Title: The potential of 360-degree Virtual Reality videos to teach water-safety skills to children

*Paola Araiza-Alba1**

paraiza@swin.edu.au

Therese Keane1

tkeane@swin.edu.au

Bernadette Matthews2

Bernadette.Matthews@lsv.com.au

Kate Simpson2

Kate.Simpson@lsv.com.au

Grace Strugnell2

Grace.Strugnell@lsv.com.au

Won Sun Chen1

wchen@swin.edu.au

Jordy Kaufman1

jkaufman@swin.edu.au

1Swinburne University of Technology, PO Box 218, Hawthorn, Victoria, Australia

2Life Saving Victoria, 200 The Blvd, Port Melbourne, Victoria, Australia

**Corresponding Author: paraiza@swin.edu.au, Phone: +61392148822*

Abstract

This study investigated the potential of Virtual Reality (VR), using 360-degree (360°) videos, as a tool to teach children about water-safety skills. Children (*n* = 182) aged 10 to 12 years were randomly assigned to learn about water safety using one of three instructional mediums:

360° VR videos, traditional video, or poster. The training was designed to address specific themes that contributed to drowning in coastal environments, allowing children to learn about dangers of rip currents in a relatively safe environment. Overall, 95% showed improved knowledge of water safety after participating in the water-safety workshop and retained their knowledge during the subsequent tests both one and eight weeks later. No difference was found in the learning outcomes obtained across the three mediums; however, participants in the 360° VR medium reported higher levels of interest and enjoyment than participants using the other two mediums (91% of students in the 360° VR video group found the activity engaging versus 61% for traditional video and 51% for the poster). Teacher feedback also indicated that 360° VR videos are a useful, engaging, and effective method of learning. Overall, we found support for the hypothesis that 360° VR videos are a useful tool to teach targeted skills, and that using 360° VR videos is more motivating and engaging than using traditional learning methods. We also found evidence to support the hypothesis that 360° VR videos are an effective tool for self-directed learning.

Key words:

360-degree VR videos, virtual reality; children's learning; water-safety education; drowning prevention.

1.0 Introduction

Drowning is ranked among the top ten leading causes of death in children and young people worldwide claiming approximately 300,000 lives per year (Franklin et al., 2020; World Health Organization, 2017). Moreover, for every child who dies from drowning, it is estimated another five receive emergency department care for nonfatal submersion injuries (Centers for Disease Control and Prevention, 2016). The vast majority of drowning deaths occur in open water, and rip currents are one of the most dangerous hazards that significantly increase death by drowning and are difficult to identify (Brander et al., 2011; Brighton et al., 2013; Sherker et al., 2010). Teaching school-age children swimming and water safety skills is a key intervention (World Health Organization, 2017). However, access to learning opportunities can be limited by cost and location (Birch & Matthews, 2013) [Author (2013). To be added following double-blind review].

This work was motivated by the possibility that a Virtual Reality (VR) experience could serve as an effective intervention to help address this problem. Indeed, a number of theoretical frameworks including "cognitive theory of multimedia learning" and "interest theory" (discussed in section 1.5) suggest that an engaging modality such as VR might help children learn.

With this view, we designed and implemented a learning experience using 360-degree (360°) VR videos that provides children with the opportunity to experience the beach or ocean, while also empowering them with knowledge and skills on key coastal waterway safety elements. The training was designed to address key areas that contributed to children's drowning at beaches. These topics are part of the top preventive beach tips identified by the International Life Saving Federation (*Public Education – International Life Saving Federation*, 2019): reading safety signs, spotting rip currents, surviving a rip current, and asking for help. While using 360° VR videos is not a substitute to replace formal swimming lessons, it is a possible tool in engaging the community in water-safety education.

1.1 Safety training: Water-safety education

Drowning, defined as the process of experiencing respiratory impairment resulting from immersion or submersion in a liquid (Van Beeck et al., 2005), is a major public health problem and the third leading cause of unintentional injury death worldwide, accounting for 7% of all injury-related deaths (World Health Organization, 2017). Proficiency in identifying hazards and developing personal survival skills in the water are particularly important for children; thus, the World Health Organization has prioritized swimming and water-safety education to prevent drowning. The recognized standards for water safety, as outlined by Royal Life Saving Society of Australia, expects children to be able to swim 50 metres or stay afloat for two minutes by the completion of primary school (*Benchmarking Australian Childrens' Swimming and Water Safety Skills: Swim School Data (Analaysing Children Aged 13-15 Years)*, 2017); however, many children do not meet these standards (Birch & Matthews, 2013) [Author (2013).To be added following double blind review].

Children between the ages of five and 12 should be taught how to swim during these formative years (Birch & Matthews, 2013; Brenner et al., 2003; World Health Organization, 2014) [Author (2013).To be added following double blind review]. However, while some argue that the responsibility to ensure children understand water safety and learn how to swim lies with parents, others argue that it should be with the school (Robertson, 2010). Even though some parents arrange formal, private, structured swimming and water-safety lessons, not all children have access to these opportunities because of cost or locality (*Benchmarking Australian Childrens' Swimming and Water Safety Skills: Swim School Data (Primary School Children Aged 5-12 Years)*, 2018). Although schools assuming responsibility may seem logical, delivering school swimming programs also has barriers such as cost, time out of the school day, and adding further programs to an already crowded curriculum (Birch & Matthews, 2013; Brenner et al., 2009) [Author (2013).To be added following double blind review]. Other sustainable solutions need to be explored to counteract identifiable issues that prevent children from accessing water-safety education.

Safety training that is engaging and provides direct and realistic experiences to the participants is more effective than passive training (Leder et al., 2019). Therefore, one such solution is the use of VR technology because it can offer a realistic environment in which students can learn water-safety skills**.**

1.2 Virtual reality technology and 360° VR videos

The term “virtual reality” refers to technology that provides simulated experiences. Typically, VR is a three-dimensional environment projected through a headset over the eyes of the user to provide this immersive experience, leading the user to perceive the virtual environment as real. The content produced for immersive VR generally consists of either a computer-generated environment or a series of images that provide 360° viewing. The different types of immersive VR content create different levels of immersion and interactivity (feeling of “being there”). Experiences vary from passive (i.e., looking around) to interactive, wherein the user can freely navigate, and interact with the VR environment (Southgate, 2018). Both types of content generate a sense of presence, high levels of motivation, and improved user experience compared with less immersive media (Urech et al., 2015).

At the least-interactive end of the VR spectrum are 360° VR videos, which are 360° videos viewed with a VR head-mounted display (HMD). A 360° video is a panoramic video filmed with an omnidirectional camera that allows the viewer to have an uninterrupted vision of the scenes in an uninterrupted circle rather than the fixed viewpoint of traditional two-dimensional (2D) videos (Rupp et al., 2019). Studies show that when such videos are viewed with a HMD rather than on a typical 2D screen, the resulting 360° VR video experience becomes more natural and immersive due to its ability to place the user in the centre of the scene and block the real world from the view of the user (Bessa et al., 2016; Hosseini, 2017; Hosseini & Swaminathan, 2017; G. Wang et al., 2018; Zhou et al., 2017).

The immersion generated using VR headsets varies depending on the type of headset. For example, the illusion and immersion generated by a low-cost phone enabled VR headset (e.g. Google Cardboard) is much lower than the one generated with a high-tech VR headset (e.g. Oculus Quest or HTC Vive) (Rupp et al., 2019).

1.3 The use of 360° VR videos in education

While there is growing evidence that interactive VR applications can have educational benefits (Araiza-Alba et al., 2020; Merchant et al., 2014; Mikropoulos & Natsis, 2011) [Author (2020).To be added following double blind review], studies using 360° VR videos with children for educational or training purposes are less common. However, two recent studies using 360° panoramas (virtual field trips) using VR HMD suggest that motivation, presence and engagement can be enhanced by the use of this technology (Cheng & Tsai, 2019; Han, 2019). These findings align with a recent study with adults. Rupp et al. (2019) reported that 360° videos displayed on a VR headset provided greater immersion, enjoyment and positive educational experiences compared to 360° videos displayed on a mobile phone screen. Similarly, a review by Snelson and Hsu (2019) concluded that viewers of 360° videos found the experience enjoyable for learning, however the results were mixed regarding the impact on learning.

1.4 The use of VR in safety skills training

Among VR's many uses is to teach people to manage dangerous or hazardous situations experienced in real life (Pantelidis, 2009). Moreover, VR has been used effectively as a training tool with adults in a variety of disciplines and fields such as the military, medicine, mining, and fire and earthquake safety (Li et al., 2017; Shewaga et al., 2018; Van Wyk & De Villiers, 2009; Yu et al., 2016). VR has several features that appear well-suited for training within different environments, particularly for hazard recognition and remedial safety action; it can expose trainees to simulated hazardous situations without putting them in any actual physical danger, it provides the opportunity for trainees to practice safety decisions and behaviors and it also simulates dangerous situations more frequently than would be encountered in the real world (Caserman et al., 2019; Makransky, Terkildsen, et al., 2019).

There are numerous studies that have shown the benefits of non-immersive VR compared with traditional learning and training methods, for example, positive results in student motivation when VR desktop applications are compared with conventional teaching (Makransky et al., 2016; Makransky, Borre-Gude, et al., 2019; Merchant et al., 2014; Smetana & Bell, 2012). This is also found in studies comparing immersive VR technology (i.e. using head-mounted displays) with traditional training methods. Results of these studies regularly found greater levels of motivation, enjoyment and self-efficacy, but inconsistent results for learning outcomes, where positive, mixed and negative results were found (Demitriadou et al., 2019; Leder et al., 2019; Makransky, Terkildsen, et al., 2019; Papanastasiou et al., 2018; Parong & Mayer, 2018; Vesisenaho et al., 2019; Zaalberg & Midden, 2013).

Immersive VR adds value when used for training as it evokes psychological processes and emotional states that are found in real-life situations (Howard & Gutworth, 2020). This is due to the first-person experience and a high level of psychological presence, which when combined provides the construction of context-dependent knowledge (Bacon et al., 2011). Studies have shown that when training happens in a context that emulates the real environment, students are able to put in practice the skills needed (Bertram et al., 2015). In other words, direct experiences in a learning environment that is similar to the situation where the skills are going to be applied, increases successful learning (Rupp et al., 2019). Many of these values and advantages such as evocation of psychological states, first-person experience, and sense of presence, found in the use of fully immersive VR technology can also be found in the use of 360° VR videos.

To our knowledge, no research has been conducted using 360° VR videos to teach water-safety skills to children. A few examples do exist in the areas of teaching fire evacuation (Çakiroğlu & Gökoğlu, 2019; Padgett et al., 2006; Smith & Ericson, 2009) and road safety awareness (Schwebel et al., 2008). Therefore, the current study aims to investigate the effectiveness and engagement of 360° VR videos as a tool to enhance children's learning about coastal water safety skills and hazard identification.

1.5 Theory related to learning from VR

Overall, our research questions (discussed below) are based on predictions that children will effectively learn water safety skills in the 360° VR modality. This prediction is based on two theoretical frameworks. The first is the cognitive theory of multimedia learning (CTML) (Mayer, 2009). This theory posits that students learn best when they engage in active cognitive processing which can be facilitated by students connecting the new information with existing knowledge. When an educational experience is based on such connections it can be described as "meaningful" leading to better learning outcomes (Hirsh-Pasek et al., 2015). The current study was carried out with the view that a compelling and immersive virtual environment will allow children to make these connections easily because the new information is presented in a world designed to emulate water-based environments familiar to the children.

The second theoretical framework is "interest theory" (Hidi & Harackiewicz (2000). A key component of this theory is that learning is best achieved when the learner is sufficiently interested in the material. Our study was inspired by the possibility that, even for children who arrive in the classroom with no apparent interest in water safety, the immersive and compelling nature of the VR experience has the potential to enhance such situational interest (see Rupp et al., 2019).

While the theoretical frameworks described above suggest that children can learn effectively from the VR experience, there are also reasons to be cautious about such expectations. In particular, as highlighted by Hirsh-Pasek et al.(2015), socially interactive situations can foster positive learning outcomes in a variety of ways. The use of VR headsets can interfere with such interactions. To better understand whether the use of VR headsets inhibits social enhancements to learning, it is vital that the precise ways that headsets are used be studied across a number of learning disciplines.

1.6 Research questions

In this study, the effectiveness of learning the same instructional content (i.e. water safety knowledge) via three different learning methods (posters, video and 360° VR videos) was examined. The poster and video conditions entailed greater social interaction because the experience was facilitated by a visiting instructor available to answer questions. The 360° VR videos condition did not involve this social interaction as we wanted to assess how well the virtual experience could foster learning without teacher-facilitated instruction. This allowed us to examine if the positive elements of the virtual experience (i.e., potentially affording greater motivation and meaningful learning) could make up for or even outweigh the lack of social interaction.

The study was designed to address three specific research questions:

- How effective are 360° VR videos as a memory aid for long- term memory in the acquisition of safety knowledge?

- How effective are 360° VR videos as a tool for teaching safety skills, compared with traditional teaching mediums?
- Do 360° VR videos provide a more engaging experience for children learning about safety skills, compared with traditional teaching methods?

Taken together, the answers to these questions should allow us to address the broader question of whether 360° VR videos can provide an effective self-directed learning experience in the absence of an instructor.

2.0 Method

This study was carried out as design-based research, with the intention to extend knowledge about developing, enacting, and sustaining innovative learning environments (Brown, 1992). Design-based research is an emerging paradigm for the study of learning in context through the systematic design and study of instructional strategies and tools (Baumgartner et al., 2003). It also provides being situated in a real educational context focusing on testing significant interventions (Çakiroğlu & Gökoğlu, 2019). The 360° VR video experience was design based on the model proposed by Yusoff, Zulkifli, & Mohamed (2011). This model involved active learning, self-directed learning, awareness of the problem, prototype development and evaluation among others. The 360° VR video learning experience was developed by the researchers and evaluated by comparing its efficacy to more conventional learning methods.

2.1 Power analysis

Previous research showed that VR based interventions tended to result in medium to large effect sizes (Cardoş et al., 2017; Fodor et al., 2018; Howard, 2017; Schutte, 2019).Therefore, based on 115 participants who completed this study with an alpha =.05, there was a 68% chance on detecting a medium effect size (η^2=.06) (Francis & Francis, 2016).

2.2 Participants

Participants included a total of 182 children aged between 10-12 years (*M* = 10.95, *SD* = 0.575). Of these, 115 students have been included in the results; these students had parental consent to participate in the evaluation and they completed all stages of the evaluation (67 participants were excluded from the data due to incomplete responses). Participants were randomly assigned to one of three instructional methods, 360° VR video, Traditional video (TV) or Poster. Due to the young age of the participants, parents' consent was taken to include children in the study. A summary of the participants characteristics is presented in Table 1.

Table 1

		Condition							
		360° VR (n = 46)		**TV (n = 28)**		**Poster (n = 41)**		**Total (N = 115)**	
Sex	**Female**	27	59%	17	61%	23	56%	67	58%
	Male	19	41%	11	39%	18	44%	48	42%
Age	**10 years**	7	15%	7	25%	8	20%	22	19%
	11 years	32	70%	18	64%	27	66%	77	67%
	12 years	7	15%	3	11%	6	15%	16	14%
Ever had swimming lessons*	**Yes**	38	83%	25	89%	34	83%	97	84%
	No	6	13%	1	4%	6	15%	13	11%
	Unsure	2	4%	2	7%	1	2%	3	3%

VR, virtual reality; TV, traditional video.

Table 1. Participant characteristics.

2.3 Context

Water-safety sessions/workshops were developed and delivered by Life Saving Victoria (LSV) trained education staff to students in Years 5 and 6 at two public primary schools in Victoria, Australia. The content was delivered through three mediums: VR cardboard headsets, TV, and a poster. Content presenting the same water-safety information was developed to maintain consistency across the three mediums. The content was divided into four topics that line up with the top preventive beach-drowning tips specified by the International Life Saving Federation (*Public Education – International Life Saving Federation*, 2019): reading safety signs, spotting a rip current, surviving a rip current, and asking for help.

2.1.1 360° VR video experience

The design of the 360° VR video water safety training followed the adapted design research methodology proposed by Yusoff, Zulkifli, & Mohamed (2011). This methodology involves awareness of problem, suggestion, development, evaluation, and conclusion. The training experience was created by integrating 360° videos (filmed at the beach) and VR technology (head mounted displays). The research team used 360° videos due to the affordable pricing to create the content compared to computer generated VR environments and also because these type of videos can provide positive educational experiences with low or non-simulation sickness (Rupp et al., 2019).

Students in the 360° VR video condition used a cardboard headset (consisting of a piece of cardboard cut into a precise shape that, when folded, creates goggles). This device contained focal lenses and a space to insert a smartphone, an ASUS ZenFon 2 mobile phone running Android 5.0. The VR cardboard split the smartphone screen image into two, one for each eye, resulting in a stereoscopic three-dimensional (3D) image with a wide field of view, and was equipped with a pair of wired headphones to watch the 360° videos on the four water-safety topics mentioned above (Fig. 1). In contrast to the participants in the video and poster conditions, participants in the 360° VR video condition did not have the opportunity to discuss or ask any questions about the water safety content with the instructor in charge of the learning experience.

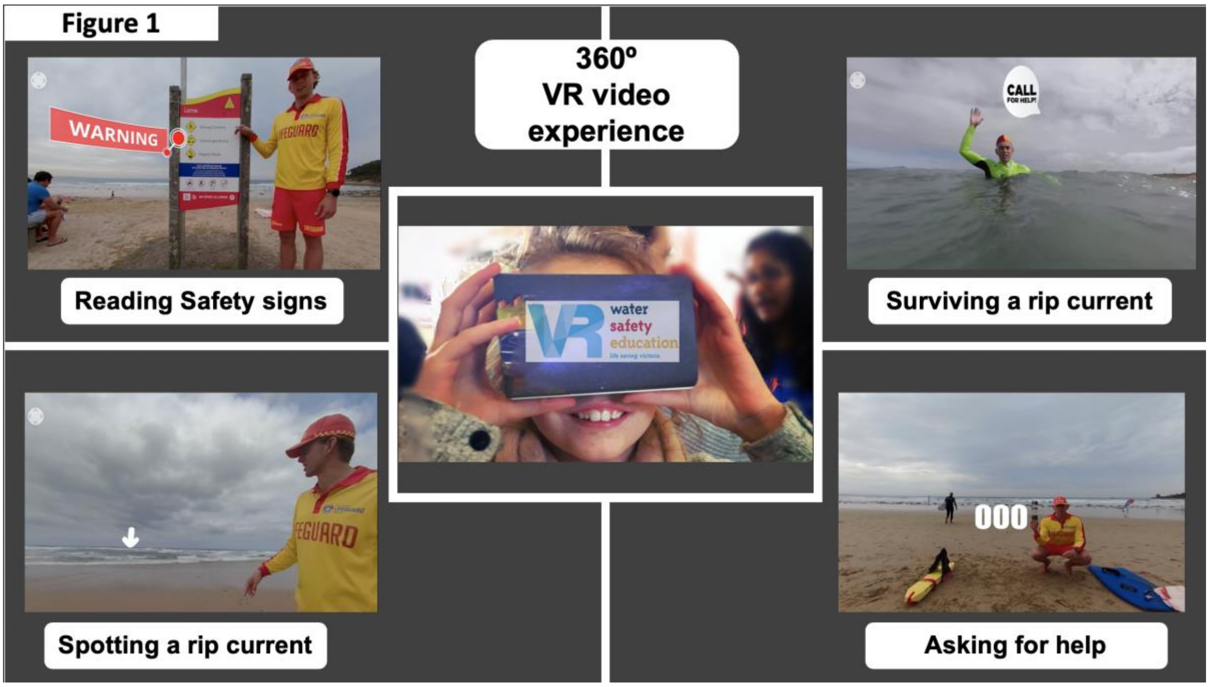

Fig. 1. Illustration of the 360° VR video experience. Photo in the middle shows participant using the VR cardboard headset; surrounding photos show snapshots of the four 360° videos used (videos can be seen on the following link, www.lsv.com.au/vr).

2.1.2 Traditional video (TV) experience

Students who were assigned to the TV modality watched four videos played through YouTube using a laptop and external speakers. The videos were 2D and were projected on a screen using a large projector. With the exception of the first video, which was animated, all recordings had images of real coastal landscapes where a narrator highlighted and explained the main topics identified above. Although the videos seen by the children in this condition were based on different material than from that used in the 360° VR experience, the video focused on the same key water safety information covered in the 360° VR videos and the poster presentation.

2.1.3 Poster

Students assigned to learning water-safety content through posters were shown four posters (61 × 91 cm) depicting the topics mentioned above. Each poster was professionally published with text and images to clearly communicate the water-safety message. The posters displayed water-safety signs, diagrams illustrating the movement of a rip current, photos of objects that can be used to ask for help, and how to help a person that has been caught in a rip.

2.2 Selection of schools and participants

Two public primary schools were selected to take part in this study. One school had approximately 700 enrollments, and the other had 250 enrollments. The schools were 130 kilometers apart and both located in coastal regions; they were selected for the following reasons (inclusion criteria):

- The higher relative risk of drowning incidents in these geographic areas, as well as the documented number of drownings.
- According to the Australian Bureau of Statistics, these schools are in regions of high relative socioeconomic disadvantage, thereby decreasing the likelihood that the students would have had exposure to private swimming lessons and water safety.
- The Year 5 and 6 students had not participated in any school-based swimming and water-safety programs in the current school year.

Prior to the study commencing, information was sent home to parents explaining the study. Parental consent was obtained prior to the instructional session. Additionally, students provided consent before participating in this study. Ethics approval for the study was obtained from Swinburne University Human Research Ethics Committee and the

Research in Schools and Early Childhood Settings (RISEC) Committee from the Victorian Government Department of Education and Training

2.3 Data collection

Six instruments were used to capture data from the water-safety workshops. (1) The Child Simulator Sickness Questionnaire (Hoeft et al., 2003), used to determined which children were predicted to experience nausea. (2) The Intrinsic Motivation Inventory (IMI) (Ryan, 2006), used to determine interest and enjoyment of the medium each student was assigned to. (3) The Sense of Presence (SofP) Questionnaire (Lessiter et al., 2001), used to gauge children's feeling of being present in the virtual environment. (4) The Water-Safety Knowledge Questionnaire devised by the research team to analyze children's understanding of water safety. (5) The workshops were video recorded for further analysis by the researchers. Finally, (6) semi structured interviews were held with teachers through a focus group at each school to get insight about their student's engagement in the workshops and their perspectives of VR headsets used in the classroom.

2.3.1 Child Simulator Sickness Questionnaire (CSSQ).

The CSSQ is an adaptation from the original Simulator Sickness Questionnaire for adults (Kennedy, Lane, Berbaum, & Lilienthal, 1993), a seven-item instrument designed to assesses specific symptoms of simulator sickness (Hoeft et al., 2003). The questionnaire poses seven questions relating to potential feelings of nausea such as, *do you have an upset stomach*, and *are you dizzy with your eyes closed*? Participants respond with one of three answers: *no*, *a little*, or *a lot*.

2.3.2 Intrinsic Motivation Inventory (IMI).

The IMI is a self-report measure of intrinsic motivation that consists of seven statements that are scored on a 7-point Likert scale, where one represents *not at all true* and seven represents *very true* (Ryan, 2006). The research team added a statement to the scale, modified the scoring scale from seven items to five, and used emoji face icons with the intention to make the scale clear and easy to interpret for children. Some examples of the statements include:

- This activity held my attention very well;
- I enjoyed doing this activity very much;
- This activity was fun to do; and
- I would describe this activity as very interesting.

2.3.3 Sense of Presence (SofP) Questionnaire for children

The SofP is a nine-statement questionnaire that gauges children's presence in a virtual environment based on Witmer & Singer's (1998) Presence Questionnaire. The research team modified and adapted the adult questionnaire's ITC-Sense of Presence Inventory (Lessiter et al., 2001) to make it suitable for use by children. The questionnaire contained nine statements about the presence perceived during the VR experience. For example:

- I felt like sounds were coming from different directions, places, all around me; and
- I felt I could have touched things in the video.

There were three possible answers that students could provide: *no, a little,* or *yes*. These three answers were given value of zero, one or two, respectively.

2.3.4 Water-Safety Knowledge Questionnaire

The Water-Safety Knowledge Questionnaire was developed by the researchers and adapted from a number of existing questionnaires. The questionnaire consisted of 11 multiple-choice questions to determine the level of understanding of water safety. A multiple-choice questionnaire was used to assess retention of basic facts and terminology (Biggs, 2011).

Examples of the questions included:

- What does a rip current look like?

- At an unpatrolled beach, how can you tell where would be safest to swim?

The questionnaire also included ten demographic questions (e.g., age and sex) and whether they had previously undertaken formal swimming lessons. This questionnaire was completed before the workshop and was repeated at the one- and eight-week marks after the workshop to determine whether the students retained knowledge.

2.3.5 Focus groups

Semi-structured interviews with the classroom teachers were conducted following the sessions to gain their feedback on: children's engagement, the sessions, and feasibility of ongoing use of VR technology. Each focus group went for 30 minutes, and the interviews from the focus group were transcribed and categorized.

3.0 Procedures

The trial consisted of five phases conducted in the following order (Fig. 2):

1. Pre-instructional phase (Test 1);
2. Instructional phase;
3. Post-instructional Test 2;
4. Post-instructional Test 3; and
5. Post-instructional Test 4.

These five phases are described in detail below.

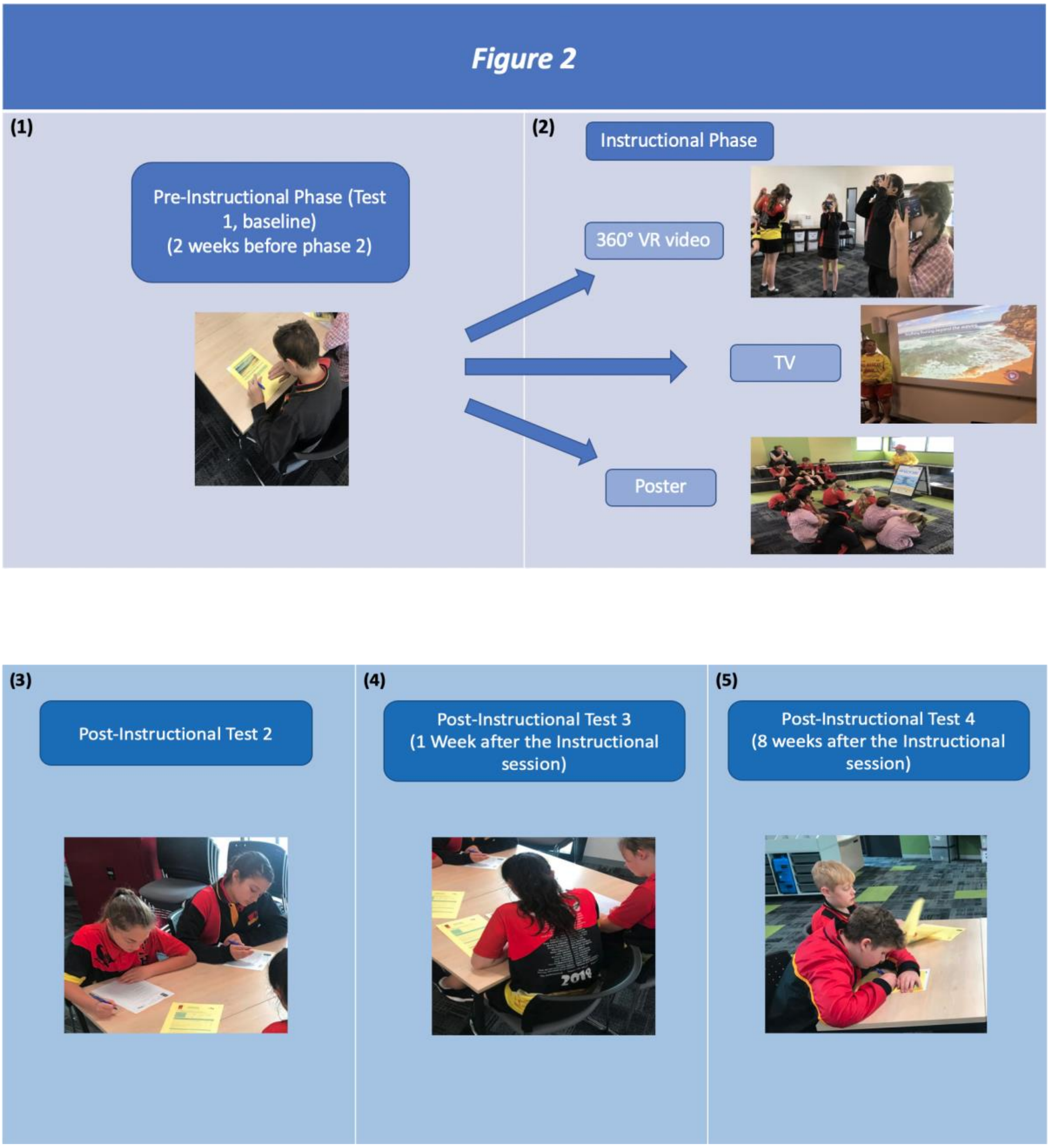

Fig. 2. Illustration of study procedures. VR, virtual reality; TV, traditional video.

3.1 Pre-instructional phase (Test 1, baseline).

Two weeks prior to the water-safety session, as part of the instructional phase, students completed the Water-Safety Knowledge Questionnaire in their classroom under supervision from their teacher. The results of this phase assessed the students baseline knowledge of water safety before the instructional phase.

3.2 Instructional phase

The delivery of the water-safety session was prearranged with the school principals and classroom teachers and was conducted in a multipurpose classroom. Students were randomly assigned by the schoolteachers to participate in the water-safety session through one of three modalities: 360° VR videos, TV, or poster (Fig. 2). As previously mentioned, the content covering four topics of water safety was identical, but the teaching tool differed. All sessions were led by a trained water-safety educator who was also a qualified lifeguard.

Over the period of four days, all children in Years 5 and 6 from the two schools participated in water-safety workshops using one of three mediums. Children were divided in groups of 10 to 13 participants, with the remaining students doing normal schoolwork until their turn to participate in the water-safety workshop. All four topics were covered in the same session on the same day for each group. The classroom teacher was present at the water-safety workshops; however, s/he remained quietly in the back of the classroom while the guest speaker took command of the class.

Students in the 360° VR video group were welcomed to the workshop by the lifeguard and filled out the CSSQ to determine if any of them were predisposed to nausea. The research team immediately checked the results of the CSSQ to ensure that none of the participants had a score indicative of simulator sickness symptoms (i.e., > 3; there were no instances of this). The students were then given specific instructions how to use the VR cardboard goggles and a brief introduction to the 360° videos they were about to watch. The research team then distributed the headsets and headphones to the students. To minimize risk and to avoid collisions between participants, the students were asked to find a place in the classroom where they could be at least two meters apart from other students. Once situated, the students watched the first video on *reading safety signs* and were asked to read aloud the sentences that appeared at the end of the video summarizing the main points of the topic. The students had to wait for all students in the group to finish each of the topics before they moved onto the next topic. This process was repeated until all four topics had been watched. The expectation by the researchers, based on literature (Liu et al., 2017; Stojšić et al., 2018), was that using 360° VR videos fostered self-directed learning; therefore, students were not given the opportunity to ask questions of the instructor, as was the case for students in the TV and poster groups.

Participants in the TV group were asked to watch the videos projected on the screen. Sitting arrangements were informal; some of the students were on chairs and some of them sat on the floor to watch the four videos. The content in the videos was introduced by the lifeguard present in the classroom, and then the video was played. At the conclusion of the video, the lifeguard summarized the key points of the topic and then answered students' questions. This process was repeated until all four videos had been viewed.

Students who were taught water safety from posters were directed by the lifeguard, who asked them to sit facing the front of the classroom. Sitting arrangements were informal; some of them were on chairs and some of them sat on the floor. The workshop was delivered using four educational posters with images and text that related to the four water-safety topics. After each topic was delivered, the lifeguard summarized the key points and answered questions from the students.

3.3 Post-instructional Test 2

Following the workshop, all participants were asked to complete the Water-Safety Knowledge Questionnaire (post-instructional Test 1) and the IMI. The Water-Safety Knowledge Questionnaire was the same one the students completed two weeks prior (pre-test phase) but without the demographic questions. Additionally, students in the 360° VR video group also completed the SofP questionnaire.

3.4 Post-instructional Tests 2 and 3

For the post-instructional Test 2 and post-instructional Test 3 phases, students were asked to complete the Water-Safety Knowledge Questionnaire both one week and eight weeks after the workshop, respectively.

3.5 Focus groups with the teachers

Classroom teachers have extensive interactions with their students and know how their students engage on a day-to-day basis; thus, they were best placed to gauge their students' engagement with the 360° VR videos. The teachers were present at the workshops and remained observers in the classroom. The research team asked semi-structured questions about the feasibility of delivering school education using 360° VR videos; students' water-safety awareness, knowledge, and engagement; and appropriateness of the resources required to deliver school education using VR headsets. These questions were designed to determine children's engagement, obtain the teachers' feedback about the sessions, and get information about whether the teachers could foresee the benefits of ongoing use of 360° VR videos within their school. In this study, four teachers were interviewed for a period of 30 minutes.

3.6 Statistical analysis

A two-way analysis of variance test was conducted to examine the influence of two independent variables (Condition and Test) on the learning outcomes of water safety and hazard identification. The Condition (workshops) included three modalities: 360° VR videos, TV, and Poster, and the Test consisted of four tests (questionnaires) conducted at different times (T1, pre-learning session; T2, immediately after the learning session; T3, one week after; and T4, eight weeks after the learning session).

Preliminary analyses revealed no significant effects on the child's sex and no interactions with sex on any of the dependent measures; therefore, sex was not considered in subsequent analyses. Preliminary analyses of the key dependent measures were confirmed to be approximately normally distributed; therefore, parametric methods were used in our key analyses.

4.0 Results

The data included 115 participants, aged between 10-12 years old. Participants were randomly assigned to one of three instructional methods: 360° VR video (*n* = 46, Mean age = 10.95 years, SD = 0.590), TV (*n* = 28, Mean age = 11.0 years, SD = 0.591), or Poster (*n* = 41, Mean age = 11.0 years, SD = 0.558). A summary of participants' information is in Table 1.

4.1 Learning outcomes

Results show the learning outcome was significantly different across the four tests conducted ($F(3, 448) = 91.187$, $p < .001$, *Partial* $\eta^2 = .38$), but not across different conditions ($F(2, 448) = 2.102$, $p = .123$, *Partial* $\eta^2 = .009$). A subsequent Fisher's Least Significant Difference (LSD) post hoc test showed that the main effect was found between T1 and all the post-learning test, T2 (Mean difference = 3.50, $p = .001$), T3 (Mean difference = 3.37, $p = .001$), and T4 (Mean difference = 3.30, $p = .001$), indicating that all students learned water safety and hazard identification and retained their knowledge during the subsequent test at one and eight weeks (Fig. 3).

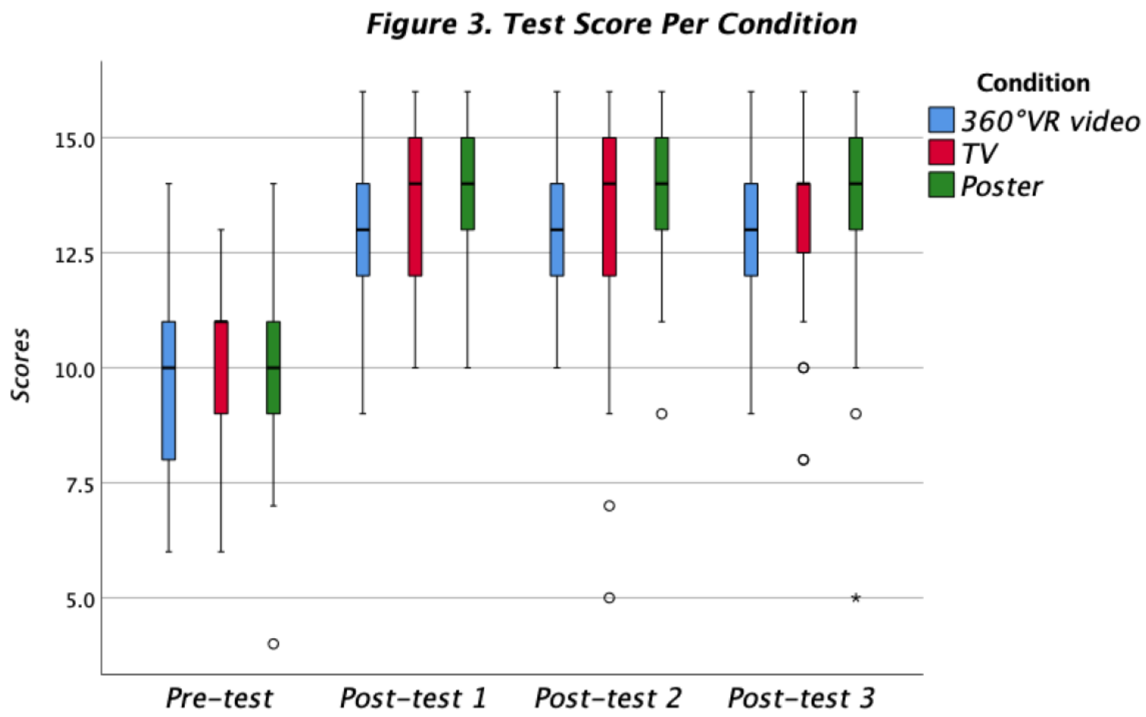

Fig. 3. Boxplot of the distribution of learning scores per condition and type of test. VR, virtual reality; TV, traditional video.

Overall, the results showed that, from the 115 participants, 109 (94.7%) increased their learning scores (Mean = 3.50, SD = 0.178) after they participated in the water-safety session.

4.2 Interest and enjoyment (IMI)

The distribution of the subscale interest/enjoyment of the IMI scores was approximately normally distributed. Therefore, a one-way analysis of variance test indicated that there was a significant difference in the average level of enjoyment across different conditions ($F(2, 167) = 18.602$, $p < .001$, *Partial* $\eta^2 = .23$). A subsequent LSD post hoc test revealed that the average level of interest/enjoyment was significantly different between 360° VR video and TV ($p < .001$) and VR and poster ($p < .001$) (Fig. 4).

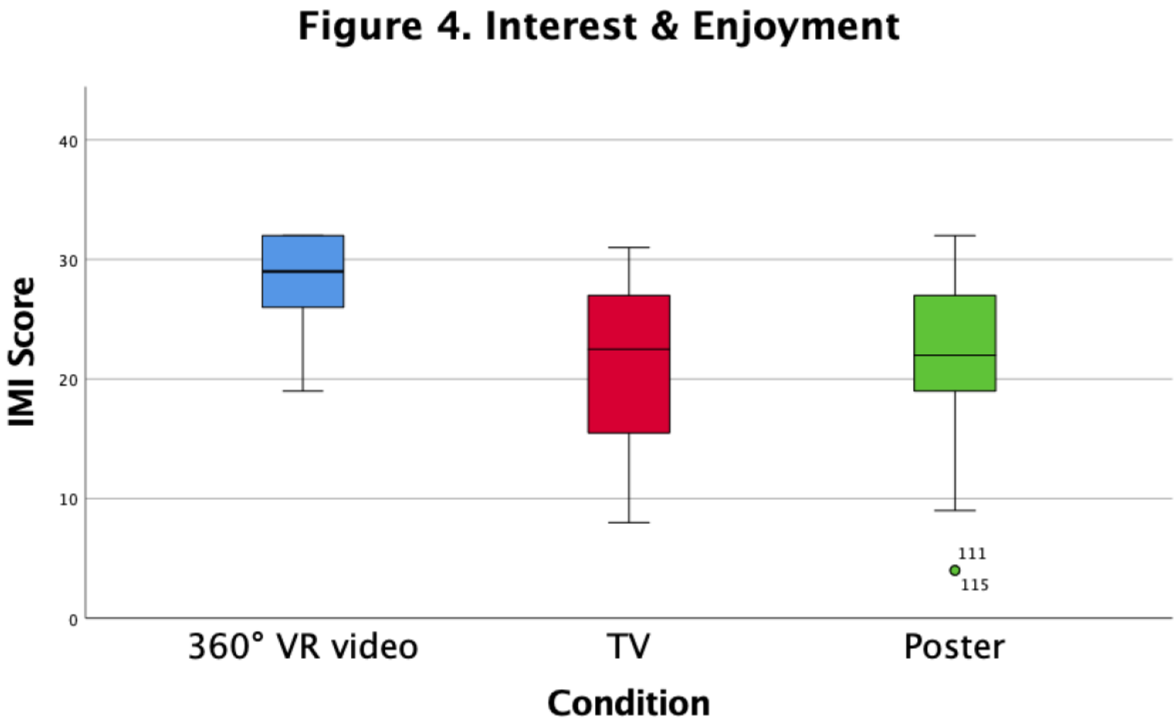

Fig. 4. Box plot of the distribution of interest and enjoyment scores per condition. VR, virtual reality; TV, traditional video.

4.3 Sense of presence

The results of the SofP Questionnaire showed that 84.7% of the children in the 360° VR video group reported low to medium sense of presence and that only 15.2% reported high levels of presence.

4.4 Teacher focus groups

The qualitative analysis of the focus groups showed that all the teachers (*n* = 4) supported the above results regarding a higher level of engagement with 360° VR videos, and one teacher noted that, "One of the things we face as a school is keeping the kids engaged. Student engagement is obviously a big factor for us here and seeing the way the kids engaged with it was fantastic —they loved it." Another noted: "…You can do so much more content (using 360° VR videos) – it can be difficult to take kids anywhere now with the extensive documentation required, cost involved in transport, and travel time to and from Melbourne. It

(360° VR videos) breaks down quite a few barriers – you couldn't take them down to the beach for a lesson in the same amount of time as we just had then."

Also, the teachers found the rip current definition particularly useful through 360° VR videos: "I particularly liked the way that rips were explained because I find it's always really hard for them to know and understand." Another teacher said, "When you're speaking about rip currents and stuff, it can get really complex, but it was kept really simple, so that was really well done." Another teacher noted that, following the VR, when students face a water emergency or need to identify water-safety hazards, they may actually stop and think before acting. One of the teachers highlighted the advantage of 360° VR videos, "If your school is not doing a physical water-safety program or swimming lessons for the year, then the VR is the next best thing because it's 'real world' relevant. You're at the beach, you're speaking to the lifeguard…it's just the next best thing to being at the beach or in the pool." In general, all teachers agreed and reported that 360° VR videos were easy to use, and they were confident to conduct a similar workshop without needing a lifeguard or a guest in the room.

5.0 Discussion

The purpose of this study was to investigate the effectiveness and engagement of 360° VR videos as a tool to enhance children's learning about coastal water safety and hazard identification. Below, we discuss our results as they pertain to each of the research questions described in Section 1.6.

5.1 How effective are 360° VR videos at fostering long- term learning of safety knowledge?

The results indicated that the students watching the 360° VR videos successfully retained water-safety knowledge over a long period of time—as learning scores at all time points were significantly improved from baseline testing scores. Moreover, there was no evidence of forgetting as scores remained stable across all post-instructional tests (immediate, one week, and eight weeks).

The retention of knowledge in the 360° VR video group may be partially attributed to the technology because it stimulates the senses of the participant and presents the information in a more realistic and authentic manner (Bell et al., 1995). Presenting media with such realism requires less active imagination of the world and thus has been argued to reduce cognitive demands, thereby facilitating memory storage (Shibli & West, 2018). Memory retention may also have benefited from the increased sense of presence and emotional involvement afforded by the VR headsets (Mantovani & Castelnuovo, 2003; Papanastasiou et al., 2018).

Furthermore, our results can be explained by the cognitive theory of multimedia learning (Mayer, 2014) that states active cognitive processing, attention to relevant information, scaffolding of the relevant information and the possibility to relate the knowledge with previous experiences (achievable by the use of 360° VR videos) during learning can facilitate long-term memory.

5.2 How effective are 360° VR videos as a tool for teaching safety skills, compared with traditional teaching mediums?

Different types of VR may have the ability to facilitate better learning outcomes than traditional learning approaches (Karkar et al., 2018). However, our results did not find a significant difference in the learning scores between the three conditions. The learning methods were equally effective in helping children gain basic knowledge of the presented material. Our results align with other studies where different instructional methods used did not impact on the learning outcomes (Leder et al., 2019; Makransky, Borre-Gude, et al., 2019).

Several possible explanations could explain why children in the 360° VR video group had similar increased water safety knowledge, compared to the children in the TV and poster groups.

Guest speakers typically add interest and bring new perspectives and communication styles to the classroom, which can increase students' involvement, critical thinking, and participation (Hemphill & Hemphill, 2007). Moreover, questions can encourage reflections and further insights and can lead to enhanced learning. Children allocated to the TV and poster groups had the opportunity to interact with the lifeguard by asking questions and engaging in a discussion, whereas the children in the 360° VR video group were not afforded the same opportunity by design. The lifeguard from LSV was very knowledgeable, and students were impressed by her knowledge. The classroom teachers reported that the students were focused on the water-safety content and freely interacted with the lifeguard.

Additionally, it is known that interactive and non-interactive learning methods, when they are both vivid in the visual or auditory aspects, had similar positive outcomes for learning (Chittaro & Buttussi, 2015). The authors of this study consider that the materials used in the three different instructional methods where relatively vivid (e.g. they provided a clear and realistic image and/or sounds of the beach and rip currents) and therefore vividness might play a particularly important role in learning outcomes.

5.3 Do 360° VR videos provide a more engaging experience for children learning about safety skills, compared with traditional teaching methods?

Our evaluation of the level of engagement indicated that 91% of the students in the 360° VR video group found the activity engaging and enjoyable compared with 61% of children in the TV group and 51% of the children taught using a poster. These results align with the teachers' observations, as reported in the focus groups, and are consistent with some studies that suggest that immersive media has the potential to engage the learner, situate the learning, and promote the learning transfer to real life (Dede, 2009). Also, the cognitive theory of multimedia learning (Mayer, 2014) and the interest theory (Harackiewicz et al., 2016; Hidi & Harackiewicz, 2000) state that media technology has the ability to engage and the potential to elicit the interest in students, which have been identified as crucial elements for learning (Huber et al., 2016) [Author (2016).To be added following double blind review]. VR technology is known to have this effect when used as a tool for active engagement (Demitriadou et al., 2019; Freina & Ott, 2015)

5.4 How effective are 360° VR video as a self-directed learning tool?

The results of this study indicated that children in the 360° VR video group (self -directed learning) learned as much as the children in the other two groups who were taught by a lifeguard. Even though the students in the 360° VR video group did not have the opportunity to clarify concepts or ask questions, unlike the other two modalities, their performance was comparable to the students in the TV and poster groups. Results suggest that 360° VR videos have the potential to be used as an educational tool in teaching students specialized topics that might be difficult to replicate in a real-life setting. It also provides the opportunity for students to repeat the experience as many times as they require to ensure they grasp the content (Liu et al., 2017; Schunk & Zimmerman, 1994). Our results suggest that 360° VR videos can be a useful tool for self-directed learning. VR technology gives learners control and regulation over their own learning activities, as well as unlimited possibilities for repetition and practice (Vesisenaho et al., 2019).

5.5 **Theoretical implications**

The research questions in this study were informed by theoretical frameworks related to children's learning from technology (outlined in Section 1.5). In particular, we noted that interest theory and the cognitive theory of multimedia learning both provided reasons why one would expect a compelling 360° VR experience to facilitate learning. This investigation was also informed by the work of Hirsh-Pasek et al., (2015) which suggests that learning in a VR environment could be hindered by the lack of social interaction inherent in the learning process.

Our study helps advance our theoretical understanding of learning using technology through its examination of what facilitates and what inhibits in the scenario. CTML theory would suggest that a well-designed 360° VR video can enhance learning by facilitating students to make connections to the real world and by reducing cognitive load through creation of a real world simulation rather than requiring students to imagine one. Similarly, interest theory would posit that the compelling virtual experience can foster situational interest which can lead students to become more interested in the topic.

Yet, Hirsh-Pasek et al.'s (2015) analysis of learning clarifies that interacting with others is an important part of the learning process because it allows learners to organize and reflect on their thoughts, and reveal gaps in their reasoning process (Hurst et al., 2013). Such advantages are not conveyed on those wearing VR headsets which generally preclude real-world social interactions.

Our findings provide evidence that even when social interaction is prevented by the use of VR headsets, learning can occur at similar levels to which occur when social interaction takes place (e.g., the poster and TV conditions). Indeed, it appears that the benefits of the technology predicted by interest theory and CTML theory may have counteracted any negative effects of reducing social interaction. Even so, we did not find learning benefits from 360° VR videos above and beyond what was obtained using traditional learning methods.

5.6 Practical implications

The findings of this study pinpoint some important characteristics of the use of 360° VR videos in education and safety training. The results regarding the practical and effective use of 360° VR video as a self-directed learning tool suggest a myriad of opportunities for the use of technology not only in formal school settings but as an informal tool for learning purposes. Organizations that provide education and training programs (such as water safety organizations and museums) could use this type of technology to support their education programs and make it accessible to more children.

Moreover, the results of this study showed the potential of 360° VR videos when used for safety training. This need not be limited to water safety but could be applied to teach about other hazards that children could experience in their lives.

Additionally, based on the findings from the teachers' interviews, 360° VR videos have the potential to be a useful tool to clarify topics that are difficult or impossible to demonstrate or explain with the use of traditional teaching methods (e.g. how to visually identify a rip current and how rip currents affect swimmers). In other words, the visualization and first-person experience that this technology brings to students can assist them to learn and understand abstract concepts (Boyles, 2017).

6.0 Limitations and future directions

The present study was designed to assess the effectiveness of 360° VR videos as a learning tool compared to more traditional methods, but it was also designed with the intention to teach children about water safety skills. For this reason, all the materials used in the three different learning methods used vivid and lively materials, and the children in the TV and poster condition were instructed by a lifeguard who encouraged students to ask questions. The interactive session with the lifeguard may explain why the poster group had positive learning outcomes. Future studies could include an experimental group that receives safety training only with still images and text to further determine the effects of vividness and interaction on attention and memory (learning).

Children in this study were not familiar with the use of VR headsets for learning purposes. They did not have a pre-training session where they could explore the technology and adjust to it. Being unfamiliar with the technology can impact learning in both negative and positive ways. From a negative perspective, it could take time before students familiarized themselves with the technology reducing their attention time spent on learning content. In a positive way, the novelty effect could be beneficial to trigger students' interest and curiosity for learning (Makransky et al., 2018; Meyer et al., 2019). Therefore, future studies that take into consideration the novelty effects and pre-training effects on learning with 360° VR videos are needed.

It should be noted that this study did not investigate the behavioral transfer of learning. The sense of presence generated with 360° VR videos ensured that the perceived experience was interpreted as being real and skills learned using the VR headset would be transferred to the real world (Romano & Brna, 2001) however, this was not tested in this research. This research tested level one and two of the four-level training evaluation model proposed by Kirkpatrick (1977). This model is a commonly used framework to classify training assessment criteria. Level one includes the learner's impressions of the training. Level two is the evaluation of the knowledge trainee gain. The third level measures how well the learning can be transfer to a real-life situation (behavioral testing) and level four is related to how well the training can be related to organizational outcomes. A study by Makransky, Borre-Gude, et al. (2019) found that the difference in learning outcomes comparing VR technologies with traditional methods were not identified until a behavioral transfer test was used. This can explain why the authors did not find group differences in learning outcomes. Future research should include a behavioral transfer test in order to fully understand the real impact of 360° VR videos on the learning process.

Additionally, the 360° videos created for this study can be considered a passive experience, where participants were limited to the role of observers. These videos are not necessarily as immersive as other types of VR content that is evolving. A highly immersive and interactive environment could have greater outcomes and improve learning results compared to traditional learning methods. Interactive and immersive environments could provide the user to test their decisions and provide immediate feedback leading to meaningful and long-lasting learning. For example, a future development of this concept could include the ability to interact with a virtual lifeguard and ask questions.

Moreover, media technology can stimulate curiosity by generating the desire for new information and experiences that could lead to positive outcomes such as better learning (Schutte, 2019). The impact of VR technologies on children's curiosity has not been explored however a recent study by Schutte (2019) with adult participants using VR showed a significant increase in their levels of curiosity, interest and positive affect when compared to participants in a control condition. Due to the positive link between curiosity and learning, future studies with children and VR should also explore the effects of this technology on children's curiosity and its impact on learning.

Finally, is important to acknowledge that educational experiences involving VR headsets remain quite novel in the educational context. Consequently, it is possible that our findings were influenced by the novelty of the experience. As society becomes more familiar with VR experiences, it is possible that the high level of interest and enthusiasm reported by students and teachers in our study could fade (Hung, 2017; Licorish et al., 2018; A. I. Wang, 2015). At the same time, educational VR experiences are also likely to improve as designers become more practiced in developing this technology and as the technology itself advances. For this reason, it is vital for research to continuously evaluate the effects that VR experiences can have on learning.

7.0 Conclusion

In this study the effectiveness and engagement of 360° VR videos as a tool to enhance children's learning was examined. As well as the potential of 360° VR videos as a self-directed learning tool. The results indicated that children in the 360° VR video group showed higher levels of engagement and enjoyment than children using the traditional learning mediums. These results contributed to the interest theory that stated that media technology can engage students in learning.

With regards to the cognitive theory of multimedia learning, our results failed to support our hypothesis that 360° VR videos provide a more effective learning experience than traditional teaching mediums. Despite the high levels of engagement using the VR headsets, significant differences in learning scores between the children in the 360° VR video group compared to those allocated to the TV and poster group were not attained. This could be attributed to two factors; the first being the type of content produced for the 360° VR video experience. The 360° video might not have been as immersive as other types of content that is evolving, such as having the ability to walk and use controls to interact with the objects in the 360° environment. Secondly, the learning was measured only with a multiple question retention test and not with a behavioral transfer test, that could be more indicative of the learning differences as demonstrated in a recent study by Makransky, Borre-Gude, et al.(2019) and Parong & Mayer (Parong & Mayer, 2018).

Regardless, the results of this study showed that 360° VR videos are an effective, safe and engaging way to teach children about water safety, hazard identification and emergency response skills. This research supports previous work highlighting the potential of VR technology as a useful tool to teach targeted skills and knowledge. 360° VR videos can be applied to high-risk activities that pose a physical threat without harming the learner and immersing them in potentially dangerous situations. Moreover, our results support the idea that 360° VR videos can be a useful tool for self-directed learning. VR technology offers the opportunity to repeat experiences. Additionally, the sense of presence ensures that the perceived experience is interpreted as being real and makes it likely that skills learned in the 360° VR videos will be transferred to the real world (context dependent knowledge).

Finally, 360° VR videos offer new ways to improve learning outcomes, and our results suggest an exciting opportunity for the role of VR as a learning tool. VR as an innovative technology, however, should be not adopted in educational settings without a careful analysis of instructional design and the integration process in the educational curricula (Makransky & Petersen, 2019; van Ginkel et al., 2019).

Acknowledgments

Details omitted for double-blind reviewing.

Declaration of interest statement

The authors have no conflicts of interest to declare.

Funding details

Details omitted for double-blind reviewing.

References

Araiza-Alba, P., Keane, T., & Kaufman, J. (2020). Are we ready for virtual reality in K-12 classrooms? *Article Submited for Publication*.

Bacon, L., Windall, G., & MacKinnon, L. (2011). The development of a rich multimedia training environment for crisis management: using emotional affect to enhance learning. *Research in Learning Technology, 19*. https://doi.org/10.3402/RLT.V19I3.7780

Baumgartner, E., Bell, P., Brophy, S., Hoadley, C., Hsi, S., Joseph, D., Orrill, C., Puntambekar, S., Sandoval, W., & Tabak, I. (2003). Design-Based Research: An

Emerging Paradigm for Educational Inquiry. *Educational Researcher*, *32*(1), 5–8. https://doi.org/10.3102/0013189X032001005

Bell, J. T., Fogler, H. S., & Arbor, A. (1995). *The Investigation and Application of Virtual Reality as an Educational Tool*. *2513*, 1–11. http://www.cs.uic.edu/~jbell/Professional/Papers/aseepap2.pdf

Benchmarking Australian childrens' swimming and water safety skills: swim school data (Analaysing children aged 13-15 years). (2017). https://www.royallifesaving.com.au/__data/assets/pdf_file/0010/22051/RLS_SwimSchoolData_BenchmarkReport_Part2_FINAL.pdf

Benchmarking Australian childrens' swimming and water safety skills: swim school data (Primary School children aged 5-12 years). (2018). https://www.royallifesaving.com.au/__data/assets/pdf_file/0009/22050/RLS_SwimSchoolData_BenchmarkReport_Part1_FINAL.pdf

Bertram, J., Moskaliuk, J., & Cress, U. (2015). Virtual training: Making reality work? *Computers in Human Behavior*, *43*, 284–292. https://doi.org/10.1016/j.chb.2014.10.032

Bessa, M., Melo, M., Narciso, D., Barbosa, L., & Vasconcelos-Raposo, J. (2016). Does 3D 360 video enhance user's VR experience? An evaluation study. *ACM International Conference Proceeding Series*, 1–4. https://doi.org/10.1145/2998626.2998669

Biggs, J. (2011). *Teaching For Quality Learning At University (Society for Research Into Higher Education)* (4th editio). www.openup.co.uk

Birch, R., & Matthews, B. (2013). *Sink or swim: The stat of Victoria primary school children's swimming ability*. http://www.lifesavingvictoria.com.au/resources/documents/sink_or_swim_report_full_report.pdf

Boyles, B. (2017). *Virtual Reality And Augmented Reality In Education*.

https://www.semanticscholar.org/paper/Virtual-Reality-and-Augmented-Reality-in-Education-Boyles/4ae770b2a4fc9c498f052b489ddb527858335bb1

Brander, R. W., Bradstreet, A., Sherker, S., & MacMahan, J. (2011). Responses of Swimmers Caught in Rip Currents: Perspectives on Mitigating the Global Rip Current Hazard. *International Journal of Aquatic Research and Education*, *5*(4). https://doi.org/10.25035/ijare.05.04.11

Brenner, R. A., Saluja, G., & Smith, G. S. (2003). Swimming lessons, swimming ability, and the risk of drowning. *Injury Control and Safety Promotion*, *10*(4), 211–215. https://doi.org/10.1076/icsp.10.4.211.16775

Brenner, R. A., Taneja, G. S., Haynie, D. L., Trumble, A. C., Qian, C., Klinger, R. M., & Klebanoff, M. A. (2009). Association between swimming lessons and drowning in childhood: A case-control study. *Archives of Pediatrics and Adolescent Medicine*, *163*(3), 203–210. https://doi.org/10.1001/archpediatrics.2008.563

Brighton, B., Sherker, S., Brander, R., Thompson, M., & Bradstreet, A. (2013). Rip current related drowning deaths and rescues in Australia 2004–2011. *Natural Hazards and Earth System Sciences*, *13*(4), 1069–1075. https://doi.org/10.5194/nhess-13-1069-2013

Brown, A. L. (1992). Design Experiments: Theoretical and Methodological Challenges in Creating Complex Interventions in Classroom Settings. *Journal of the Learning Sciences*, *2*(2), 141–178. https://doi.org/10.1207/s15327809jls0202_2

Çakiroğlu, Ü., & Gökoğlu, S. (2019). Development of fire safety behavioral skills via virtual reality. *Computers and Education*, *133*, 56–68. https://doi.org/10.1016/j.compedu.2019.01.014

Cardoş, R. A. I., David, O. A., & David, D. O. (2017). Virtual reality exposure therapy in flight anxiety: A quantitative meta-analysis. In *Computers in Human Behavior* (Vol. 72, pp. 371–380). Elsevier Ltd. https://doi.org/10.1016/j.chb.2017.03.007

Caserman, P., Zhang, H., Zinnäcker, J., & Göbel, S. (2019). Development of a directed teleport function for immersive training in virtual reality. *2019 11th International Conference on Virtual Worlds and Games for Serious Applications, VS-Games 2019 - Proceedings*, 1DUUMY. https://doi.org/10.1109/VS-Games.2019.8864599

Centers for Disease Control and Prevention. (2016). *Unintentional Drowning: Get the Facts: Home and Recreational Safety*. Centers for Disease Control and Prevention. https://www.cdc.gov/homeandrecreationalsafety/water-safety/waterinjuries-factsheet.html

Cheng, K. H., & Tsai, C. C. (2019). A case study of immersive virtual field trips in an elementary classroom: Students' learning experience and teacher-student interaction behaviors. *Computers and Education*, *140*(June), 103600. https://doi.org/10.1016/j.compedu.2019.103600

Chittaro, L., & Buttussi, F. (2015). Assessing knowledge retention of an immersive serious game vs. A traditional education method in aviation safety. *IEEE Transactions on Visualization and Computer Graphics*, *21*(4), 529–538. https://doi.org/10.1109/TVCG.2015.2391853

Dede, C. (2009). Immersive interfaces for engagement and learning. In *Science* (Vol. 323, Issue 5910, pp. 66–69). American Association for the Advancement of Science. https://doi.org/10.1126/science.1167311

Demitriadou, E., Stavroulia, K.-E., & Lanitis, A. (2019). Comparative evaluation of virtual and augmented reality for teaching mathematics in primary education. *Education and Information Technologies*. https://doi.org/10.1007/s10639-019-09973-5

Fodor, L. A., Coteţ, C. D., Cuijpers, P., Szamoskozi, Ş., David, D., & Cristea, I. A. (2018). The effectiveness of virtual reality based interventions for symptoms of anxiety and depression: A meta-Analysis. *Scientific Reports*, *8*(1). https://doi.org/10.1038/s41598-

018-28113-6

Francis, G., & Francis, B. (2016). *Building On The Foundations Of Statistics* (5th ed.). Pearson. https://www.pearson.com.au/products/D-G-Francis/Building-On-The-Foundations-Of-Statistics-Pearson-Original/9781488613296?R=9781488613296

Franklin, R. C., Peden, A. E., Hamilton, E. B., Bisignano, C., Castle, C. D., Dingels, Z. V, Hay, S. I., Liu, Z., Mokdad, A. H., Roberts, N. L. S., Sylte, D. O., Vos, T., Abady, G. G., Abosetugn, A. E., Ahmed, R., Alahdab, F., Andrei, C. L., Antonio, C. A. T., Arabloo, J., … James, S. L. (2020). The burden of unintentional drowning: global, regional and national estimates of mortality from the Global Burden of Disease 2017 Study. *Injury Prevention*, injuryprev-2019-043484. https://doi.org/10.1136/injuryprev-2019-043484

Freina, L., & Ott, M. (2015). *A Literature Review on Immersive Virtual Reality in Education: State Of The Art and Perspectives*. http://www.google.com/patents/US3050870

Han, I. (2019). Immersive virtual field trips in education: A mixed-methods study on elementary students' presence and perceived learning. *British Journal of Educational Technology*, *0*(0), 1–16. https://doi.org/10.1111/bjet.12842

Harackiewicz, J. M., Smith, J. L., & Priniski, S. J. (2016). Interest Matters: The Importance of Promoting Interest in Education. *Policy Insights from the Behavioral and Brain Sciences*, *3*(2), 220–227. https://doi.org/10.1177/2372732216655542

Hemphill, L. S., & Hemphill, H. H. (2007). Evaluating the impact of guest speaker postings in online discussions. *British Journal of Educational Technology*, *38*(2), 287–293. https://doi.org/10.1111/j.1467-8535.2006.00622.x

Hidi, S., & Harackiewicz, J. M. (2000). Motivating the Academically Unmotivated: A Critical Issue for the 21st Century. *Review of Educational Research*, *70*(2), 151–179. https://doi.org/10.3102/00346543070002151

Hirsh-Pasek, K., Zosh, J. M., Golinkoff, R. M., Gray, J. H., Robb, M. B., & Kaufman, J. (2015). Putting Education in “Educational” Apps: Lessons From the Science of Learning. *Psychological Science in the Public Interest, Supplement*, *16*(1), 3–34. https://doi.org/10.1177/1529100615569721

Hoeft, R. M., Vogel, J., & Bowers, C. a. (2003). Kids Get Sick Too: A Proposed Child Simulator Sickness Questionnaire. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *47*(20), 2137–2141. https://doi.org/10.1177/154193120304702013

Hosseini, M. (2017). View-aware tile-based adaptations in 360 virtual reality video streaming. *Proceedings - IEEE Virtual Reality*, 423–424. https://doi.org/10.1109/VR.2017.7892357

Hosseini, M., & Swaminathan, V. (2017). *Adaptive 360 VR Video Streaming: Divide and Conquer*. 107–110. https://doi.org/10.1109/ism.2016.0028

Howard, M. C. (2017). A meta-analysis and systematic literature review of virtual reality rehabilitation programs. In *Computers in Human Behavior* (Vol. 70, pp. 317–327). Elsevier Ltd. https://doi.org/10.1016/j.chb.2017.01.013

Howard, M. C., & Gutworth, M. B. (2020). A meta-analysis of virtual reality training programs for social skill development. *Computers & Education*, *144*(June 2019), 103707. https://doi.org/10.1016/j.compedu.2019.103707

Huber, B., Tarasuik, J., Antoniou, M. N., Garrett, C., Bowe, S. J., & Kaufman, J. (2016). Young children’s transfer of learning from a touchscreen device. *Computers in Human Behavior*, *56*, 56–64. https://doi.org/10.1016/j.chb.2015.11.010

Hung, H. T. (2017). Clickers in the flipped classroom: bring your own device (BYOD) to promote student learning. *Interactive Learning Environments*, *25*(8), 983–995. https://doi.org/10.1080/10494820.2016.1240090

Hurst, B., Wallace, R., & Nixon, S. B. (2013). The Impact of Social Interaction on Student Learning. Reading Horizons: A. In *Journal of Literacy and Language Arts* (Vol. 52, Issue 4).

International Lifesaving Federation. (2019). *Drowning facts and figures*. International Lifesaving Federation. https://www.ilsf.org/drowning-facts-and-figures/

Karkar, A., Salahuddin, T., Almaadeed, N., Aljaam, J. M., & Halabi, O. (2018). A Virtual Reality Nutrition Awareness Learning System for Children. *2018 IEEE Conference on E-Learning, e-Management and e-Services, IC3e 2018*, 97–102. https://doi.org/10.1109/IC3e.2018.8632634

Kirkpatrick, D. L. (1977). Evaluating training programs: evidence vs. proof. *Training Dev J*.

Leder, J., Horlitz, T., Puschmann, P., Wittstock, V., & Schütz, A. (2019). Comparing immersive virtual reality and powerpoint as methods for delivering safety training: Impacts on risk perception, learning, and decision making. *Safety Science*, *111*, 271–286. https://doi.org/10.1016/j.ssci.2018.07.021

Lessiter, J., Freeman, J., Keogh, E., & Davidoff, J. (2001). A Cross-Media Presence Questionnaire: The ITC-Sense of Presence Inventory. *Presence: Teleoperators and Virtual Environments*, *10*(3), 282–297. https://doi.org/10.1162/105474601300343612

Li, C., Liang, W., Quigley, C., Zhao, Y., & Yu, L. F. (2017). Earthquake Safety Training through Virtual Drills. *IEEE Transactions on Visualization and Computer Graphics*, *23*(4), 1388–1397. https://doi.org/10.1109/TVCG.2017.2656958

Licorish, S. A., Owen, H. E., Daniel, B., & George, J. L. (2018). Students' perception of Kahoot!'s influence on teaching and learning. *Research and Practice in Technology Enhanced Learning*, *13*(1), 1–23. https://doi.org/10.1186/s41039-018-0078-8

Liu, D., Bhagat, K. K., Gao, Y., Chang, T.-W., & Huang, R. (2017). The Potentials and Trends of Virtual Reality in Education. In *Introduction: Virtual, Augmented, and Mixed*

Realities in Education (pp. 105–130). https://doi.org/10.1007/978-981-10-5490-7_1

Makransky, G., Bonde, M. T., Wulff, J. S. G., Wandall, J., Hood, M., Creed, P. A., Bache, I., Silahtaroglu, A., & Nørremølle, A. (2016). Simulation based virtual learning environment in medical genetics counseling: an example of bridging the gap between theory and practice in medical education. *BMC Medical Education*, *16*(1), 98. https://doi.org/10.1186/s12909-016-0620-6

Makransky, G., Borre-Gude, S., & Mayer, R. E. (2019). Motivational and cognitive benefits of training in immersive virtual reality based on multiple assessments. *Journal of Computer Assisted Learning*, *December 2018*, 1–17. https://doi.org/10.1111/jcal.12375

Makransky, G., & Petersen, G. B. (2019). Investigating the process of learning with desktop virtual reality: A structural equation modeling approach. *Computers and Education*, *134*, 15–30. https://doi.org/10.1016/j.compedu.2019.02.002

Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning and Instruction*, *60*, 225–236. https://doi.org/10.1016/j.learninstruc.2017.12.007

Makransky, G., Wismer, P., & Mayer, R. E. (2018). A gender matching effect in learning with pedagogical agents in an immersive virtual reality science simulation. *Journal of Computer Assisted Learning*, *35*(3), 349–358. https://doi.org/10.1111/jcal.12335

Mantovani, F., & Castelnuovo, G. (2003). Sense of Presence in Virtual Training: Enhancing Skills Acquisition and Transfer of Knowledge through Learning Experience in Virtual Environments. *Being There: Concepts, Effects and Measurement of User Presence in Synthetic Environments*, *January*, 168–181.

Mayer, R. E. (2009). Multimedia learning, second edition. In *Multimedia Learning, Second Edition*. Cambridge University Press. https://doi.org/10.1017/CBO9780511811678

Mayer, R. E. (2014). Cognitive theory of multimedia learning. In *The Cambridge Handbook* *of Multimedia Learning, Second Edition* (pp. 43–71). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.005

Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. *Computers and Education*, *70*, 29–40. https://doi.org/10.1016/j.compedu.2013.07.033

Meyer, O. A., Omdahl, M. K., & Makransky, G. (2019). Investigating the effect of pre-training when learning through immersive virtual reality and video: A media and methods experiment. *Computers and Education*, *140*(June), 103603. https://doi.org/10.1016/j.compedu.2019.103603

Mikropoulos, T. A., & Natsis, A. (2011). Educational virtual environments: A ten-year review of empirical research (1999–2009). *Computers & Education*, *56*(3), 769–780. https://doi.org/10.1016/J.COMPEDU.2010.10.020

Padgett, L. S., Strickland, D., & Coles, C. D. (2006). Case study: Using a virtual reality computer game to teach fire safety skills to children diagnosed with fetal alcohol syndrome. *Journal of Pediatric Psychology*, *31*(1), 65–70. https://doi.org/10.1093/jpepsy/jsj030

Pantelidis, V. (2009). Reasons to use virtual reality in education and training courses and a model to determine when to use virtual reality. *Themes in Science and Technology Education*, *2*(1), 59–70. https://files.eric.ed.gov/fulltext/EJ1131313.pdf

Papanastasiou, G., Drigas, A., Skianis, C., Lytras, M., & Papanastasiou, E. (2018). Virtual and augmented reality effects on K-12, higher and tertiary education students' twenty-first century skills. *Virtual Reality*, *23*(4), 425–436. https://doi.org/10.1007/s10055-018-0363-2

Parong, J., & Mayer, R. E. (2018). Learning science in immersive virtual reality. *Journal of*

Educational Psychology, *110*(6), 785–797. https://doi.org/10.1037/edu0000241

Public Education – International Life Saving Federation. (2019). https://www.ilsf.org/drowning-prevention/public-education/

Robertson, S. (2010). Teaching young people to learn to swim. *Teaching and Learning*, *3*, 22–26.

Romano, D. M., & Brna, P. (2001). Presence and Reflection in Training: Support for Learning to Improve Quality Decision-Making Skills under Time Limitations. *CyberPsychology & Behavior*, *4*(2), 265–277. https://doi.org/10.1089/109493101300117947

Rupp, M. A., Odette, K. L., Kozachuk, J., Michaelis, J. R., Smither, J. A., & McConnell, D. S. (2019). Investigating learning outcomes and subjective experiences in 360-degree videos. *Computers and Education*, *128*(February 2018), 256–268. https://doi.org/10.1016/j.compedu.2018.09.015

Ryan, R. M. (2006). *Intrinsic Motivation Inventory (IMI)*.

Schunk, D. H., & Zimmerman, B. J. (1994). *Self-regulation of learning and performance : issues and educational applications*. L. Erlbaum Associates. https://psycnet.apa.org/record/1994-97658-000

Schutte, N. S. (2019). The Impact of Virtual Reality on Curiosity and Other Positive Characteristics. *International Journal of Human-Computer Interaction*, *00*(00), 1–8. https://doi.org/10.1080/10447318.2019.1676520

Schwebel, D. C., Gaines, J., & Severson, J. (2008). Validation of virtual reality as a tool to understand and prevent child pedestrian injury. *Accident Analysis and Prevention*, *40*(4), 1394–1400. https://doi.org/10.1016/j.aap.2008.03.005

Sherker, S., Williamson, A., Hatfield, J., Brander, R., & Hayen, A. (2010). Beachgoers' beliefs and behaviours in relation to beach flags and rip currents. *Accident Analysis and*

Prevention, *42*(6), 1785–1804. https://doi.org/10.1016/j.aap.2010.04.020

Shewaga, R., Uribe-Quevedo, A., Kapralos, B., Lee, K., & Alam, F. (2018). A serious game for anesthesia-based crisis resource management training. *Computers in Entertainment*, *16*(2). https://doi.org/10.1145/3180660

Shibli, D., & West, R. (2018). Cognitive Load Theory and its Application in the Classroom. *Journal of the Chartered College of Teaching*, *2*(Science of Learning). https://impact.chartered.college/article/shibli-cognitive-load-theory-classroom/

Smetana, L. K., & Bell, R. L. (2012). Computer Simulations to Support Science Instruction and Learning: A critical review of the literature. *International Journal of Science Education*, *34*(9), 1337–1370. https://doi.org/10.1080/09500693.2011.605182

Smith, S., & Ericson, E. (2009). Using immersive game-based virtual reality to teach fire-safety skills to children. *Virtual Reality*, *13*(2), 87–99. https://doi.org/10.1007/s10055-009-0113-6

Snelson, C., & Hsu, Y. C. (2019). Educational 360-Degree Videos in Virtual Reality: a Scoping Review of the Emerging Research. *TechTrends*, *64*(3), 404–412. https://doi.org/10.1007/s11528-019-00474-3

Southgate, E. (2018). *Immersive virtual reality , children and school education : A literature review for teachers.* (Issue 6).

Stojšić, I., Ivkov-Džigurski, A., & Maričić, O. (2018). Virtual Reality as a Learning Tool: How and Where to Start with Immersive Teaching. In *Didactics of Smart Pedagogy* (pp. 353–369). Springer International Publishing. https://doi.org/10.1007/978-3-030-01551-0_18

Urech, A., Krieger, T., Chesham, A., Mast, F. W., & Berger, T. (2015). Virtual reality-based attention bias modification training for social anxiety: A feasibility and proof of concept study. *Frontiers in Psychiatry*, *6*(OCT), 1–6. https://doi.org/10.3389/fpsyt.2015.00154

Van Beeck, E. F., Branche, C. M., Szpilman, D., Modell, J. H., & Bierens, J. J. L. M. (2005). A new definition of drowning: Towards documentation and prevention of a global public health problem. In *Bulletin of the World Health Organization* (Vol. 83, Issue 11, pp. 853–856). https://doi.org//S0042-96862005001100015

van Ginkel, S., Gulikers, J., Biemans, H., Noroozi, O., Roozen, M., Bos, T., van Tilborg, R., van Halteren, M., & Mulder, M. (2019). Fostering oral presentation competence through a virtual reality-based task for delivering feedback. *Computers and Education*, *134*(October 2018), 78–97. https://doi.org/10.1016/j.compedu.2019.02.006

Van Wyk, E., & De Villiers, R. (2009). Virtual Reality Training Applications for the Mining Industry. In *Afrigraph*. http://delivery.acm.org/10.1145/1510000/1503465/p53-van_wyk.pdf?ip=136.186.248.250&id=1503465&acc=ACTIVE SERVICE&key=65D80644F295BC0D.8CC58AB4E41E133F.4D4702B0C3E38B35.4D4702B0C3E38B35&__acm__=1567563233_91c4019573d969093dfbb910de6fefac

Vesisenaho, M., Juntunen, M., Häkkinen, P., Pöysä-Tarhonen, J., Fagerlund, J., Miakush, I., & Parviainen, T. (2019). Virtual Reality in Education: Focus on the Role of Emotions and Physiological Reactivity. *Journal For Virtual Worlds Research*, *12*(1). https://doi.org/10.4101/jvwr.v12i1.7329

Wang, A. I. (2015). The wear out effect of a game-based student response system. *Computers and Education*, *82*, 217–227. https://doi.org/10.1016/j.compedu.2014.11.004

Wang, G., Gu, W., & Suh, A. (2018). The effects of 360-degree VR videos on audience engagement: Evidence from the New York Times. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *10923 LNCS*, 217–235. https://doi.org/10.1007/978-3-319-91716-0_17

World Health Organization. (2014). Global report on drowning: preventing a leading killer. In *World Health Organisation*.

https://www.who.int/violence_injury_prevention/global_report_drowning/Final_report_full_web.pdf

World Health Organization. (2017). *Preventing drowning: an implementation guide*. https://apps.who.int/iris/bitstream/handle/10665/255196/9789241511933-eng.pdf?sequence=1

Yu, F., Hu, X., Ma, C., Zhao, Y., Liu, Y., Yang, F., & Chen, G. (2016). MDIS cloth system: Virtual reality technology for firefighter training. *Proceedings - VRCAI 2016: 15th ACM SIGGRAPH Conference on Virtual-Reality Continuum and Its Applications in Industry*, *1*, 219–225. https://doi.org/10.1145/3013971.3013977

Yusoff, M. F., Zulkifli, A. N., & Mohamed, N. F. F. (2011). Virtual Hajj (V-Hajj) - Adaptation of persuasive design in Virtual Environment (VE) and multimedia integrated approach learning courseware methodology. *2011 IEEE Conference on Open Systems, ICOS 2011*, 256–261. https://doi.org/10.1109/ICOS.2011.6079280

Zaalberg, R., & Midden, C. J. H. (2013). Living behind dikes: Mimicking flooding experiences. *Risk Analysis*, *33*(5), 866–876. https://doi.org/10.1111/j.1539-6924.2012.01868.x

Zhou, C., Li, Z., & Liu, Y. (2017). A measurement study of oculus 360 degree video streaming. *Proceedings of the 8th ACM Multimedia Systems Conference, MMSys 2017*, 27–37. https://doi.org/10.1145/3083187.3083190