A QUANTITATIVE RESEARCH ON GAMIFYING VOCABULARY ACQUISITION AND RETENTION IN VIRTUAL REALITY

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Abstract

Despite being a building block in language learning, vocabulary can be a learning obstacle for some learners. This study explores the effects of virtual reality (VR) games on English as an additional language (EAL) EAL learners' content-based vocabulary acquisition and retention. Six Year 9 Middle Eastern students from an independent school in Western Australia were randomly selected to experience this VR approach. A Google Cardboard headset was utilised to immerse players in a 3D environment, enabling them to acquire target vocabulary while exploring the content in VR games. Data was collected through a pre-test (to screen pre-existing vocabulary knowledge), post-test (to measure vocabulary acquisition via VR games) and delayed post-test (to measure vocabulary retention). Marked differences were found between pre- and post-tests (p = .021) and pre- and delayed post-tests (p = .033), suggesting that the gamified VR environment can stimulate content-based vocabulary acquisition and enhance its retention. This 3D approach to vocabulary learning implicates the pedagogical benefits of VR games for struggling EAL learners.

Keywords: games; augmented and virtual reality; simulation; mobile learning; vocabulary acquisition and retention; EAL learners

1. Introduction

Although there are various approaches and methods available to teach vocabulary, its difficulty in acquisition and retention is generally perceived as an obstacle by language learners (Yousefi & Biria, 2016; Ahmadian & Tajabadi, 2020). This is particularly the case in an independent school in Western Australia (WA), in which 350 students were enrolled in 2020, 90 % of whom were from an EAL background. Migrating from the Middle East in early childhood, the students mostly come from families who do not speak English at home. As reported in previous

studies (Arifani et al., 2020; Erturk & Mimford, 2017; Kohnke & Ting, 2021), these EAL learners have difficulty learning content-specific vocabulary items related to Maths, Science, Humanities and Social Science, Art and English with specialist teachers attributing low achievement to students' limited vocabulary knowledge. This problem was also echoed in Laufer's (2021) research, in which EFL learners from an English for Academic Purposes class had to increase their content-specific vocabularies by a significant level to read and understand academic texts. Previous research could explain the role of vocabulary knowledge on these learners' academic success, stressing that a learner must know at least 6,000 words for daily language use, such as watching a movie or reading a novel in the target language, and 9,000 words to read books and academic texts in the target language (Laufer, 2021; Nation, 2006; Schmitt & Schmitt, 2014; Sonbul & Siyanova-Chanturia, 2022). Therefore, EAL learners' limited vocabulary knowledge in this study hinders their understanding of the content in their mainstream classroom. As a result, these EAL learners are struggling to complete tasks related to the mainstream subjects, which, however, determine their academic performance in school and in national assessments. The situation is high-stakes when these culturally and linguistically diverse (CaLD) students need to achieve a scaled mark of 50 or above in their end of semester exams to meet subject competency requirements mandated by the WA curriculum (School Curriculum and Standards Authority (SCSA), 2022).

Learning content-based vocabulary has the potential to improve EAL students' academic success, as retaining content-based vocabulary helps EAL students acquire new knowledge across subjects in mainstream classes (Helman et al., 2019). Given the digital age, previous research suggests that Virtual Reality (VR) games are conducive for situated learning as they enable EAL students to acquire the target lexis, whilst immersing themselves and engaging in topic-related scenarios (Alfadil, 2020; Chen, 2016). Therefore, this pilot study was conducted to investigate whether VR games could enhance content-based vocabulary acquisition and retention of Middle Eastern EAL adolescents. This is in response to a call for further studies to fill the gaps in determining the effects of VR on vocabulary acquisition and offer pedagogical implications for game developers, language practitioners and educational institutions that support at-risk English language learners (Alfadil, 2020; Godwin-Jones, 2016).

2. Literature review

2.1. Vocabulary learning via VR games

Vocabulary is a core element in second language acquisition (SLA) and the building block for

the development and construction of language skills such as reading, writing, speaking and listening in the target language (Laufer & Nation, 2012). Yousefi and Biria's (2016) study found that teachers put considerable effort into teaching vocabulary in EAL classes, but learners have complained that they are only able to recall a minimal amount of words. This has led researchers to explore different approaches to improving language learners' vocabulary acquisition and retention (Chen et al., 2021).

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). Steuer (1992, p. 7) defined VR "as a real or simulated environment in which a perceiver experiences telepresence" and valued the human experience over the technological hardware aspect. In other words, VR presents the telepresence in a mediated environment which provides individual experience for the user and allows one to interact with 3D objects in a virtual space (Chen, 2016). Moreover, VR games immerse learners in authentic experiences to interact with virtual objects in a gamified context, which may not be possible or difficult to carry out in a classroom environment (Chen, 2016; Dawley & Dede, 2014; Feng et al., 2018).

VR can render digital games effective for learning mainstream subjects by enabling learners to interact with objects not normally available (Blyth, 2018; Shaffer et al., 2005). Learners can immerse themselves in authentic experiences, such as travelling through a human body, which are otherwise generally not possible (Gregory et al., 2014). Kastoudi (2011) developed a VR quest game to investigate learners' English language skills through interaction with native speakers in Second Life and showed that it enhanced vocabulary acquisition through interaction, negotiation of meaning, and recognition of vocabulary. York et al.'s (2021) research suggests that VR provided the most fun and effective environment for English learning to 30 undergraduate students, in comparison to the video computer-mediated communication mode.

In Chen's (2016) study, EAL learners gained new English words as they interacted with other residents in Second Life, whilst being exposed to multimodal 3D input. They acquired the target lexis by interacting with 3D objects they built and used both text and voice chats to communicate in English as they explored different Second Life islands. The results also showed that 3D virtual worlds enhanced learners' virtual learning experience, triggered the fun element, and provided an open, immersive, and creative space that further fostered their EAL learning. Similarly, Berns et al. (2013) found that gamified 3D VR learning made vocabulary acquisition easier and motivated students, as words were presented in context and the virtual

environments offered real-time feedback. Alfadil's (2020) study explored the influence of "House of Languages," a headset-enabled VR game, on Middle Eastern intermediate school English language learners' vocabulary acquisition. The study found that students who played the VR game – enabling learners to communicate with a native English-speaking teacher (Mr. Woo – raccoon character host) – attained a greater improvement in vocabulary acquisition in comparison to those using the traditional method. VR offers a sense of exploration, an immersive experience, active learning, and a higher concentration on topics (Hussein & Nätterdal, 2015).

Given recent technological developments, an affordable VR headset device, Google Cardboard, was released in 2015. This made language learning supported by a VR headset possible as these headsets block the vision of real-life environments and increase the sense of telepresence in the VR world in unique settings related to the content of games (Dawley & Dede, 2014; Chen, 2020). 3D immersion enhanced by the sight and sound provided by the headsets offers an innovative approach to retaining new knowledge for learners who prefer visual, kinesthetic, or auditory learning styles (Freina & Ott, 2015). Given the primacy of vocabulary acquisition (Laufer & Nation 2012), headset-enabled content-based VR games (e.g., InCell, which teaches cells in science; Luden.io, 2017) enable learners to be part of a 3D world in that they can explore the content and build their own experience through telepresence, thus fostering active vocabulary learning (Chen, 2020). These video games can be powerful learning tools offering a large variety of contexts in which to learn (Martinez-Garza et al., 2013), as they enhance experiential learning and enable players to construct their own knowledge through experience (Gee, 2005). In this sense, allowing students to play content-based VR games to support the WA curriculum has the potential to boost these EAL students' vocabulary learning. Building content-based vocabulary knowledge may facilitate subject learning of these low performing students in order to meet their ultimate academic needs and future study and job demands.

3. Methodology

3.1. The aim of the study

To investigate the effects of a headset-enabled, game-based VR learning environment on EAL learners' vocabulary acquisition and retention, the main research question is:

> *Does a VR game-based, headset-enabled approach enhance the content-specific vocabulary acquisition and retention of struggling EAL learners?*

3.2. Participants and the context

This study took place during a seven-week period in an independent K-12 school in Western Australia. Twenty-four Year 9 EAL learners, whose English proficiency levels had been assessed at the lower band (SCSA, 2022), were pre-selected. This lower proficiency level places these struggling students in a high-stakes situation where they have to grapple with the demands of learning subject knowledge with limited English proficiency and insufficient content-based vocabulary. From these 24 students, six Year 9 EAL learners were selected via simple random sampling. Table 1 summarises the background information of these Middle Eastern EAL participants.

Table 1. Summary of Participants' Demographic Information (Albayrak et al., 2022)

	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

Ethical approval was first obtained from the related University Human Research Ethics Committee. The independent school Curriculum Director's approval was gained, informed consent was received from the students, and their guardians received a copy of the informed consent and information form. The consent form clearly stated that students would not be penalised for not participating or withdrawing from the study, using simple language that was understandable for the students and their guardians. Pseudonyms were adopted for all students to protect their identity and confidentiality as participants were drawn from a refugee and immigrant population that fears the disclosure of sensitive information.

3.3. Design and procedure

This study adopted a quasi-experimental design in that pre-test, post-test and delayed post-tests were employed to measure the levels of students' acquisition and retention of target vocabulary

items (Mackey & Gass, 2015). The pre-test was designed to gauge the number of target vocabulary items each student knew before playing the VR games. The post-test was designed to measure the number of vocabulary items they learnt after playing the VR games, taking the pre-test results into account. The delayed post-test was designed to determine if they retained those target vocabulary items after playing the VR games.

VR games that included the content-based vocabulary items were chosen for this study. Table 2 below provides an overview of vocabulary items related to subject areas in pre-, post- and delayed post-tests which were visualised and configured in VR games. For example, the target vocabulary items found in the InCell VR game were related to the WA curriculum (SCSA, 2022), in Year 9. They included mitochondrion organelle, invasion, inflating cell, influenza virus, nucleus, molecular machine, centrosome, lysosome, vehicle, microtubes and mitochondrion (See Figure 1 for the InCell VR game).

Table 2. Vocabulary items related to subject areas in pre-, post-, and delayed post-tests

Science	**Humanities and Social Sciences (HASS)**	**Art**
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
Nucleus	Seabass	Dominance
Diamond	Polar Vortex	Neutralism
Inflating Cell	Symmetrical	Scenery
Cortex	Rockfish	Converse
Red neurons	Architecture	Abstract
Nanotube	Continent	Non-objective
Lysosome	Rig	Form
Noradrenaline	Substructure	
Graphite	Exosphere	
Serotonin	Constellation	

Atom	Sculpture
Super Virus	Ancient
Cell	Orbit
	Solar System’
	Citadel
	Pharaoh
	Opel eye
	Harbour

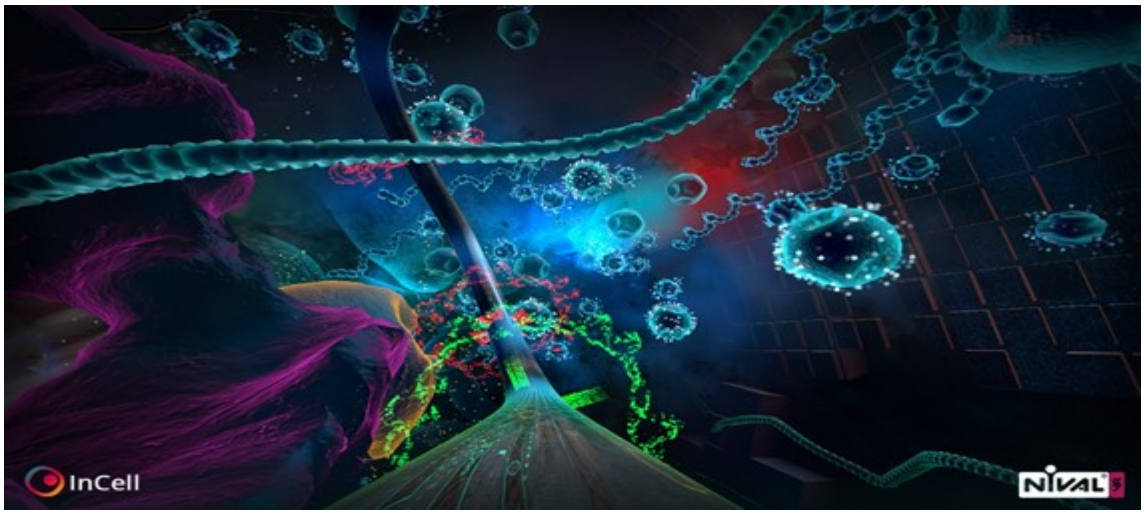

Figure 1. A screenshot from InCell (Luden.io 2017)

3.4. Data collection tools and procedures

3.4.1. Vocabulary test construction vis-à-vis VR games

The vocabulary test design was based on the vocabulary items currently used in Year 9 textbooks, following the WA curriculum. The chosen vocabulary items related to the subject content covered in the curriculum informed the selection of VR games as presented in Table 2. Each of the three tests included three question types: *match the target vocabulary items with their meanings* (21 questions), *fill in the blanks using the appropriate vocabulary items listed in the box* (21 questions) and *multiple choice* (21 questions). There was a pool of questions in each question type and seven test items were randomly selected from each pool for each test. To reduce the possibility of the practice effect, a counter-balance design was used to ensure that participants did not receive the questions in the same sequence (Mackey & Gass, 2015).

3.4.2. Selection of VR games

Teachers of the mainstream subjects approved the content-suitability of nine different games (see Table 3 for all VR games and relevant subject areas) that were carefully selected by the lead researcher (three related to science, one related to art, and five related to humanities and social sciences (HASS)). The curriculum coordinator also confirmed the games suitability for the chosen year group. The chosen games provided a 3D visualisation of the target vocabulary items, as well as written and audio information about the content. Based on Gee's (2005) good game principles, these headset-enabled VR games enabled players to interact with the game, reach a goal, explore and think about the relationships between the subject matter and vocabulary items. EAL students played two games each week, except for the last week when they played one, and each student played each of the nine games once. To illustrate, InMind VR is an action and racing game where players explore cells in a micro world with the task of stopping the virus advance (Luden.io, 2017). At the end of the game, a progress report is provided to players about their achievements (e.g., killing all viruses). The other eight games (see Table 3) were also related to the content of the WA curriculum. All games were played using Google Cardboard, an affordable VR headset device that enables VR gaming in a 3D environment.

Table 3. Summary of VR games and relevant subject areas (Albayrak et al., 2022)

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

3.4.3. Data collection

Before students started to experience the VR games, the pre-test was conducted in the first week of the study in order to screen their pre-existing knowledge of the target words. After the pre-test, six randomly selected Year 9 students attended their regular class and only went to a separate classroom to play the vocabulary games, whilst the rest of the class were completing

the normal review activities from their worksheet. One of the researchers, who also works at the independent school, guided the students to play headset-enabled VR games. After each student was given a headset and a phone with the VR game application, they received instructions on how to start the game, move themselves, and select options.

Throughout the first five weeks of VR gaming intervention, they played the content-specific games to learn new vocabulary items. Students played two games each week, except for the last week (Week 5) when they only played one, and each student played each of the nine games once. The VR game session took approximately 30 minutes. The post-test was administered in Week 5. The data collected from the pre-tests and post-tests helped to answer the question of whether or not using game-based VR with headsets increased vocabulary acquisition. A delayed post-test was followed up in Week 7, with the aim to determine the level of EAL learners' vocabulary retention. The delayed post-test took place two weeks after the post-test, as applying a delayed post-test more than two weeks after the treatment may lead to maturation and losing participants (Mackey & Gass, 2015).

The five-week intervention was conducted during the regular class time (in the beginning of the school term) to avoid the issue of not having sufficient accumulated change to measure students' performance in a short intervention period (Alfadil, 2020).

To exemplify, in Week 1, the students played InCell, an action and racing game. They began the period by reading about cells, the parts of cells and their function from their Science Worksheet. The target vocabulary items related to the Year 8 Science curriculum (SCSA, 2022), and the reading passage included vocabulary such as mitochondrion organelle, invasion, and molecular machine. Once the worksheet was completed, each student received a Google Headset with an iPhone attached and the game pre-opened ready for the students to play. Students were instructed on how to play the VR game. The game also provided written and audio information about the content and the players' mission. Players were in a human cell and had to stop the virus advance. At the end of the game, players received a progress report. Table 4 presents a summary of data collection across all the tests and VR game intervention weeks.

Table 4. Summary of data collection procedure

Week	Pre-test	VR Games	Post-test	Delayed Post-test
1	✓	✓		
2		✓		
3		✓		
4		✓		

5		✓	✓	
6				
7				✓

3.4.4. Data analysis

The pre-, post-, and delayed post-test results were co-marked by the researcher and a colleague to check 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 average scores the six students were awarded for each test is listed in Table 5, in which the Minimum and Maximum shows the range of scores for each test.

Table 5. Descriptive statistics of the three tests' 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 5 were analysed as follows and explained in detail in the Results and Discussion Section. 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 6), which is appropriate for small sample sizes, shows that the results fail to meet normality (i.e., delayed post-test result is $p = .020$). As such, a non-parametric Friedman test, which does not require a normal distribution to meet the assumptions of analysis, was employed to compare the repeated vocabulary tests.

Table 6. Shapiro-Wilk Test to ascertain whether results meet normality

	M (SD)	**df**	***P***
Pre-Test	10.50 (4.593)	6	.789
Post-Test	14.33 (3.077)	6	.256
Delayed Post-Test	13.00 (5.514)	6	.020*

Note. *p < .05

Whilst the Friedman test (Table 7) 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 and the results are discussed in the Results and Discussion section.

Table 7. Friedman test statistics to determine whether there is a difference between tests

	M (SD)	***df***	***P***
Pre-Test	10.50 (4.593)	2	.041*
Post-Test	14.33 (3.077)		
Delayed Post-Test	13.00 (5.514)		

Note. *p < .05

4. Findings and discussion

In the results of Table 7, the null hypothesis, which specifies that there is no significant difference between the test results, is rejected (p = .041). Hence, it shows that vocabulary gains 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 indicates that there is 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 shows that students improved their content-specific vocabulary, as they recognised more target words accurately in the post-test after experiencing the immersive environment. The 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 VR Diving Pro – Scuba Dive with Google Cardboard (Wang, n.d.) 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, which aligns with previous research (Barab & Duffy, 2000; Y.J. Lin & H.C. Wang, 2021; Shih & Yang, 2008). Therefore, feeling highly immersed in the subject matter context could be an innovative approach to deepening understanding and acquiring content specific words.

Table 8. 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 (the average accurate responses) in the delayed post-test increased by 24 per cent from T1. Another finding is that students' vocabulary gains did not show a marked difference in their scores between post-test and delayed post-tests (p = .229). Although the post-test scores are higher than the delayed post-test scores (T1: M = 14.33 > T3: M = 13.00), it still shows students' retention in two ways: there is a significant difference between the pre-test and delay post-test (p = .033), and the mean difference between the post- and delayed post-tests is 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). Although EAL students' mean scores in T3 did not outperform those in T2, students still retained those content-specific target words to a certain degree, even not being exposed to those target words via the VR games after two weeks, which could be a result of the interactive feature of VR environments. 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), 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. However, a strong claim cannot be made due to the limited number of participants. The small sample size may have decreased the statistical power, as there was no control group put in place and the effect size was not computed in the results. Nevertheless, the purpose of this study was to trial

the research design and test the suitability of VR games to be used on a larger scale of a future study. In this sense, the findings drawn from this pilot study still provide insightful information for researchers and EAL practitioners. A further constraint is also acknowledged since only a limited number of educational VR games in three mainstream subjects were available and complied with the year 9 curriculum.

In conclusion, 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. Content and 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.

Indeed, 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 most of those target words after the intervention. Immersive gamified learning seems to be a pedagogically appropriate approach to stimulating content-based vocabulary acquisition and retention as EAL learners in this study inferred meaning of unfamiliar vocabulary items through context, and consequently retained the target vocabulary items. This study echoes previous studies that VR games can be conducive to not only acquiring but also retaining content-based vocabulary for language learners (Alfadil, 2017; Berns et al., 2013; Chen, 2016; Kastoudi, 2011). Hence, content-based VR games can have pedagogical benefits in helping EAL students comprehend mainstream subject content and may be applicable to other subject matter in different year levels.

5. Conclusion

As evidenced in this study, headset-enabled VR games are potentially promising learning tools to foster content-based vocabulary acquisition and retention. VR games provide learners with rich exposure to the target vocabulary, and the visuals immerse the players in an artificially generated 3D world to explore the content, thus reinforcing students' vocabulary acquisition and retention. Additionally, students can construct knowledge and immersive learning experiences through directly interacting with content-specific vocabulary visualised in the VR environment. As vocabulary is learnt and retained more effectively in context, there is a strong connection between interaction and SLA (Laufer & Nation, 2012). If selected carefully, this 3D interaction with content can be made available through VR games and turn a mundane English classroom into an engaging 3D gamified playground for learners. The findings in this study are

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

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