researcher took all precautions, such as keeping test results in a locked cabinet. Although the basic transcripts of participants' interviews were used uncorrected, with changes only to punctuation or parts that were hard to comprehend, anonymity was preserved. Any detail that had the potential to reveal a participant's identity was removed from the transcript. To guarantee privacy, the transcript was transcribed and preserved in the researcher's personal laptop and Curtin University's Research Drive.

3.7 Instruments

This section begins with the presentation of the VR games used in this research. Specifically, it links the VR games to the relevant subject areas and explains the selection criteria of the 3D content-based VR games. This is followed by outlining how the VR games were implemented in the classroom each week. This includes the following: the nature of the VR games, how each game is played, and the description of target content-specific vocabulary items related to each game.

Subsequently, this section also elaborates the data collection tools used in this concurrent mixed methods design (see Table 3.3) to collect data throughout the 12 weeks. The data aimed to determine whether the students acquired and retained the target words after playing these immersive VR games. Additionally, the data helped to elicit the students' viewpoints to understand what worked or did not work. This was possible through combining the qualitative and quantitative research approaches (Creswell, 2013). Therefore, the qualitative data collection tools are described, which comprised the following: the pre-game survey (open-ended survey questions), semi-structured focus group interviews, exit slips, observation notes, and the researcher's journal. Next, the quantitative data collection instruments that included the following are explained: pre-game survey (close-ended survey questions), pre-vocabulary test, post-game survey, post-vocabulary test, delayed post-vocabulary test, and post-game survey.

Table 3.3

Summary of Instruments Used in Data Collection Throughout the 12 Weeks

Week	Pre-game survey	Exit slip	Group interview	Observation scheme	Journal	Post-game survey	Pre-vocabulary test	Post-vocabulary test	Delayed post-vocabulary test
1	√		√				√		
2		√		√	√				
3		√		√	√				
4		√		√	√				
5		√		√	√				
6		√	√	√	√				
7		√		√	√				
8		√		√	√				
9		√		√	√				
10		√	√	√	√	√		√	
11									
12									√

3.7.1 Headset-enabled VR games

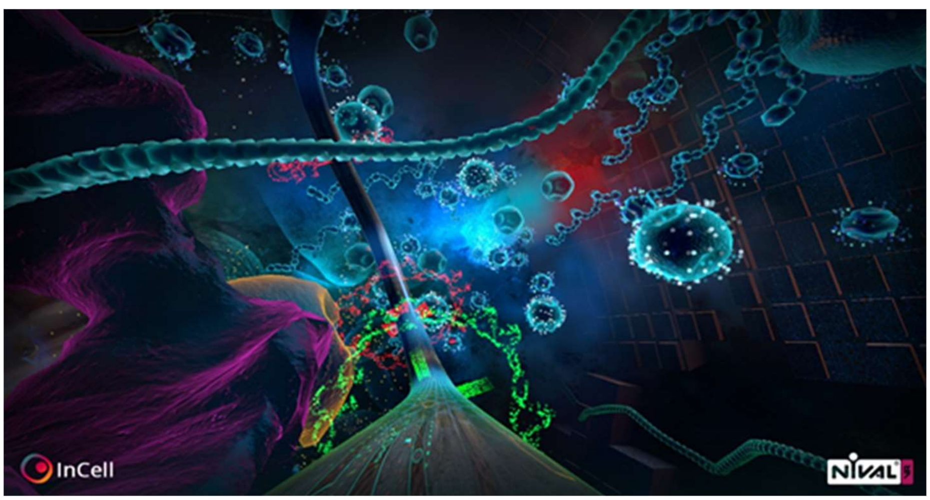
All games were played using Google Cardboard, a VR headset device that enables gaming in the 3D VR world (MacIsaac, 2015). Nine games related to three different subjects covered in the curriculum (see Table 3.4. below) were carefully selected by the researcher by researching affordable 3D VR games online. As educational VR games available for Google Cardboard were scarce, only nine games in three different subjects were found to comply with the Year 7 and Year 8 curricula. These games were consistent with Gee's (2014) 'good' games description, as summarised in Table 3.5.

Specialist teachers of mainstream subjects approved the selected games for content suitability. The chosen games provided a 3D picture of the target vocabulary items, as well as written and audio information about the content. The games enabled the players to engage with the content in a 3D form to reach a goal (e.g., mission is killing all viruses in the InCell game) or find the visual of the target words which they had read in the reading passages. These content-based games encouraged students to explore and make associations about the relationships between the content and the visualised vocabulary item (Gee, 2005). A detailed illustration of the games is explained below. See Table 4 for a summary of games played.

The first game students played was InCell, an action and racing game (see Figure 3.2). In the game, players were in a human cell and had to stop the advancing virus. The game provided textual and audio information about the content and the player's mission. At the end of the game, players would receive a report about their progress.

Figure 3.2

A Screenshot from InCell (Luden.io, 2017a)



The second game related to Science learners played was InMind (see Figure 3.3). This was a short scientific game where players travel in the micro world of a human brain. Players had to shoot the virus to heal the person. Each time they shot the virus, they collected points. The target vocabulary items related to the Australian Science curriculum (ACARA, 2016c) at the Year 8 level found in the VR game InMind included the following: red neurone, neuromediators, serotonin, dopamine, noradrenaline, prefrontal cerebral cortex, and dopamine.

Figure 3.3

A Screenshot from InMind Showing a Cell (Luden.io, 2017b)

The third game, the Toumanian Museum AR/VR app (see Figure 3.4), was related to HASS, where students had to find and visit target ancient destinations. Players experienced the target vocabulary items ancient, antique, archeologic and architecture (ACARA, 2016c).

Figure 3.4

A Screenshot from Toumanian Museum Showing Old Ages (Arloopa, n.d.)

The fourth game related to HASS was Toumanian Museum (see Figure 3.5) about Ancient Egypt. Students went to ancient Egypt in a virtual reality environment and explored an Egyptian temple. They were able to move freely in the temple and find the target words including statue, citadel, reconstruct and substructure (ACARA, 2016c). Once they entered the temple, players were able to move as they like. For example, if they moved next to a statue, they could listen to information related to the chosen statue with reference to ancient Egypt.

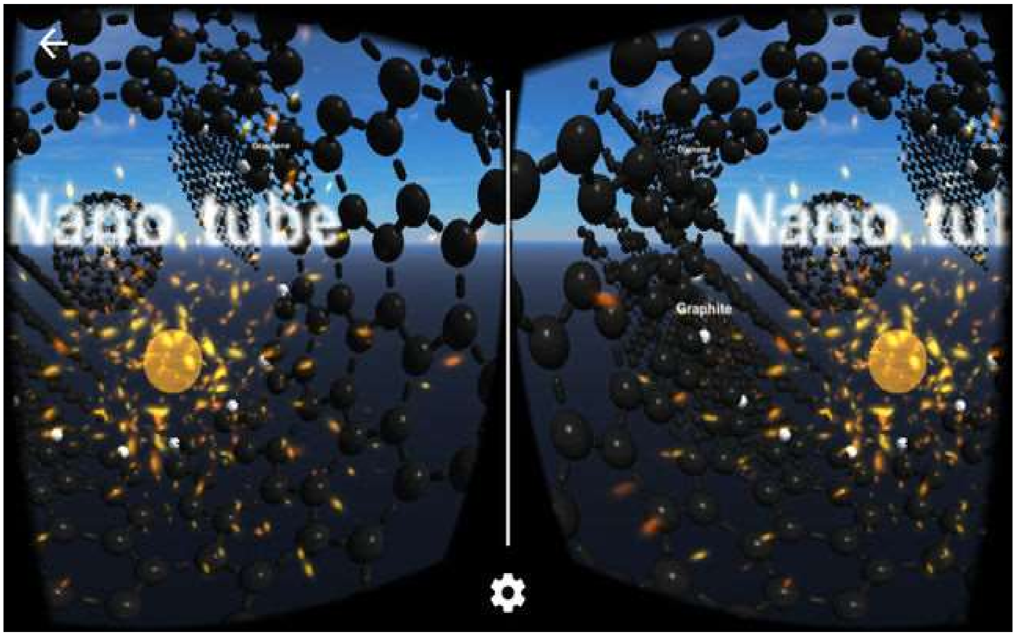
Figure 3.5

A Screenshot from Ancient Egypt Showing an Old Building with an Ancient Drawing of Pharaoh (Inspyro, 2016)

The fifth game was the Carbon game related to Science (see Figure 3.6). In the immersive virtual environment of atoms and molecules, players observed their 3D shape and electrostatics. Their target was to pass through each carbon. As they were passing through the carbon, the target vocabulary items appeared, of whichever carbon they were travelling through. The target vocabulary items related to the Australian science curriculum (ACARA, 2016c) at the Year 8 level found in the Carbon game included nanotube, graphite, graphene, fullerene, and diamond.

Figure 3.6

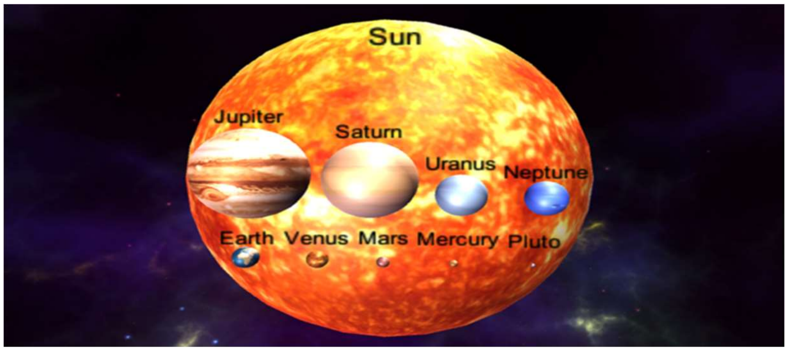
A Screenshot from Carbon Showing the Form of a Nanotube and a Graphite (EduChem VR, n.d.)



The sixth game students immersed themselves in Week 5 was Solar System (see Figure 3.7), related to Geography. First, players visited a solar museum, explored the planets in a 3D immersive environment, and listened to information about the planet's features. Students had the choice to select any planet and listen to information related to the chosen planet. Whilst they listened to information, they also closely observed the external features of the chosen planet. Once they finished exploring the features of planets, they moved onto playing an adventure game where the objective was to protect Earth from asteroids, which was also one of the target words. This second part of the game allowed students to observe the external features of asteroids. The students had to stop the asteroids to win the game, and so avoid damage to the world. The target vocabulary items related to the Australian HASS curriculum (ACARA, 2016c) at the Year 8 level found in the Solar System game included cortex, continent, solar and polar vortex.

Figure 3.7

A Screenshot from Solar System Showing the Size of the Sun Compared to Other Planets (Yin, 2016)



The seventh game was Magi Chapel VR (see Figure 3.8) related to The Arts. A museum in Italy about the splendour of Renaissance Italy and the opulence of the Medici Family was presented in a 3D environment. Students' tasks included finding paintings related to their target vocabulary items (ACARA, 2016c), such as contrast colours, symmetrical objects and mediums used in paintings. Students had the choice to move around freely in the museum and find the target paintings related to the content-specific vocabulary. They received audio information about the paintings they observed.

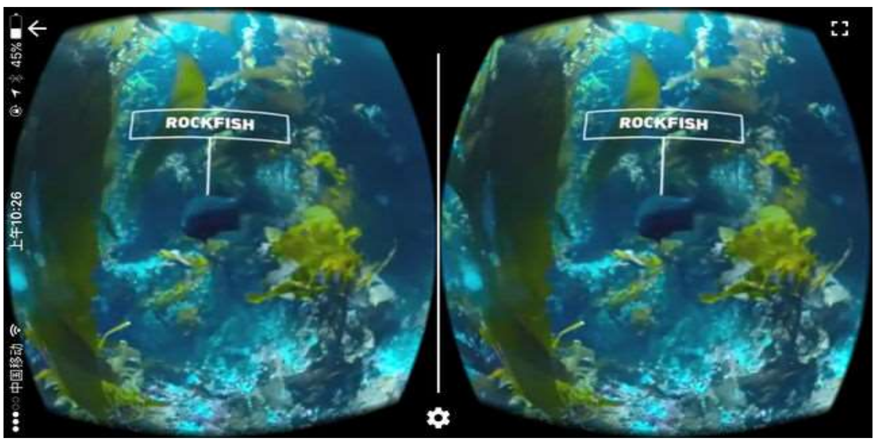
Figure 3.8

A Screenshot from Magi Chapel Showing a Portrait of Horses and People (EON Reality, n.d.)

The eighth game learners played was Diving VR related to Science in Week 9 (see Figure 3.9). The aim was to move underwater to experience the visualisation of the target vocabulary items which included marine, reef, coral, and rockfish based on the Australian HASS curriculum (ACARA, 2016c) at the Year 8 level. The written form of the target vocabulary items supported the visuals, to help students practice the target vocabulary items visualised in the VR game.

Figure 3.9

A Screenshot from Diving VR Showing a Rockfish (Y. Wang, n.d.)



The ninth and final game students played was Qantas VR related to HASS (see Figure 3.10). Students' goal was to explore target vocabulary items like the harbour and coral scenery (ACARA, 2016c). The game took the players to Sydney Harbour in a plane and learners experienced the scenery and listened to information about the harbour. The Qantas VR game was different from all the other games listed as it was not 3D animated but contained a real video of the harbour. Players were provided with limited opportunity to move around the harbour in this final game. Players movements were restricted to certain places of the harbour as demonstrated in Figure 3.10.

Figure 3.10

A Screenshot from Qantas VR Showing the Sydney Harbour Bridge (Qantas, 2018)

Table 3.4

Summary of VR Games and Relevant Subject Areas

Week	Science	The Arts	Humanities and Social Sciences (HASS)
2	InCell (Luden.io, 2017a)		
3	InMind 2 (Luden.io, 2017b)		
4			Toumanian Museum VR (Arloopa, 2016)
5			Ancient Egypt VR (Unimersiv, n.d.)
6	Learning Carbons VR (EduChem VR n.d.)		
7			Solar System – Space Museum – VR/AR (Yin, 2016)
8		Magi Chapel VR (EON Reality, n.d.)	
9			VR Diving Pro – Scuba Dive with Google Cardboard (Wang, n.d.)
10			Qantas Guided Meditation Series in 360 – Sydney Harbour, New South Wales (Qantas, 2018)

Table 3.5

Summary of VR games' Characteristics According to Gee's (2014) Good Games' Principles

VR Games	Characteristics of the VR game	Links to Gee's Good Games' Principles
InCell (Luden.io 2017a)	Immerses player in human cell	Identity Enhances experiential learning Explore
	Opportunity to learn new vocabulary related to cells by experiencing them by travelling in human body	Situated meanings
	Player has control over where to shoot	Agency
	Interacts by hitting viruses in human body	Interaction
	Produces the story through killing viruses and completing a level	Production
	Players think in a bigger picture on how the human cells and viruses function in the human body	System thinking
InMind 2 (Luden.io 2017b)	Immerses player in human mind Opportunity to learn new vocabulary related	Identity Enhance experiential learning Explore
	to human mind by experiencing them by travelling in human mind	Situated meanings
	Player has control over where to shoot	Agency
	Interacts by hitting viruses in human mind	Interaction
	Produces the story through killing viruses and completing a level	Production
	Players think in a bigger picture on how the brain cells and viruses function in the human mind	System thinking
Toumanian Museum VR (Arloopa, 2016)	Immerses player in an ancient environment	Identity Enhance experiential learning Explore
	Opportunity to learn new vocabulary related to ancient times by visiting target ancient destinations	Situated meanings
	Player has control over which venues to visit	Agency
	Interacts by walking to destinations	Interaction

Ancient Egypt VR (Insypiro, 2016)	Immerses player in ancient Egypt environment Opportunity to learn new vocabulary related	Identity Enhance experiential learning Explore
	to an Egyptian temple by moving freely in ancient Egypt	Situated meanings
	Players have control over the information they choose to listen	Agency
	Interacts by choosing where to walk and which information to listen to in the temple	Interaction
Learning Carbons VR (EduChem VR, n.d.)	Immerses player in carbons	Identity Enhance experiential learning Explore
	Opportunity to learn new vocabulary by the immersive virtual environment of atoms and molecules where players travelled through their 3D shape and electrostatics	Situated meanings
	Players have control over where to look	Agency
	Interacts by travelling through atoms and molecules and choosing where to observe	Interaction
	Players think in a bigger picture on how the different types of carbons bond	System thinking
Solar System – Space Museum – VR/AR (Yin, 2016)	Immerses player in the solar system	Identity Enhance experiential learning Explore
	Opportunity to learn new vocabulary by travelling to the Solar System and visiting planets	Situated meanings
	Players have control over which planet to travel to and which asteroid to hit	Agency
	Interacts by choosing which planet to travel to and stopping asteroids from falling to earth.	Interaction
	Produce story by saving the world from asteroids	Production
	Players think in a bigger picture on how the planets link and function in the solar system and the impact of asteroids	System thinking

Magi Chapel VR (EON Reality, n.d.)	Immerses player in a museum	Identity Enhance experiential learning Explore
	Opportunity to learn new vocabulary by visiting a museum in Italy where students listen and observe art pieces, they choose of the splendour of Renaissance Italy	Situated meanings
	Players have control over the which artwork to choose	Agency
	Interacts by walking to the chosen art piece	Interaction
VR Diving Pro – Scuba Dive with Google Cardboard (Wang, n.d.)	Immerses player under sea	Identity Enhance experiential learning Explore
	Opportunity to learn new vocabulary by swimming underwater with sea creatures	Situated meanings
	Interacts by swimming with the sea creatures and reading their features	Interaction
	Player has control over where to swim	Agency
Qantas Guided Meditation Series in 360 – Sydney Harbour, New South Wales (Qantas, 2018)	Immerses player in Sydney Harbour	Identity Enhance experiential learning Explore
	Opportunity to learn new vocabulary by experiencing the Sydney Harbour scenery and listening to information about the harbour	Situated meanings
	Players have control over where to look	Agency
	Interacts by walking at the harbour and listening to information	Interaction

3.7.2 Qualitative Data Collection Instruments

Qualitative data was collected from multiple sources: the pre-game survey (open-ended survey questions), semi-structured focus group interviews, exit slips, observation notes, and the researcher's journal. The triangulated data helped to develop a holistic understanding of how students perceived learning vocabulary via the VR games.

3.7.2.1 Pre-game Survey

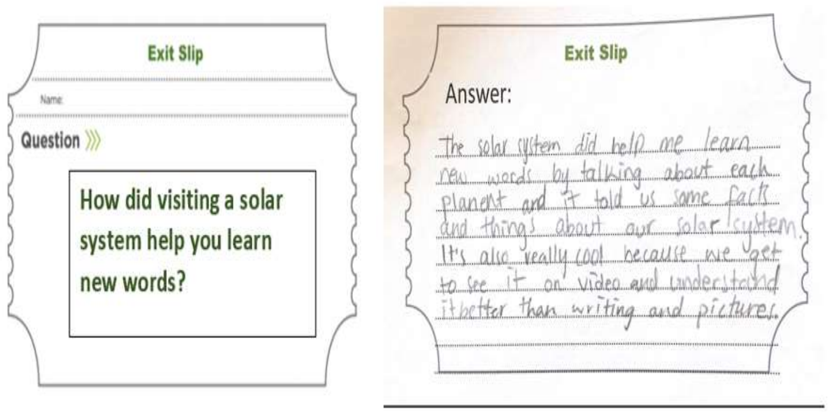
To collect initial data and demographic information, all students completed a survey consisting of closed and open-ended questions (see Appendix C). The survey of 28 questions took place in Week 1 before the treatment began and consisted of three sections. The first section was designed to collect data on the students' judgement of the importance of vocabulary to understand subject areas. The second section was developed to collect information on whether students had experience with VR games. The last section, consisting of open-ended questions, was developed in an effort to provide evidence on students' linguistic and cultural backgrounds. Students recorded their name, age, where they were born, how old they were when they moved to Australia, the age they started to learn English, and the language they spoke at home.

3.7.2.2 Exit Slips

Exit slips were generated to obtain introspective data on students' self-assessment and self-reflection (Marzano, 2012). All treatment group students filled in an exit slip for five to ten minutes every week after playing each game. This enabled the gathering of first-hand response when their memory was still fresh (Alfadil, 2020) (see Figure 3.11). The exit slip questions consisted of *one* question to make suggestions for improving their VR experience to monitor students' understanding (Basco, 2021). The exit slip prompts were designed to not only elicit students' opinions, but also required students to write the vocabulary items and the content they learnt via the VR games. Thus, this assisted the researcher to learn more about the students' attitude and understanding of the topic and the VR games (Marzano, 2012). These questions were formulated in simple and clear language to draw out 12- to 13-year-old students' viewpoints (Merriam & Tisdell, 2015).

Figure 3.11

Sample Exit Slip Question, and the Answer from a Participant



Each week, the exit slip had different questions as shown below:

- Week 2: How did the science game you played today helped you learn new words?
- Week 3: List the vocabulary items you learnt today.
- Week 4: How did the HASS game you played today helped you learn new words?
- Week 5: What did you like about the game you played today?
- Week 6: Did you enjoy the science game today while you learnt new words? Why or why not?
- Week 7: Did visiting a solar museum in HASS help you learn new words? If yes, how?
- Week 8: Write down what you didn't like about the game today.
- Week 9: Which parts of the VR game did you like most?
- Week 10: What did you like about the feature of the game you played today?

3.7.2.3 Semi-Structured Focus Group Interviews

The interviews explored the effects of 3D VR games via headsets on students' attitudes, motivation, and viewpoint to learn new content-specific vocabulary items. It encouraged learners to communicate their learning experience after they played the immersive games. The interviews aimed to explore students' opinions by asking them to recall their experience playing the VR games (Mackey et al., 2000). The questions were formed according to Patton's (2014) good question suggestions, which aimed to stimulate responses on (1) experience and behaviour in an immersive environment; (2) opinions on playing VR games to learn new content-based vocabular; (3) acquired knowledge about headset-enabled VR games and the vocabulary items in the VR environment; and (4) sensory questions to elicit experience. Interviews enabled the researcher to develop insight of the direct experience students had with the phenomenon and to allow them to have their voice heard (Merriam & Tisdell, 2015).

Semi-structured interviews were selected to provide flexibility for the researcher. The semi-structured model enabled the researcher to be open to unexpected responses whilst bringing interviewees back to the core research questions (Merriam & Tisdell, 2015).

Three phases of semi-structured group interviews were conducted -at the beginning, middle and end of the study to track how students' attitudes changed. All interviews were recorded with an iPhone and transcribed (see Appendix D for all interview questions). The semi-structured interviews were conducted in English as this was 'lingua franca' for these participants.

The pilot study trialled the interview questions before the actual research took place. This trial aimed to test interview questions, eliminate any ambiguous questions, or evaluate whether any questions required rewording (Merriam & Tisdell, 2015).

3.7.2.4 Observation Scheme and Field Notes

To document students' learning practices, the researcher took observation notes while the participants were playing the games. These notes enabled the researcher to record behaviour as it was happening to facilitate the analysis of the data (Mackey & Gass, 2015). The elements of the observation scheme were divided into five subsections (see Figure 3.12) to note (a) student attitudes, (b) students' reactions, (c) target vocabulary utterance whilst playing the games, (d) unexpected learning of non-target vocabulary items, and the unexpected behaviours. For example, next to the descriptor where it says, ‘new vocabulary items students call out while playing the game’, the researcher noted that a participant verbalised a target word by saying “I’m in the mitochondria” whilst playing the InCell game.

The observation scheme was carefully designed in line with the research questions by recording: (1) the physical setting and whether the students were able to use the headsets appropriately; (2) participant interactions with the VR games; (3) whether any conversation occurred amongst students or to themselves whilst playing the games; (4) participant attitudes towards VR game playing, and 5) whether students uttered any target vocabulary items when being immersed in the VR games (Patton, 2014).

Figure 3.12

A Screenshot of the Observation Scheme Template Used by the Researcher

Subject: ___________________________

Observer: ___________________________

Date and Time: ______________________

Time	Review Section	Description	Researcher’s Reflection
	1. **Student attitudes towards each VR game across subjects** **(Science, Humanities and Social Sciences (HASS) and Art)** • Students’ engagement with the game (adjectives students use while playing the headset enabled VR games) • Students’ emotional reaction to the game • Students’ concentration level whilst playing the game (whether they pause playing or talk about off task topics)		
	2. **Students’ reaction to headset enabled VR features** • Students’ level of comfort holding the headset • Students’ expression of feeling presence in the game • Students’ body language while playing the game		
	3. **Vocabulary Acquisition** • New vocabulary items students call out while playing the game		
	4. **Unexpected Learning Activities** • Learning of new vocabulary items that are in the game but not identified as a target word		
	5. **Unexpected Behaviour Activities** • Unexpected verbal utterances or non-verbal signals (body language) while playing the game		

Field notes taken by the researcher addressed specific points while playing the games to produce useful data for contributing to identify students' views (Mackey & Gass, 2015). These points included (a) what students enjoyed, (b) what they found easy or hard, (c) the target vocabulary items they said aloud while playing and (d) the reactions they had. The field notes were a valuable resource for noting the sequence of the procedure and students' reactions when learning new words. These notes also allowed the researcher to compare the observation notes against vocabulary test results, and student self-reflective data via interviews and exit slips. This comparison allowed the researcher to explore the nuanced factors and strengthen the findings of this research.

3.7.2.5 Research Journal

The researcher also kept a research journal right after each session in conjunction with the observation and field notes. The journal enabled to document the features of VR games that seemed to work (and those that did not) in learning content-specific vocabulary. Any other issues that affected the research or considered as relevant by the researcher were also noted in this journal. To illustrate, the following notes from the research journal prompted the researcher to analyse data from a different perspective, whilst exploring whether technical issues hindered vocabulary acquisition: "Students who experienced technical issues with the VR headset tended to call out less words whilst playing the games" (Research Journal, 2018).

The research journal is also a self-disclosure by the researcher, to address reflexivity, about the positioning in the research (see Section 3.4). The researcher aimed to achieve reflexivity by holding herself accountable to the standards of knowing and telling of the student's VR experience (Creswell, 2016). The following questions were considered when taking notes in the researcher journal; "What do I know? How do I know what I know? What student verbatim has shaped my perspective? With what voice do I share my perspective? What do I do with what I have found?" (Marshall & Rossman, 2014, p. 118). By considering "how do I know what I know", the researcher ensured that the evidence speaks for itself. Therefore, only the student's behaviours/expressions or what the researcher observed, such as "game application turned off in the middle of the game", were noted. This data was embedded in the data analysis process with other qualitative data. The researcher followed this criterion to minimise researcher's biases and ensuring that the evidence speaks for itself.

3.7.3 Quantitative Data Collection Instruments

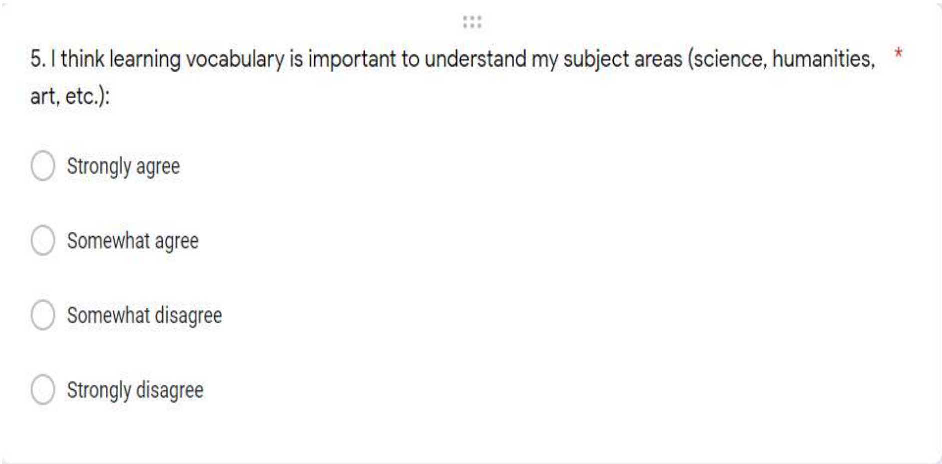
Data collected through pre-game and post-game surveys (closed-ended survey questions) were applied to screen whether students' preferred method for learning new words had changed after the intervention. The pre-test, post-test, and delayed post-test helped to measure how many target vocabulary items students already knew, acquired and retained via playing the VR games.

3.7.3.1 Pre-game Survey

In order to measure the students' level of agreement, on whether content-based vocabulary is important to understand their subjects and English skills (reading, writing, speaking, and listening), seven questions were asked. Responses were in a 4-point Likert scale format (from *strongly agree* to *strongly disagree*) (see Figure 3.13) (Mackey & Gass, 2015).

Figure 3.13

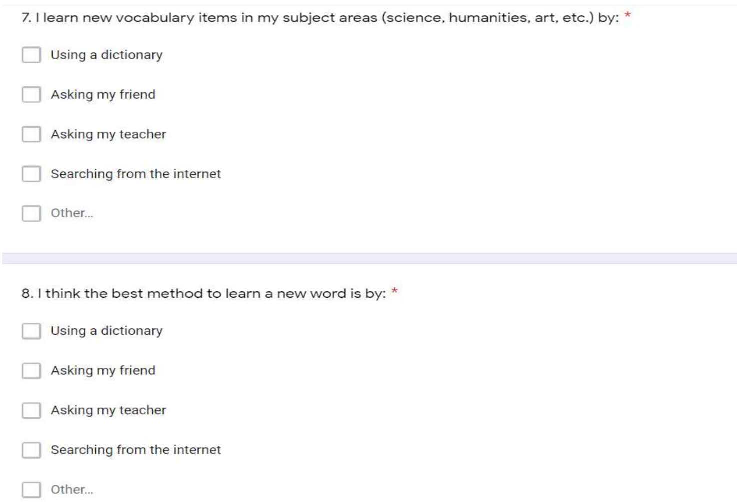
A Screenshot of a Sample Question Designed with a 4-Point Likert Scale to Measure Students' Agreement on the Importance of Vocabulary



The survey also consisted of questions on whether students thought that VR headsets would help them learn new words, and which methods they thought was the best to learn a new word. Students were provided with the descriptors from which to choose the best approach. If the best method was not listed in the options, they were provided space to write their preference. Figure 3.14 provides a sample of pre-game survey closed-ended questions. The variables were chosen for the pre-game survey as indicators to enable the researcher to make a comparison of whether treatment group students' preferred methods of learning a new word had changed after playing VR games. In the 4-point Likert scale format of this survey, the 'not sure' option was eliminated as it was difficult to interpret a 'not sure' response in this research. The 4-point scale also enabled to collect sufficient data on student perceptions of the importance of vocabulary to understand mainstream subjects in English.

Figure 3.14

A Screenshot of a Sample Question Designed with a 4-Point Likert Scale to Measure Students' Preferred Method of Learning a New Word



3.7.3.2 Vocabulary Test Construction

To address the final research question, the vocabulary tests were designed to examine the immediate effect of treatment, and the extent to which the treatment resulted in learning (Mackey & Gass, 2015). A paper-based vocabulary test was designed according to the vocabulary items currently used in student textbooks or worksheets, following the WA curriculum. The chosen VR games, related to the curriculum, also informed the selection of the vocabulary items. For example, one of the science games, InCell (see Figure 3.2) included many target vocabulary items related to the curriculum (see Section 3.7.1) (see Table 3.6 for all vocabulary items). All of the target vocabulary items were chosen based on those involved in the VR games that complied with the Year 7 and Year 8 curricula. These target words were included either the pre-, post-, or delayed post vocabulary test to ensure content validity.

Each of the tests included three question types which were most commonly used in their previous exam subjects: (1) Match the target vocabulary items with their meanings (21 questions); (2) fill in the blanks using the appropriate vocabulary item that matches the meaning (21 questions); and 3) multiple choice questions where students needed to select the meaning of the target vocabulary item (21 questions) (see Appendix E for pre-, post- and delayed post-vocabulary tests). At the beginning of the study, the pre-test was conducted to screen students' pre-existing knowledge of the target words. The post-test was applied after 10 weeks of treatment. The data collected from the pre-tests and post-tests answered the question of whether using game-based VR with headsets increases vocabulary acquisition.

The delayed post-test was conducted two weeks after the treatment ended in order to determine the level of learners' vocabulary retention.

Table 3.6

The Pool of the Target Vocabulary Related to Subject Areas in Pre-, Post-, and Delayed Post-Tests

Science	HASS	The Arts
Bond	Marine	Motif
Microtubules	Asteroid	Exhibit
Influenza virus	Archeologic	Texture
Dopamine	Reconstruct	Portrait
Molecular Machine	Statue	Medium
Organelle	Coral	Volume
Centrosome Cells	Reef	Rectilinear
Solid	Antique	Contrast Dominance
Nucleus	Seabass	Neutralism
Diamond	Polar Vortex	Scenery
Inflating Cell	Symmetrical	Converse
Cortex	Rockfish	Abstract
Red neurons	Architecture	Non-objective
Nanotube	Continent	Form
Lysosome	Rig	
Noradrenaline	Substructure	
Graphite	Exosphere	
Serotonin	Constellation	
Atom	Sculpture	
Super Virus	Ancient	

Cell	Orbit
	Solar System
	Citadel
	Pharaoh
	Opel eye
	Harbour

There was a pool of each question type, and test items were randomly selected from each pool to avoid the threat of test practice effect. This also helped to ensure there was no test bias, that is ensuring that no test is easier than the other. For example, the pre-test was not easier than the post or delayed post-test and vice versa (Mackey & Gass, 2015). To reduce the possibility of the ordering effect, counter-balance design was used to ensure that each participant did not receive the questions in the same sequence (Mackey & Gass, 2015).

The researcher ensured that the test procedures the students used were familiar from their subject exams. The test conditions consisted of no noise, no communication amongst participants, and no access to information nor dictionaries. The researcher and another specialist teacher supervised the students.

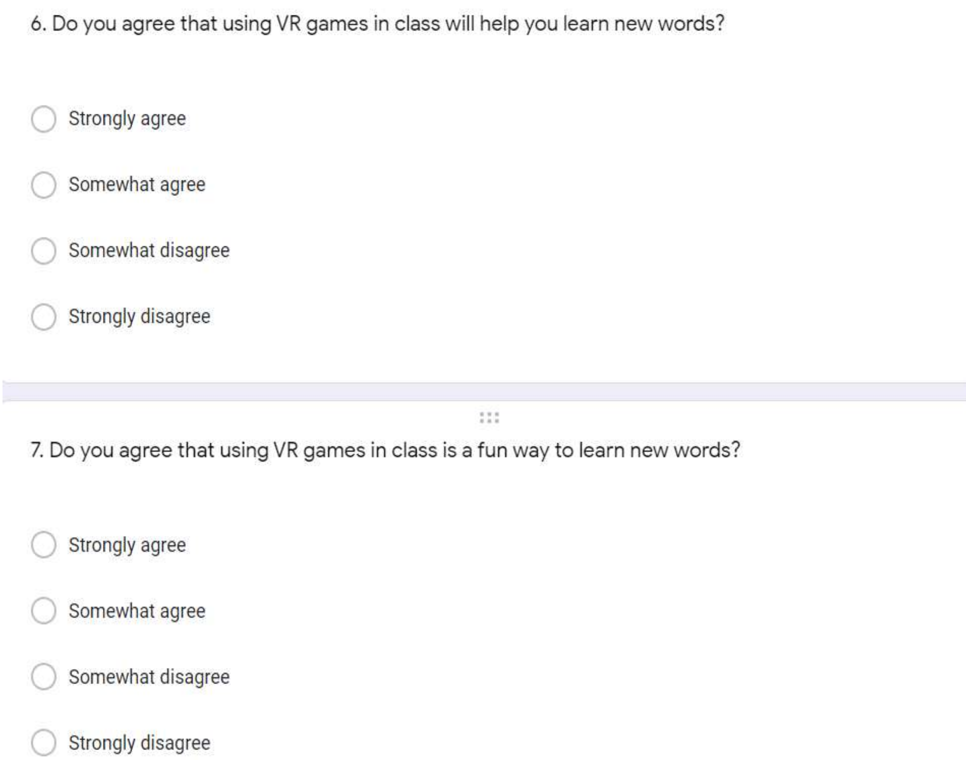
The pre-tests, post-tests, and delayed post-tests were co-marked by the researcher and a colleague to test inter-rater reliability (see results in Section 3.8.2). Each test was scored out of 21 (each test consisted out of 21 questions and each correct answer was awarded one mark). Any missing responses were treated as missing data, which meant students did not receive marks for that question.

3.7.3.3 Post-game Survey

The post-game survey was designed to collect data to ascertain whether treatment group students' opinion of learning content-based vocabulary via VR games had changed. Therefore, only the treatment group students completed the survey. This survey consisted of eight questions from the pre-game survey (see Appendix F). These questions were chosen to monitor students' understandings of how they think they learn new words, and whether their answer related to using VR to learn new words had changed after they played all the VR games (see Figure 3.15).

Figure 3.15

Screenshot of Sample Questions of Post-Game Survey on Using VR to Learn New Words



6. Do you agree that using VR games in class will help you learn new words?

- Strongly agree
- Somewhat agree
- Somewhat disagree
- Strongly disagree

7. Do you agree that using VR games in class is a fun way to learn new words?

- Strongly agree
- Somewhat agree
- Somewhat disagree
- Strongly disagree

3.8. Procedure

The data collection procedure took place in two phases: the pilot study, and the main study. This section begins with presenting the procedure of the pilot study. It describes the participants of the pilot study and the instruments used. Next, it discussed the methods of analysis and the results of the pilot study. Subsequently, it explained how the results of the pilot study informed the main study. Following this, the procedure of the main study, the data analysis methods of the qualitative and quantitative data instruments were elaborated.

3.8.1 Pilot Study

The pilot study was conducted to test the content validity of the VR games and the data collecting instruments prior to the main study. Face validity for qualitative and quantitative data was met as content materials in subject textbooks (following the Australian curriculum) have already been used in their regular classes (Mackey & Gass, 2015).

The purpose of the pilot study was to test the following in preparation for the larger study: (a) the reliability of the data collection instruments, (b) the research protocols, (c) other research techniques such as identifying time needed to complete each data collecting instrument, and (d) the suitability of the length of each data collection instrument. By trialling the materials in the pilot study, it was possible to ensure the suitability of the VR games and the data collection instruments. A key aspect of conducting a pilot study was to ensure that the data collection instruments were designed or chosen accurately to thoroughly answered the research questions (see Data Analysis below). This section was followed by introducing pilot study participants, the instruments, the data analysis, and the results of the pilot study.

3.8.1.1 Pilot Study Participants

Twenty-four Year 9 EAL learners, whose English proficiency levels had been assessed at the lower band (ACARA, 2016a), were pre-selected. This lower proficiency level places these struggling students in a high-stakes situation. These students had to grapple with the demands of learning subject knowledge with limited English proficiency and insufficient content-specific vocabulary. From these 24 students, six Year 9 EAL learners were selected via manual simple random sampling. The students selected for the pilot study did not participate in the main study. Table 3.7 summarises the background information of the pilot study Middle Eastern EAL participants:

Table 3.7

Summary of the Participants' Demographic Information

	Aisha	**Fatma**	**Zaynab**	**Aleen**	**Lara**	**Ali**
Gender	Female	Female	Female	Female	Female	Male
Country	Egypt	Somalia	Syria	Jordan	Egypt	Egypt
Age	14	14	14	14	14	14
Age when moved to Australia	6	7	13	8	6	0
Home language	Arabic	Somali	Arabic	Arabic	Arabic	Arabic
Ways of learning new words	Using a dictionary	Asking my teacher	Asking my teacher	Reading	Asking my friend	Internet

3.8.1.2 Pilot Study Instruments

As mentioned in Section 3.7, the instruments for the pilot study consisted of qualitative and quantitative tools (see Table 3.8). These instruments were tested in the pilot study to demonstrate that the tools, and the methods of analysis (for both qualitative and quantitative data) were effective to produce useful knowledge in order to address all research questions. Based on the analysis of pilot study results, minor amendments were made to the data collection instruments that were used in the main study (see discussion 'Pilot Study Results Informing Main Study' below).

Qualitative data collection instruments consisted of the following:

(1) The exit slips comprised three questions in the first week. After multiple student comments noted in the research journal such as, "oh do we have to answer all of these?" (Research Journal, 2018), it was revised to two questions in the second week. After students' verbal feedback ("Can't we choose one to answer?" (Research Journal, 2018)), amendments were made accordingly so students only answered one question in Weeks 3, 4, and 5.

(2) The interview questions were tested to see whether the open-ended questions were formulated to thoroughly elicit students' experiences.

(3) Observation scheme, field notes and research journal were also tested in the pilot study. The comments in the research journal were either students' verbatim expressions or intended to verify that happened or did not happen such as, "oh this asteroid is going coming towards me it is going to kill me" (Observation Scheme, 2018). This was a practice for the researcher to ensure reflexivity was evident.

(4) The pre-game survey was tested to collect data on student's demographic background. Students used an iPad to complete the survey.

Quantitative data collection instruments consisted of the following:

(5) The post-game survey was tested to assess whether formed questions collect data on student's preference of conveying the meaning of an unknown content word. The students also used an iPad to complete this.

(6) A significant part of applying the vocabulary tests was to determine the following: if the designed instruments were effective to collect data on whether participants knew the target words prior to playing the games via headsets, whether learning took place or not, and finally, whether they did retain the content lexis.

Table 3.8

Summary of Pilot Study Data Collection Procedure

Week	Pre-test	VR Games	Post-test	Delayed Post-test	Pre-game Survey	Post-game Survey	Exit Slips	Semi-structured Interviews
1	√	√			√		√	√
2		√					√	
3		√					√	√
4		√					√	
5		√	√			√	√	√
6								
7				√				

3.8.1.3 Pilot Study Procedure

Students in both the control and treatment groups attended their regular class to read information about the content. Reading passages were chosen and adjusted by the specialist teachers who introduced and taught the content to both groups only during this reading time. As mainstream teachers are required to apply literacy teaching strategies in the subject areas, teachers in this school frequently presented the content via reading tasks. By implementing reading tasks, subject teachers aimed to improve both mainstream and EAL students' literacy skills (Australian Professional Standards for Teachers [AITSL], 2017). The reading tasks, designed to cover the content in mainstream classrooms, were familiar to students across all subject areas. However, these reading passages, which explained the subject content with subject specific vocabulary items, were not tailored to the CALD students in the school.

As a post-reading activity, the treatment group students played the vocabulary HMD VR games in a separate room whilst the control group students completed the normal review activities in the regular class. These activities required the control group students to participate in intentional vocabulary learning methods, that is, researching the meaning of the same target words via a dictionary after locating them in a reading passage. Then, the students were asked to answer questions regarding the content. For example, after reading the passage related to cells, the students searched and wrote the meaning of the target word ‘nucleus’. Afterwards, they responded to a question on the function of a nucleus. The researcher, who also worked at the school, guided the students’ game-based activities during the VR intervention. Each student was given a headset and a smartphone with the downloaded VR game application. Students received instructions on how to start, select options, move themselves around and play the headset-enabled VR games by the researcher. The VR game session took approximately 30 minutes, followed by a 10-minute session for students to respond to the Exit Slip question (see below).

3.8.1.4 Pilot Study Data Analysis

The following subsections present the results of the pilot study. It aims to demonstrate that the data collection tools, and the method of analysis (for both qualitative and quantitative data) were effective to produce useful knowledge in order to address all research questions.

- Qualitative data analysis

A thematic analysis was employed to analyse the triangulated data that tapped into the introspective (exit slips and semi-structured group interviews) experiences of students (Merriam & Tisdell, 2015). This method of analysis aimed to provide a richer understanding of the investigated phenomenon (Braun & V. Clarke, 2006).

The data was coded and analysed following the process of (a) familiarisation with data, (b) generating initial codes from the data, (c) searching for common themes among codes, (d) reviewing, refining, and labelling themes, and (e) presenting the findings using the students’ feedback to support the themes that emerged (Merriam & Tisdell, 2015).

Initial codes were generated from the notes jotted down in regard to the interview, exit slip responses, and the researcher’s journal. An open coding technique was adopted for identifying the units of data. A unit of data had to meet two criteria: standing by itself to be interpretable and stimulating the reader to think beyond the particular information (Merriam & Tisdell, 2015). For example, in the interview, the student verbally expressed that the games were fun to play by forming a few sentences such as "that it was fun" (Field Notes, 2018), and wrote one sentence as a response to the exit slip question of his/her opinion of the game. The researcher identified these as a unit of data (from 3 interviews, 125 exit slips, 9 observation scheme sheets, and journal entries), and attached the code 'fun' to the text (see Table 3.9).

After assigning open codes to the data, an axial coding technique was employed to construct thematic categories and make connections across categories, where codes were sorted into lists, resulting in groups of codes (Merriam & Tisdell, 2015). These groups of codes were related to each other, which formed the thematic category scheme (Merriam & Tisdell, 2015) (see Table 4.1).

Table 3.9

Sample of Selecting a Unit of Data and Coding to Construct Thematic Categories

Unit of Data Identified	Code Attached	Theme
But when it's geography and stuff it goes through one ear and comes out the other because it's so boring and we never pay attention but with VR, I have fun with it. I remember what is going on. (Lara, Pilot Study Interview, June 2018)	VR is fun	The fun element
It put a picture in my mind so showed me how the word looked like. (Aisha, Pilot Study Exit Slip, June 2018)	VR visualises words	VR visualisation of content-based vocabulary
I got to explore the solar system in a new way. (Fatima, Pilot Study Exit Slip, June 2018)	VR provides innovative 3D experience	Learning through 3D simulation

- Qualitative Data Results

Table 4 outlines the themes grouped under the two conceptual categories: students' perceptions of VR game-based learning and the effects of headset-enabled VR games on content vocabulary learning. Each category intersects the positive and negative aspects of learning content-specific vocabulary using headset-enabled VR games.

Table 3.10

Summary of EAL Learners' Overall Perceptions and Effects of Headset-Enabled VR Games on Vocabulary Acquisition

Perceptions of headset-enabled VR games	**Effects of headset-enabled VR games on content vocabulary learning**
Positive aspects	
• Immersive learning environment • The 'fun' element	• Learning through 3D simulation • VR visualisation of content-based vocabulary items • Enhanced vocabulary acquisition
Negative aspects	
• Lack of adequate educational features	• Technical issues in using VR headsets

- Quantitative Data Analysis

The pre-, post-, and delayed post-test results were co-marked by the researcher and a colleague to ensure inter-rater reliability, and the percentage of agreement was 100 per cent (Mackey & Gass, 2015). The tests were scored out of 21, where each correct answer was worth one mark, and were then compared to assess language gains. The average scores the six students were awarded for each test is listed in Table 3.11, in which the minimum and maximum showed the range of scores for each test.

Table 3.11

Descriptive Statistics of the Three Vocabulary Test Scores

	N	***M (SD)***	**Minimum**	**Maximum**
Pre-test	6	10.50 (4.593)	3	16
Post-test	6	14.33 (3.077)	9	17
Delayed Post-test	6	13.00 (5.514)	3	17

Descriptive statistics in Table 3.11 were analysed as follows: As the sample size was small, the Shapiro-Wilk normality test was chosen and run before further statistical procedures could be conducted in order to determine whether the data set (scores) was drawn from a normally distributed population (Mackey & Gass, 2015). The Shapiro-Wilk test (Table 3.12), which was appropriate for small sample sizes, showed that the results failed to meet normality (i.e., delayed post-test result is $p = .20$). As such, a non-parametric Friedman test, which did not require a normal distribution to meet the assumptions of analysis, was employed to compare the repeated vocabulary tests.

Table 3.12

Shapiro-Wilk Test to Ascertain Whether Results Meet Normality

	M (SD)	***F***	***df***	***P***
Pre-test	10.50 (4.593)	.956	6	.789
Post-test	14.33 (3.077)	.877	6	.256
Delayed Post-test	13.00 (5.514)	.751	6	.020*

Note. $*p < .05$.

Whilst the Friedman test (Table 3.13) showed a statistically significant difference between tests, it did not indicate in between which tests the difference occurred. In order to find whether there was a marked difference between pre- and post-tests, or whether the 3D content-based games had an effect on vocabulary retention (delayed post-test), the Wilcoxon test was employed as a post-hoc test.

Table 3.13

Friedman Test Statistics to Determine Whether There is a Difference Between Tests

	M (SD)	***F***	***df***	***P***
Pre-test	10.50 (4.593)	.956		
Post-test	14.33 (3.077)	.877	2	.041*
Delayed Post-test	13.00 (5.514)	.751		

Note. *$p < .05$.

- Quantitative Data Results

In the results of Table 3.14, the null hypothesis, which specified that there was no significant difference between the test results, was rejected (p = .041). Hence, it showed that vocabulary gained differ significantly between pre-, post-, and delayed post-tests. In order to determine the location of the difference between groups (tests), the Wilcoxon test was applied (see Table 8). The Wilcoxon test indicated that there was a statistically significant difference between pre-test and post-test (p = .021), as well as pre-test and delayed post-test (p = .033). The post-test mean increased by 41 per cent in comparison to the pre-test mean, which showed that students improved their content-specific vocabulary, as they recognised more target words accurately in the post-test after experiencing the immersive environment.

Table 3.14

Wilcoxon Test Statistics of Differences in Vocabulary Acquisition Across Three Tests

	M (SD)			***Post Hoc (Wilcoxon Tests)***			
	T1	T2	T3	p	T1 -T2	T1-T3	T2-T3
Vocabulary test scores	10.50 (4.593)	14.33 (3.077)	13.00 (5.514)	.041*	.021*	.033*	.229

Note. T1 = pre-test; T2 = post-test; T3 = delayed post-test.
*$p < .05$.

Delayed post-test scores (M = 13.00, SD = 5.514) indicated that the Middle Eastern students retained the target English words they learnt after exploring the content related lexis in a simulated environment. The mean, which correlated with the average accurate responses, in the delayed post-test increased by 24 per cent from T1. Another finding was that students' vocabulary gains did not show a marked difference in their scores between the post-test and delayed post-tests (p = .229). Although the post-test scores were higher than the delayed post-test scores, (T1: M = 14.33 > T3: M = 13.00), it still showed students' retention in two ways: There was a significant difference between the pre-test and delayed post-test (p = .033), and the mean difference between the post- and delayed post-tests was quite small. In other words, the average number of target vocabulary EAL students recognised correctly in T2 and T3 test results were quite similar albeit a slight decrease in the delayed post-test results even after a two-week gap from VR game treatment (M = 13.00, SD = 5.51).

Indeed, the analysis and results of the pilot study demonstrated that the data collection instruments, and the method of analysis enabled the researcher to respond to Research Question 3. Middle Eastern EAL students showed marked improvement as they not only learnt content-based vocabulary items when playing VR games, but also managed to retain those target words after the intervention.

3.8.2 Pilot Study Results Informing Main Study

The following points discuss how the pilot study informed the main study:

- The researcher asked whether there was anything the students did not understand or needed further clarification in the consent forms. The researcher journal noted that the students found the consent form clear. The information statement sent to parents was effective as the research journal noted that there were no calls to the office, or no concerns of parents communicated. The parents were provided with two interpreters (who are office staff members as the school needs interpreters to communicate school related issues with parents) from the office in case they preferred to communicate in their home language. Therefore, the ethics procedure was replicated in the main study (see Section 3.6) as there were no discovered or foreseen risks.
- Students found the VR games stimulating with one exception. The only game that the student commented on as being boring was the InMind game ("The InMind game where you just shoot the red things was boring" (Zaynab, Interview, 2018)). The researcher was able to address this critique and replace the game with InMind 2 for the main study. The only reason this was possible was since another game in the same learning area was available and accessible. Testing how long it would take participants to complete each

game was also essential as it informed the time booking of an empty class for treatment and communicating with specialist teachers to sequence the lessons. Although the time range differed depending on the student's performance, whether any technical issues occurred or the length of the games, the maximum time recorded was approximately 20 minutes.

- The exit slips comprised of one question for the main study, after students were reluctant to answer multiple questions in the pilot study. Five to ten minutes was found to be sufficient for all students to answer the exit slip questions right after playing the content-based games. Consequently, this timing was considered for the main study.
- Six students were adequate to collect data on their views on immersive games in the pilot study, where all participants attended the semi-structured group interview. As data collected from six students was found sufficient, this was reflected in the main study. However, as the main study was implemented on a larger scale, the following criteria was applied to select six students from the treatment group: three students from each year were level selected via maximum variation for transferability (Merriam & Tisdell, 2015); that is, students were chosen according to their achievement scores from the games, being either high achievers, low achievers, or average students. For the first interview, students were selected based on the answers they provided in the pre-game survey. The study consisted of two students who did not play with a VR headset before, two who only played once and two students who used a VR headset more than once. The second and third interviews were conducted with different six students selected based on the exit slip responses and field notes with; two high achievers who managed to complete the game fast and successfully, two low achievers who were unsuccessful to complete the game or needed extra support from the researcher, and two average students.

The length of each interview was also found to be approximately 40 minutes to 60 minutes, and this was found to be adequate and appropriate for the main study. The length increased in the second and final interview, as there were more experiences to reflect upon towards the end of the treatment. This time length was taken into consideration in the main study.

- The items in the observation scheme were not changed, however, the researcher amended the structure of the observation scheme to provide more space to note observations. The researcher trialled the research journal to produce useful knowledge by eliminating any bias held by the researcher. The comments in the research journal were either students' verbatim expressions or intended to verify that happened or did not happen, such as a comment by a student "oh this asteroid is going coming towards me it is going to kill me" (Observation Scheme, 2018). This was a practice for the researcher to ensure reflexivity was evident.
- The questions in the surveys were not amended for the main study, as they were proven to collect data on student's demographic background and preference of conveying the meaning of an unknown content word. However, the method of answering the survey questions shifted from using school iPads to filling in the survey on paper. This decision was made due to technical issues such as students finding it difficult to select an answer on the iPads or the iPads running out of battery or closing the application. As the main study included more participants, there was a possibility that the technical issues would escalate.
- The time assessed in the pilot study that needed to be allocated to complete the test was determined as 35 minutes and was adequate for students to complete each vocabulary test. This was applied to the main study.

3.8.3 Main Study

The main study instruments and procedure mirrored the pilot study. However, there were minor aspects of the presented instruments, and the VR games that differed from the pilot study. These differences occurred based on the analysis of the pilot study results, as discussed above.

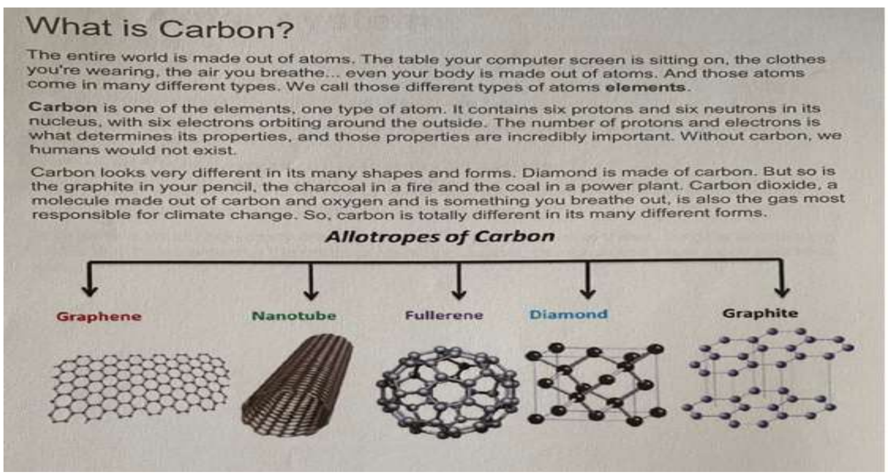
The following sections provide a description of the procedure and how the data was collected. The methods of analysis, including description of the qualitative and the quantitative data analysis, was also discussed.

3.8.3.1 Main Study Procedure

The procedure was the same with the pilot study, except students played one game instead of two each week. Therefore, the data for this study was collected over a period of 12 weeks. In Week 1, students completed a pre-game survey and the pre-vocabulary test. Once they started playing games in Week 2, the Year 7 and Year 8 students were combined in one class. The control and treatment group students still attended their regular class to read information about the content. All students read the passage related to the curriculum content (Carbons in Science) that also related to the VR game they played (Carbon VR game) See Figure (3.16). During the reading time, the specialist teacher introduced and taught the content to both groups by elaborating on the information read through the reading passages.

Figure 3.16

Sample Reading Passage on Carbon



What is Carbon?

The entire world is made out of atoms. The table your computer screen is sitting on, the clothes you're wearing, the air you breathe... even your body is made out of atoms. And those atoms come in many different types. We call those different types of atoms **elements**.

Carbon is one of the elements, one type of atom. It contains six protons and six neutrons in its nucleus, with six electrons orbiting around the outside. The number of protons and electrons is what determines its properties, and those properties are incredibly important. Without carbon, we humans would not exist.

Carbon looks very different in its many shapes and forms. Diamond is made of carbon. But so is the graphite in your pencil, the charcoal in a fire and the coal in a power plant. Carbon dioxide, a molecule made out of carbon and oxygen and is something you breathe out, is also the gas most responsible for climate change. So, carbon is totally different in its many different forms.

After reading the passage, the control group stayed in the classroom to answer the reading comprehension questions related to the reading passage under the supervision of the specialist teacher. Students had 40 minutes to complete the post-reading activity.

Meanwhile, the 14 students in the treatment group were pulled out of class to a separate classroom, so as not to distract their counterparts. Instead of answering the reading comprehension questions, the treatment group students were given a headset and a phone each with the VR game. Under the supervision of the researcher, the students also received instructions on how to play the headset-enabled games, in order to learn content-specific vocabulary items. As there were only seven headsets, students took turns playing the VR games. The students who were not playing watched the players. Each student was given approximately 30 minutes to play each game and 10 minutes to fill in the Exit Slip question (see Qualitative Data Collection Tools in Section 3.7.2). Thus, the treatment took 40 minutes each time they played the game. Students played one game each week which totalled nine games.

3.8.3.2 Main Study Qualitative Data Analysis Methods

The qualitative data analysis method mirrored the one in the pilot study, employing a thematic analysis approach. However, a software program, Computer Assisted Qualitative Data Analysis Software (CAQDAS) was used to organise data. The CAQDAS assisted in the analysis process, by presenting data in visual and written categories, so it can be more easily analysed from various perspectives (Mackey & Gass, 2015). CAQDAS was selected as it was suitable for importing, analysing, and synthesising qualitative data from multimodal data sources. It could incorporate audio data, data written by hand, and survey data. CAQDAS helped the researcher not only visualise data, but also link qualitative data to quantitative data and calculate interrater agreement, thus strengthening the findings of this research (Mackey & Gass, 2015). It enabled the detection of the frequently used words, whilst also providing for self-reflection. By displaying the most frequently used words in a word cloud from the triangulated data, it helped provide a visualisation of triangulated data. The visualisation enabled the researcher to 'look at a bigger picture' of connecting all the emerging themes (see word cloud in Chapter 4, Figure. 4.1).

3.8.3.2 Main Study Quantitative Data Analysis Methods

Each student was given a unique code and the scores from the tests were entered into the SPSS a software package (version 25) for statistical data analysis. An analysis of covariance

(ANCOVA) was selected in order to compare the language gains across the three tests. There was a difference between students in the pre-test results. The difference meant that the pre-existing knowledge of the vocabulary items each student knew was different (see SPSS result in Chapter 4, Section 4.3.2). To assure that gains were attributable to the tests, differences were also controlled by adopting ANCOVA. The pre-existing differences (the pre-vocabulary knowledge of the students before playing the VR games was not equal) were controlled and referred to as the covariate. The post-test results were adjusted as there was a pre-existing difference in the pre-tests amongst students' test results. In order to find where the significant difference occurred, whether there was a statistically significant difference between pre and post-test, or whether the 3D VR content-based games had an effect on vocabulary retention (delayed post-test), the Wilcoxon test was selected as a post-hoc test of power.

The post-game survey asked students to give a retrospective commentary on their learning experience with the content-specific vocabulary items in VR games. Student responses to the eight close-ended survey questions assisted to discern the change in their views between pre- and post-game surveys. The comparison of the student responses in the pre-game survey, and the same eight questions listed in the post-game survey, were analysed by adopting a paired samples Wilcoxon test. A paired samples Wilcoxon test was adopted to measure the difference between treatment group students' perceptions before treatment compared to their belief after treatment.

A paired samples Wilcoxon test was appropriate as it compared the participant's progress before treatment with the participant's own progress after treatment (Mackey & Gass, 2015). As the sample size only consisted of the treatment group, the Shapiro-Wilk normality test was chosen and run before further statistical procedures could be conducted. This normality test helped to determine whether the data set (the scores) was drawn from a normally distributed population

(Mackey & Gass, 2015). The results of these analyses are presented in Chapter 4. A summary of the qualitative and quantitative data collection procedure and analysis are presented in Table 3.15.

Table 3.15
Summary of Data Collection Procedure and Analysis for the Main Study

Timeline	Stage	Procedure	Type of data	Analysis of data	RQ
Week 1	Pre-test	Collect baseline data on pre-existing vocabulary	Quantitative	ANCOVA	RQ 3
	Pre-game survey	Demographic data from both groups Ask treatment group students their preferred method of learning content-specific vocabulary before playing the 3D VR games to learn new words	Qualitative and Quantitative	Paired t-test	RQ 1
Week 2	Field observations of treatment	Treatment group: post-activity with VR; control group: traditional method -observations take place throughout the research and field notes taken by researcher	Qualitative	Thematic Analysis	RQ 1-2
	Exit slips	Students complete exit slips	Qualitative	Thematic Analysis	RQ 1-2
Week 1, 5 & 10	Interview	Interview with focus group	Qualitative	Thematic Analysis	RQ 1-2
Week 10	Post-test	Post-test questions to determine vocabulary gains	Quantitative	ANCOVA	RQ 3
	Post-game survey	Collect data on whether students' preferred methods of learning new words changed after using VR games	Quantitative	Paired t-test	RQ 1
Week 12	Delayed post-test	Final phase of collecting data to determine vocabulary retention	Quantitative	ANCOVA	RQ 3

Research rigour in this study was ensured following the criteria suggested by Creswell and

Poth (2018). Credibility was ensured by establishing an audit trail to document and reflect on the whole process through the research journal and observation scheme. This documentation included reflections, questions and decisions made about the technical issues of using the Google Cardboard for selecting games, and how students reacted to this VR gamified approach to content vocabulary learning.

The multiple data sources helped to ensure trustworthiness, and text data was collected to better understand the nuanced factors that influence VR-based vocabulary learning, supported by students' perceptions. Triangulated data provide evidence to corroborate the qualitative data and capture a holistic picture of the investigated phenomenon (Mackey & Gass, 2015). Data triangulation, -by drawing on transcribed interviews, exit slip responses, and the observation notes to capture VR learning episodes and dynamics also helped to strengthen credibility. Transferability was considered by employing the strategy of maximum variation to select interviewed participants (see semi-structured focus group interviews in Section 3.8.2). Transferability was considered by providing a thick description (see Section 3.4 and 5.5) and supported by concrete evidence from participant interviews, field notes and documents of the study, thus allowing other like-minded educators to determine the applicability of findings to their own teaching context (Merriam & Tisdell, 2015) (see all findings supported by student verbatim in conjunction with field notes in Chapter 4).

3.9 Chapter Summary

This chapter discussed the methodology used in this research by providing an outline first. The three research questions were presented and the rationale to explain the use of a mixed methods approach was discussed. The setting of the research was explained followed by the description of information with reference to the participants and their background were.

The rationale for selecting and developing each VR game and the data collection instrument were presented, explaining why they were appropriate to collect the data needed to answer the research questions.

Due to the complex nature of qualitative and quantitative data being collected simultaneously, the data collection procedure was demonstrated in detail and the pilot study conducted to support the reliability of these instruments were addressed. The methods of analysis used to analyse the qualitative and quantitative data were also elaborated in this chapter.

Chapter 4 presents the analysis and results of the main study.

Chapter 4: Results

4.1 Chapter Overview

The previous chapter described the methodology employed in the current study. It summarised the research questions (RQ) and provided a description of the mixed methods research design. Chapter 3 also elaborated on the setting and participants, ethical considerations, headset-enabled 3D virtual reality (VR) games and the data collection tools used in this study. Information on data collection procedures, discussion of the pilot study results, the process of analysis, including the coding and data treatment, were also presented in detail in Chapter 3.

Chapter 4 presents the findings of the current research. The findings of qualitative results apposite to answer RQ 1 and 2 are reported in Section 4.2. It starts by providing details relating to the sample of participants and their responses to open-ended pre-game survey questions in Section 4.2.1. Subsequently, findings from this analysis are described in Section 4.2.2, in relation to seven themes generated by the data coding process: (1) highly immersive learning environment, (2) the fun factor (3) interaction with content-specific vocabulary items, (4) VR visualisation of content-specific vocabulary items, (5) enhanced vocabulary acquisition and retention, (6) insufficiency of adequate educational properties, and (7) technical problems in playing VR games.

The results of quantitative data analysis pertinent to the aims of Research Questions 1 and 3 are reported in Section 4.3. Section 4.3.1 explains descriptive statistics for the pre-game survey figures, displaying all students' views on the importance of content-specific words apropos of mainstream subjects. The statistical analysis of post-game survey data, monitoring change in student perceptions pre to post game, is also discussed in this section. Next, Section 4.3.2 details the analysis of pre-, post-, and delayed post-tests, comparing treatment and control groups' vocabulary test scores via Freidman and post-hoc tests. The chapter concludes with a summary in

Section 4.4.

4.2. Qualitative Data Analysis and Results

Section 3.7 in Chapter 3 outlined the VR games used in this research. Specifically, it linked the VR games to the relevant subject areas and explained the selection criteria of the 3D content-based VR games. Subsequently, it explained the data collection tools used to collect data throughout the 12 weeks which comprised the following: game survey (open-ended survey questions), semi-structured focus group interviews, exit slips, observation notes, researcher's journal.

This section presents the analyses of the qualitative results with regard to Research Questions 1 and 2. Section 4.2.1. provides information on whether these treatment group participants experienced playing VR games prior to their involvement, besides presenting their demographic background.

Next, in Section 4.2.2, details of how themes were generated by coding qualitative data were provided, specifically on student perceptions of head mounted display (HMD) VR game environments to learn content-specific vocabulary. The results from this analysis are presented in the same section, in relation to the explored themes. Seven themes emerged from the coding of the interview, exit slip, observation scheme and research journal data on the perceptions of HMD VR game-based learning. These subsections provide an in-depth presentation of the findings under each theme, with reference to English as an additional language (EAL) learners' own quotes, the research journal, and observation notes to answer Research Questions 1 and 2:

- **RQ 1.** How do EAL learners perceive their first-hand experience of using headset-enabled, educational VR games to engage with the content-specific vocabulary items?
- **RQ 2.** What aspects of a headset-enabled, VR game-based learning environment do EAL learners perceive that can facilitate or hinder content-specific vocabulary learning?

4.2.1 Pre-game Survey Results

Table 4.1 presents the data from open-ended survey questions to provide information about all students' demographic background, aside from treatment group students' experience history with VR games. According to the responses, the languages these culturally and linguistically diverse learners (CALD) speak at home consist of Arabic, Somalian, Turkish, and Urdu. These CALD learners hail from a number of different countries: Egypt, Iraq, Jordan, Kuwait, Libya, Pakistan, Somalia Syria, Turkey, and the United Arab Emirates (UAE). Whilst the treatment group consisted of ten female and three male students, there were nine female and four male students in the control group. Within the treatment group, only one student had not played online games before. Whilst six students never played VR games prior to the treatment, only two of treatment group learners had previously used HMD VR and had only played once.

Table 4.1

Students' Pre-game VR Experience and Demographic Background Sorted by Group and Gender

Name	Gender	Country	Age	Age learnt English	Language spoken at home	Pre-game experience
			Treatment Group			
Laila	Female	UAE (Dubai)	13	10	Arabic	HMD VR experience
Lena	Female	Syria	13	11	Arabic	No online game experience
Zehra	Female	Turkey	13	5	Turkish	Online game experience
Ayten	Female	Turkey	13	6	Turkish	Online game experience
Salma	Female	Iraq	12	4	Arabic	Online game experience
Fatma	Female	Turkey	12	3	Turkish	VR game experience
Sada	Female	Pakistan	12	5	Urdu	Online game experience
Sulafa	Female	UAE	12	8	Arabic	HMD VR experience
Reem	Female	Jordan	12	5	Arabic	Online game experience
Rania	Female	Egypt	13	4	Arabic	VR game experience
Kareem	Male	Kuwait	12	5	Arabic	VR game experience
Hassan	Male	Libya	13	6	Arabic	VR game experience
Yousef	Male	Iraq	12	8	Arabic	VR game experience
			Control Group			
Jamila	Female	Syria	13	11	Arabic	Not Applicable (N/A)
Sahar	Female	Syria	13	11	Arabic	N/A
Nadia	Female	Syria	12	11	Arabic	N/A
Nesrin	Female	Turkey	13	11	Turkish	N/A
Talia	Female	Iraq	12	5	Arabic	N/A
Esra	Female	Somalia	12	6	Somalian	N/A
Aysha	Female	UAE	12	4	Arabic	N/A
Batool	Female	Egypt	13	2	Arabic	N/A
Alya	Female	Iraq	12	10	Turkish	N/A
Amir	Male	Libya	12	8	Arabic	N/A
Ahmad	Male	Jordan	12	7	Arabic	N/A
Farooq	Male	Turkey	13	3	Turkish	N/A
Hussein	Male	Egypt	13	4	Arabic	N/A

Data from exit slips, interviews, research journal and observation scheme were only collected and analysed from treatment group students. In the treatment group, Middle Eastern EAL participants purposefully selected via maximum variation (Merriam & Tisdell, 2016) were asked to participate in semi-structured group interviews. Each interview was recorded and transcribed into Microsoft Word for further data analysis. Similarly, the same course of action was taken for exit slips and observations written in the research journal and observation scheme. As explained in Ethical Considerations in Chapter 3, Section 3.6, to protect the identity of the participants, each student was assigned a pseudonym. The data set was then transferred to NVivo 11 software to assist qualitative data analysis and coding (QSR International, n.d.).

4.2.2 Text Analysis and Results

The world cloud feature in NVivo enabled the researcher to generate a visualisation of the main words used by students in the treatment group who immersed themselves in content-based VR games. This word cloud intended to describe EAL players' perceptions of HMD VR game-based environments to learn content-specific lexicon. As presented in Figure 4.1, the word cloud procedure showed the main words students used whilst responding to qualitative data collection instruments. These words included terms like 'game', 'showed', 'helped', 'learn', 'understand', 'new', 'words', 'fun'. This figure is consistent with the interview and exit slip data (see Table 4.2). Observation notes from the researcher's journal and observation scheme were entered into NVivo after the word cloud was formed. This was to ensure the word cloud only consists of participant quotes, not researcher's observation notes.

Figure 4.1

Results of Word Frequency Analysis via NVivo Word Cloud Procedure

The thematic analysis procedure employed an open coding technique. The researcher first read all the data line by line and highlighted text that pinpointed to the recurring participant data verbatim. These codes were generated to represent the main ideas students expressed or the researcher observed. As the texts were being highlighted in NVivo, initial codes were attached (Merriam & Tisdell, 2015). Once the initial open coding process was completed, an axial coding technique was employed. Using this technique, the researcher explored the attached codes to identify any consistency amongst codes (Braun & V. Clarke, 2006). Thereby, these codes were combined into lists, resulting in groups of codes. Through this process, these groups of codes related to each other were further collapsed into higher conceptual levels that formed the thematic categories (Merriam & Tisdell, 2015) as presented in Table 4.2. Table 4.2 shows a summary of the list of codes and pertinent themes, each represented by samples of unit of data.

Table 4.2

Summary of Data Analysis Procedure

Unit of Data	Code Attached	Theme	Number of codes of the data source related to each theme
"It's like you are actually there [at the harbour] because you can actually see it." (Rania, Interview, 2018)	Feeling of presence.	Highly immersive learning environment	Exit Slips: 15 Interviews: 21 Observation Scheme and Research Journal: 9
"It [diving game] helped me learn the words because it was like I was seeing it in real life". (Kareem, Exit Slip, 2018)	Presence in game.		
Reem called out "We are in the brain, oh my God!" playing the InMind game. (Reem, Observation Scheme, 2018)	Presence in human mind.		
"If we actually do it in class, we would enjoy what we are doing. Let's say the teacher gives us homework, we can do it on VR, it will be actually more fun because you want to do it so you will spend more time to do it and you can learn more." (Hassan, Interview, 2018)	Enjoy learning.	The fun factor	Exit Slips: 11 Interviews:18 Observation Scheme and Research Journal: 12
It [Solar System game] helped me learn a lot about Pluto and it was fun as well. (Kareem, Interview, 2018)	Fun game.		
Zehra called out, "I love this game; it is so much fun" as she was playing the Solar System Museum game. (Zehra, Observation Scheme, 2018)	Fun.		
"You want to interact and see other places than just one classroom, so it basically helps us with learning words instead of just looking at them you basically get to see it and what the actual thing is." (Salma, Interview, 2018)	Interact with target.	Interaction with content-specific vocabulary items	Exit Slips: 8 Interviews:19 Observation Scheme and Research Journal: 4
Laila called out, "Red cells are dangerous, I have to shoot them" playing the InMind game. (Laila, Observation Scheme, 2018)	Interact with cells.		
"It [Solar Museum] helped me learn new words by allowing me to pick any planet and I picked Pluto. It	Interact with planets.		

told me all about Pluto and a lot of things about it." (Kareem, Exit Slip, 2018)			
"[In] The carbon game where it showed the carbon it was nice to be able to see how they arranged the atoms because it showed how the graphited the atoms arranged, and it wrote the words on the diagram, so it was helpful to learn the words." (Fatma, Interview, 2018)	View 3D form of carbons.	VR visualisation of content-specific vocabulary items	Exit Slips: 13 Interviews: 34 Observation Scheme and Research Journal: 8
"It took me in atoms to see what they look like." (Hassan, Exit Slip, 2018)	View atoms.		
Mustafa said, "I see green and red cells" playing the InMind 2 game. (Mustafa, Observation Scheme, 2018)	View cells.		
"We learnt the new words and the new types of bacteria that was bad and good for you." (Zehra, Interview, 2018)	Learnt target words.	Enhanced vocabulary acquisition	Exit Slips: 17 Interviews: 37 Observation Scheme and Research Journal: 14
"It [InCell game] helped me a lot because if you play the game you have to understand it. The concept of the game are the words. I had to know the words to play the game and I did and knew what was good and bad." (Abdurrazak, Exit Slip, 2018)	Learnt target words.		
Sada called out, "Mitochondria" playing the Incell game. (Sada, Observation Scheme, 2018)	Use of target vocabulary.		
"What I didn't like is the fact that it didn't have much information about each portrait and there wasn't much action to learn from." (Salma, Exit Slip, 2018)	Requested more information.	Lack of adequate educational features	Exit Slips: 13 Interviews: 18 Observation Scheme and Research Journal: 7
"It shows ancient Egypt buildings giving it the feeling that you are in Egypt. It just showed the words, but it didn't explain what the words were." (Fatma, Interview, 2018)	Request explanation.		
"EAL learners expressed (via exit slips and interviews) that the written form of the target vocabulary, the written explanation of meaning and audio information contributes to understand the target word in context." (Research Journal, 2018)	Request written and audio information.		

"What I didn't like about the game is it gets you dizzy, and you feel like you are going to fall down." (Lena, Exit Slip, 2018)	Dizzy.	Technical issues in using VR headsets	Exit Slips: 6 Interviews: 7 Observation Scheme and Research Journal: 5
"I did not learn any new words because it didn't speak in the game." (Zehra, Interview, 2018)	Audio not working.		
The research journal noted that the amount of time each student played the game could vary as there were a few occasions where the 3D VR game applications did not play in VR mode and had to be restarted to play. (Research Journal, 2018)	Timing issue.		

Seven themes emerged from the coding of the triangulated data on the perceptions and effects of using HMD VR games to learn content-specific vocabulary. The first theme in Table 4.2, '*Highly immersive learning environment'*, represented students' views on the sense of telepresence in the VR learning environment. The next theme, '*The fun factor'*, reflected how VR makes learning enjoyable. '*Interaction with content-specific vocabulary items'* was also derived from the thematic analysis, indicating perceptions on engaging with target words through interaction. Following this, '*VR visualisation of content-specific vocabulary items'* echoes students' opinions on how 3D images solidified the meaning of target words. Subsequently, '*Enhanced vocabulary acquisition and retention'* represented positive outcomes of vocabulary learning and remembering, based on exit slip responses, quotes from interviews, and observation notes. The theme '*Insufficiency of adequate educational properties'* considered students' ideas of incorporating explicit content information to improve the educational facets of VR games. Finally, '*Technical problems in playing VR games'* mirrored these EAL players perspectives on technical difficulties hindering vocabulary learning.

Table 4.3 outlined these seven themes grouped under two conceptual categories: '*Students' perceptions of VR game-based learning*' and '*the effects of headset-enabled VR games on* *vocabulary acquisition and retention*'. Each category intersected with the positive and negative aspects of learning content-specific vocabulary using headset-enabled VR games. In the following sections, these two categories provided the structure for the in-depth presentation of the findings, by reference to CALD students' own words, research journal, and observation notes.

Table 4.3

EAL Learners' Overall Perceptions and Effects of Headset-Enabled VR Games on Vocabulary Acquisition

Perceptions of headset-enabled VR games	**Effects of HMD VR games on vocabulary acquisition and retention**
Positive aspects	
• Highly immersive learning environment • The fun factor	• Interaction with content-specific vocabulary items • VR visualisation of content-specific vocabulary items • Enhanced vocabulary acquisition and retention
Negative aspects	
• Insufficiency of adequate educational properties	• Technical problems in playing VR games

4.2.2.1 Positive Aspects: Perceptions of Headset-Enabled VR Games

- Highly Immersive Learning Environment

The theme of Highly immersive learning environment was reflected to describe learners' views on the HMD VR learning environment. Table 4.4 presents these students' viewpoints on how the immersive property of VR environments were found to be superior to conventional language instruction to heighten engagement with the subject matter. Treatment group students identified the sense of telepresence offered by HMD as an advantage to encounter with the content, in comparison to answering questions through pen and paper. Besides, participants repeatedly echoed that headset-configured games presented a unique learning environment enabling them to encounter 'very realistic' experiences, such as swimming with the fish whilst learning about marine life. Furthermore, these language learners suggested that the headset tool presented the virtual environment almost indistinguishable from the real world to the extent that the sense of telepresence felt like they actually visited the harbour in real life: “The thing I liked about the game [Qantas VR] was the Harbour Bridge because it was interesting. You can also see the real things, so you don’t have to go there, it felt real” (Sada, Exit Slip, 2018).

Thus, according to language learners’ perceptions, this theme played an important role to empower learner engagement with the target content. One EAL student explained her belief on how immersion propelled her to learn the target content: “It’s a lot better [the VR environment]. It’s like you are in there. You can see how it looks like if you actually want to know [learn]” (Kareem, Interview, 2018).

Moreover, EAL players suggested that the highly immersive nature of artificially generated 3D environments afforded them to be a part of the context and view target objects closely. The researcher’s observations indicated that students were excited to be involved in playful 3D simulations to explore the topic, and related terminology through the highly immersive technology. It was also noted in the Observation Scheme that there were a few occasions where players were trying to catch the target object with their hands, whilst immersed in the game. Considering the realistic experience, these students seemed surprised by the high immersion offered to be a part of the context to learn about the subject matter. Learners expressed how headsets intensify the sense of telepresence, by believing that they could reach out and touch the visualised 3D objects in the simulation as if they were really in front of them, despite not using a wearable hand sensor. Accordingly, students claimed that the experience of telepresence in content-based environments fostered their acquisition process of the subject terminology: “It will help learn new words as you might understand it better in 3D where you feel like you are actually there. It's a good experience" (Laila, Interview, 2018).

Respondents also noted or verbally expressed comments about the game characteristics they favoured related to the highly immersive environment, such as feeling like a fish or relaxing whilst walking by the harbour. Overall, students' quotes focused on being in a realistic and appealing learning environment. A sample of these responses alongside the researcher's notes is presented in Table 4.4 (see Appendix G to view extended sample responses).

Table 4.4

Sample Comments Reflecting the Theme 'Highly Immersive Learning Environments'

Sample Unit of Data
(1) "It's [HMD VR games] more engaging. Let's say if you were in the classroom looking at a picture of it you wouldn't feel that you are there and you wouldn't feel as if it is something important." (Ayten, Interview, 2018)
(2) "I really enjoyed the game [Qantas VR] because it made me relax and the view looked very good. I could turn around, look at different things, it made me feel like I'm in the game." (Kareem, Interview, 2018)
(3) Hassan said, "I can touch it Miss" playing the InMind 2 game. (Observation Scheme, 2018)
(4) Reem called out, "We are in the brain, oh my God!" playing the InMind 2 game. (Reem, Observation Scheme, 2018)
(5) "It [Diving VR] helped me learn the words because it was like I was seeing it in real life." (Kareem, Exit Slip, 2018)

- The Fun Factor

The Fun factor theme shown in Table 4.5 represented participants' attitudes of 'having fun' whilst using games and mobile phones for vocabulary acquisition and retention. According to most players, VR makes learning fun, by offering an alternative learning environment beyond sitting in a chair, facing the board, listening to the teacher, looking up unknown words from the dictionary, answering questions via paper, or even watching 2D videos to engage with the content: "It was really fun because especially a lot of us don't like looking up listening to the teacher and looking up the board and sometimes it helps us what to learn in a game" (Kareem, Interview, 2018).

Furthermore, EAL learners indicated that 3D simulations fostered players to actively explore the content makes the content and language integrated learning environment enjoyable. Moreover, according to interview and exit slip responses, participants suggested that this fun property offered by VR games made learning easier. A case in point was mentioned by Reem, voicing that playing these games in a highly immersive environment was entertaining because it made learning easier: "It's easier to understand instead of hearing it. It makes learning fun, and we can be more engaged" (Reem, Interview, 2018).

Additionally, students formed a belief that the fun factor may have increased their focus to encounter with the subject matter whilst immersed in the playful environment. Accordingly, based on these EAL players views, being motivated to engage with the content for an extended time correlated to heightened attendance in learning unfamiliar words which ultimately increased their engagement. Hassan illustrated his sentiment on the positive impact the fun property had on engagement and how it stimulated the content-specific vocabulary acquisition process:

> If we actually do it in class, we would enjoy what we are doing. Let's say the teacher gives us homework, we can do it on VR, it will be actually more fun because you want to do it so you will spend more time to do it and you can learn more. (Hassan, Interview, 2018)

Further sample comments relating to the entertaining effects of HMD VR games are shown in Table 4.5 (see Appendix H to view extended sample responses). These quotes and researcher's notes showed that players considered learning vocabulary pleasurable due to teleporting in the content-based highly immersive environment. There were also a few remarks about the relationship between clear 3D visuals of target words leading to having fun while learning, such as going through the carbons in a simulation instead of viewing 2D pictures.

Table 4.5

Sample Comments Reflecting the Theme 'The Fun Factor'

Sample Unit of Data
(1) "I enjoyed the game [Carbon] as I got more around, I learnt the appearances of the types of carbons. It was a great way to learn the allotropes of carbon." (Fatma, Exit Slip, 2018)
(2) "I enjoyed it because you learn easier and quicker." (Sada, Exit Slip, 2018)
(3) "It showed what the word is, and it will show the picture of it instead of saying words so that made it fun." (Hassan, Interview, 2018).
(4) After Hassan completed playing the first game (InCell VR), he said, "Miss [addressing the teacher], this is so much fun I have to buy one". Following Hassan, Laila asked, "Where can we buy one?" [Research Journal, 2018]
(5) Zehra called out, "I love this game; it is so much fun" as she was playing the Solar System. (Zehra, Observation Scheme, 2018)
(6) "We learn it in a more fun way instead of watching videos and writing [which] was boring." (Hassan, Interview, 2018)

4.2.2.2 Positive Aspects: Effects of HMD VR Games on Vocabulary Acquisition and Retention

- Interaction with Content-Specific Vocabulary Items

As with the previous themes, this theme (see Table 4.6) also emerged from the triangulated data, referring to students' considerations of the importance of HMD VR games stimulating interaction with target words. According to participants, interacting with unknown vocabulary items in the artificially generated 3D world elucidated their meaning. Interview and exit slip responses showed that students interacted with visualised target vocabulary. This included fighting the virus and going to the nucleus in the InMind 2 VR game or choosing a planet and encountering its features, including turning the selected planet around or listening to information about its properties. Therefore, many EAL students linked interaction to improvement in lexicon gains: "It helped me learn new words because it was very interactive, and it was talking walking you through the words" (Yousef, Exit Slip, 2018).

The favoured interactive property of VR was also compared to conventional learning methods by language learners. Students argued that this innovative tool enabled them to encounter the actual word in context and view other locations than just a classroom. A student highlighted how 3D games enabled him to interact with objects without restraint, in a way that was not possible in the traditional classroom:

> It's a lot better [than a traditional classroom] because you can observe from every different way you can look from the side or turn around. Unlike the worksheet you can only look from one way you can't see from another way. (Kareem, Interview, 2018)

It was also noted in the research journal that players were audibly describing their position in the Qantas, Toumanian Museum, Diving VR, and the Ancient Egypt games. Although all games were played individually these players were interacting by asking each other to describe what they saw in the game. The more EAL students interacted with each other, the more likely it was that they used target items. For instance, while playing Diving VR, each time they saw a fish in the 3D environment, the students described the scene to their friends so they could discover marine life together, although they could not see each other in the VR game, and it was not a requirement of the game. Also documented in the research journal, the collaborative interaction whilst playing in the 3D VR environment also seemed to have fostered students' use of target words in context.

As presented in the sample of statements in Table 4.6 (see Appendix I to view extended sample responses), these EAL learners found interaction a valuable property to engage with the content and learn the related vocabulary. This was principally due to their preference for interaction as a more effective mean of connecting context and meaning with the target words. Concrete examples were provided in students' responses demonstrating their interactive experiences with target objects such as fish, planets, cells, and marine life.

Table 4.6

Sample Comments Reflecting the Theme 'Interaction with Content-specific Vocabulary Items'

Sample Unit of Data
(1) "You want to interact and see other places than just one classroom, so it basically helps us with learning words instead of just looking at them you basically get to see it and what the actual thing is." (Salma, Interview, 2018)
(2) "InCell helped me learn new words because you have to try and fight of the virus and go to the nucleus." (Rania, Interview, 2018)
(3) "I think it's [VR games] cool because we like to rather be interactive and do something instead of writing paragraphs and essays." (Rania, Interview, 2018)
(4) "It (HMD VR games) was much more interactive. We got up walked around and saw new things instead of sitting down and looking at one direct screen we could look at 360-degree rotations." (Zehra, Interview, 2018)
(5) Reem said, "I crashed with an asteroid" playing Solar System and uttering a target vocabulary item. (Research Journal, 2018)
(6) Laila called out, "Red cells are dangerous, I have to shoot them" playing InMind 2. (Observation Scheme, 2018)

- VR Visualisation of Content-Specific Vocabulary Items

VR visualisation of vocabulary was frequently mentioned by students responding to exit slip and interview questions. Triangulated data indicated that 3D visuals presented in these games clarified the meaning of the words. Language learners expressed that viewing concrete examples of target items in context assisted them to engage with the subject matter and solidify the meaning of the unknown lexis. Besides, learners remarked how visualisations in highly immersive environments could present content information more effectively: "In the images you just look at the molecules in a 2D [two dimensional] form but in the VR game you can actually see a better view from how it is actually formed" (Ayten, Interview, 2018).

Therefore, according to the analysed qualitative data, the effects of 3D visualisation of target words not only prompted learner investment in the content, but it also fostered the topic-oriented lexis learning process. Through interviews and exit slip responses, language learners formed a belief that the visual components of a VR environment facilitated vocabulary acquisition: “It helped me learn new words because it showed me the actual object instead of like the teacher explaining to me what the objects looking like” (Sulafa, Exit Slip, 2018).

Importantly, students highlighted that these visual representations were different to watching a video, in regard to the feature that players can control their observation of the 3D visualised target vocabulary according to their preference. An example could be related to going through each atom to closely view how they were formed from each angle. Consequently, data from participant quotes and written responses showed that VR may have clarified the subject matter by connecting meaning of content-specific vocabulary with 3D visual representations:

> [In] The Carbon game where it showed the carbons, it was nice to be able to see how they arranged the atoms because it showed how the graphited the atoms arranged, and it wrote the words on the diagram, so it was helpful to learn the words. (Fatma, Interview, 2018)

Furthermore, the research journal also noted that players were calling out target words as they saw the visual representation of the topic terms. As students were describing how they learnt vocabulary items through the immersive world, they were also using the target words to describe the acquisition process. As evidenced below, sample comments in Table 4.7 (see Appendix J to view extended sample responses) included statements associating content-specific vocabulary learning to discerning these words in a 3D form in the highly immersive environment.

Table 4.7

Sample Comments Reflecting the Theme ‘VR Visualisation of Content-specific Vocabulary Items’

Sample Unit of Data
(1) “The worksheet told us what it is it gave the name, but VR showed us what it was so the graphics and all that it showed us what it looked like and what it meant.” (Hassan, Interview, 2018)
(2) “I learnt new words by showing us how they looked like. For example, fullerene looks like circle.” (Laila, Interview, 2018)
(3) It [InMindVR] helped me learn new words because I was seeing the actual cells. (Sulafa, Exit Slip, 2018)

(4) Lena said, “I see the cells” playing InCell VR. (Research Journal, 2018)
(5) If you don’t know the meaning of the word or what word it is, you can see in VR, and it actually feels like it’s there and you can touch it and you are actually inside. (Hassan, Exit Slip, 2018)
(6) Yousef said, “I see green and red cells” playing InMind 2. (Observation Scheme, 2018)

- Enhanced Vocabulary Acquisition and Retention

Enhanced vocabulary acquisition and retention was identified as a positive theme related to the effects of HMD VR games on vocabulary acquisition, that emerged from the triangulated data. Learners claimed that besides learning knowledge about the content, they also acquired the relevant words. In support of the following quote, participants’ comments about learning new words after playing InCell VR were also documented in the research journal, further interviews and exit slip responses (see Table 4.8): “We had to kill the bacteria in the game. We learnt the new words and the new types of bacteria that was bad and good for you” (Zehra, Interview, 2018).

Another important finding is concerning how the VR simulation was integrated to language learners’ lesson plans related to Humanities and Social Sciences (HASS), The Arts, and Science, fostering content-specific vocabulary acquisition. Students reported that playing the VR games as a post-reading activity helped them learn the subject terminology. Moreover, games enabling players to select the target object, then presenting a label of the name, and providing further audio or written information about the context of the item was suggested as a VR property that increased language learners' word knowledge:

> We read the passage, we saw the words in the passage as you played the game and you saw the words because you can see what the word actually means, and you see what it [vocabulary] looks like in the game so it [VR games] kind of helps. (Fatma, Interview, 2018)

EAL students also asserted that the gamified VR environments fostered their newly acquired word knowledge to reach the objective of the game, which enhanced their lexis acquisition in

English. Responding to an exit slip question, Kareem detailed how the storyline and objective of InCell VR boosted his science vocabulary:

> It [InCell VR] helped me a lot because if you play the game you have to understand it. The concept of the game are the words. I had to know the words to play the game and I did and knew what was good and bad. (Kareem, Exit Slip, 2018)

A further case in point was the comments made in exit slips asking players to describe the vocabulary items they learnt from playing the InMind 2 and Carbon games (see Table 4.8 and Appendix K to view extended sample responses). The data shown in Table 4.8 also displayed the presentation of the subject matter in the VR games, through multiple means. These included visuals, written and audio information, empowering these linguistically diverse students to build their content lexicons. Finally, the table below showed students' claims that this new technology enhanced their content-specific vocabulary acquisition, due to the HMD VR's unique properties offering an alternative learning environment.

Table 4.8

Sample Comments Reflecting the Theme 'Enhanced Vocabulary Acquisition and Retention'

Sample Unit of Data
(1) "The game that we played today was Ancient Egypt. It helped me learn many new words because when you focus on a red dot it tells you the name of the picture and the kings (Pharaoh) of the time." (Rania, Exit Slip, 2018)
(2) "I learnt nanotube, graphite, diamond." (Hassan, Exit Slip, 2018)
(3) "I learnt methane, ethene, diamond, fullerene, nanotube, graphite, and graphene." (Kareem, Exit Slip, 2018)
(4) "The solar system tour helped me learn new words as it clearly shows and explains what it is, where it is and what it does in the solar system. It shows the order of the planets and the sizes of the planets." (Fatma, Exit Slip, 2018)
(5) Sada called out, "Mitochondria" playing InCell VR. (Observation Scheme, 2018)
(6) Rania said that, "this is very effective to learn" after playing InMind 2. (Research Journal, 2018)

4.2.2.3 Negative Aspects: Perceptions of Headset-Enabled VR Games

- Insufficiency of Adequate Educational Properties

This theme emerged as a result of these CALD participants demanding further detailed written or verbal explanation of the subject content (see Table 4.9). Although learners previously stressed in the identified themes above that 3D gamified learning through VR was an effective method to engage with the subject matter and related words, learners suggested that its properties that fostered vocabulary acquisition could be strengthened. For instance, despite the Magi Chapel game presenting information in a visual form, Salma stated it lacked particular details: "What I didn't like is the fact that it didn't have much information about each portrait and there wasn't much action to learn from" (Salma, Exit Slip, 2018).

Another important aspect was mentioned by a student after playing Ancient Egypt, claiming that missing audio information hindered the vocabulary acquisition process. These EAL players recommended that it would have been beneficial to explain the words visualised in the games via audio features. Equally important, most respondents also had recommendations, suggesting a balance between content information and action in VR games. Students implied that too much action might disperse the focus from learning, whilst lack of movement obstructs interaction, resulting in less engagement with target objects. In a reverse situation, the positive impact of a good storyline on vocabulary learning could be supported by Kareem's comment, illustrating the effects of this facet on vocabulary acquisition:

> It [InCell VR] was quite nice because everything in the game had a different purpose like the green one would be the good one and it will tell us the meaning and what it would do and the red one will be the bad one and it will tell us the name so we would memorise it to win and if you win you remember all the cells. (Kareem, Interview, 2018)

Additionally, students expressed concerns over lack of literacy skills, as the VR games do not enable students to exercise their writing skills. Further, learners conveyed that they could be sidetracked by having too much fun playing the VR games, and that frequent usage of these games could lead to poor literacy skills. Thus, students expressed that these games should be played when it is necessary and useful to view the content-based objects in a 3D fashion: "I think it could be used sometimes for example in science when you actually need to look at [a] cell" (Fatma, Interview, 2018).

The data shown in Table 4.9 reflects students' quotes and the researcher's observation notes about the lack of educational features, such as interactivity and action alongside with further audio and written information. However, despites the comments above, a student mentioned that he would prefer a 'boring' VR game to studying from worksheets (see Appendix L to view extended sample responses).

Table 4.9

Sample Comments Reflecting the Theme 'Insufficiency of Adequate Educational Properties'

Sample Unit of Data
(1) "What I didn't like about the game [Magi Chapel] was that you just look at the picture and observe the texture, colour etc. I think it would be much more fun if there were mini activities related to the pictures displayed." (Ayten, Exit Slip, 2018)
(2) "It [learning new words] depends on the game. If it is a game with a lot of action but a little bit of learning, it might not help but of it is a lot of learning and little bit of action, it might help." (Hassan, Interview, 2018)
(3) "I didn't learn any new words because there were no talking in it." (Zehra, Exit Slip, 2018)
(4) "If we do it every day we are going to forget how to write and we will be concentrating on electrical devices and we will rely only on electronic devices to do things. We only need it once a week maybe or three times a week like we use iPads." (Lena, Interview, 2018)
(5) EAL learners expressed (via exit slips and interviews) that the written form of the target vocabulary, the written explanation of meaning and audio information contributes to understand the target word in context. (Research Journal, 2018)
(6) "What I didn't like about the game [Magi Chapel] was that the function was limited and there was nothing we can interact with." (Kareem, Interview, 2018)

4.2.2.4 Negative Aspects: Effects of HMD VR Games on Vocabulary Acquisition and Retention

- Technical Problems in Playing VR Games

EAL learners expressed concerns that possible technical problems could interfere with their learning experience. Two learners reported they felt dizzy, and the poor sound quality prevented two EAL players from hearing the pronunciation of target words in the InMind 2 game. A few players also complained about the blurry vision caused by the inexpensive optics of Google Cardboard. Importantly, students claimed that these technical issues hindered the vocabulary acquisition process: "I didn't learn anything because all the words are all blurry and there was no voice to explain what was happening" (Yousef, Exit Slip, 2018).

In the same way, the research journal noted that the amount of time each student was in play varied as there were a few occasions where the 3D VR game applications did not play in VR mode and had to be restarted. This technical problem then reduced the fun factor. The researcher also observed that the amount of time each student played the game could vary as there were a few occasions where players could not hear the instructions provided in the game (see Table 4.10).

Participating in the highly immersive games, players were walking around the classroom to explore the VR environment, so there was a possibility that players could bump to each other. Whenever this happened, the researcher had to interrupt these students playing Ancient Egypt, Tourmanian Museum, and Diving VR, asking them to walk back to their initial spots by taking off their HMD. Table 4.10 displays sample comments on how technical issues negatively affected the vocabulary learning process:

Table 4.10

Sample Comments Reflecting the Theme 'Technical Problems in Playing VR Games'

Sample Unit of Data
(1) "What I didn't like about the game [Carbon] is it gets you dizzy, and you feel like you are going to fall down." (Lena, Exit Slip, 2018)
(2) "The game [Magi Chapel] also made me very dizzy because I had to tilt and turn my head so much. The screen was also very blurry and was not clear it disturbed my eyes." (Zehra, Interview, 2018)
(3) "I did not learn any new words because it didn't speak in the game." (Zehra, Interview, 2018)
(4) "I did not learn any new words because the words on the screen blurry, so I was confused." (Zehra, Exit Slip, 2018)
(5) "It did not help me learn new words because everything was blurry. But it felt real because I was around there." (Reem, Exit Slip, 2018)
(6) In order to hear the directives, learners had to restart the game. (Research Journal, 2018).

The following section presents the findings of the quantitative data analyses to explore whether students' perception of positive vocabulary gains could be verified by the statistical results.

4.3 Quantitative Data Analysis and Results

This section presents the results of quantitative data analysis. It begins with expounding pre- and post-game survey results, explaining the data screening procedures employed and the methods to validate the close-ended survey items through alpha analysis in Section 4.3.1. Specifically, figures of all participants' beliefs are explained based on how word knowledge effects their comprehension of the content. This is followed by the explanation of paired samples Wilcoxon test results, employed to analyse the pre- and post-game surveys and monitor any shift in treatment group learners' viewpoints after playing the nine VR games (see Chapter 3, Section 3.7.1). These results aimed to contribute answering Research Question 1:

- **RQ1.** How do EAL learners perceive their first-hand experience of using headset-enabled, educational VR games to engage with the content-specific vocabulary items?

Section 4.3.2 elaborates the findings from the vocabulary tests, with respect to control and treatment groups. First, it explains testing the normality assumption procedure as well as homogeneity of regression results in regard to the vocabulary tests. Then, a detailed description of control group students' performance is provided by presenting the *p* value, mean scores and mean placement of their marks generated by Freidman and post-hoc tests.

An identical course of action was undertaken to analyse treatment group EAL learners' scores, and the findings are presented in the following subsection. Finally, all results are compared and are displayed in the last section, revealing the similarities and differences between the two groups, to answer Research Question 3:

- **RQ3.** To what extent does a VR game based, headset-enabled approach's effects differ from a traditional textbook-based approach in EAL learners' acquisition and retention of content-specific vocabulary?

4.3.1 Pre- and Post-Game Survey Results

4.3.1.1 Selection and Exclusion Criteria

The closed-ended pre-game survey data was collected from all participants, whereas post-game survey responses were only collected from students who played with the HMD VR games. Pre- and post-game survey responses were prepared for analysis by first screening each dataset to determine potential biases, such as insufficient effort (J.L. Huang et al., 2012), extreme responding (Weijters et al., 2021) or an acquiescence bias (Kuru & Pasek, 2016). One case from the post-game survey was identified where the answers reflected insufficient effort. Thus, this case was deleted, and the student's data was removed from analysis, due to many missing values. Subsequently, data collected on paper from participants were manually entered into Google Forms by the researcher. As a result, 26 responses from pre- and 12 out of 13 responses from post-game survey were analysed.

4.3.1.2 Scale Reliability

The closed-ended survey data, from 12 students, was subjected to Cronbach's alpha using SPSS in order to establish the reliability (Cronbach & Shavelson, 2004). In other words, Cronbach Alpha was used to measure the internal consistency of the Likert scale items. Cronbach's alpha reliabilities were calculated (.76) and are presented in Table 4.11. The analysis showed all items had a good level of reliability (Cronbach & Shavelson, 2004). The high reliability of the whole scale, with an alpha coefficient of .76, were considered to be internally consistent. In view of these results, the surveys were adequately constructed for statistical analysis.

Table 4.11

Cronbach`s Alpha Reliability Measure

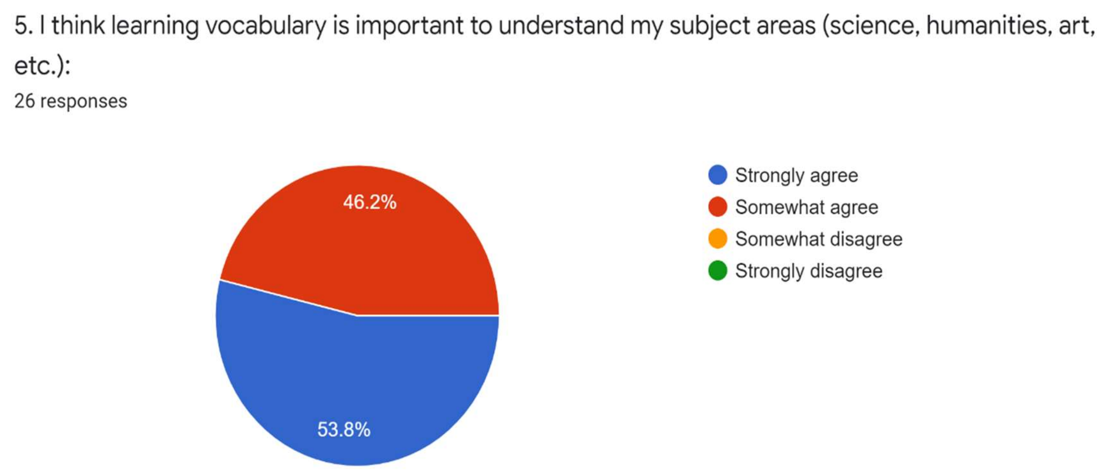
Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardised Items	N
.769	.771	12

4.3.1.3 Descriptive Analysis of Pre-Game Survey Results

The pre-game survey ordinal data collected via Likert scale items, (Sullivan & Artino, 2013), was analysed by performing descriptive statistical analysis (Wei & L. Lan, 2015). Pre-game survey data collected from 26 CALD students provided insight into their beliefs about the importance of content-specific vocabulary in mainstream classrooms. All students agreed that learning a new word is important to understand their subject areas, while more than half of these participants strongly agreed to this statement (see Figure 4.2).

Figure 4.2

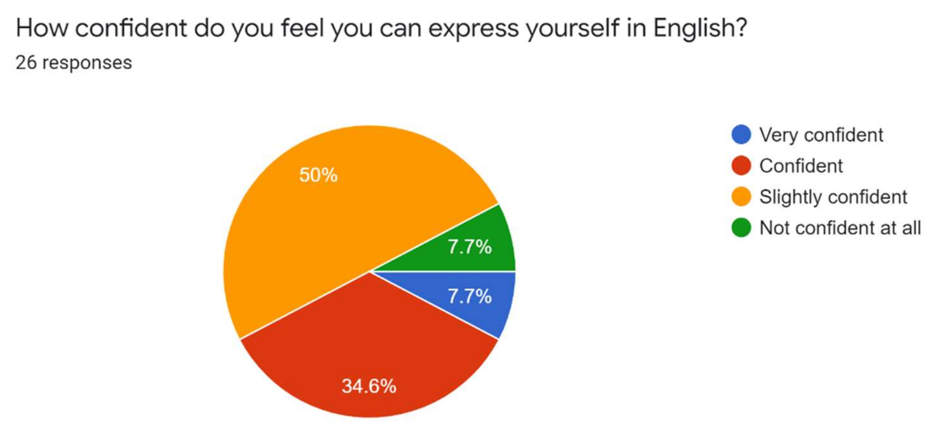
Visual Representation of Survey Results on Importance of Vocabulary and Confidence Level



However, as illustrated in Figure 4.3, nearly 60 per cent of all participants did not feel confident expressing themselves in the target language:

Figure 4.3

Visual Representation of Survey Results on Confidence of Expression in English



Furthermore, Figure 4.4 showed that more than 90 per cent of these EAL learners agreed that they did not understand the topic if they do not know the meaning of the related words:

Figure 4.4

Visual Representation of Survey Results on Content Comprehension and Difficult of Learning Words

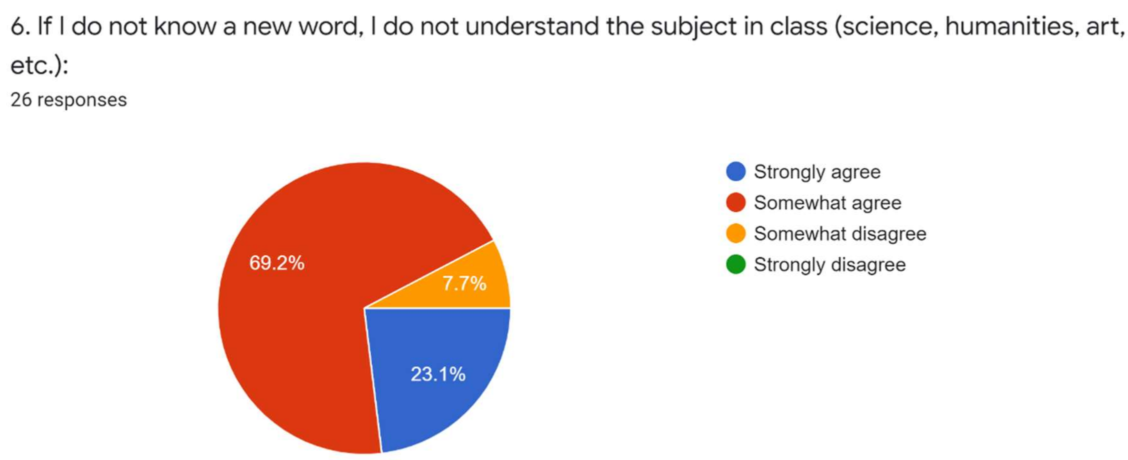
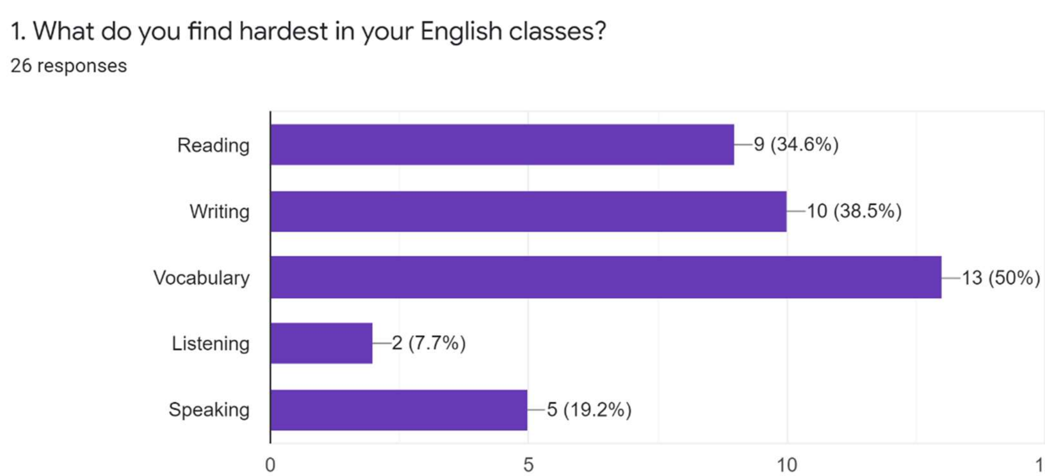


Figure 4.5 showed the expected results, which echoed the research problem and confirmed the motivation behind this study. The results also showed that half of these students are aware they were struggling with target vocabulary items (N = 13).

Figure 4.5

Visual Representation of Survey Results on What Learners Find Hardest in English



4.3.1.4 Statistical Analysis of Post-Game Survey

A few identical questions in the pre-game survey were also answered by only treatment group students in the post-game survey to monitor whether treatment group students' (N = 12) perceptions of using HMD VR games to learn vocabulary related to mainstream subjects shifted. A number was assigned to each response (4 = *strongly agree*; 3 = *somewhat agree*; 2 = *somewhat disagree*; 1 = *strongly disagree*) and data was entered into SPSS to determine whether there was a statistically different change to students' perceptions from pre- to post-game. The Shapiro-Wilk normality test was chosen and run before further statistical procedures could be conducted in order to determine whether the data set (scores) was drawn from a normally distributed population (Mackey & Gass, 2015). The results indicated that the data was significantly different from normal distribution (pre-game survey: $p = .004$, post-game survey: $p < .001$) (see Table 4.12). Wilcoxon test was the alternative to the parametric paired t-test when the assumption of normality is not met (Mackey & Gass, 2015; Meléndez et al., 2021). In other words, this non-parametric test provided valid results when the data violated assumptions (Helwig, 2019). Thus, a paired samples Wilcoxon test was adopted to measure the difference between treatment group students' perceptions before treatment compared to their belief after treatment.

Table 4.12

Test to Ascertain Whether Results Meet Normality

Shapiro-Wilk Test of Normality		
	N	*P*
Pre-game Survey	26	$.004^{*}$
Post-game Survey	12	$<.001^{**}$

Note. *$p < .05$. ** $p < .01$.

Data collected from each question was analysed, and the findings of the two questions which have resulted in a statistically significant difference are presented below. While this statistical analysis offered a collective view of opinions, it also captured the number of players that demonstrated reverse changes (i.e., from *agree* to *disagree)* in their opinions.

4.3.1.5 Statistical Findings of Post-Game Survey

Table 4.13 presents the results of common items related to the pre- and post-game survey question asking about their perceptions of whether VR game learning helped them learn new words, and whether the VR games was a fun way to learn new words. The results regarding Q1 suggested that there was a statistically significant difference (set at $p > .05$) between the pre- and post-game responses (RQ1: $p = .030$).

Regarding Q1, the post-game mean treatment group students ($N = 12$) increased by more than 30 per cent in comparison to pre-game mean ($M = 3.25 > M = 2.50$). Although most of these EAL students selected ‘somewhat disagree’ or ‘somewhat agree’ in the pre-game survey, their perception shifted to ‘strongly agree’ following their VR experience. The mean result indicated that despite the majority initially marking ‘somewhat disagree’, post-game experience, the treatment group students found VR games a useful method to learn target vocabulary. All in all, according to the results in Table 4.14 utilising headsets in a VR environment to learn new lexicon had been rated positively by the majority of these EAL players ($N = 7$).

Moreover, Table 4.13 also displays the statistical results of whether EAL pupils found VR games an appealing strategy to learn content terminology. CALD learners showed a statistically significant difference (Q2: $p = .008$*)* pre- to post-game experience. Although pre-game mean results revealed that not all students ‘strongly agreed’ that 3D simulation could be a fun method to learn target vocabulary, the significant increase in mean scores (by more than 26 per cent) manifested that, attitudes towards the entertaining factor of VR were found remarkably positive (*M* = 4.00 > *M* = 3.17). By way of explanation according to Table 4.14, these undergraduates had a great perception change about the appealing feature of these games. All EAL students strongly agreed that VR was a fun method to learn new words (*N* = 12, Q2: *M* = 4).

Table 4.13

Results of Paired Samples Wilcoxon Test to View Changes in Beliefs Pre- to Post-game Survey

Perception Question:	*M (SD)*		*p*	*N*	Minimum		Maximum		Nature of change pre- to post-game
	Pre-game	Post-game			Pre-game	Post-game	Pre-game	Post-game	
Q1. Do you agree that using VR games will help you learn new words?	2.50 (.798)	3.25 (452)	.030*	12	1	3	4	4	Somewhat disagree to somewhat agree
Q2. Do you agree that using VR games in class is a fun way to learn new words?	3.17 (.718)	4.00 (.000)	.008*	12	2	4	4	4	Agree to strongly agree

Notes. Paired t-test (two-tailed). * 4 = Strongly agree; 3 = Somewhat agree; 2 = Somewhat disagree; 1 = Strongly disagree. *p < .05

Table 4.14

Results of Mean Placement According to Perception by Wilcoxon Signed Ranks Test

Perception Question	**Negative Means**	**Positive Means**	**Ties**
Do you agree that using VR games will help you learn new words?	1[a]	7[b]	4[c]
Do you agree that using VR games in class is a fun way to learn new words?	0[a]	8[b]	4[c]

Notes. a. Pre-game > Post-game; b. Post-game > Pre-game; c. Pre-game = Post-game

4.3.2 Statistical Analysis of Pre-, Post- and Delayed Post-Tests

The pre- (T1), post- (T2), and delayed post-test (T3) results were co-marked by the researcher and a colleague to ensure the inter-rater reliability, and the percentage of agreement was 100 per cent (Mackey & Gass, 2015). The tests were scored out of 21, where each correct answer was worth one mark, and were then compared to assess language gains. The statistical analysis of these tests was conducted via a non-parametric Friedman test to compare total knowledge scores within each responder before, after, and two weeks after being exposed to the traditional or experimental methods. The average mean scores the 26 students were awarded for each test are listed in Table 4.15. In this case, the mean correlated with the average accurate responses. Data was collected from 13 control and 13 treatment group participants. Although the average mean of the control group increased in T2, it declined to its initial mean score (T2: $M = 8.15 > $ T3: $M = 6.23 =$ T1: $M = 6.23$) in the delayed post-test results. The mean of the treatment group also increased in T2 from T1, however, the decline of mean in T3 still outperformed T1 (T2: $M = 13.07 >$ T3: $M = 10.46 >$ T1: $M = 8.61$). Correspondingly, the difference between the mean score between T1 and T2 was higher for the treatment group (by more than 51 per cent) than the control group (by more than 30 per cent). This finding indicates that treatment group students' overall recognition of vocabulary items in post-test was higher than the control group (see Figure 4.6).

Table 4.15

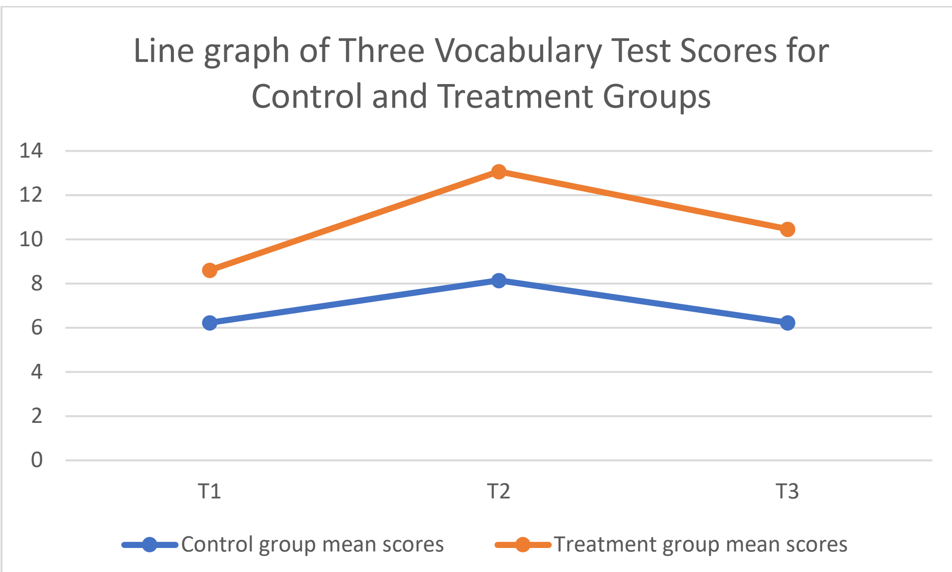
Descriptive Statistics of the Three Vocabulary Test Scores for Control and Treatment Groups

	Control				Treatment			
	N	*M (SD)*	Minimum	Maximum	*N*	*M (SD)*	Minimum	Maximum
T1	13	6.23 (3.767)	.00	13.00	13	8.61 (4.093)	.00	13.00
T2	13	8.15 (3.782)	3.00	14.00	13	13.07 (4.310)	2.00	19.00
T3	13	6.23 (3.2308)	1.00	13.00	13	10.46 (4.33)	2.00	17.00

Note. T1 = pre-test; T2 = post-test; T3 = delayed post-test.

Figure 4.6

Line Graph Visually Representing Three Vocabulary Test Scores for Control and Treatment Groups



The control and treatment groups' scores for each vocabulary test results were entered into SPSS to check for normal distribution and homogeneity of regression. P value of .05 was set for significance. Table 4.16 shows the results of the Shapiro-Wilk Test, indicating that there no statistically significant difference ($p > 0.5$), (pre-test: $p = .082$, post-test: $p = .158$, and delayed post-test $p = .245$). In other words, the results indicated that the data was not statistically significantly different from normal distribution. However, the assumptions for homogeneity of regression slopes were not met, ($p = .012$) (see Table 4.16), thus a non-parametric test was required as the null hypothesis was rejected. When the assumptions were not met, the non-parametric Friedman test was considered as an alternative to repeated-measures ANCOVA (Mackey & Gass, 2015; D.W. Zimmerman & Zumbo, 1993). That being the case, the Friedman test was found appropriate and applied to analyse the vocabulary test results.

Table 4.16

Tests to Ascertain Whether Results Meet Normality and Homogeneity of Regression

Shapiro-Wilk Test of Normality				**Test of Homogeneity of Regression**	
	M (SD)	*N*	*P*	*F*	*P*
T1	10.50 (4.593)	26	.082		
T2	14.33 (3.077)	26	.158	7.393	.012*
T3	13.00 (5.514)	26	.245		

Note. T1 = pre-test; T2 = post-test; T3 = delayed post-test.
*p < .05.

In the results of Table 4.17, the null hypothesis, which specified that there was no significant difference between the test results, was rejected for both control (p = .001) and treatment groups (p = .001). Results showed that the overall differences in the means of three tests measuring vocabulary gains differed significantly across tests. Whilst the Friedman test in Table 4.17 showed a statistically significant difference between tests for both groups, it did not indicate in between which tests the difference occurred. In order to determine whether there was a marked difference between pre- and post-tests, or whether the 3D games had an effect on vocabulary retention (delayed post-test), the Wilcoxon test was employed as a post-hoc test (D.W. Zimmerman & Zumbo, 1993). The post-hoc test also showed the difference within control group test results. Bonferroni correction (a more conservative approach to control the Type I error) was required to alleviate the statistical issue in multiple comparisons of the vocabulary tests (Ginns, 2005; Norris, 2015).

With respect to these multiple tests, the results of Bonferroni correction was supported by the findings reported by other metrics as well, such as mean scores and mean placement by Friedman Ranks Test, to decrease the possibility of a Type II error (Mathur & VanderWeele, 2018; VanderWeele & Mathur, 2019). Therefore, after Bonferroni adjustments, significance of paired comparisons amongst T1, T2, and T3 was the P value of .017 (Abdi, 2010; Ganguli et al., 2021). Thus, the analysis and findings of the control group are first described, followed by treatment group results. Later, a comparison between the groups' Wilcoxon test results was conducted. This comparison enabled the researcher to ascertain whether content-specific vocabulary acquisition and retention of those who experienced learning via HMD VR games statistically differed from EAL students exposed to the traditional method. This finding also addresses Research Question 3.

Table 4.17

Friedman Test Statistics to Determine Whether There is a Difference Between Tests

	Control			**Treatment**		
	N	*M (SD)*	*P*	*N*	*M (SD)*	*P*
T1	13	6.23 (3.767)		13	8.61 (4.093)	
T2	13	8.15 (3.782)	<.001*	13	13.07 (4.310)	<.001*
T3	13	6.23 (3.2308)		13	10.46 (4.33)	

Note. T1 = pre-test; T2 = post-test; T3 = delayed post-test. *p < .05.

4.3.2.1 Control Group

The Wilcoxon test results of control group participants, displayed in Table 4.18, indicated that there is a statistically significant difference between T1 and T2 (*p* = .003). On that account, students participating in the traditional classroom environment did acquire target lexis. However, the magnitude of the overall increase between T1and T2 is 30 per cent. The results also displayed that these EAL learners failed to retain these acquired target words in two ways: First, there was a statistically significant difference between T2 and T3, with the mean score higher in the former test than the latter (*M* = 8.15 > *M* = 6.23, *p* = .001), indicating a difference between participant performance in T2 and T3. That is, students answered more vocabulary questions accurately in T2 than T3 which caused the dissimilarity. The post-hoc test on word retention also showed that there was no statistically significant difference between T1 and T3 (*p* = .877). Students' average vocabulary knowledge two weeks after the T2 was found to be like their T1 scores.

Table 4.18

Wilcoxon Test Statistics of Differences for Control Group in Vocabulary Acquisition Across Three Tests

	M (SD)				***Post-hoc (Wilcoxon Tests)***		
	T1	T2	T3	p	T1 -T2	T1-T3	T2-T3
Vocabulary test scores	6.23 (3.767)	8.15 (3.782)	6.23 (3.230)	.001*	.003*	.877	.001*

Note. T1 = pre-test; T2 = post-test; T3 = delayed post-test.
*p < .017 with Bonferroni correction.

Table 4.19 displayed ties and positive and negative means for T1-T2, T1-T3, and T2-T3 according to their performance. According to these results, most control group students (*N* = 11) received a positive mean (T2 > T1), denoting that they recognised more words in T2 than T1. Nevertheless, two students' T1 and T2 results were equal (ties T1 - T2: *N* = 2), suggesting that they failed to acquire new words via the conventional method. Furthermore, all (*N* = 13) received a negative mean between T2 and T3 (T2 > T3), suggesting they recognised less target words in T3 in comparison to T2 results. In other words, none of the control group participants in the traditional classroom setting retained content-specific terminology (ties T2-T3: N = 0), however, five students recognised slightly more vocabulary items in T3 in comparison to their T1 (T3 > T1: N = 5).

Table 4.19

Control Group Students' Mean Placement According to Performance by Friedman Ranks Test

	Control Group Students' Mean Placement		
	T1 -T2	T1-T3	T2-T3
	N	N	N
Positive Means	11[b].	5[e]	0[h]
Negative Means	0[a]	5[d]	13[g]
Ties	2[c]	3[f]	0[i]

Notes. a. T2 < T1; b. T2 > T1; c. T2 = T1; d. T3< T1; e. T3 > T1; f. T3 = T1; g. T3 < T2; h. T3 > T2; i. T3 = T2

4.3.2.2 Treatment group

Table 4.20 presents the Wilcoxon test results of the treatment group, revealing a significant difference between T1 and T2 (p = .001), thus rejecting the null hypothesis. In light of these results, playing HMD VR games increased EAL students' content-specific linguistic repertoire. The magnitude of the general increase between T1 and T2 was computed as 51.8 percent, with an average of 4.46 vocabulary items post intervention (T2: M = 13.07 > T1: M = 8.61).

The results also showed that there was no significant difference (p = .018) between T2 and T3 results, although the mean score was higher in the former test than the later (T2: M = 13.07 > T3: M = 10.46). Thus, there was no notable change in students' vocabulary gains two weeks after the VR experience, in comparison to T2 results. Even two weeks after being immersed in a content-based 3D simulation, average T3 mean scores indicated that these learners still maintained 41.48 per cent of their new acquired vocabulary knowledge.

This finding indicated that the treatment group students did not only perform better in T2 in comparison to T1, but they also retained the target lexis as suggested by their T3 scores.

Table 4.20

Wilcoxon Test Statistics of Differences for Treatment Group in Vocabulary Acquisition Across Three Tests

	M (SD)				***Post-hoc (Wilcoxon Tests)***		
	T1	T2	T3	p	T1 -T2	T1-T3	T2-T3
Vocabulary test scores	8.61 (4.093)	13.07 (4.310)	10.46 (4.33)	.001*	.001*	.099	.018

Note. T1 = pre-test; T2 = post-test; T3 = delayed post-test.
*p < .017 with Bonferroni correction.

Table 4.21 presents the number of treatment group participants placed across the three tests according to their mean placement of their marks generated by the Freidman Ranks Test. In accordance with these results, all students (*N* = 13) had a higher mean (T2 > T1) after they played nine immersive games and increased their content word knowledge upon their intervention. Furthermore, the majority of treatment group students (*N* = 10) received a higher mark for T3 than T2 (positive mean: T3 > T1), denoting that they recognised more words in the latter. Only three of these learners recognised less target words in T3 than T1 (negative mean T1 > T3: *N* = 3). Importantly, despite seven participants receiving negative means with reference to the final test, (negative mean T2 -T3: *N* = 7), six students received similar scores in T2 and T3 (ties T2-T3: *N* = 6). Although most students (*N* = 7) recognised less target vocabulary in T3 in comparison to the T2 results, a noteworthy number (*N* = 6) retained their knowledge even after not being exposed to those target words via the VR games two weeks after their treatment.

Table 4.21

Treatment Group Students' Mean Placement According to Performance by Friedman Ranks Test

	Treatment Group Students' Mean Placement		
	T1 -T2	T1-T3	T2-T3
	N	N	N
Positive Means	13[b].	10[e]	0[h]
Negative Means	0[a]	3[d]	7[g]
Ties	0[c]	0[f]	6[i]

Notes. a. T2 < T1; b. T2 > T1; c. T2 = T1; d. T3< T1; e. T3 > T1; f. T3 = T1; g. T3 < T2; h. T3 > T2; i. T3 = T2

4.3.2.3 Comparison of Control and Treatment Group Results

In light of the results presented above, for the control group the T2 mean increased by 30 per cent in relation to the T1 mean ($M = 6.23$), while the treatment group mean increased by 51.8 per cent, showing that students who played HMD VR games improved their content-specific vocabulary with a higher score, as they recognised more target words accurately in T2. Even though vocabulary gains in neither group showed a significant difference in their scores between T1 and T3 (treatment group T1-T3: $p = .099$ vs. control group T1-T3: $p = .877$), the post-hoc test measuring vocabulary retention showed that treatment group students' vocabulary knowledge in the final test (T3) outperformed the pre-test (T1) by more than 21 per cent ($M = 10.46 > M = 8.61$). In contrast, control group students' improvement between T1 and T3 was 0 per cent ($M = 6.23 = M = 6.23$).

The T3 comparisons supported the claim of vocabulary retention in two ways: The average number of target vocabulary treatment group students recognised correctly in T2 and T3 test results were quite similar albeit a slight decrease in the most recently conducted test results (T2: $M = 13.07 >$ T3: $M = 10.46$). However, in contrast to treatment group, there is a statistically significant negative mean difference between T2 and T3 ($p = .001$) for control group students, suggesting learners did not remember the words they accurately recognised in T2.

The mean placement according to performance showed difference between control and treatment groups. Whilst there was no difference of positive means for T1 and T2 between the two groups (positive means T1-T2: treatment; $N = 13 >$ control; $N = 11$), the treatment group outperformed the control group regarding T2 and T3 (ties T2-T3: treatment; $N = 6 >$ control; $N = 0$) and T1 and T3 (positive means T1-T3: treatment; $N = 10 >$ control; $N = 5$). In other words, only 50 per cent of the control group performed better in the delayed post-test than in the pre-test. This rate was significantly increased in the treatment group, where 76 per cent increased their vocabulary score in T3 compared to the control group. Similarly, in comparison to T2, 46 per cent of the treatment group remembered the same amount of target items in T3 (treatment group ties T2-T3: $N = 6$), two weeks after playing the immersive games. However, this number was zero in the control group (control group ties T2-T3: $N = 0$), indicating that none of these EAL learners retained the content-specific vocabulary following the traditional instruction.

4.4 Chapter Summary

This chapter presented the qualitative and quantitative findings that arose from the analysis of the data. First, an outline of this chapter was provided. Then, results of qualitative data were reported. Next, participant responses to the pre-game survey were set forth, describing these culturally and linguistically diverse students' demographic background. Subsequently, the methods used to code and analyse the qualitative data were elaborated. Following this, a description of seven themes explored from the analysis process were provided.

Results of the quantitative data were also reported in this chapter. Students' perceptions on the significance of content lexis conducive to understanding subject matter was illustrated via pie charts. The shift in treatment group EAL learners' perceptions pre- to post-game was demonstrated through non-parametric paired t-test results. The analysis and correlation amongst vocabulary scores of control and treatment group participants were detailed separately in by way of Friedman and post-hoc tests. Thereafter, an explanation was given about the comparison of results, revealing significant similarities and differences between EAL students regarding vocabulary acquisition and retention.

Chapter 5 presents the discussion of the qualitative findings and quantitative results.

Chapter 5: Discussion

5.1 Chapter Overview

The previous chapter provided an in-depth presentation of the qualitative and quantitative findings that address the research questions (RQ) of this study. Chapter 3 discussed the methods used to code and analyse the qualitative data. Following this, results of qualitative data were reported in the first section of Chapter 4 (Section 4.2). Chapter 4 provided a description of the following seven themes which emerged from the analysis: (1) highly immersive learning environment, (2) the fun factor (3) interaction with content-specific vocabulary items, (4) virtual reality (VR) visualisation of content-specific vocabulary items, (5) enhanced vocabulary acquisition and retention, (6) insufficiency of adequate educational properties, and (7) technical problems in playing VR games.

This was followed by the explanation of quantitative data results in the second section of Chapter 4 (Section 4.3). It reported the results of pre- and post-game surveys. Then, the analysis and correlation amongst vocabulary scores of participants in both control and treatment groups were compared and a detailed description was given about the comparison of results regarding vocabulary acquisition and retention.

Chapter 5 discusses and integrates the qualitative and quantitative results of this research. It reiterates the objective of this study, the three research questions, the methods employed to explore the results related to the current investigation, and the participants in Section 5.2. Section 5.3 discusses the findings from the closed-ended pre- and post-game survey results, and the results derived from the triangulated qualitative data to answer RQ 1. This section presents a discussion on how Middle Eastern English as an additional language (EAL) learners perceived playing head mounted display (HMD) VR games to engage with content-specific vocabulary items.

Next, Section 5.4 presents the answer to Research Question 2. It discusses the knowledge and general application of HMD VR games to educational environments and identifies specific aspects of this VR approach that either facilitate or hinder vocabulary acquisition and retention of culturally and linguistically diverse (CALD) students in mainstream classrooms.

Subsequently, Section 5.5 associates and discusses the central findings of quantitative results to answer Research Question 3. This section also establishes a link between the answers to the three Research Questions to synthesise and discuss the results holistically. Finally, a summary of Chapter 5 is provided in Section 5.6.

5.2 The Research Problem

To address a gap in the research knowledge and contribute to education initiatives, the aim of this thesis is to investigate the impacts of HMD VR games on content-specific vocabulary acquisition and retention, tapping into Middle Eastern EAL students' perceptions of experiencing 3D simulation environments to engage with the content. The following central research questions were addressed in this study:

- **RQ 1.** How do EAL learners perceive their first-hand experience of using headset-enabled, educational VR games to engage with the content-specific vocabulary items?
- **RQ 2.** What are the aspects of a headset-enabled, VR game-based learning environment that can facilitate or hinder content-specific vocabulary learning?
- **RQ 3.** To what extent does a VR game based, headset-enabled approach's effects differ from a traditional textbook-based approach in EAL learners' acquisition and retention of content-specific vocabulary?

The empirical part of this thesis entailed a concurrent mixed-methods research design (see Chapter 3, Section 3.3) to collect qualitative data via open-ended survey questions, semi-structured interviews, exit slip responses, an observation scheme and field notes, and a research journal. Quantitative data was collected through closed-ended survey items, and vocabulary test results. A sample of 26 Middle Eastern learners aged 12 and 13 participated in this research for 12 weeks. Students were divided into two groups via simple random sampling to form a treatment and control group. The control group was exposed to the traditional method of completing post-reading tasks on paper to learn new words, whilst the experimental group played nine HMD VR games as an alternative.

Consequently, this study explores these CALD students' perspectives on using VR technologies in classrooms to engage with the content related to Humanities and Social Sciences (HASS), The Arts, and Science, with respect to the Western Australia (WA) curriculum. Moreover, it aims to bring light to students' experiences on the facets of 3D immersive games that can facilitate or hinder vocabulary acquisition and retention. The research in this thesis also investigates whether there is a difference in content-specific vocabulary acquisition and retention of Middle Eastern EAL students between control and treatment groups.

5.3 Discussion of Findings to Answer Research Question 1

- **RQ 1. How do EAL learners perceive their first-hand experience of using headset-enabled, educational VR games to engage with the content-specific vocabulary items?**

Findings drawn from the result of the paired t-test and qualitative data (semi-structured focus group interviews, exit slips, research journal, and observation notes) related to the first research question showed experimental group students' attitude towards the new learning method. The following three distinct themes were generated in Chapter 4 from Middle Eastern EAL learners' viewpoints on their first-hand experience using educational HMD VR games to engage with the content-specific vocabulary items: (1) highly immersive learning environment, (2) the fun factor, and (3) insufficiency of adequate educational properties.

5.3.1 Positive Aspects: Perceptions of Headset-Enabled VR Games

5.3.1.1 Highly Immersive Learning Environment

Highly immersive environment refers to how Middle Eastern EAL players perceived the sense of telepresence afforded by HMD as an advantage to engage with the content-lexis. Students articulated that VR environments augmented by headsets allowed players to be immersed in discovering the topic via telepresence. A case in point was made by Reem, who called out *"*We are in the brain, oh my God!" whilst playing the InMind 2 game (Observation Scheme, 2018) (see Chapter 4, Table 4.4). After playing the Diving VR game, Kareem said *"it [diving game] helped me learn the words because it was like I was seeing it in real life"* (Exit Slip, 2018) (see Chapter 4, Table 4.2). This feeling of high immersion could be a result of players teleporting to virtual spaces and being able to easily manipulate the 3D objects or characters in the HMD VR games. This feeling of telepresence may have made these EAL participants feel like their bodies and minds were literally merged into the games. Another example could be related to Hassan saying, "I can touch it [cells] Miss" whilst playing the InMind 2 game (Observation Scheme, 2018) (see Chapter 4, Table 4.4), reflecting on this experience by conceptualising even abstract concepts based on concrete experiences.

EAL learners' views of high immersion in a 3D simulation environment may have formed an effective basis to learn new content-based lexis through direct experiential experience, such as diving with sea creatures in the Diving VR game. This immersive simulation approach seems to have helped learners explore the low frequency target words that are hard to grasp only in text. In such a reflective and learner-centred immersive environment, language learners may have incidentally acquired the academic terminology. For example, they may have learnt the names of the cells by self-directing their movements, monitoring and reflecting on their first-hand experiences through these games, thus developing learner autonomy. Also reported in previous research (Barab & Duffy, 2000; Y. J. Lin & Wang, 2021; Shih & Yang, 2008), feeling highly immersed in the subject matter context could be an innovative approach to deepening understanding and acquiring content-specific words.

Moreover, students' responses about feeling fully involved in the game (see Chapter 4, Table 4.4) inferred that these immersive games enhanced their motivation to deeply engage with the content. For example, Kareem expressed how he favoured the VR environment over the traditional classroom: "It's a lot better [the VR environment]. It's like you are in there. You can see how it looks like if you actually want to know [learn]" (Interview, 2018) (see Chapter 4, Section 4.2.2). Learners in this study embraced the identity of astronauts in space when playing the Solar System Museum VR game. They teleported to their preferred planets and listened to information about each planet upon landing. The strong sense of telepresence amplified by headsets could have increased the learners' attention and involvement in the context. This experience of teleporting to new environments and manipulating objects related to the subject matter differed positively from learning these content-based words by sitting on a chair, reading texts, and looking up meanings through an English dictionary. As confirmed by previous research (Alizadeh, 2019; Faiola et al., 2013; Ravenscroft, 2007), telepresence may have led to greater engagement and interaction with the target vocabulary related to the solar system that was situated in the context (A. Cheng et al., 2017; Kaplan-Rakowski & Wojdynski, 2018; Legault et al., 2019).

Qualitative data presented in Chapter 4, Table 4.4 showed the perceived highly immersive nature of HMD VR situated learning, enabling students to gain palpable experience and acquire target vocabulary through actively accomplishing real-life like tasks. An instance of this occurrence was detailed by Laila, claiming that being immersed in situations helped her learn new words: “It will help learn new words as you might understand it better in 3D where you feel like you are actually there. It’s a good experience” (Interview, 2018) (see Chapter 4, Section 4.4). As learning a foreign language cannot be dissociated from the contextual engagement (Fox, 1997), students may have learned through situational involvement. This may have been accomplished by integrating HMD to content-based VR environments, which differs positively from conventional instruction methods. Previous research also suggested that high immersion was conducive to situated learning, as this empowered learners to learn the target lexis through teleporting in content-based situations and involving them in contexts to accomplish real-like tasks by using the target words or interacting with the target words (Blyth, 2018; J.C. Chen, 2016; A. Cheng et al., 2017; Y.J. Lan, 2020; P. Li et al., 2020).

On the whole, despite EAL participants inability to dissect a body in anatomy, travel to space, interact with asteroids, travel in time, or swim to discover marine life in the classroom, highly immersive simulations configured in a 3D virtual environment enabled these CALD learners to construct new knowledge and create new understanding whilst being exposed to content-specific lexicon. Therefore, findings suggest that high immersion in situated contexts may have assisted students to learn new words by living in the content (Alfadil, 2020). This could be a result of word knowledge being created and built up through direct experiences (Godwin-Jones, 2019; Sykes, 2019), where language learners have a better chance at grasping, retaining, and conceptualising new knowledge via learning-by-doing situations (Parmawati, 2019; Winner & Crooke, 2021; Youngblut, 1998). VR, in this sense, allowed students to be actively engaged in a task and being a part of the content to recall acquired knowledge through immersive simulation, thus providing more memorable first-person experiences (Mantovani et al., 2001; Minocha, 2015).

The sense of immersion and telepresence afforded by HMD VR games leading to stronger and positive influence on EAL's vocabulary gains was also reported in previous research (Alfadil, 2020; K. W. K. Lai & Chen, 2021). To conclude, an authentic setting with a sense of exploration and presence was offered by this novel method. Consequently, learners' perception of virtually exploring these contexts may have led them to engage with the subject matter and related target vocabulary (see also Craddok, 2018; Deutschmann & Panichi, 2009; Su et al., 2022**)**.

5.3.1.2 The Fun Factor

Another salient feature of adopting HMD VR that was frequently mentioned by players in their responses was the element of 'fun' (see Chapter 4, Table 4.5). This fun factor offered by highly immersive VR games was compared to the traditional classroom environment by Salma as follows: "I think it's [HMD VR games] really useful and it's actually quite fun because if [you] want to learn you don't want to sit down on your chair and look at one screen which is the board" (Interview, 2018) (see Appendix I). Besides learners' perception that gaining knowledge through situated immersive learning was far more appealing than answering questions about the content via pen and paper: having fun may have motivated them to invest more time and effort in learning target words (Bavi, 2018; Ebrahimzadeh & Alavi, 2016) as implied by Hassan below:

> If we actually do it [play VR games] in class, we would enjoy what we are doing. Let's say the teacher gives us homework, we can do it on VR, it will be actually more fun because you want to do it so you will spend more time to do it and you can learn more. (Hassan, Interview, 2018) (see Chapter 4, Table 4.2)

This perception of fun may be related to EAL learners being increasingly invested in online games outside of school (Alfadil, 2020; Rhodes, 2017). This fun element was important as it could have played a significant role in boosting student motivation, leading to higher engagement with the situated learning environment (Cameron & Bizo, 2019; J.C. Chen & Kent, 2020; Sun & Hsieh, 2018). Moreover, the fun factor was useful for vocabulary acquisition, as it increased students' engagement with the HMD VR games by providing creative learning methods through telepresence in a virtual environment (e.g., Alfadil, 2020; Calvo-Ferrer, 2017; Tseng & Schmitt, 2008).

In addition to the motivation aspect, qualitative data showed that learners enjoyed interacting with realistic visuals of target content vocabulary. This enjoyment may have enhanced the vocabulary learning process. For instance, Kareem expressed that it was fun to see the 3D version of the carbons (Exit Slip, 2018) (see Appendix I), and Hassan echoed his peer, stating that visualising the target content words through VR made abstract concepts concrete and learning fun (Interview, 2018) (see Chapter 4, Section 4.2.2). This motivation factor offered by the innovative technology may explain how students experiencing high immersion achieved higher vocabulary mean scores than their peers using the traditional method. Whilst the control group increased their vocabulary knowledge by 30 per cent, treatment group's vocabulary acquisition score increased by 51.8 per cent. This suggested that students who played HMD VR games demonstrated a greater improvement in their content-specific vocabulary as they recognised more target words accurately in the post-test than their control group counterparts. Therefore, artificially generated 3D environments may have fostered vocabulary acquisition and retention by involving players in the context for a longer time in a fashion that was not boring.

As a result, learners indicated two main reasons to explain how the fun element stimulated their engagement with the content-specific vocabulary items. Firstly, previous research (see Chandramouli et al., 2014; C.H. Chen et al., 2021) supports the notion that EAL players favoured discovering the content through highly immersive games to learn academic knowledge in comparison to traditional method. The excitement of playing games through encountering situations they had not experienced in real life and by freely moving around to discover contexts may have led to their growing investment of time and effort in learning the topic and content vocabulary (see J.C. Chen, 2016; Lewis et al., 2019; J.W. Lin et al., 2017; Nah et al., 2013). Secondly, viewing target objects in a 3D fashion through being a part of the game, therefore content, may have reinforced their opinion of having fun learning academic content and related terminology (see also Gadelha, 2018; Sala, 2016). Altogether, the fun feature of VR games may have bolstered learner engagement and empowered them to immerse themselves in and deeply connect with the content (see similar findings in Gadelha, 2018; Wichadee & Pattanapichet, 2018).

5.3.2 Negative Aspects: Perceptions of Headset-Enabled VR Games

5.3.2.1 Insufficiency of Adequate Educational Properties

Although the HMD VR applications introduced the target vocabulary items in 3D form, and most games contextualised meaning-making supported by multimodality, learners wanted better storylines and more textual or audio explanation of the subject matter (see Chapter 4, Table 4.9). A case in point was made by Salma, claiming that Magi Chapel lacked presenting sufficient content information: "What I didn't like is the fact that it didn't have much information about each portrait and there wasn't much action to learn from" (Exit Slip, 2018) (see Chapter 4, Table 4.2). Therefore, according to EAL players' frame of reference, not all games equally supported content vocabulary learning. Zehra clearly stated the effects of inadequate educational features on vocabulary acquisition: "I didn't learn any new words because there was no talking in it" (Exit Slip, 2018) (see Chapter 4, Table 4.9). In other words, learners suggested that properties such as the presentation of audio and textual information and storylines of each educational game should be considered as a whole and aligned with lesson objectives. This finding could explicate the negative impact of missing written and verbal information on language learners' vocabulary acquisition.

This theme could have emerged as a result of not all games offering learners effective interaction with the content and target words. For example, action games (e.g., InCell VR, and InMind 2) prompted students to apply word knowledge in order to progress to the next level were preferred over the Magi Chapel game in that learners only observed portraits and received limited information.

Conversely, sufficient educational properties had a positive impact on vocabulary learning. Kareem's quote best describes this situation:

> It [InCell VR] helped me a lot because if you play the game you have to understand it. The concept of the game are the words. I had to know the words to play the game and I did and knew what was good and bad. (Kareem, Exit Slip, 2018) (see Chapter 4, Table 4.2)

Students indicated that HMD VR games were beneficial when they promoted practice and applied the target vocabulary items as a strategy in order to accomplish the mission (goal) in the games. Games that which provided the motivation and knowledge to use the target words could result in the elaboration of the meaning of the target words (Gee, 2005; Hulstijn & Laufer, 2001a; Hulstijn & Laufer, 2001; Namaziandost et al., 2020). Like the current study, previous research has also shown the importance of carefully considering educational facets of designed games, as these educational properties have a vital effect on learning outcomes (e.g., Dawley & Dede, 2014; Gee, 2005; Hooshyar et al., 2018; Klopfer, 2017).

One of the findings of this study is that learners demanded further content information. This request was illustrated by Salma as follows: "Even though you get to see it [artwork] from different angles it [Magi Chapel] didn't have as much information as it did in the worksheet" (Interview, 2018) (see Chapter 4, Section 4.2.2). Interestingly, in contrast to the cognitive load theory, which suggests that multimodal instruments may have presented too many visuals and information all at once, thus cognitively overloading the students (Mutlu-Bayraktar et al., 2019), the result of this study suggested the opposite. This could be explained as a result of the nature of HMD VR games. The realistic perception of learners feeling like they were part of the simulation could have decreased the cognitive load as working capacity may be increased by the visual, auditory, and haptic stimuli through immersive simulation (Killi, 2005). For instance, in the InCell VR game, learners were virtually living inside the human body, interacting with the content-specific objects related to internal organs. Although discovering cells and how organelles functioned resulted in a high cognitive load due to the abstract concept, InCell VR may have helped to visualise and situate key vocabulary within the simulated context. Thus, the cognitive load was reduced as only reading the target word and its meaning was removed as the necessary component to understand the subject matter and content-specific vocabulary. Instead, learners were presented with visual audial and written cues in life like scenarios to acquire the target lexis (Craddock, 2018).

Besides requesting further content information, as suggested by Kareem below, these EAL players demanded opportunities to interact with the content whilst playing the immersive games: "What I didn't like about the game [Magi Chapel] was that the function was limited and there was nothing we can interact with" (Interview, 2018) (see Chapter 4, Table 4.9). Thus, these EAL adolescents may have been better at spreading their attention over a wide range of events. For example, whilst travelling in the human body in the InCell game, players also needed to make quick decisions if they come across a virus. Should they have decided it was a virus, they needed to shoot the virus whilst also reading information about the function of each cell. Thus, games such as InMind 2, where players travelled in the human mind, read labels, listened to content information may have aligned with students' learning styles that enabled parallel content processing and multitasking (Prensky, 2001). As a result, participants in this study did not complain about being overloaded cognitively. On the contrary, they requested better storylines and more opportunities to multitask and parallel process whilst engaging with the subject matter.

To summarise, the most significant findings for this research question were in relation to the aspects that explore how EAL learners perceived their first-hand experience of using headset-enabled, educational VR games to engage with the content-specific vocabulary items. It was found that these CALD participants perceived the feeling of telepresence amplified by HMD as an advantage to engage with the content-lexis. Moreover, these players frequently mentioned that learning content-specific vocabulary items through HMD VR games was 'fun' and heightened their engagement with the subject matter. Another key finding was where learners demanded further content information. Interestingly, this finding contrasted with the cognitive load theory, which suggested that multimodal instruments may cognitively overwhelm the students with too many visuals and information presented all at once (Mutlu-Bayratar et al., 2019). To better understand the meaning of content lexis, learners in this study demanded further written and audial information alongside the 3D visualisation of the target words related to the subject matter.

Drawing upon the perspectives of the CALD students, the findings in response to Research Question 1 could provide the basis for an alternative method to language learning in a traditional setting. That is, headsets configured in 3D simulations could be implemented in classrooms to engage students in discovering the context and entertain them whilst they were learning the subject matter and academic terminology (J.C. Chen, 2016; Dawley & Dede, 2014; Kaplan-Rakowski & Gruber, 2019). Student criticisms about the educational properties of games could serve as selection criteria for teachers to consider when using effective games to teach academic vocabulary in mainstream subjects. Moreover, ensuring that there is enough space in the classroom to play these games is important to prevent possible injuries due to students moving around whilst playing the games. Teachers also need to plan and upskill, based on pedagogical guidance, to implement this technology, and seek technical support from schools.

5.4 Discussion of Findings to Answer Research Question 2

- **RQ. 2 What are the aspects of a headset-enabled, VR game-based learning environment that can facilitate or hinder content-specific vocabulary learning?**

To answer the second research question, findings of the qualitative data (semi-structured focus group interviews, exit slips, research journal, and observation notes) analysis, conducted through a thematic analysis that employed an open coding technique. After assigning open codes to the data, an axial coding technique was employed to construct thematic categories and make connections across categories, where codes were sorted into lists, resulting in groups of codes (see Chapter 4, Section 4.2.2). To address this research question, the positive aspects of VR game-based learning that were found to facilitate content-specific vocabulary acquisition include (1) Interaction with content-specific vocabulary items, (2) VR visualisation of content-specific vocabulary items and, (3) Enhanced vocabulary acquisition and retention. Finally, (4) Technical problems in playing VR games were identified as a negative aspect hindering vocabulary learning.

5.4.1 Positive Aspects: Effects of HMD VR Games on Vocabulary Acquisition and Retention

5.4.1.1 Interaction with Content-Specific Vocabulary Items

According to the data presented in Chapter 4, Table 4.6, EAL learners reflected on their gaming experience and commented that interacting with content words, such as manipulating planets and asteroids, fostered their acquisition of subject terminology. Yousef's response to an Exit Slip question showed how direct interaction assisted with the vocabulary acquisition process: *"*It helped me learn new words because it was very interactive and it was talking walking you through the words*"* (Exit Slip, 2018) (see Chapter 4, Section 4.2.2). Salma also pointed out how interaction with virtual spaces affects the vocabulary acquisition process in comparison to the traditional environment: “You want to interact and see other places than just one classroom, so it basically helps us with learning words instead of just looking at them you basically get to see it and what the actual thing is” (Interview, 2018) (see Chapter 4, Table 4.2). The fact that interaction fosters vocabulary learning was also echoed by Kareem: “It [Solar System] helped me learn new words by allowing me to pick any planet and I picked Pluto. It told me all about Pluto and a lot of things about it” (Exit Slip, 2018).

CALD learners opined that HMD VR games made their learning experience rewarding via interaction could be a further explanation for treatment group learners’ high mean scores gained from the vocabulary tests. The post-hoc test measuring vocabulary retention showed that treatment group students’ vocabulary knowledge in the delayed post-test outperformed the pre-test by more than 21 per cent ($M = 10.46 > M = 8.61$). In contrast, control group students’ improvement between pre- and delayed post-test was 0 per cent ($M = 6.23 = M = 6.23$). The finding that interactivity promoted the vocabulary learning process could have been a result of VR games allowing players to choose target objects (such as carbons) and observe them in 360-degree views, to directly ‘touch’ the virus in the InCell VR game or catch asteroids to stop them in Solar System Museum VR game. This result suggested that the unique property of highly immersive VR games enabled EAL to interact not only with content learning, but also the related target words.

Furthermore, participants associated interacting with the topic to active learning of new words. Rania referred to the InCell game, explaining how active engagement prompted target lexis acquisition: “InCell helped me learn new words because you have to try and fight of the virus and go to the nucleus” (Interview, 2018). This could be a result of HMD VR enabling learners to explore the subject matter and satisfy their minds’ curiosity by solving issues (Kassem, 2018; Schcolnik et al., 2006). As the students’ minds were highly activated in the immersive environment through headsets, this interaction may have stimulated the working memory to be readily available to acquire new lexis and actively hold content-specific words gained through the visuals and audio information (Amiryousefi & Ketabi, 2001; Baddeley, 2002; Preston & Edwards, 2007; Ramezanali, 2017).

Further explanations of how interacting and observing the visualisations of target words in 360-degree rotations were provided by EAL participants:

> I think it's [VR games] cool because we like to rather be interactive and do something instead of writing paragraphs and essays. (Rania, Interview, 2018)
> It (HMD VR games) was much more interactive. We got up walked around and saw new things instead of sitting down and looking at one direct screen we could look at 360-degree rotations. (Zehra, Interview, 2018) (see Chapter 4, Table 4.6)

These participants' verbatim accounts implied that making interconnections with content words and contexts through 3D simulations may have assisted learners to link form to meaning (González-Fernández & Schmitt, 2020; Reynolds et al., 2015; Van Zeeland & Schmitt, 2013). For example, whilst playing the InCell VR game, students were virtually travelling in a human body for the whole game and probably interacting with target words, such as identifying the virus and trying to shoot it. This direct interaction with the virtual environment and related content lexis could have deepened their understanding and acquisition of academic words. Coinciding with previous research findings (Alfadil, 2020; Monteiro & Ribeiro, 2020; Tai et al., 2020; Zhonggen, 2018), the interactive property of HMD VR games that enable language learners to solidify experiences by virtually touching or manipulating objects were seen as an invaluable and effective approach to foster vocabulary learning.

5.4.1.2 VR Visualisation of Content-Specific Vocabulary Items

Another salient feature of highly immersive VR that facilitated lexicon acquisition, arising from the triangulated data reported in Chapter 4, Table 4.7, manifested target items in a three-dimensional (3D) fashion. According to the interview and exit slip data, students commented that the visual components in the VR environment made knowledge construction of vocabulary items more concrete and manageable. Thus, it reduced their cognitive load by presenting visual cues of the target words related to complex concepts. A point in case was mentioned by Fatma:

> [In] The Carbon game where it showed the carbons, it was nice to be able to see how they arranged the atoms because it showed how the graphited the atoms arranged, and it wrote the words on the diagram, so it was helpful to learn the words. (Interview, 2018) (see Chapter 4, Table 4.2)

This perception could be supported by the cognitive theory of multi-modal learning, indicating that language learners may have actively constructed new knowledge of unfamiliar words through working memory supported by visuals and textual modes (e.g., see Mayer, 2014). Specifically, this may have linked to students perceiving information exposure and visuals to be a natural and preferred way of receiving information, where text could be mixed with graphics to activate the sensory mechanisms in working memory through the content-based games (e.g., see Prenksy, 2001). Put differently, as information came to sensory memory (through ears or eyes), learners may have selected the verbal and visual language items presented. Then, CALD students may have organised these selected items by establishing a link between the verbal and visual modes, such as mapping out the text 'graphite' to the corresponding 3D visual.

Furthermore, Hassan explained the role of immersive games whilst learning about carbons in Science: "The worksheet told us what it is it gave the name, but VR showed us what it was so the graphics and all that it showed us what it looked like and what it meant" (Interview, 2018). As such, 3D visual representations may have clarified the abstract content by connecting the meaning of content-based vocabulary, making cognitively demanding content more concrete and therefore manageable (Gadelha, 2018; Pigatt & Braman, 2016). Eliminating the difference between the acquisition of concrete and abstract nouns by supplying visualised contextual information could have escalated this learning process (Liebscher & Groppe, 2003; Schwanenflugel & Shoben, 1983; Wattenmaker & Shoben, 1987). This positive result was also found in previous research, where visuals were identified as one of the key attributes of HMD VR to optimise EAL's vocabulary (e.g., see Monteiro & Ribeiro, 2020).

Another explanation for 3D visualisation of content vocabulary that fosters word acquisition could be due to this advanced technology presenting real like target objects indistinguishable from real life. For example, whilst playing the Qantas VR game, one student said, "Wow, I get to see what a harbour is" (Observation Scheme, 2018), as if she had seen it in real life. HMD VR may have encouraged language learners to associate their virtual experiences with direct experiences (see Kwon, 2019) since they could literally travel through an atom to look at the bonding of carbons or visiting historical venues to interact with content vocabulary items in 3D form. Previous research also suggests that learners evaluating and reflecting on direct experiences could positively influence the vocabulary acquisition process (e.g., Hasnine et al., 2020; Sariakin et al., 2021)

Furthermore, visuals in HMD VR may have contributed to positive vocabulary gains as visualised target words were not presented to the players all at once. The appearance of the target lexis embedded in these games were determined by the storylines of these applications. In other words, these vocabulary items were gradually released in the games for students to use or see it when they need to. Due to the limited capacity assumption (Mayer, 2005), learners can only process a few visuals and words in the working memory capacity at a time as the sensory memory could only last a few seconds (Mayer, 2005). Thus, travelling through each carbon one by one and reading the name visually labelled on each molecule, rather than seeing all 3D visuals at once, could have provided sufficient time for language learners to transmit the name of each carbon from short-term memory to working memory.

In short, students indicated four main reasons for the positive impact of realistic visualisation of academic words on vocabulary gains. First, the games presented academic terminology through realistic visuals synchronised with text, enabling learners to map out the meaning of the objects with its corresponding visuals, thus making cognitively demanding content more concrete. Secondly, HMD VR, by reason of realistic visuals, may have propelled players to reflect on virtual experiences as direct experiences. Next, the gradual release of visualised academic lexis may have rendered EAL students enough time to process and concentrate on each target word. Finally, VR games strategically placing the visuals of target words throughout the game, rather than presenting them all at once, may have, led to better vocabulary acquisition and retention (see Parenti et al., 2018).

5.4.1.3 Enhanced Vocabulary Acquisition and Retention

This theme emerged as a result of EAL participants explicitly stating that 3D environments assisted them to construct and recall their word knowledge of the subject terminology (see Chapter 4, Table 4.8). For example, Fatma explained this procedure as:

> We read the passage, we saw the words in the passage as you played the game and you saw the words because you can see what the word actually means, and you see what it [vocabulary] looks like in the game so it [VR games] kind of helps. (Interview, 2018) (see Chapter 4, Section 4.2.2)

Based on the triangulated qualitative data, findings show that students were aware of the intentional learning process whilst being explicitly exposed to unknown academic terms through reading a passage prior to the game intervention. Students were provided with the reading passage beforehand, so they could notice the gap in their knowledge. Awareness raising in the learning process was critical as it may have led to 'noticing' the gap in content or linguistic knowledge learners are still lacking (Schmidt, 2001). Based on Schmidt's (1994) work, these EAL students could have acquired target vocabulary by noticing the gap in their interlanguage system through increased conscious attention paid to target vocabulary situated in context in the 3D gamified environment. That is, they were exposed to more comprehensible and rich input situated in context and provided with opportunities for language production (using the target words in the games). This process helped them develop implicit knowledge of target words (incidentally), rather than intentional input (using dictionaries to search meaning of unknown words as in the control group). Thus, learners described their VR experience as conducive to content-based vocabulary acquisition and retention, which was also found in previous research (e.g., C.H. Chen et al., 2021; J.C. Chen, 2016; K.W.K. Lai & Chen, 2021).

In addition to noticing a new vocabulary item in the HMD generated 3D world, Zehra explained how the InCell VR game required learners to know the academic terminology to successfully complete the level: "We had to kill the bacteria in the game. We learnt the new words and the new types of bacteria that was bad and good for you" (Interview, 2018) (see Chapter 4, Section 4.2.2).

It could be understood that the storyline of the games may have driven learners to use the target vocabulary in order to successfully reach their goal. This may have led to the deep elaboration of the vocabulary items, increasing learners' involvement in the situated learning environment which determined the effectiveness of vocabulary learning (Hulstijn & Laufer, 2001). As a result, it could be interpreted via the students' feedback that the storyline of the games played a vital role in encouraging students to discover and construct their own content and word knowledge.

These EAL participants also stressed that receiving content information upon request whilst immersed in the game enhanced their lexis learning process. Fatma detailed how the Solar System Museum VR game helped her with the vocabulary acquisition process:

> The solar system tour helped me learn new words as it clearly shows and explains what it is, where it is and what it does in the solar system. It shows the order of the planets and the sizes of the planets. (Exit Slip, 2018)

According to Fatma's response above, the features of educational VR games that embodied verbal and written information in the 3D target items drew student increased attention to those observed content words. The immersive games adopted in this research also offered a sense of telepresence in the VR environment, which could have led to the increased growth of vocabulary knowledge. Rania's comment vividly captured a better understanding of the nuanced factors related to this theme:

> The game that we played today was Ancient Egypt. It helped me learn many new words because when you focus on a red dot it tells you the name of the picture and the kings (pharaoh) of the time. (Exit Slip, 2018)

The highly immersive experiences which enabled learners to observe and 'touch' the objects closely and receive information on demand may have reinforced their positive perception of acquiring new knowledge. Moreover, students also viewed the labelled vocabulary items one at a time. The game presented the written version of these words on the visuals. For example, whilst diving, students were swimming with fish labelled by the written version of their name, such as 'Rockfish', in the Diving VR game. The 'Just in Time' and 'On Demand' principle from Gee's (2005) good games' principles may explain how these educational 'good' games reduced the cognitive load of students. These good games may have assisted learners to form mental presentations of the target words by linking phonological and orthographic elements to their meaning.

Although students were not able to see each other while playing the Diving VR game, they communicated with each other. For example, when the EAL participants saw a fish in the 3D environment, they described the scene to their friends. Students intended to discover marine life together, despite not seeing each other in the VR game. Moreover, discovering marine life together was not a requirement of the game (Research Journal, 2018). The collaborative interaction whilst playing in the Diving VR game also seemed to have fostered students' use of target vocabulary items in context, which could have led to better word gains, as reported in previous research (e.g., J.C. Chen, 2016; Tseng et al., 2020). The finding of this theme also supports previous studies stating that 3D VR environments enhance immersive vocabulary learning (e.g., J.C. Chen 2016; Dawley & Dede, 2014; Kaplan-Rakowski & Gruber, 2019).

5.4.2 Negative Aspects: Effects of HMD VR Games on Vocabulary Acquisition and Retention

5.4.2.1 Technical Problems in Playing VR Games

Although learners enjoyed playing games using VR headsets, they also expressed concerns that possible technical issues could interfere with their learning experience. For example, Chapter 4, Section 4.2.2 reported that poor sound quality of the game prevented two of the learners from hearing the pronunciation of target words in the InMind game. Yousef explained the effects of technical issues on his vocabulary learning as follows: "I didn't learn anything because all the words are all blurry and there was no voice to explain what was happening" (Exit Slip, 2018). The players identified this technical issue as a significant problem, hindering their learning of new content-based words. Moreover, two players reported they felt dizzy from tilting their head because of the goggles whilst looking around or walking to their destination. Lena stated how she did not feel safe: “What I didn’t like about the game [Carbon] is it gets you dizzy, and you feel like you are going to fall down” (Exit Slip, 2018) (Chapter 4, Table 4.10). This could mean that students who felt dizzy were not able to stay focused in order to continue their mission in the game, let alone engage with the content or target objects. Players also complained about the blurry vision caused by the low-cost optics of Google Cardboard, which prevented them from seeing the target words on the screen. The research journal also noted that the amount of time each student played the game could vary. There were a few occasions where the 3D VR game applications on the phones froze while the learners were still playing. In order to complete the task, learners had to restart the game, which then reduced the fun factor.

As discussed above, technical issues may have reduced the game time for learners to stay engaged with the content, thus negatively affecting the language learning process. Technical issues could have thwarted these players from associating the visualised target objects with lexis, resulting in poor vocabulary gains. In fact, this reporting of dizziness was found in previous research (Kaplan-Rakowski & Wojdynski, 2018; Pinto et al., 2021). Similarly, HMD which caused blurry vision was also witnessed in previous studies (Dede et al., 2017; Sakamoto, 2018). In point of fact, the discomfort of HMD, dizziness, poor visuals, or tired eyes were also reported previously (e.g., A. Cheng et al., 2017; Cho, 2018; Ebert et al., 2016; Kaplan-Rakowski & Wojdynski, 2018; Lloyd et al., 2017; Ludlow & Hartley, 2016).

The findings in answering Research Question 2 illustrated how VR games could either facilitate or hinder vocabulary learning processes as in the case of Middle Eastern language learners. CALD students’ perspectives of the positive properties of headset-configured VR games suggested that these VR games could be utilised as an effective approach to teach vocabulary in context with reference to mainstream subjects. This positive outcome was found to be a result of direct interaction with the content-based environment via telepresence. Moreover, the increase in word knowledge could also be due to the 3D visualisation of topic related words. Besides, high immersion could have positively affected the language learning process offered by this innovative technology. Although the unique qualities of VR facilitated EAL learners' vocabulary acquisition, technical problems were identified as a significant factor that needs to be considered whilst using VR. More specifically, technical glitches such as blurry vision, sound issues or applications suddenly shutting down could disadvantage students and jeopardise the vocabulary learning process.

5.5 Integration and Discussion of the Findings to Answer Research Question 3

- **RQ 3. To what extent does a VR game based, headset-enabled approach's effects differ from a traditional textbook-based approach in EAL learners' acquisition and retention of content-specific vocabulary?**

With respect to the final research question, the three vocabulary tests were analysed via a non-parametric Friedman test to compare the total word knowledge scores of each student participant before, after, and two weeks after being exposed to the traditional or experimental methods (see Chapter 4, Section 4.2.3). The results showed that although the average mean of the control group increased in the post-test from the pre-test, it declined to its initial pre-test mean score in the delayed post-test results (post-test: $M = 8.15 >$ delayed post-test: $M = 6.23 =$ pre-test: $M = 6.23$). In contrast, the mean of the treatment group also increased in the post-test from the pre-test; however, the decline of mean in the delayed post-test still outperformed the pre-test results (post-test: $M = 13.07 >$ delayed post-test: $M = 10.46 >$ pre-test: $M = 8.61$). Correspondingly, the difference between the mean scores in pre- and post-vocabulary tests was larger for the treatment group (by more than 51 per cent) than the control group (by more than 30 per cent) (see Chapter 4, Section 4.3.1). This indicated that treatment group students' overall recognition of vocabulary items in post-test was higher than their control group counterparts. Students who had engaged with the VR game-based approach also retained more content-specific words than those participating in the traditional approach. These results suggested that the VR game-based, headset-enabled approach differs positively from the traditional approach in not only learning content-specific vocabulary items related to Science, Humanities and Social Sciences (HASS), and The Arts, but also retaining them. These EAL participants in this research had greater achievement when they played nine different games in VR environments as a learning method to acquire target lexicon related to the subject matter.

Overall, the treatment group increased their content lexicon by 50 per cent by playing HMD VR games as a post-reading activity. Furthermore, the delayed post-test scores indicated that these EAL players retained more than 40 per cent of the target words they had learnt. However, this was not the case for students in the control group who completed the post reading activities by only responding to focus questions in paper. Although the control group also improved vocabulary gains in post-test by 30 per cent, they failed to recall the content lexicon they had previously learnt. On balance, the quantitative test results of this investigation revealed that one of the most salient effects of VR games was not limited to content-specific vocabulary acquisition. It also had a positive effect on word retention. This finding was consistent with previous research in that 3D VR technologies are conducive to vocabulary knowledge building (e.g., K. W. K. Lai & Chen, 2021; Tai et al., 2020 (see Chapter 2)).

As presented in Chapter 4, Section 4.3.1, the post-hoc test on word retention also showed that there was no statistically significant difference between the pre- and delayed post-test scores ($p = .877$) in the control group. It was found that these participants' average vocabulary knowledge was found to be like their initial scores in pre-test. Conversely the results also showed that there was no significant difference (*p* = .018) between the post- and delayed post-test results in the treatment group. Indeed, there was no notable change in students' vocabulary gains two weeks after the VR experience in comparison to the post-test results. Furthermore, even two weeks after being immersed in a content-based 3D simulation, average delayed post-test mean scores (T2: $M = 13.07$ > T3: $M = 10.46$) indicated that these learners still maintained 41.48 per cent of their new acquired vocabulary knowledge (see Chapter 4, Section 4.3.1).

These results implied that the VR game-based, headset-enabled approach was proven to facilitate students' acquisition and retention of content-specific vocabulary related to Science, HASS, and The Arts. Language integrated learning could be cognitively demanding as learners are expected to acquire content-specific language alongside learning knowledge about the subject matter. Thus, the novel HMD VR approach adopted in this research, were found to facilitate language learners' vocabulary acquisition and retention. Highly immersive games may have reduced the cognitive load by situating target language into context, where language learners relied on interaction, visual, or other contextual cues to clarify and solidified the meaning of the subject-specific terms. For instance, specialised vocabulary related to cells in the InCell VR game were presented in a human body. The function of each cell was also visually displayed along with written and audio information. These functional descriptive cues (information describing the functions of the cells) alongside casual enablement cues (information regarding possible causes of or enabling conditions for cells), could have clarified the meaning of these unknown words (Sternberg & Powell, 1983).

Another example was the Solar System Museum VR game where players visited planets and received stative descriptive cues about the target words, such as cues regarding properties of asteroids as in size, colour, and shape, etc. It also received equivalence cues (information regarding the meaning of asteroids). Similar contextual cues were presented in Diving VR game, where the target marine life visual displays were explicitly labelled to communicate their meaning through realistic 3D visuals. Finally, class membership cues (information regarding the members of carbons) were provided to explain how atoms are formed in the Carbon VR game. 3D simulations presenting subject terminology through contextual cues may have made it easier for EAL students to form meaningful links between content-based words and its meaning.

Whilst the EAL players interacted with the new content vocabulary items in the games, their activated schemata may have assisted them to understand unknown words through contextual cues. That is, when learners are engaged with the certain topic in the content-based HMD VR games, the schemata in the student's mind, related to that topic, may have been activated (Ladendorf et al., 2019; Xie et al., 2021). As a result, these content-based VR games may have modified EAL players' cognitive structures as a result of the ongoing interaction between the schema in their mind and the situated VR environment. The VR environment may also have assisted to establish strong connections between meanings and target words through contextual cues to fill in knowledge gaps, clarify meaning of unknown words, and interpret meaning out of context. Learners using their existing knowledge presented through contextual cues to absorb and understand the target words may have expanded their current schema through interacting with the highly immersive situated games. This may be one explanation of how the acquired words were stored in long-term memory which, lead to higher vocabulary retainment.

Chapter 4, Section 4.3.1 also showed that the mean placement scores based on performance showed difference between control and treatment groups. The treatment group outperformed the control group in post- and delayed post-tests. In other words, only 50 per cent of the control group performed better in the delayed post-test than in the pre-test (positive means T1-T3: control; N =

5). This rate was significantly higher in the treatment group, where 76 per cent increased their vocabulary score in the delay post-test compared to the control group. Similarly, in comparison to post-test scores, 46 per cent of the treatment group remembered the same amount of target items in delayed post-test (treatment group ties in post and delayed post-tests scores: $N = 6$), two weeks after playing the immersive games. However, this vocabulary gain was zero in the control group (control group ties post and delayed post-tests: $N = 0$), indicating that none of these EAL learners retained the content-specific vocabulary following the traditional instruction. A further explanation to these findings could be related to the high immersion and telepresence afforded by 3D environments augmented by headsets, that may have led to a stronger and more positive influence on vocabulary achievement. EAL players, with headsets blocking the vision of the 'real world', appeared fully immersed in the subject content during game play. For example, whilst playing the InMind 2 game, Hassan was trying to catch the cells with his hands. Furthermore, most students were tilting their heads, demonstrating their concentration on progressing in the game and no evidence was found in students talking 'off-topic' whilst playing. Hence, this may also have indicated that they were cognitively engaged with the target words in the course of play time.

High immersion may also be more advantageous than the traditional approach, as it offered students the opportunity to utilise multiple skills to discover the subject matter and acquire target terms, in a way not possible with a pencil and paper. This new method may have made vocabulary learning appealing to learners. The headset-augmented games in this study rendered the subject content in 3D form, allowing CALD learners to personalise and deepen individual learning experience by discovering the subject-words through telepresence. For example, in the Diving VR game, each player had the choice to swim towards the direction they preferred in order to explore the marine life. This experience simulated an adventure they could have had in real life, amplified by enjoying the environment and creating vivid memories by exploring (Kwon, 2019). Thus, treatment group learners may have increased their content-specific vocabulary bank from pre- to delayed post- tests (post-test: $M = 13.07$ > delayed post-test: $M = 10.46$ > pre-test: $M = 8.61$) through their engagement in context-based experiential language learning tasks. As a result, this situated learning could have enabled students to construct vocabulary knowledge through actively accomplishing a real-life task as using foreign language in real life motivates language learners to learn vocabulary (Mills, 2011). This may be due to the fun factor fostering students' engagement with the content and the situated experiential learning opportunity that was not available to learners using traditional methods (Krokos et al., 2019). The findings related to expanding vocabulary learning beyond classrooms through situated learning environments confirm and extend previous research (J. C. Chen, 2016; K. W. K. Lai & Chen, 2021; Palmeira et al., 2020).

Moreover, the Carbon VR game visualised how atoms bonded to form carbons by attaching a label floating above the object with the name printed to each carbon. Players having the ability to travel through each carbon and reading the target vocabulary of the visualised items displayed by the label could have positively contributed to their exposure to rich input related to science. Likewise, in the Solar System Museum VR game, players had the ability to teleport amongst planets, manipulate planets to closely observe them, and receive verbal and written information about the content. HMD VR games that enabled students to interact directly with the target words may have contributed to the positive outcome in better vocabulary acquisition and retention of the treatment group. This could also be a result of the interpersonal interaction process, where the EAL players clarified the meaning of a lexis in the context that facilitates comprehensible input. Then, this may have triggered intrapersonal operations where language learners constructed the meaning of target items in cooperation with their contextual cues. This phenomenon may be explained by learners' cognitive structures being modified due the constant interaction between the human mind and the content-based VR simulations, leading to the assimilation or accommodation of new vocabulary items into their existing schemas (Chun & Plass, 1997). As reported in previous research (K. W. K. Lai & Chen, 2021), direct interaction with the 3D visualised target words may have increased students focus, leading to better engagement with the content, and consequently, giving rise to topic-oriented word learning.

Additionally, a further explanation about the positive vocabulary test results of the treatment group participants could be linked to the interactive element. The interactive immersive games could have piqued language learners' attention and led to their heightened cognitive engagement with the content words. Previous research also supported that interact and manipulated the target words could have cognitively promoted the acquisition and retention of topic related terminology (Berns et al., 2013; Ranalli, 2008; Tai et al., 2020; Townsend, 2009) by addressing visual, kinaesthetic, or auditory learning styles (Freina & Ott, 2015).

To summarise, a highly immersive VR approach differed evidently from a traditional textbook-based approach with reference to EAL learners' acquisition and retention of content-specific vocabulary. Treatment group students' overall recognition and retention of content-specific vocabulary items related to Science, HASS, and The Arts was higher than the control group in post- and delayed post-tests, after the pre-existing differences were controlled. Drawn from the integration of the findings, possible explanations were established to explain the positive impact of immersive games on vocabulary acquisition and retention. Firstly, highly immersive games may have reduced the cognitive load by situating challenging academic subjects and abstract content knowledge and vocabulary into context (Barrios & Acosta-Manzano, 2020; McDougald, 2018; Sidorenko & Kudryashova, 2021). Next, learners may have used their existing knowledge presented alongside with contextual cues to absorb and understand the target words (Castellano-Risco et al., 2020). EAL students may have expanded their current schema through interacting with the highly immersive situated games and acquired words which transferred to the long-term memory that resulted in higher vocabulary retainment (Amiryousefi & Ketabi, 2011; Mayer, 2014). Another important finding was in relation to teleporting to highly immersive, situated learning environments that could have deepened learner experiential experience through actively accomplishing a real-life like task by using the target vocabulary items (Lave, 1993). Finally, activeness via telepresence and direct interaction with the 3D visualised target words may have focused EAL learner attention on engaging with the content and related lexis, giving rise to topic-oriented word learning (Christoforou et al., 2019; Pinto et al., 2019).

After the integration of the findings to answer Research Question 3, the discussion above confirmed the hypothesis of this thesis posited in Chapter 2, Section 2.9. It was found that there was a significant relationship between Middle Eastern language learners' vocabulary test results and their perception of using headset-configured VR games to learn subject specific vocabulary. Moreover, the discussion above established that Middle Eastern language learners' perception of using HMD VR games was significant to explaining the vocabulary test results. The interpretation of the vocabulary test results was also explained by the themes emerging from the qualitative data analyses. These results could support specialist teachers delivering academic subject matters to CALD learners in a mainstream classroom. Immersive gamified learning could be a pedagogically appropriate approach to stimulate content-based vocabulary acquisition and retention through experiential learning. This could be that the unique features of HMD VR games afford a highly immersive, situated, interactive, and appealing environment with 3D representations of target lexis. The CALD learners in this study acquired meaning of unfamiliar vocabulary items by teleporting to interact with the visualised target lexis where the multimodal, contextual cues were displayed in concrete situations. Consequently, treatment group participants demonstrated better acquisition and retention of the target vocabulary knowledge than their control group counterpart. Likewise, students who teleported themselves to real life like scenarios constructed their academic word knowledge by interacting and manipulating he target lexis. On the other hand, students who participated in conventional methods were not able to expand their word knowledge as their treatment group peers.

5.6 Chapter Summary

This chapter discussed the qualitative, followed by the integration of quantitative findings of this dissertation, by first providing an outline of this chapter. Next, a summary of the three research questions, the methods used to explore the results, and the background information of participants were reviewed. Following this, the next section examined the perceptions of Middle Eastern EAL learners in regard to using HMD VR games to learn content-specific terms, to respond to Research Question 1. Certain aspects of highly immersive games facilitating or hindering vocabulary acquisition were discussed to answer Research Question 2. By the same token, the results of the quantitative data to answer Research Question 3, with respect to the positive outcome of experiential groups' vocabulary test results were discussed. This chapter also integrated the discussion of qualitative data findings to explain the increase in treatment group students' vocabulary knowledge.

Chapter 6 presents the implications, limitations, and conclusion of the research.

Chapter 6: Conclusions

6.1 Chapter overview

The previous chapter discussed the qualitative and quantitative findings of this research. It examined the perceptions of English as an additional language (EAL) learners with reference to using head mounted display virtual reality (HMD VR) environments to learn content-specific vocabulary. The properties of the HMD VR environment that facilitate, or hinder vocabulary acquisition were also discussed. The final section of Chapter 5 presented a discussion of the quantitative data, regarding the positive test results of treatment groups' vocabulary gains and retention. This section also integrated the discussion of qualitative data findings to explain the knowledge gains in the treatment group related to content-specific vocabulary.

Chapter 6 begins with a summary of the mixed methods research findings in Section 6.2, followed by key implications for pedagogy and research (Section 6.3). The limitations of the study are also identified in Section 6.4, followed by recommendations for future research presented in Section 6.5. The chapter ends with Section 6.6, which concludes the thesis.

6.2 Summary of Findings

This section summarises the findings discussed in the previous chapter. It presents a synopsis of the findings concerning the effects of HMD VR games on vocabulary acquisition and retention, and the interrelationship between culturally and linguistically diverse (CALD) learners' perceptions and lexical learning outcomes.

6.2.1 Perceptions of Headset-Enabled VR Games

In this study, students' perceptions towards using headset-enabled VR games were examined (see Chapter 5, Section 5.3.1), and evidenced in paired *t* test and the semi-structured focus group interviews, exit slips, observation notes, and a research journal. As a result of the paired-t test and thematic analysis processes that employed an open coding technique followed by axial coding the data sources to form categories (see Chapter 4, Sections 4.2.2 and 4.3.2), three distinct themes were generated from Middle Eastern EAL learners' perspectives on their first-hand experience using educational HMD VR games to engage with the content-specific vocabulary items, namely (1) highly immersive learning environment, (2) the fun factor, and (3) insufficiency of adequate educational properties.

With regard to the highly immersive learning environment (see Chapter 5, Section 5.3.1.1), the findings showed that VR simulations augmented by headsets allowed the players to discover the topic via telepresence. After playing the games, the learners' positive attitudes towards heightened immersion and engagement may have led to their acquisition of new content-based lexis through experiential learning. In such an immersive and learner-centred environment, language learners may have guessed the meaning of unknown words through comprehensible input, thereby 'picking up' target vocabulary items supported by contextual cues, such as unknown words explained through interactive visuals (Groot, 2000). The highly immersive feature may have also provided them the opportunity to explore the content as if they were physically part of the game. Consequently, their sense of telepresence may have led them to associate the subject matter with the content-specific vocabulary.

In terms of the fun factor (see Chapter 5, Section 5.3.1.2), the learners favoured acquiring academic knowledge and vocabulary through headset-configured games over traditional methods (e.g., looking up words in a dictionary). The excitement generated by interacting in game-based similations and freely 'moving around' to discover the subject matter may have bolstered the time and effort they invested in learning. Lastly, interacting with target objects in 3D and being part of the game may have reinforced their view of having fun in learning academic content and terminology.

Despite the positive claims indicated above, the findings also (see Chapter 5, Section 5.3.1.3) showed that the participants formed a negative perception of the inadequate educational features of the VR games. These factors were related to requests for better storylines in games, more opportunities to interact with the 3D objects, and more textual or audio explanation of the subject matter. This finding indicated that insufficient verbal or written information in 3D games could have a negative impact on language learners' vocabulary acquisition (Dawley & Dede, 2014; Gee, 2005; Hooshyar et al., 2018; Klopfer, 2017).

Additionally, one of the key findings was that learners demanded further content information, which contrasted with prior findings in cognitive load theory; that is, that multimodal instruments presenting too much information all at once could cognitively overload language learners (Mutlu-Bayratar et al., 2019). However, the sense of telepresence afforded by VR games could have decreased the cognitive load because working capacity may be maximised by the visual, auditory, and haptic stimuli through immersive simulation, as evidenced in this study.

6.2.2 Effects of HMD VR Games on Vocabulary Acquisition and Retention

The impact of HMD VR games on lexical learning were gleaned from the qualitative and quantitative data.

The qualitative data analysis was conducted through a thematic analysis that employed an open coding technique followed by axial coding the data sources to form categories (see Section 6.2.3). The results showed that positive aspects of VR game-based learning that facilitated content-specific vocabulary acquisition included (1) interaction with content-specific vocabulary items, (2) VR visualisation of content-specific vocabulary items, and (3) enhanced vocabulary acquisition and retention. Finally, (4) technical problems in playing VR games were identified as a negative aspect hindering vocabulary learning.

Interaction with content-specific vocabulary was perceived positively and highly related to lexical learning (see Chapter 5, Section 5.4.1.1), particularly in manipulating the visual representations of target words.This result suggested that the unique feature of HMD VR games enabled the students to interact with not only content learning but also the associated target words.

Students indicated three main reasons for the positive impact of simulated visualisation on vocabulary gains (see Chapter 5, Section 5.4.1.2). First, the games presented academic terminology through simulation synchronised with text, enabling them to map out the meaning of the objects with its corresponding visuals; this made cognitively demanding content more concrete and manageable. Secondly, HMD VR may have stimulated players to reflect on virtual experiences through direct experiences, enhanced by the unique features of HMD VR, including prolonging learner engagement via the fun factor, optimising active learning in context as a form of telepresence to fulfill a player's mission based on storylines, and encouraging interaction with visualised target words. Finally, the gradual release of visualised academic lexis may have allowed the students enough time to process and concentrate on each target word; the VR games strategically placing the visuals of the target words throughout the game, rather than presenting them all at once, may have led to better vocabulary acquisition and retention.

Findings on enhanced vocabulary acquisition and retention (see Chapter 5, Section 5.4.1.3) emerged as a result of the participants stating that 3D immersion assisted them to construct and recall the subject terminology. They could have acquired the target vocabulary by noticing the gap in their interlanguage system through increased conscious attention paid to target vocabulary situated in the 3D gamified environment (Schmidt, 1994). This situated language learning process helped them develop implicit knowledge of target words (incidentally), rather than using a dictionary to search for meaning of unknown words as in the control group (intentionally).

Nevertheless, technical problems in playing the VR games (see Chapter 5, Section 5.4.2.1) were identified as a negative impact by the learners. These issues could have thwarted them from associating the visualised target objects with lexis, resulting in poor vocabulary gains. More specifically, technical glitches such as blurry vision, sound issues or applications suddenly shutting down could disadvantage the students and jeopardise the vocabulary learning process.

6.2.3 Integration of the Findings

The evidence of lexical learning, as shown by the statistical analysis of the three vocabulary tests via a non-parametric Friedman test, is complemented by discussions of findings from the thematic analysis and the vocabulary test results (see discussion in Chapter 5, Section 5.5). Findings from the Friedman test analysis of the pre-, post-, and delayed post-tests showed that lexical learning occurred after the treatment group learners engaged with highly immersive games, and their overall recognition of vocabulary items in the post-test was higher than that of their control group counterparts. According to the delayed post-test results, students who had engaged with the VR game-based approach also retained more content-specific words than those participating in the traditional approach. These positive results suggested that the outcomes of the VR game-based, headset-enabled approach differs significantly from the traditional approach in not only learning content-specific vocabulary items related to Science, Humanities and Social Sciences, and The Arts but also retaining them.

From the integration of the findings, research-informed explanations were established to explicate the positive impact of immersive games on vocabulary acquisition and retention. Firstly, highly immersive games situate challenging academic subjects and abstract content knowledge and vocabulary into context, thus reducing cognitive load (Barrios & Acosta-Manzano, 2020; McDougald, 2018; Sidorenko & Kudryashova, 2021). Next, learners may have used their existing knowledge alongside contextual cues and interaction to process and understand the target words and expand their current schema leading to higher vocabulary retainment (Amiryousefi & Ketabi, 2011; Castellano-Risco et al., 2020; Mayer, 2014). Another important finding relates to teleporting to content-based environments which could have deepened learner experiential experience through accomplishing realistic tasks (Lave, 1993). Finally, direct interaction with the 3D visualised target words may have focused learner attention on engaging with the content and related lexis, giving rise to content vocabulary learning (Christoforou et al., 2019; Pinto et al., 2019).

To summarise, the research findings indicate that HMD VR games could be integrated in mainstream classrooms to pique learner interest and investment in learning content knowledge and vocabulary. Learners expressed that using headsets to play games was an appealing and highly immersive way to learn new words associated with the subject terminology (see Chapter 5, Section 5.3). The integration of findings further demonstrated that learners were able to gain content-specific vocabulary knowledge by reducing their cognitive load through the games (see Chapter 5, Section 5.5). These students believed that the interactive, simulated, and immersive nature of HMD VR enabled them to manipulate visualised target words in context, thus making the vocabulary acquisition process easier for them (see Chapter 5, Section 5.4). Therefore, the study postulates that educational HMD VR games could heighten Middle Eastern EAL students' vocabulary acquisition and retention in an immersive 3D environment beyond a conventional classroom.

6.3 Implications

This research has implications for both teachers and researchers. In terms of the research design, there were only limited studies that reported the quantitative results of vocabulary tests and explained the effects of HMD VR on language learners (Palmeira et al., 2020). However, none of the reported research adopted a mixed-methods research design and focused on teaching vocabulary items related to mainstream school subject matters as in this study. The design of a mixed method research approach was proven to be a viable approach to verify the hypothesis of this thesis, thus adding new perspective to the current quantitative-dominant literature. An implication of these findings is that qualitative data could compliment quantitative data via a mixed method. Thus, researchers could adopt mixed methods by opening a study through presenting the interconnected complexities of why HMD VR games enhance or hinder vocabulary acquisition and retention from EAL students' perspective.

A further implication that links effectiveness of 3D simulations to the educational objectives could resonate with mainstream subject teachers and researchers. Specifically, it concerned those keen to support CALD learners, who are grappling with the subject demands whilst trying to master the target language. Although previous research also linked learner outcomes in vocabulary acquisition to situated immersive learning environments (Alharthi, 2020; Hsu, 2019; Papi, 2018; Uz Bilgin & Tokel, 2019), to the researcher's best knowledge, studies done on Middle Eastern language learners' content-specific vocabulary acquisition and retention in a mainstream classroom, following a state-wide curriculum are still in paucity. Furthermore, unlike most studies on adopting VR headsets to learn target vocabulary as an additional language, this research chose a variety of headset-configured games in order to situate the target words in the context. Thus, the findings of this study are not limited to the effects of only one game application. Choosing nine different games in this study enabled the production of rich data about the effects of VR game to learn content-specific vocabulary related to mainstream subjects. Additionally, different from prior research that utilised VR games as the main instruction, the findings of this research are drawn from EAL students playing these games as a part of their lesson after reading a passage about the subject matter. The implementation of HMD VR games provides solutions in a realistic, practical, flexible, and cost-efficient way to researchers and teachers in the field who seek for effective strategies to support EAL students (Bower et al., 2020). When it comes to cost-effectiveness, the inexpensive Google Cardboard was a viable option despite that it requires a smartphone to work. Using headsets could be transferred to other subject areas if chosen according to Gee's good games' principles (Gee, 2005).

Another key indicator of the effectiveness of using 3D simulation in learning mainstream subjects was EAL learners' improved vocabulary learning and content knowledge. This study demonstrated that language learners could positively engage in cognitively demanding tasks and mainstream subjects can be taught in this setting beyond the three subjects presented in this research.

Moreover, headset-configured digital games can enable players to construct their own knowledge through situated experiences. Evidently, incorporating 3D games in education could stimulate meaningful discovery learning (see Abdulhussein & Alimardani, 2021; Breien & Wasson, 2021; Dietrich et al., 2021; Gee, 2005; Goode & Vasinda, 2021; Ying et al., 2017). Meaningful discovery could motivate learners, facilitate vocabulary learning by reinforcing learners' cognitive engagement with the subject matter. It could also create an enjoyable learning atmosphere where learning anxiety may be decreased (Horwitz, 2010). Ultimately, the interactive, immersive, and simulated nature of the highly immersive VR environments could foster language learners' engagement with the subject matter and related terminology via telepresence. Moreover, the immersive, interactive, and entertaining nature of headset-configured VR has attracted many young learners (Prensky, 2005). Highly immersive simulations created life-like experience (Li et al., 2020) that mirrored direct experiences (Dawley & Dede, 2014), and allowed players to interact with the target words they would never come across in a traditional classroom (Lan, 2020).

From the pedagogical lens, content-oriented highly immersive VR environments allowed language learners to link the meaning of topic terminology to the context in which they were teleported and immersed in. Also evidenced in this study, the rich exposure to and immersive engagement with 3D objects in HMD gamified environments were evidenced to heighten language learners' vocabulary acquisition and retention beyond the physical classroom. (J. C. Chen, 2016; Kaplan-Rakowski & Wojdynski, 2018). Another implication for like-minded researchers was the link between VR games and EAL learners' schemata.

When EAL learners are introduced to a new content topic, VR games could enable them to get the first-hand immersive learning experience by activating their schemata due to the 3D embodiment of target vocabulary items. This highly intensive engagement could provide additional contextual cues that help assist EAL students to understand unknown words in situated language learning (see Gao, 2021; Kukulska-Hulme & Viberg, 2018; Moody et al., 2018; van den Broek et al., 2018).

This research also showed that carefully designed educational games could provide contextual cues to support implicit vocabulary acquisition, thereby reducing the cognitive load (see Bergsma, 2022; Tai & Chen, 2021; Vázquez Machado, 2018). Finally, HMDs could enable language learners to interact with the content-based simulation during the duration of the game.

Extending the interaction with the content could play a role in modifying CALD students' cognitive structures. This extensive interaction with the target words might lead to the accommodation of new vocabulary items into their existing schemas (Chun & Plass, 1997). Hence, HMD VR games were able to make complex concepts more concrete, accelerating target word learning into long-term memory and leading to higher vocabulary acquirement and retainment. Taken together, the nature of headset-configured VR rendered content information by stimulating learners' understanding and acquisition of word knowledge (see Chun et al., 2016; Cooke-Plagwitz, 2008; González-Lloret, 2015; Ortega & González-Lloret, 2015). The findings of this study implied that this immersive VR approach could be a potentially optimal instruction for CALD learners to engage with the target language and prepare them for further study and future job opportunities. Teachers supporting EAL students in mainstream classrooms could adopt a HMD VR approach to teach complex concepts and vocabulary related to mainstream subjects in a more concrete way without cognitively overloading language learners.

6.4 Limitations

Like any study, this research also has limitations. Firstly, as mentioned in Chapters 1 and 3, a pragmatic, mixed methods design was employed in this study to collect and analyse both quantitative and qualitative data in order to answer the research questions. As with all mixed method studies, there were potential pitfalls concerning the results of this research that were beyond the researcher's control for different reasons. However, each limitation below was concluded by offering suggestions to mitigate the constraints in future research.

Due to the limited number of educational VR games available for Google Cardboard, only nine games in three different subjects were found to comply with the Year 7 and Year 8 curricula. There was a possibility that applications adopted for this research in 2018 may not be identical to the versions of the games in 2022. Therefore, any inferences made from the current findings about the effectiveness of HMD VR games among other year levels, or in different subject areas should be treated with relative caution. In the future, educational VR game developers could design more customised educational games across subjects to benefit both language teachers and students. Additionally, teachers should have the flexibility to choose the topics and vocabulary items to be visualised in the VR game based on their students' knowledge and skill levels. Educational institutions may also consider gamified VR learning as an alternative for like-minded EAL teachers and curriculum developers to design relevant materials and lesson activities that could further support ESL learners' vocabulary acquisition in mainstream subjects.

Findings should be interpreted with caution, as positive claims of learning are based on a small sample size. It should also be noted that the Wilcoxon Test adopted to measure the changes in student beliefs could be notoriously difficult, especially with just one item. However, it was used to present an additional finding that was supported by other metrics as well, such as the triangulated data reporting on students' perceptions using HMD VR to acquire content-specific vocabulary items. Moreover, the VR game applications in this study required each student to play individually without interacting with each other. Although students were highly immersed in the game and able to verbalise the VR scenes, those games lacked features to allow for collaborative learning.

Inevitably, some technical issues arose whilst students were engaged in the HMD VR games. A few of the game applications operated in mobile phones suddenly turned off. Poor screen resolution also led to eye strain due to the inexpensive lenses of Google Cardboard. Furthermore, in two occasions, the written target words were not intelligible, hindering the vocabulary learning process. Limited space in a classroom environment also caused disruption to HMD VR game players when they were moving around with headsets that blocked their visions in class. To avoid any physical injuries, the researcher had to interrupt a few students who were moving whilst playing. This interruption may have reduced EAL players' concertation and engagement time in the game. Additionally, EAL teachers who are interested in using this technology could also face challenges, such as not receiving technical support from the school, needing sufficient space, and allocating extra time to provide instructions to students without prior VR experience.

6.5 Recommendations for Future Directions

As Williams (2020, p. 16) stated, "nearly each day we hear about the speed of technology and get reminded that kids operate faster than any generation that has come before". There is a need for future research on headset-configured VR environments regarding content-specific lexicon acquisition and retention to extend on the context of EAL students in mainstream schooling by offering games related to subject topics. This generation's response and attitude towards adopting highly immersive games is also an area future studies need to shed light on (Alfadil, 2020; J. C. Chen, 2016). This section discusses the aspects drawn from the lessons learned from this study and how these can help teachers and researchers develop a better plan for their own setting.

It would be worthwhile to determine the extent to which the 3D immersive game properties can make a difference in CALD learners' performance in other language skills, such as reading, writing, speaking and listening. To do so, experimental research design through random allocation of participants into controlled and experimental groups is recommended in order to measure how the VR game features (independent variables) would impact their performances in those skills (dependent variables). A mixed methods research design with qualitative research components may be beneficial to gather more in-depth information to explain the statistical results from the participants' perspective whilst researching about the impacts of headset-configured games on improving language skills.

A further avenue for future research would be to consider the educational factors, such as detailed written or verbal explanation of the subject content presented in the immersive games that may moderate the efficacy of using headset-configured 3D environments in conventional classrooms. As reported in this thesis, it is likely that the effectiveness of HMD VR games may vary according to the storyline of games. Without considering a balance of interaction with target words and the information presented in games, the highly simulated environments could cognitively overload EAL learners with presenting the target vocabulary items all at once (DeHaan et al., 2010). Moreover, the findings (see Chapter 4, Table 4.9) suggested that too much action might disperse the focus from learning, whilst lack of movement obstructs interaction, resulting in less engagement with target objects. Future research could also focus on showing if certain vocabulary associated with specific VR games is better retained. This would also allow for comparing the characteristics of each of the selected application and how they each associate with learning gains.

Caution should be taken to avoid using technology for the sake of fun without research-informed guidance. Integrating this VR approach in lesson planning needs to be grounded in game-based learning theory (J.C. Chen, 2016; Ortega & González-Lloret, 2015). If selected carefully, subject content and academic vocabulary learning could be optimised through VR simulations and turn a mundane language classroom into an engaging 3D gamified environment for learners. For example, this study showed that selecting digital games based on Gee's good games' principles (Gee, 2005) could enhance EAL students' content-specific vocabulary acquisition and retention. Hence, it was essential to raise awareness among language teachers that HMD VR games could be a viable lexicon instruction method as long as they chose suitable educational games guided by research-informed pedagogy, such as game-based learning and the situated learning theory (Fox, 1997; Gee, 2005).

This study demonstrated that language instructors could integrate 3D games in their lessons as an extension activity or a follow-up assessment. Previous research also suggested that intentional learning activities conducted via traditional methods needed to be complemented by incidental learning activities (N.C. Ellis, 2005; Schmidt, 1993; Shintani & Ellis, 2013; Skehan, 2014) as this would facilitate students in acquiring meaning about the unknown words (Joyce, 2018; Laufer & Nation, 2012). Further research may also shed light on whether implementing these games would be efficient to deliver the content as the main task in a lesson, or whether it could be played as a pre-warm-up activity to increase learner engagement before teaching the subject matter.

Although this study involved EAL participants in Years 8 and 9, applying content-based, HMD VR learning environments to different grade levels of foreign language learners could engender useful results. These results could provide insights. into how other CALD student cohorts engage with the topic and whether similar positive findings would also be evidenced (Park, 2018). Such studies could help verify the findings across different year levels and learners with different CALD backgrounds and language learning needs besides English.

Also noteworthy are students' perspectives about how immersive, simulative, visualised, and interactive situated learning environments help them engage with the subject matter and vocabulary acquisition and retention. These aspects could possibly extend the implementation of this HMD VR application to new scenes. For example, the School Curriculum and Assessment Authority (SCSA, 2014a) has identified sustainability as a cross-curriculum priority and 3D VR settings could make creation of sustainable scenarios and topics possible. Moreover, Williams (2018) has stated that research on sustainability using technology is still in paucity despite being a cross-curriculum priority in Australia which requires attention from researchers.

This study was conducted using the cost-efficient Google Cardboard headsets. However, research could be conducted to compare a different headset application to Google Cardboard, such as Oculus, to monitor and evaluate whether the system quality has an impact on learner engagement and investment in content knowledge and associated vocabulary learning. Both researchers and teachers who are keen to adopt this strategy should also exercise caution regarding the technical difficulties students may face when applying the HMD VR application. Sufficient spatiality in the room needs be considered prior to the gaming experience to pre-empt any disruption or injuries within the lesson. Having a pre-prepared plan, such as having an extra VR set, to address possible technical problems could be useful to mitigate such situations, in order not to disadvantage learners and to avoid jeopardising the data collection procedure (J.C. Chen, 2016).

One of the key findings of this study is that learners' outcomes of implicitly acquiring content-specific vocabulary were explained by the following three theories: (a) the situated language theory, (b) cognitive constructivist theory, (c) and the cognitive theory of multimedia learning. Expanding current theories, or developing a new theory related to how haptic information presented through high immersion could affect the cognitive processes of vocabulary acquisition and retention could be possible via further research adopting highly immersive environments to teach vocabulary.

6.6 Conclusion

This study addressed the established relationship between students' perceptions of and attitudes towards a headset-configured learning environment and lexical learning. This relationship is both unique and important. It is unique because limited studies, albeit on vocabulary acquisition, have addressed lexical learning in the light of presenting content-based words to Middle Eastern EAL students through headset-configured games. This study demonstrates that integrating VR technology into the classroom to engage CALD learners is not only a pedagogically feasible approach but proven to be more effective in content-specific vocabulary acquisition and retention than the traditional learning method. More importantly, the VR game based, headset-enabled approach could immerse players in an artificially generated 3D world for content exploration, thus reinforcing students' vocabulary acquisition and retention through rich exposure to the target terminology. The study supports the positive claim that HMD VR can effectively foster language learners' English vocabulary acquisition and retention (see Alfadil, 2020; K.W.K Lai & Chen, 2021; Tai et al., 2020).

It can also be concluded that highly immersive games instill the fun factor in heightening learner engagement, optimise active learning in context through telepresence, and encourage interaction with visualised target words. The fun factor could stimulate learner interaction with the content and make learning academic content more appealing and concrete. As EAL students favoured even the most 'boring' VR game where they visit a museum and listen to information (Magi Chapel) whilst still interacting in the VR environement over traditional vocabulary learning and memorisation in the classroom, this study confirms that teleporting in the content-based environment is a highly immersive method to teach unknown words by simulating and visualising them. Considering these results, this study ascertains that there is a strong link between interaction and vocabulary acquisition as VR games could make content and vocabulary processing more concrete, visualised, and situated in context.

In contrast to the cognitive load theory, telepresence through immersive simulation in the content-based environment could decrease the cognitive load, as working capacity can be increased by the visual, auditory, and haptic stimuli (Killi, 2005). It can be concluded that the cognitive theory of multimedia learning (Mayer, 2005), situated learning theory (Lave, 1993), and experiential learning (Kolb, 1984) assisted to explain the immersive interactive experience. More important, the study was able to show evidence that content-based immersive games could enable CALD language learners to comprehend the subject matter, acquire and retain the target lexis despite their low English proficiency.

The findings in this study are a step towards understanding the effects of 3D gamified learning and how this highly immersive VR environment can foster vocabulary acquisition, retention, and content learning of EAL students, particularly those who are struggling with mainstream subjects.

Learning by doing and through direct immersive experience has been proven more engaging, fun and has linked implicit vocabulary acquisition and retention. Whilst learning content-specific vocabulary is challenging to most CALD learners, teachers could activate HMD VR games to teleport students to inside a human body and observe cells to construct content knowledge, or virtually climb an active volcano to witness how tsunamis, flash floods, earthquakes could be triggered as a result of an explosion without any risk to the students. This highly immersive technology could give a new lease of life to EAL students in mainstream classrooms by offering learners to be a part of realistic scenes that are not possible in real life and could provide an alternative to traditional methods.

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Appendices

Appendix A: Consent Form

HREC Project Number:	HRE2018-0253
Project Title:	The Impacts of Virtual Reality Games on English Language Learners' Vocabulary Acquisition
Chief Investigator:	*John Williams, School of Education*
Student researcher:	*Muleyke Sahinler*
Version Number:	
Version Date:	

OPTIONAL CONSENT

☐ I do	☐ I do not	consent to you using any data I provided before withdrawing from the study, if relevant

☐ I do	☐ I do not	consent to being audio-recorded

☐ I do	☐ I do not	consent to being photographed

☐ I do	☐ I do not	consent to be contacted about future research projects that are related to this project

☐ I do	☐ I do not	consent to the storage and use of my information in future ethically-approved research projects related to this (project/disease)

- I believe I understand the purpose, extent, and possible risks of my involvement in this project.
- I voluntarily consent to take part in this research project.
- I have had an opportunity to ask questions and I am satisfied with the answers I have received.

- I understand that this project has been approved by Curtin University Human Research Ethics Committee and will be carried out in line with the National Statement on Ethical Conduct in Human Research (2007).
- I understand I will receive a copy of this Information Statement and Consent Form.

Participant Name	
Participant Signature	
Date	

Declaration by researcher: I have supplied an Information Letter and Consent Form to the participant who has signed above, and believe that they understand the purpose, extent and possible risks of their involvement in this project.

Researcher Name	
Researcher Signature	
Date	

Appendix B: Information Statement

PARTICIPANT INFORMATION STATEMENT

HREC Project Number:	HRE2018-0253
Project Title:	The Impacts of Virtual Reality Games on English Language Learners' Vocabulary Acquisition
Chief Investigator:	John Williams, School of Education
Student researcher:	Muleyke Sahinler
Version Number:	
Version Date:	

What is the Project About?
English as a second language (ESL) students struggle to learn subjects without vocabulary support. The new technology of Virtual Reality (VR) headsets has the potential to provide this support. This is a pilot study that aims to look at the effects of VR games on vocabulary learning.

Who is doing the Research?
The project is being conducted by Muleyke Sahinler, Dr Julian Chen, and Prof John Williams, as part of Muleyke Sahinler's PhD thesis for Curtin University.

Why am I being asked to take part and what will I have to do?

- You have been asked to take part because you are in the year level we want to study.
- Apart from your normal class requirements, we will ask you to play a virtual reality game, fill out a survey, and answer some questions about your experiences. Your answers will be recorded, and this will be done during class time.
- The study will take 12 weeks.
- There will be no cost to you for taking part in this research and you will not be paid or given extra marks for taking part.

Are there any benefits to being in the research project?

- The research may help you better understand your subject.
- You will get to play games to help with your English vocabulary.

Are there any risks, side-effects, discomforts or inconveniences from being in the research project?

- We don't see there are any risks in being a part of this project. Your name, test results, survey and audio recordings will be kept confidential.
- We have been careful to make sure that the questions in the survey do not cause you any distress. But, if you feel anxious about any of the questions you do not need to answer them.
- During the research project we may find out new information about the risks and benefits of this study. If this happens we will tell you the new information and what it means to you.
- Apart from giving up your time, we do not expect that there will be any risks or inconveniences for you.

Who will have access to my information?

- The information collected in this research will identify you, but we will then remove identifying information and replace it with a code. Any information we collect will be treated as confidential and used only in this project and related presentations and publications.
- Electronic data will be password-protected and hard copy data (including video or audio tapes) will be in locked storage.
- The information we collect in this study will be kept under secure conditions at Curtin University for 7 years after the research is published and then it will be destroyed.

Will you tell me the results of the research?

If you are interested in a summary of the results of the research, that will be supplied. The PhD thesis will be available online when it is finished.

Do I have to take part in the research project?

Taking part in a research project is voluntary. If you decide to take part and then change your mind, that is okay, you can withdraw from the project up until the time we start analysing the data. If you choose not to take part or start and then stop the study, it will not affect your relationship with your teacher or other students at school.

What happens next and who can I contact about the research?

To obtain further information you can contact Muleyke Sahinler at her office at Fountain College or via email; 19054630@student.curtin.edu.au or Prof John Williams; pjohn.williams@curtin.edu.au or Dr Julian Chen; julian.chen@curtin.edu.au. If you decide to take part in this research we will ask you to sign the consent form. By signing it is telling us that you understand what you have read and what has been discussed. Signing the consent indicates that you agree to be in the research project.

Please take your time and ask any questions you have before you decide what to do. You will be given a copy of this information and the consent form to keep.

Curtin University Human Research Ethics Committee (HREC) has approved this study (HREC number HRE2018-0253). Should you wish to discuss the study with someone not directly involved, in particular, any matters concerning the conduct of the study or your rights as a participant, or you wish to make a confidential complaint, you may contact the Ethics Officer on (08) 9266 9223 or the Manager, Research Integrity on (08) 9266 7093 or email hrec@curtin.edu.au.

Appendix C: Pre-survey Questions

Student Background Survey

This survey aims to collect data about your language background. Please read each statement, then check the answers that reflects how you feel about it. There is no right or wrong answer. Thank you for your participation.

*Required

Curtin University

LEARNING NEW VOCABULARY

1. I think learning new words is important to improve speaking in English: *

- Strongly agree
- Somewhat agree
- Somewhat disagree
- Strongly disagree

2. I think learning new words is important to improve writing in English: *

- Strongly agree
- Somewhat agree
- Somewhat disagree
- Strongly disagree

3. I think learning new words is important to improve listening in English:

- Strongly agree
- Somewhat agree
- Somewhat disagree
- Strongly disagree

4. I think learning new words is important to improve reading in English: *

- Strongly agree
- Somewhat agree
- Somewhat disagree
- Strongly disagree

5. I think learning vocabulary is important to understand my subject areas (science, humanities, art, etc.): *

- Strongly agree
- Somewhat agree
- Somewhat disagree
- Strongly disagree

6. If I do not know a new word, I do not understand the subject in class (science, humanities, art, etc.): *

- ◯ Strongly agree
- ◯ Somewhat agree
- ◯ Somewhat disagree
- ◯ Strongly disagree

7. I learn new vocabulary items in my subject areas (science, humanities, art, etc.) by: *

- ☐ Using a dictionary
- ☐ Asking my friend
- ☐ Asking my teacher
- ☐ Searching from the internet
- ☐ Other: ______________________

8. I think the best method to learn a new word is by: *

- ☐ Using a dictionary
- ☐ Asking my friend
- ☐ Asking my teacher
- ☐ Searching from the internet
- ☐ Other: ______________________

VIRTUAL REALITY

1. Have you played online games before? *

- ◯ More than once
- ◯ Only once
- ◯ I have never played an online game before
- ◯ Other: ______________________

2. Have you heard about virtual reality (VR) before? *

- ◯ Yes
- ◯ No

4. If you have played online games and VR games before, which one would you prefer to play?

- VR games
- Online games

5. If you have played VR games before, did you play it with a phone and a headset?

- I have played it just with a phone
- I have played it with a phone and a headset
- I have played it on a computer

6. I play VR games using headsets

- Every day
- Once a week
- Once a month
- Never
- Other: ____________________

6. If you have played VR games before do you agree that using VR games in class will help you learn new words?

- Strongly agree
- Somewhat agree
- Somewhat disagree
- Strongly disagree

7. If you have played VR games before do you agree that using VR games in class is a fun way to learn new words?

- Strongly agree
- Somewhat agree
- Somewhat disagree
- Strongly disagree

LANGAUGE BACKGROUND

1. What do you find hardest in your English classes? *

- [ ] Reading
- [ ] Writing
- [ ] Vocabulary
- [ ] Listening
- [ ] Speaking

2. How confident do you feel while talking in English with your friends? *

- ◯ Very confident
- ◯ Confident
- ◯ Slightly confident
- ◯ Not confident at all

How confident do you feel you can express yourself in English? *

- ◯ Very confident
- ◯ Confident
- ◯ Slightly confident
- ◯ Not confident at all

4. How confident do you feel while reading in English in your class? *

- ◯ Very confident
- ◯ Confident
- ◯ Slightly confident
- ◯ Not confident at all

5. How confident do you feel while writing in English? *

- ◯ Very confident
- ◯ Confident
- ◯ Slightly confident
- ◯ Not confident at all

6. How confident do you feel while listening in English at school? *

- ◯ Very confident
- ◯ Confident
- ◯ Slightly confident
- ◯ Not confident at all

PERSONAL DATA

1. Your name: *

Your answer

2. Your age: *

Your answer

3. Your gender: *

Your answer

4. Country you were born in: *

Your answer

5. If you were not born in Australia, how long have you lived in Australia for? *

Your answer

6. At what age did you first begin to learn English? *

Your answer

7. What language did the teachers use in your primary school? *

Your answer

8. What language do you use most of the time at home? *

Your answer

Appendix D: Semi-structured focus group interview questions

Week 1

- Have you seen this VR headset before?
- What do you think about using VR games in science class to learn about cells?
- What do you think about learning sculptures by making a virtual sculpture in your art class using a VR game?
- What do you think about learning history by visiting those places in a virtual world?
- Do you think it can help you learn new words? How?

Week 6

- How did you find using headsets to play VR games?
- Did you like using VR games in classrooms? Why?
- How did the VR game help you learn new words?
- What do you think about catching cells in the science game?
- Did it help you learn new cells? How?
- How did observing sculptures in the game help you learn new concepts in art?
- Was there any game that you did not enjoy? Why?

Week 10

- Which one was your favourite game? Why?
- How did the games help you learn new vocabulary items?
- Was there any game that you did not like? Why?
- How do you feel about using VR games in classrooms to learn about history?
- How did the VR game help you learn new words about geography?
- Did the science game help you learn new chemical substances? How?
- Would you like to use VR games more frequently at school to learn new words? Why or why not?

Appendix E: Vocabulary Tests

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Pre-Vocabulary Test

A. Match the terms with their correct meanings. Write the letter in the space next to the word.

1. Motif ……
2. Bond ……
3. Exhibit ……
4. Microtubules
5. Marine ……
6. Texture ……
7. Asteroid ……

a) A small rocky body moving around the sun
b) A force that holds chemicals together
c) A decorative design with a repeated pattern.
d) Helps to support and shape the cells
e) To show an art item in a gallery
f) Coral or sand just above or below the sea level
g) The feel, appearance, or consistency of a surface or a substance.

B. Circle the correct answer

8. Which of the following is the correct definition of 'archeologic'?

    a) The study of past events, particularly in human affairs
    b) The study of the buildings, graves, tools, and other objects that belonged to people who lived in the past
    c) The study of the physical and natural features of the earth that took place in the past
    d) The study of human activity on the atmosphere and its affects in the past.

9. A portrait is a painting of:

    a) The whole body
    b) Only the face
    c) Between the face and the knees
    d) A family

10. Which of the following is caused by the influenza virus?

a) Cancer
b) Diabetes
c) Flu
d) Kidney disease

11. Medium in art is defines as:

a) A term given to a work of art that has subject.
b) The totality of the work of art
c) A form of balance in art
d) The materials used by the artist

12. The amount of 3-dimensional space an object covers is defined as:

a) Sound
b) Volume
c) Degree
d) Power

13. Which of the following best describes the function of ‘dopamine’?

a) Helps control cells
b) Helps control blood flow
c) Helps control brain
d) Helps control muscles

14. In art, rectilinear refers to:

a) Triangle and rectangle shapes
b) Circles
c) Polygons
d) Straight lines

C. Fill in the blanks with the correct words from the box.

Reconstruct	**Molecular Machine**
Contrast	**Dominance**
	Organelle
Statue	**Coral**

15. A ………………..is a sculpture, representing one or more people or animals.
16. ……………… is strictly being different from something else.
17. ……………………. consumes energy in one form and changes it into mechanical work.
18. ……………………………… is to form something again after it has been destroyed.
19. ……………… is when certain elements are more important than others.
20. Anything that is organised in a cell is called ……………
21. ………………. is formed from the bones of very small sea animals

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Post-Vocabulary Test

D. Match the terms with their correct meanings. Write the letter in the space next to the word.

1. Neutralism …….
2. Solid ……
3. Reef ……
4. Antique ……
5. Seabass ……
6. Centrosome Cells ……
7. Polar Vortex ……

a) Art that has a high value because of its age and quality.
b) Relating to or found in the sea
c) A large pocket of very cold air
d) A small body in a cell where microtubules are made
e) The approach to art where the artist describes the things he sees.
f) *A* common name for a variety of different species of marine fish
g) Firm and stable in shape

E. Circle the correct answer.

8. The command centre of our cells is called:

a) Lysosome
b) Microtubes
c) Nucleus
d) Neurone

9. Having parts that match each other is called

a) Symmetrical
b) Irregular
c) Stabilized
d) Graphic

10. Any of various fishes that live among rocks are called

a) Stonefish
b) Bedrock fish
c) Rockfish
d) Reef fish

11. A clear and colourless crystalline form of pure carbon is called a:

a) Diamond
b) Crystal
c) Graphine
d) Fullerence

12. The art of designing buildings and non-building structures is called:

a) Superstructure
b) Architecture
c) Manufacture
d) Infrastructure

13. Any of the world's very large main parts of land is called:

a) A country
b) A state
c) A continent
d) A territory

14. When a cell inflates, it means the cell is:

a) Getting bigger
b) Moving faster
c) Getting warmer
d) Changing colour

F. Fill in the blanks with the correct words from the box.

Cortex		
Red neurons	**Contrast**	**Scenery**
Rig	**Harbour**	
Converse	**Substructure**	

15. A supporting part of a structure is called……………….
16. A ……… can be used to drill oil from the sea ………
17. ………………. is the outer layer of brain and other organs.
18. ………………… is found in neurons when there is an injury.
19. The general appearance of the natural environment is defined as ………………….
20. Being strikingly different from something else is called ……………….
21. ………………… is an area of deep water which is protected from the sea by land or walls.

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Delayed post Vocabulary Test

G. Match the terms with their correct meanings. Write the letter in the space next to the word.

1. Exosphere ……..
2. Fullerene……
3. Noradrenaline……..
4. Graphite ……..
5. Abstract ………
6. Constellation ………
7. Serotonin ……..

a) Stars in the sky that seem from earth to form a pattern
b) Does not attempt to represent an accurate depiction of a visual reality
c) A chemical in the body that carries messages from the brain
d) A molecule of carbon in the form of a sphere
e) A soft, dark grey form of carbon
f) Acts as a stress hormone
g) The outermost region of the earth's atmosphere

H. Circle the correct letter

8. The smallest particle of a chemical element that can exist is called a/an:

    a) Chip
    b) Flake
    c) Dab
    d) Atom

9. An object made from a hard material, especially stone or metal, to look like a person or animal is called a:

    a) Sculpture
    b) Drawing
    c) Portrait
    d) Diagram

10. Which of the following defines ‘ancient’?

a) belonging to the very past that does not exist any more
b) having lived for a long time
c) having a high value because of age
d) Something that is old fashioned

11. Objects in space ………. around a planet or star

a) fly
b) orbit
c) slow down
d) stop

12. A virus that is hard to treat is called a:

a) Hard virus
b) Strong virus
c) Super Virus
d) Non-treatable virus

13. Which of the following is the correct definition of ‘Solar System’?

a) The sun and the group of planets that move around it
b) A collection of stars
c) A large group of gas.
d) A group of stars moving around other planets

14. Which one is the correct definition of ‘cell’ in science?

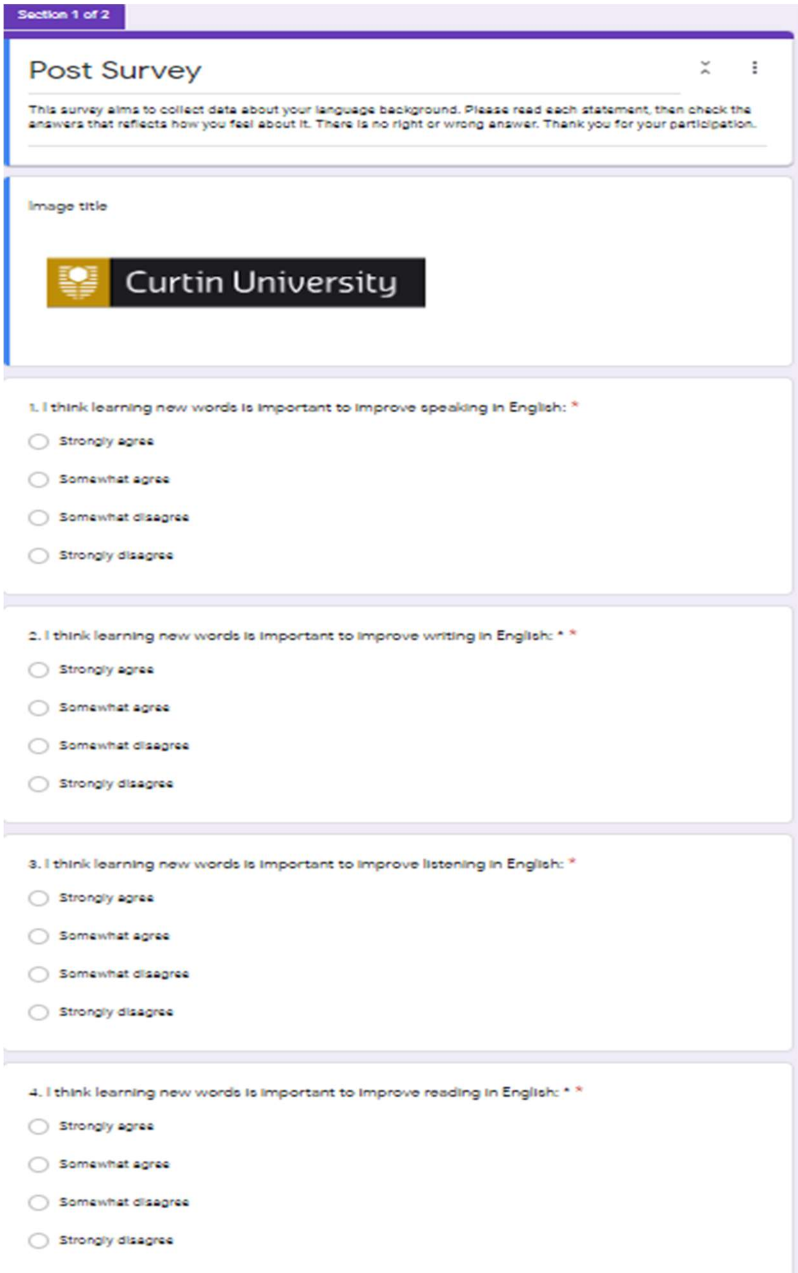
a) The smallest unit of an organism
b) A hormone naturally made in the body
c) The central part of an atom
d) A class of molecules

I. Fill in the blanks with the correct words from the box.

Citadel	Pharaoh	
Non-objective		
Nanotube	Lysome	
Opal eye		Form

15. The function of a …………………. is to digest food.
16. …………………………….. art defines a type of art where there is no aim.
17. A small green shore fish is called the ………………………………
18. A special castle in a city where people can shelter during a war is called ……………….
19. The **…………….** in ancient Egypt was the political and religious leader of the people.
20. The totality of the work of art is ……………..
21. A molecule composed of a large number of carbon atoms is called a …………

Appendix F: Post-game Survey



Section 1 of 2

Post Survey

This survey aims to collect data about your language background. Please read each statement, then check the answers that reflects how you feel about it. There is no right or wrong answer. Thank you for your participation.

Image title

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1. I think learning new words is important to improve speaking in English: *

- Strongly agree
- Somewhat agree
- Somewhat disagree
- Strongly disagree

2. I think learning new words is important to improve writing in English: * *

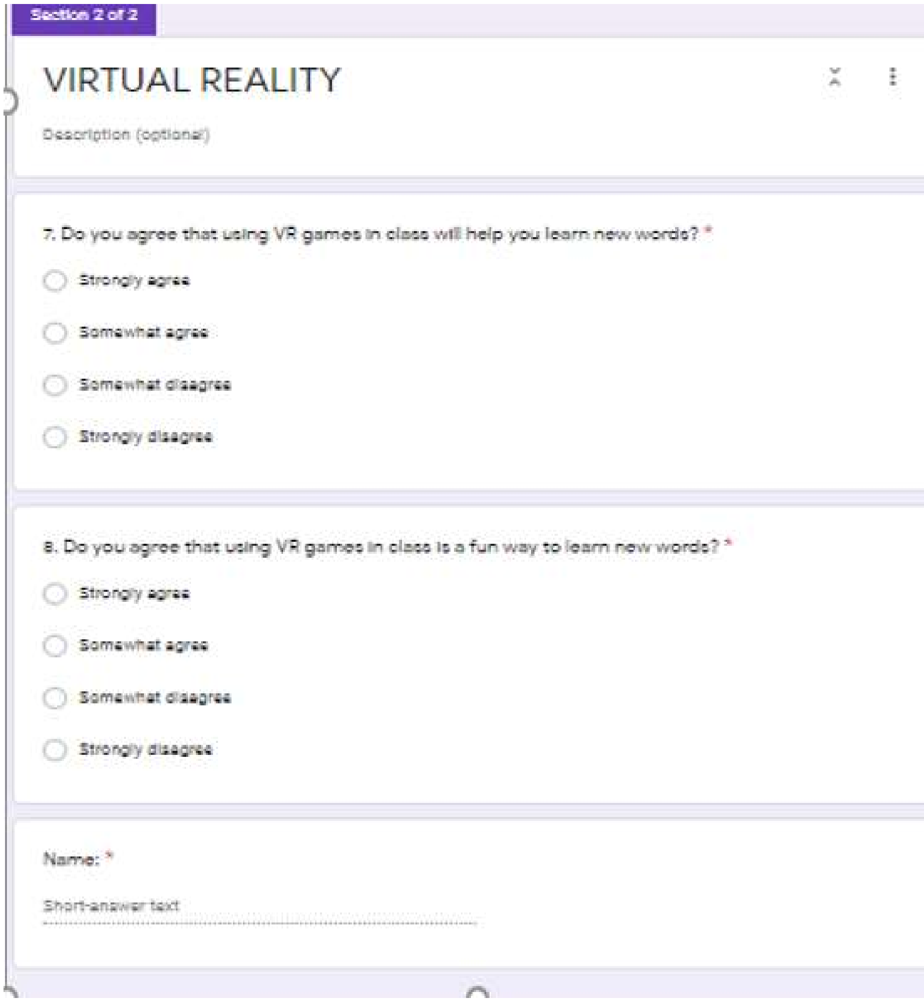
- Strongly agree
- Somewhat agree
- Somewhat disagree
- Strongly disagree

3. I think learning new words is important to improve listening in English: *

- Strongly agree
- Somewhat agree
- Somewhat disagree
- Strongly disagree

4. I think learning new words is important to improve reading in English: * *

- Strongly agree
- Somewhat agree
- Somewhat disagree
- Strongly disagree



Section 2 of 2

VIRTUAL REALITY

Description (optional)

7. Do you agree that using VR games in class will help you learn new words? *

- Strongly agree
- Somewhat agree
- Somewhat disagree
- Strongly disagree

8. Do you agree that using VR games in class is a fun way to learn new words? *

- Strongly agree
- Somewhat agree
- Somewhat disagree
- Strongly disagree

Name: *

Short-answer text

Appendix G: Extended Sample Comments Reflecting the Theme 'High Immersive Learning Environments'

Extended Sample Unit of Data
(1) I saw the game [Qantas VR] and it was so good and especially the water because it's like I'm at the river by myself. (Lena, Interview, 2018)
(2) It's like you are actually there [at the harbour] because you can actually see it. (Rania, Interview, 2018)
(3) I really liked the game [Qantas VR] because it was very vibrant and beautiful. It is also very lifelike. (Rania, Exit Slip, 2018)
(4) My favourite part was when I got to swim like the fish it was fun, and you get to feel like a real fish. (Reem, Exit Slip, 2018)
(5) All students turned their heads around frequently playing the InMind 2 game. Salma said, "This is weird, I am inside a brain". (Research Journal, 2018)
(6) Laila stood up and said "I'm going through the atoms now" playing Carbon (Research Journal, 2018)
(7) Sada said, "I feel like I am really in the house" playing Toumanian Museum. (Observation Scheme, 2018)
(8) Zehra tried to use her hand to catch the red cells playing InCell. (Research Journal, 2018)
(9) I think it's [HMD VR games] amazing because, you actually have that feeling and urge that you have to learn something in the actual game since you are right in front of it. (Salma, Interview, 2018)
(10) The thing that I liked most about this game [Diving VR] is that you are actually able to see the fish, corals and the seaweed and swim along the fish. It was very cool. (Ayten, Exit Slip, 2018)
(11) The thing I really liked about the game [Diving VR] is how it was active and colourful which made me feel excited and calm because I'm under water. It was very realistic. (Salma, Interview, 2018)

Appendix H: Extended Sample Comments Reflecting the Theme 'The Fun Factor'

Extended Sample Unit of Data
(1) I think it's really useful and it's actually quite fun because if [you] want to learn you don't want to sit down on your chair and look at one screen which is the board. (Salma, Interview, 2018)
(2) I enjoyed it [Carbon] while I learnt it because I get to see the 3D version of it, and it was fun. (Kareem, Exit Slip, 2018)
(3) I enjoyed [Carbon] and learnt new words. (Salma, Exit Slip, 2018)
(4) I enjoyed [Carbon] it because it showed us the atoms. (Laila, Exit Slip, 2018)
(5) I enjoyed the science game [Carbon] because it showed me all the carbons in much more detail. (Sulafa, Exit Slip, 2018)
(6) It [HMD VR games] makes me excited and [is] easier to learn. (Salma, Interview, 2018)
(7) It [Solar System] helped me learn a lot about Pluto and it was fun as well. (Kareem, Interview, 2018)
(8) The VR game [Solar System] was more fun than normal learning and easier. (Sada, Exit Slip, 2018)
(9) Zehra said, "cool" whilst playing the Magi Chapel VR game. (Observation scheme, 2018)
(10) Whilst playing the InCell game, Reem stated, "this is amazing", Kareem said, "this is cool", and Hassan said, "look at this, wow!". (Observation Scheme, 2018)
(11) Rania. said, "this is cool" as she started playing the InCell VR game. (Observation Scheme, 2018)
(12) "I really enjoyed the game and it's really good. I like it because it's really fun." (Lena, Exit Slip, 2018)
(13) "Yes I enjoyed it and it's very cool. I love it so much I would love to try it again." (Lena, Exit Slip, 2018)

Appendix I: Extended Sample Comments Reflecting the Theme 'Interaction with Content-specific Vocabulary Items'

Extended Sample Unit of Data
(1) It [Solar System] helped me learn new words by allowing me to pick any planet and I picked Pluto. It told me all about Pluto and a lot of things about it. (Kareem, Exit Slip, 2018)
(2) I like the cell game [InCell VR] because you actually try to do something not just stand there. (Sulafa, Interview, 2018)
(3) I liked how we were moving in the game [Diving VR], and we were able to observe the coral and plantation under the sea. (Zehra, Exit Slip, 2018)
(4) Zehra said, "I have to get the white ones" playing InCell VR. (Observation Scheme, 2018)
(5) Lena said, "I never noticed that [unclear what she is referring to]" playing Toumanian Museum and Hassan expressed his fear interacting with asteroids saying, "I am scared of the asteroid". (Research Journal, 2018)
(6) It helped us interact so we can actually see what it [target vocabulary item] is. (Hassan, Interview, 2018)
(7) What I like about the game [Diving VR] is the contrast of colours and how I can look and interact with new fish. (Yousef, Exit Slip, 2018)

Appendix J: Extended Sample Comments Reflecting the Theme 'VR Visualisation of Content-specific Vocabulary Items'

Extended Sample Unit of Data
(1) It shows what the word is, and it has an image or like the 3D view of what the word means helps. (Fatma, Exit Slip, 2018).
(2) It took me in atoms to see what they look like. (Hassan, Exit Slip, 2018).
(3) Yes, because it gave you a clear view of the carbon. It also helped because you felt how each thing was shaped. (Reem, Interview, 2018)
(4) The game [InCell VR] helped me learn new words because I was seeing in the 3D. (Sulafa, Exit Slip, 2018)
(5) Yes, you can actually see the object like in 3D you can see around it instead of just watching a video. (Sulafa, Interview, 2018)
(6) Hassan called out, "look at those planets" playing Solar System. (Observation Scheme, 2018)
(7) The game [InCell VR] helped me by looking at things I have never seen. It showed cells which helped me when the virus tries to get me it's super hard and I know what cells look like there are different ones. (Sulafa, Interview, 2018)
(8) Lena said "I am very close to the fish" playing Diving VR. (Research Journal, 2018)
(9) "Wow, I get to see what a harbour is" whilst immersed in the Qantas VR (Observation Scheme, 2018).

Appendix K: Sample Comments Reflecting the Theme 'Enhanced Vocabulary Acquisition and Retention'

Sample Unit of Data
(1) Neutrals, neuron. (Sulafa, Exit Slip, 2018)
(2) Neutraliser, dopamine. (Salma, Exit Slip, 2018)
(3) Neurons. (Hassan, Exit Slip, 2018)
(4) Neurons, dopamine and how emotions are created in your brain and how you decide on things. (Kareem, Exit Slip, 2018).
(5) I saw mitochondria, influenza. (Sada, Exit Slip, 2018).
(6) I learnt what a monument was as I saw what a monument was and what a temple was. (Fatma, Exit Slip, 2018)
(7) I did enjoy the Carbon game. Today I learnt new words which were graphene and fullerene. (Ayten, Exit Slip, 2018)
(8) Yes, I enjoyed and learnt new words because the words were clear, and I memorized all of the carbons. (Salma, Exit Slip, 2018)
(9) I enjoyed the game because I learnt more about the allotropes of carbon and their atoms. (Yousef, Exit Slip, 2018)
(10) Zehra called out "nanotube" playing Carbon. (Observation Scheme)
(11) Yousef called out, "fullerene" playing the Carbon game. (Observation Scheme)
(12) Fatma called out a target vocabulary item while playing Toumanian Museum; "Wow, architecture". (Research Journal, 2018)
(13) My favourite was the cell game because you actually get to learn new words as you do it. (Hassan, Interview, 2018)
(14) I did learn about the allotropes of carbon and how they looked like. (Zehra, Interview, 2018).
(15) Neutralizer, neuron. (Reem, Exit Slip, 2018)

Appendix L: Sample Comments Reflecting the Theme 'Insufficiency of Adequate Educational Properties'

Sample Unit of Data
(1) I didn't like the art museum [Magi Chapel] but because it didn't have much action and didn't let us move from the spot. It kept us in one place, and we didn't get to interact much. (Hassan, Interview, 2018)
(2) What I didn't like about the game [Magi Chapel] is that you only get to observe the pictures and it was really boring. Also, there was not a lot of action in the game. Plus, the pictures didn't show us the texture or any of these kinds of things. (Laila, Interview, 2018)
(3) I didn't like the game where we had to look at the carbons, the black carbons and the diamonds. Because it was boring you couldn't move by yourself, it moved for you. It wasn't really fun. At least it was better than looking at a sheet. (Hassan, Interview, 2018)
(4) According to responses from interview and exit slips, students wanted a balance between action and content information presented in VR games. (Research Journal, 2018)
(5) I didn't really like the game [Magi Chapel] because it wasn't really action packed. (Rania, Exit Slip, 2018)
(6) The game [Magi Chapel] wasn't as interactive and only observing paintings were not interesting at all. (Zehra, Exit Slip, 2018)
(7) I didn't like the fact that you can't move or interact with the game which is boring about the game. (Kareem, Interview, 2018)
(8) You get distracted by the game, so you don't pay attention for the words. (Fatma, Interview, 2018)
(9) Based on responses from interview and exit slips, players wanted games with better storylines as they believed this would be more engaging in the VR environment. (Research Journal, 2018)
(10) The game that I didn't like was where we were looking at this picture [Magi Chapel]. It wasn't fun because I was just looking at a picture. (Sulafa, Interview, 2018)