Immersive capability and spatial presence in virtual reality photo-based tours: implications for distance education

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Abstract

Purpose – The purpose of this study is to describe an educational virtual reality (VR) photo-based tour used in an online course and investigate the influence of immersive capability on the dimensions of spatial presence and their relationship with learning-related variables.

Design/methodology/approach – The study employs a descriptive and an experimental methodological approach. The research objectives were achieved using a two-group (n1 = 29 and n2 = 30) experiment, employing descriptive statistics, *t*-test and correlation analysis.

Findings – The *t*-test revealed that the immersive capability had a significant effect on the sense of physical space (SP) , Engagement (EN) and negative effects (NE) dimensions. Correlations between the dimensions of spatial presence were found to confirm reports from the literature. Furthermore, some of the dimensions were found to be correlated with motivational and learning variables.

Research limitations/implications – The study reported the results of a one-off experiment among 59 participants. While the results were promising, a longitudinal qualitative study could confirm the results in an actual distance learning context.

Practical implications – The study confirmed that adding VR photo-based tours as learning activities may enhance the learning experience of distance learners.

Social implications – The study shared a case of a learning activity that can be employed for flexible education. Virtual tours can support the need for context-based learning that the geographical or political constraints may limit.

Originality/value – While the paper confirms previous reports on the benefits of using VR photo-based tours as learning activities, this paper has empirically shown the relationship between the dimensions of spatial presence and immersive capability in this specialized context.

Keywords Virtual reality, Spatial presence, Immersive learning

Paper type Research paper

Introduction

Open and distance education (ODE) has established itself as a competitive option to traditional classroom settings by broadening people's access to educational opportunities and enhancing their quality of life (Ju *et al.*, 2021; Paliwal, 2019; Qayyum and Zawaki-Richter, 2018). However, several challenges threaten its successful implementation. Low motivation among learners manifested in high attrition rates has been a consistent problem as observed by practitioners and researchers (Badali *et al.*, 2022 and Reparaz *et al.*, 2020). At times, finishing the course was different from the aim of many learners. Some just wanted to

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experience studying online, while others wanted to obtain a particular piece of information from an open course. Furthermore, when the massive open online courses (MOOCs) were only supplementary options, extrinsic motivation levels were relatively low.

However, with the massive shift to online learning strategies, which were collectively called emergency remote teaching (ERT), by formal education institutions due to government-initiated lockdowns, the stakes of finishing online courses have become much higher. Nevertheless, the experience of students taking online courses for the first time determined the viability of this strategy for these learning institutions when society has started returning to normal.

Keeping students motivated while taking online courses is as important, if not more, than having them take in-person classes. This is because online courses are conducted in less controlled environments, which makes it easy for students to disengage from the learning material when they get distracted by more interesting tasks. It is also more difficult to monitor learner behavior when they are not in the same geographical location as their instructor. Thus, maintaining their motivation throughout the course is essential to learner success. While studies showed that social and teaching presence through the information and communication technology (ICT) based interactions in forums and other related technologies can increase learner engagement and motivation (Kang and Zhang, 2020), novel technologies are aggressively being tried and tested for greatly improving the benefits reaped from online learning. One novel technology that has been gradually changing the landscape of education is virtual reality (VR).

Virtual reality

VR is a part of a collection of technologies called immersive technologies. Immersive technology is a combination of hardware and software that provides some level of immersion for users to experience a digitally created world or interact with digital objects in the physical world. Immersive technology can also refer to a range of technologies that cater to individuals who want to experience a reality different from physical reality. Among immersive technologies, VR and augmented reality (AR) appear to be the most often used tools for teaching and learning.

Though AR has been used commonly in educational contexts and research, it is believed that VR has much more potential in online learning due to its environmental features. While there are many competing perspectives on VR, two main views can be extracted from the list of definitions presented by Kardong-Edgren *et al.* (2019). The first view is that VR is a theoretical concept, which pertains to any technology that can immerse the senses while optionally providing interactivity. Another similar definition is that it is simply a computer-generated world (Pan and Hamilton, 2018). In this view, VR can be exemplified by video games, synchronous internet-based communication technologies and participation in a 2D virtual world. This perspective was widely accepted and subscribed to by scholars and educators at the end of the 20th century.

The other view has a stricter and technology-based standpoint. In this view, VR is defined as a computer-generated artificial environment that provides multisensory stimuli to simulate real or imagined worlds. It also refers to the complex media system that combines hardware and software technologies to produce that artificial environment (Makransky and Petersen, 2021).

A virtual environment where users interact using desktop computers or mobile devices but still allows them to move around the 3D virtual world is called non-immersive VR. In a strict sense, it should be offered as a mode that cannot exist without an immersive version. Thus, applications like Second Life are usually referred to as virtual worlds instead of VR, because they were created solely for non-immersive experiences. However, VR applications like Google Expedition have both an immersive and a non-immersive mode. Therefore, non-immersive VR in this context can be seen as a mode and not as a stand-alone term.

Immersive VR, which is also often called VR-mode or immersive mode, is commonly experienced using a cave automated virtual environment (CAVE) or a head-mounted display (HMD; Buttussi and Chittaro, 2017). A CAVE, which is a recursive acronym, is an enclosed space of high-definition monitors, which are usually powered by the light emitting diodes (LED) that are synchronized with one another to simulate an environment. On the other hand, an HMD is a device that is usually worn by the users, like a helmet, to provide a stimulus to their vision. Usually earphones, integrated or otherwise, are also connected to the HMD to provide auditory input that is synchronized with the visual input. A few decades ago, VR only found its way to military, space and medical contexts. There were only a few educational VR applications during those times because an immersive experience would have required a huge amount of investment in hardware and software.

Nowadays, the democratization of VR has reached the classroom because of portable commercial HMDs like the *Oculus Quest* as well as extremely cheap smartphone add-ons like the *Google Cardboard*. It is essential to distinguish the two modes of experiencing VR in the design of this paper as they could contribute to the variation of two important aspects of a VR experience: *immersion* and *presence.*

Immersive capability

Immersion has an established definition in education, psychology and gaming. Agrewal *et al.* (2020) discussed two main groups of these definitions. One of the most famous theories that define immersion is the *flow theory*. Immersion is defined as the feeling of being fully absorbed in as described by Murray (2017), using the metaphor of being submerged in water. This definition was very much related to attention–a psychological phenomenon. Though the previous definition in psychology is being used in many research projects and articles involving virtual worlds and VR, a different perspective was adopted by the technologists and presence researchers. Immersion, in their perspective, is an objective technological capability instead of a human condition (Slater, 2018), which differentiates the term from what is called *presence* among virtual experiences.

Among researchers of presence in VR, immersion refers to objective aspects of hardware and software systems such as display quality, stereoscopy, resolution and field of view, which could facilitate presence. However, to distinguish it from other views widely taken by educational researchers, the term *immersive capability* will be consistently used in this paper.

Spatial presence

The construct of presence contributed to the widespread development of VR and other virtual environments (VEs). However, there has not yet been an agreed standard for defining or operationalizing it, leading to its multiple definitions based on the researchers' theoretical underpinnings. Skarbez *et al.* (2017) grouped these definitions into three: *being there, non-mediation* and *others.* The first grouping is widely represented by telepresence and spatial presence.

Telepresence pertains to transportation or the feeling of being there (Schuemie *et al.*, 2001). However, Sheridan (1992) made it more specific by defining it as the sense of being in a real remote location and not in the VE. In recent studies, the term *spatial presence* has emerged. A study by Weibel *et al.* (2015) subscribed to the definition of Heeter (1992) that spatial presence refers to the experience of *being there* in a mediated environment. This phenomenon is also called self-location.

Researchers from information technology and psychology developed instruments to measure spatial presence reflecting various interpretations and epistemologies of the construct and its dimensions. In a systematic review of the literature regarding self-reported and physiological measures (Grassini and Laumann, 2020), the most used questionnaire was reported to be the presence questionnaire (PQ).

Witmer and Singer developed (PQ) with immersive tendencies questionnaires (ITQ) in 1998. Items were rated using a semantic differential scale, where participants were asked to put an "X" on the location of the scale near the label that matches how they felt. From an initial 32 items, 19 were retained, with 17 loading into three subscales. From the analysis, 11 items were loaded into the Involved/Control subscale, three items were loaded into the Natural subscale and three items were loaded into the Interface Quality subscale. Items were also grouped into factors. The major factor categories were control factors (CF), sensory factors (SF), distraction factors (DF) and realism factors (RF).

Lessiter *et al.*'s (2001) ITC Sense of Presence Inventory (ITC-SOPI) included a comprehensive list of items were loaded into the four dimensions of presence. These were the *sense of physical space (SP), engagement (EN), naturalness (N)* and *negative effects (NE)*. They included the sense of *being there,* the extent to which the virtual environment becomes more real or present compared to physical reality, and the extent to which the VE is thought of as a place that was visited rather than a set of images. Although it was not as widely used as PQ, it included two essential dimensions in this study: *NE* and *SP*, where the latter represents the core definition of spatial presence.

Research on VR in online learning contexts

Numerous studies have claimed the potential of VR in training and educational applications. Huang *et al.* (2020) agreed with previous studies in asserting that experiencing presence may lead to positive learning outcomes provided that the content of the VR application does not produce too much cognitive load.

Another phenomenon found to be experienced in VR is embodiment, which may be described as the experience of owning a virtual body through an avatar, and the combined cognitive and affective processes that occur based on the avatar's appearance and agency, leading to the possibility of feeling sensorial effects from stimuli around it (Makransky and Petersen, 2021). It has been reported that embodiment in VR can bring about empathy among its users (Bertrand *et al.*, 2018).

Various researchers have found that VR applications were able to contribute positively to learning motivation among adult learners, such as health care professionals (Mantovani *et al.*, 2003) as well as young learners. VR applications were found to provide enjoyment (Vogel *et al.*, 2006) and help concretize abstract concepts (Harley *et al.*, 2016).

Meanwhile, three studies agreed that students who used VR-based educational activities showed greater learning achievement, gave higher satisfaction ratings and showed greater interest than in other activities. The first example was a virtual campus system that is based on VR that was developed for distance education in China (Chang-qin *et al.*, 2016). Another recent case involved teaching pharmacy online, where it was reported that team-based learning done in VR could provide engaging elements without learners being physically present in the same room (Coyne *et al.*, 2018). The most recent report was from Japanese students who used VR tours remotely during the COVID-19 pandemic (Figueroa *et al.*, 2022).

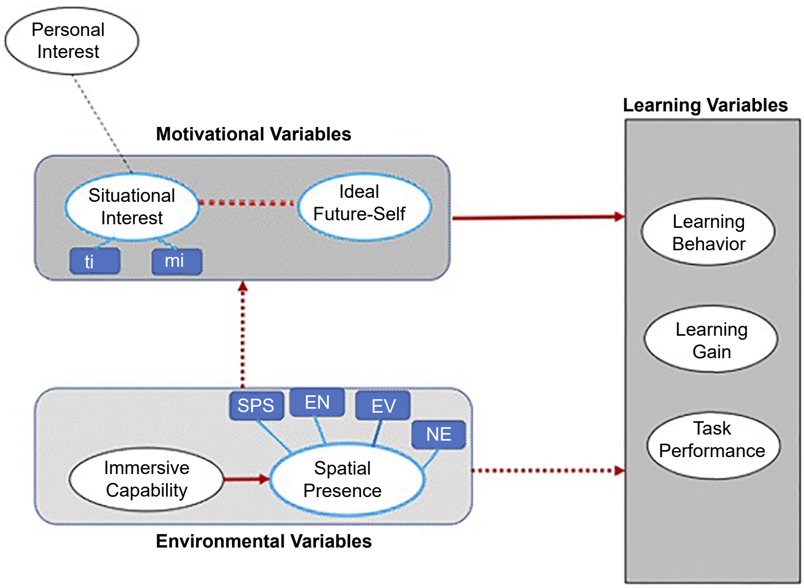
Despite the numerous studies on VR and its benefits in learning and training contexts, the underlying factors contributing to these benefits are empirically lacking. Scholars have criticized research on VR-based educational interventions as being mostly developmental and lacking theoretical foundations. This was exemplified by a review article conducted by Radianti *et al.* in 2020. In their paper, they revealed that most of the 38 reviewed articles on VR-based educational innovations were development research. These were described further as studies that merely documented the overall development process. Other papers followed an experimental design with usability and user-testing research. While the experimental design was mixed with usability and user-testing research in one category, most articles reviewed did not apply any data analysis method. Only two used *t*-test and correlation analysis. Besides this, only four studies used qualitative methods such as observation and focus group discussion. Related to this are gaps that were reported in similar review articles on immersive VR regarding the lack of validated instruments in measuring learning and motivation related outcomes (Di Natale *et al.*, 2020 and Hamilton *et al.*, 2021).

Furthermore, most of these articles did not present the theoretical foundation on which the studies were based. Finally, only a few papers evaluated learning outcomes as most of them were usability oriented. They echoed the dearth of empirical qualitative and quantitative research on VR-based interventions in learning contexts.

The gaps found in the literature could be summarized into three themes. Firstly, there was a lack of research on spatial presence and immersive capability and their relationship with situational interest, ideal future-self and learning outcomes. Secondly, past studies were mostly developmental, and the effects were measured using the usability framework. Lastly, most past studies did not use motivation and learning theories as a framework. Instead, they often merely documented how an app was developed, used and evaluated. This paper describes the third of four interrelated studies that have been part of a dissertation guided by a theoretical framework developed to address these research gaps. The study attempted to address the first theme with a focus on empirically investigating the influence of immersive capability on dimensions of spatial presence in an educational online VR photo-based tour.

Theoretical framework

The theoretical framework developed was guided by assumptions gathered from the theories and empirical studies reviewed. Figure 1 is an initial model illustrating the constructs and



Note(s): TI: Triggered Interest; MI: Maintained Interest; SPS: Sense of Physical Space; EN: Engagement; EV: Environmental Validity; NE: Negative Effects
Source(s): Figure by author

Figure 1. Theoretical framework in VR-based learning

their theoretical relationship with each other and learning-related variables. The model served as a theoretical framework for the interrelated studies carried out by the author.

Two constructs were found to be apt for observing motivation in VR-based learning contexts after a critical literature review on motivational theories. The first construct is situational interest (SI), a psychological state that makes attention and learning effortless. In such a state, affective reactions, cognitive functioning and perceived value intertwine (Ainley, 2006; Hidi and Renninger, 2006 and Schiefele, 2009). The second construct is the ideal future-self (IF), a future-self guide that represents one's desired possible self that also encapsulates his/her dreams and goals (Dörnyei, 2009).

Situational interest and its relationship with personal interest were based on the theories of Krapp (1999) and Hidi and Renninger (2006). The two phases of the SI, triggered interest and maintained interest, were established by Hidi's (1990, 2000) early studies and supported by associates (Hidi and Harackiewicz, 2000; Hidi and Renninger, 2006 and Linnenbrink-Garcia *et al.*, 2010).

Solid lines represent relationships that were empirically proven by studies, while broken lines represent theoretical relationships that were implied by previous research but lacked empirical evidence. Thus, the studies aimed to validate the previously proven relationships in various VR-based learning contexts and provide empirical evidence supporting assumed relationships. The definition of spatial presence was based on what has been established by Slater *et al.* (1995), and supported by other researchers (Lessiter *et al.*, 2001 and Weibel *et al.*, 2015). The effects of different aspects of VR's immersive capability on spatial presence were supported by Slater *et al.* (1994), Witmer and Singer (1998), Sheridan (1992) and Steuer (1992). The studies were also built upon the assumptions that the SI, IF and spatial presence have an influence on certain aspects of learning such as academic and task performance (Kim and Biocca, 1997; Rotgans and Schmidt, 2009 and Welch, 1999), behavior (Dörnyei and Chan, 2013) and actual outcomes like retention and grades (Kim and Biocca, 1997).

Using a portion (*highlighted in yellow*) of the theoretical framework as a guide, the following research questions for the study presented in this paper were formulated:

(1) How does immersive capability influence the dimensions of spatial presence?

(2) How are the dimensions of spatial presence related to motivation?

(3) How are the dimensions of spatial presence related to learning outcomes?

Research objectives

The purpose of this study was to determine how immersive capability influences the various aspects or dimensions of spatial presence felt by participants. Furthermore, the study intends to investigate the connection between the dimensions of spatial presence and motivation, as well as their bearing on learning outcomes. By addressing the research questions, the study intends to contribute to the existing literature on VR in online learning contexts, specifically in terms of motivation, spatial presence and learning outcomes. Furthermore, the study seeks to fill gaps identified in prior research, such as the lack of empirical investigation into the influence of immersive capability on spatial presence, its connection to certain aspects of motivation and the contextualization of findings for distance education.

This paper is structured to briefly describe the VR photo-based tour used in the study. This is followed by a description of the participants and how they were recruited. The setup of the experiment and how the data were collected and analyzed are then discussed. The findings from the analyzed data are organized according to the three research questions presented in the theoretical framework, which is followed by a discussion on how they bridge the gaps in the literature. The paper concludes with implications for instructional designers, teachers and researchers of OED institutions embarking on similar initiatives and future research.

Methodology

The VR photo-based tour designed and developed in this study was one of the materials of the MOOC on forest ecosystem services jointly developed by universities specializing in forestry. The learning activity was designed to teach the different types of forest ecosystem services while virtually situated in a protected forest in the Philippines. Plate 1 shows a snapshot of one area in the tour.

The tour was developed using *Kuula* (kuula.co) but was later redesigned using *A-frame*. It had hotspots that represented one type of forest ecosystem service. Hotspot audio was played every time an information icon was clicked when using a computer or gazed at when using a VR headset or HMD. Text labels were made to float as markers for each hotspot. Gazing in VR refers to direct one's focus on a particular area, usually represented by a small white dot. It is usually counted as a gaze when the dot stays on a specific area for at least 2s.

Participants

A total of 60 participants who had experience in or were taking online courses were recruited, using purposive sampling as Filipino adult learners. However, only 59 responses were deemed to be valid as one participant was not able to complete the questionnaire after the experiment. The study had 15 male and 44 female participants. Most participants were in their twenties (44) and thirties (11). Three were in their forties and fifties and one participant was in her sixties.

The instruments used in this study included the following: (1) the SI scale; (2) the IF scale; (3) the original ITC-SOPI scale for measuring the four dimensions of presence (Lessiter *et al.*, 2001) and (4) the learning outcomes operationalized by getting the difference between the post-test and pre-test of an eight-item quiz. All scales used in this study were found to be valid and reliable.

The quiz was developed to test participant knowledge of concepts taught in the VR photo-based tour. The difference was called score gain.

Source(s): Plate by author

Plate 1. A screenshot of a VR tour on forest ecosystem services

Experiment setup

The participants were randomly assigned to one of the two groups. In *Group 1, 29* participants experienced the VR photo-based tour on a laptop computer or smartphone without HMD or VR glasses. This was referred to as the *low immersive capability group*. Meanwhile, 30 participants in *Group 2* experienced a VR photo-based tour with an HMD. Specifically, they used an *Oculus Go* to experience the tour immersively. This was also referred to as the *high immersive capability group*. The step-by-step procedure of the experiment is outlined in Table 1, with the time allotment for each step.

Each participant was asked to answer a short quiz containing items regarding the topic before experiencing the activity. Then, they were asked to experience the VR photo-based tour within ten minutes. Those in Group 1 used a laptop with a headset that the researcher provided during the experiment to experience the tour. Those in Group 2 used Oculus Go with the tour already loaded. They were then asked to answer the same short quiz given before the experience, followed by a survey containing items pertaining to SI, IF and spatial presence.

Data analysis

Data were subjected to statistical analysis to achieve the objectives of the study. The effects of immersive capability on the dimensions of spatial presence, SI, IF and learning outcomes, were tested through *t*-tests. The tests were performed using the *R stat* package, while mean comparisons were visualized using the *ggplot2* package (Wickham, 2016).

Relationships between variables were determined using correlation analysis. A visual correlation matrix was generated using the *Performance Analytics* package (Peterson *et al.*, 2018).

Findings

Findings are presented according to each research question. The first research question deals with the influence of immersive capability on the SP, EN, ecological validity and NE, which are the four dimensions of spatial presence operationalized by Lessiter *et al.* (2001). The second research question deals with the relationship between dimensions of spatial presence and the motivation represented by the SI and the IF. The last research question deals with the relationship between the dimensions of spatial presence and learning gain, which was operationalized by the difference between post- and pre-test scores or score gain.

RQ1. Influence of immersive capability on dimensions of spatial presence

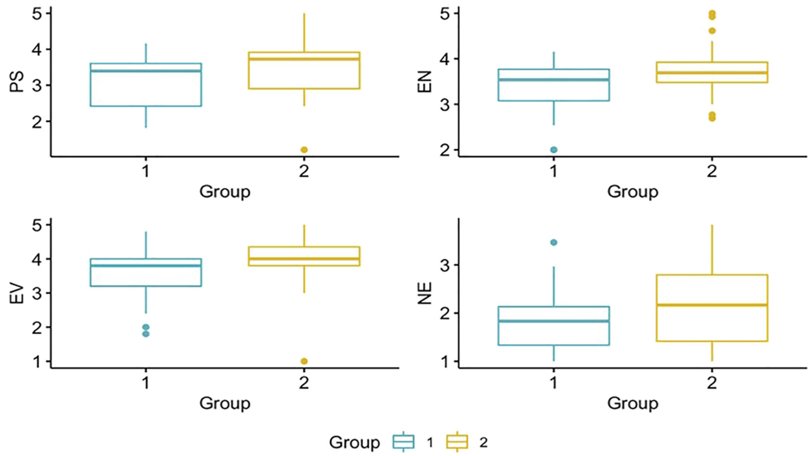
Figure 2 compares boxplots of the four dimensions of spatial presence between the two groups. Participants in Group 2 (high immersive capability group) had higher means of PS, EN, EV and NE than those in Group 1 (low immersive capability group).

These differences were statistically tested and a summary of results from the *t*-test performed for the four dimensions is shown in Table 2.

Table 1. Procedure of the experiment in the study

Time	Group 1	Group 2
5 min	Orientation	Orientation
10 min	Pre-test	Pre-test
10 min	VR photo-based tour without HMD	VR photo-based tour with HMD
10 min	Post-test	Post-test
15 min	Survey	Survey

Source(s): Table by author



Source(s): Figure by author

Figure 2. Box plots of the four dimensions of spatial presence

Variable	t	p-value
PS	2.24	0.03*
EN	2.65	0.01*
EV	1.59	0.12
NE	2.33	0.02*

Note(s): PS: Sense of physical space; EN: Engagement; EV: Environmental validity and NE: Negative effects
Asterisks: * (p < 0.05), ** (p < 0.01) and *** (p < 0.001)
Source(s): Table by author

Table 2. Mean difference in spatial presence dimensions

Results from the t-test revealed that the influence of immersive capability on the SP, EN and NE dimensions was statistically significant, with t (57) = 2.24, p = 0.03; t (57) = 2.65, p = 0.01 and t (50) = 2.35, p = 0.02, respectively. However, the influence of immersive capability on the EV dimension was not statistically significant, with t (57) = 1.59, p = 0.12.

RQ2. Dimensions of spatial presence and motivation

The PS and EN were found to be strongly correlated, r (57) = 0.82, p < 0.001. PS and EV were also strongly correlated, r (57) = 0.80, p < 0.001. Lastly, EN and EV were strongly correlated, r (57) = 0.77 p < 0.001. None of the other dimensions of spatial presence was significantly correlated with NE.

Among participants, SI was found to be moderately correlated with PS, r (57) = 0.38, p < 0.01, EN, r (57) = 0.47, p < 0.001 and EV, r (57) = 0.37, p < 0.01. Meanwhile, IF was found to be weakly correlated with PS, r (57) = 0.25, p < 0.05, EN, r (57) = 0.23, p < 0.05 and inversely correlated with NE, r (57) = −0.31, p < 0.05. The SI and IF were found to be strongly correlated, r (57) = 0.52, p < 0.001.

RQ3. Dimensions of spatial presence and learning gain

Score gain was weakly correlated with the SP dimension, r (57) = 0.24, p < 0.05, and was found to be statistically significant. However, the weak correlation between score gain and other dimensions of spatial presence, such as EN, EV and NE, were not found to be statistically significant with r (57) = 0.14, p > 0.05; r (57) = 0.14, p > 0.05 and r (57) = 0.025, p > 0.05.

A summary of how statistical results answered each of the three research questions is presented in Table 3 for the appreciation of a broad variety of readers.

Discussion

Confirming theoretical assumptions

The purpose of this study was to investigate the relationships between the environmental, motivational and learning-related variables among the participants who experienced an educational VR photo-based tour. Furthermore, the study was meant to confirm assumptions made in the theoretical framework.

Major assumptions in the initial model were empirically supported by the results of this study. The statistically significant results from the *t*-test regarding the difference in spatial presence dimensions between participants in high and low immersive capability supported earlier studies claiming that immersive capability influences spatial presence (Sheridan, 1992; Slater *et al.*, 1994; Steuer, 1992 and Witmer and Singer, 1998).

Results from the correlational analysis echoed factor inter-between the SP, EN and EV (Lessiter *et al.*, 2001). Furthermore, these findings provided evidence for hypothesized associations between dimensions of spatial presence, IF, and SI, which was previously

Research questions	Statistical result	Brief explanation
1. How does immersive capability influence the dimensions of spatial presence?	The *t*-tests revealed that differences in PS, EN and NE, between Group 1 and Group 2, were statistically significant at the 0.05 level. While the *t*-test revealed that the difference in EV between the two groups was not statistically significant	Immersive capability influences spatial presence in terms of its three dimensions: SP, EN and NE. However, the study does not support its influence on EV
2. How are the dimensions of spatial presence related to motivation?	The correlation analysis revealed that the moderate positive association between SI and EN was statistically significant at the 0.01 level, and with the other two dimensions: PS and EV at the 0.05 level. The weak positive association between IF and the two dimensions: PS and EN was statistically significant at the 0.05 level, while the weak negative correlation between IF and NE was statistically significant at the 0.05 level. The moderate positive association between SI and IF was statistically significant at the 0.001 level	Spatial presence was positively associated with the SI through its three dimensions: SP, EN and EV. It was associated with one's IF positively through its two dimensions: SP and EN. IF was associated inversely with the NE dimension
3. How are the dimensions of spatial presence related to learning outcomes?	The correlation analysis revealed that the weak positive association between score gain and PS was statistically significant at the 0.05 level	Spatial presence, as manifested by the SP is positively associated with learning gain

Note(s): PS: Sense of physical space; EN: Engagement; EV: Environmental validity; NE: Negative effects; SI: Situational interest andIF: Ideal future-self
Source(s): Table by author

Table 3.
Research questions and findings

supported, albeit suggestively, by earlier studies of the author and his colleagues. The weak correlation between the SP and score gain was illuminating. Previous studies could not empirically prove the association, even though such a relationship has been widely hypothesized.

This could be explained by the cognitive theory of multimedia learning (Mayer, 2019). This theory assumes that humans limit the amount of information they can process, and that information is processed via two channels: auditory and visual. Thus, providing coherent verbal and visual input to the learners reduces the cognitive load, enhancing learning. The terms featured in VR tours were represented by objects stereoscopically experienced by the learners. Textual labels near the object representing the word served as a text-based scaffold so that when the learners looked at an area representing the term to be learned, they could easily associate it with the term before it passed through the optical channel. At the same time, the addition of audio-based narration reinforced this information as it passed through the auditory channel.

However, compared to other multimedia materials, VR could have added another dimension that made the terms easier to remember. Spatial presence may have caused learners to process the tour as a text-augmented navigable space aside from just a set of text and images. Studies that deal with spatial memory attribute it to the hippocampus, which is the portion of the brain that is both responsible for navigation and episodic memory (O'Keefe and Nadel, 1978).

Spatial information processed by the hippocampus was proposed to produce a cognitive map or a mental representation of the environment's layout, including nonspatial objects (Manns and Eichenbaum, 2009).

Therefore, presenting the terms as part of the environment in the virtual tour to the learners may have also been processed by the hippocampus and stored together with spatial information and associated with landmarks of that location. Therefore, these objects could be more easily remembered by the learners rather than the images presented with text on a PowerPoint slide or a printed page.

Immersive capability and ecological validity

While the effects of immersive capability on the sense of physical space and engagement were already expected, it offered novel evidence of its effects on individual dimensions of spatial presence (i.e. SP, EN, EV and NE). A recent within-group study by Yildirim *et al.* (2019) did not find any of the four dimensions to be affected by the type of immersive technique used in the VE. Furthermore, the present study provided evidence of immersive capability's influence on the other two dimensions (i.e. EN and NE).

One study that was found to be closely related to this result dates to 2011, when Gorini *et al.* (2011) performed a between-group study among 80 participants divided into four groups ($k = 20$) and found that the SP, EN and EV were affected by immersive capability. However, unlike the present study, they did not report the influence of immersive capability on the *NE* dimension.

On the other hand, Lessiter *et al.* (2001) included a sensitivity study in their seminal paper, providing evidence that all four dimensions were affected by different media formats. However, these may have been due to the stark differences in the media formats that were used in their experiment (e.g. IMAX 3D, IMAX 2D, video shorts and interactive games), and were performed in different experimental studies. Furthermore, they did not include VR in their media. Thus, their study did not test the influence of VR's capability in these dimensions, but only the latter's sensitivity to various media types.

Contrary to the findings of Gorini *et al.* (2011), the present study was not able to provide evidence of the influence of immersive capability on EV–the level of naturalness or realism of the environment. Looking back at the findings, the boxplots showed that participants in the high immersive group felt higher levels of EV than those in the low immersive group. Thus, this trend was apparent among the participants.

This discrepancy can be explained in two ways. One probable reason is that the sample size may have been too small to make the evidence generalizable to the population (Kim, 2009). Another possible explanation could come from the notion that EV may not be sensitive to immersive capability in VR photo-based tours as it was originally constructed to detect the sensitivity of various media formats and contents. Lessiter *et al.*'s (2001) study compared media with different formats and content. Thus, EV or the realness of what they were watching would vary as expected.

Furthermore, Gorini *et al.*'s (2011) study showed that while using a VR-based application, it severely lacked realism, as shown in Plate 2. Thus, experiencing the application using an HMD could have significantly increased the environment's realism. On the other hand, the current study featured stereoscopic images of locations taken from the real world. It featured ambient stereophonic audio that changed according to how they navigated the environment as if they were in a real place. Furthermore, ambient light coming from the sun was also replicated in the virtual tour, which added to the inherent realism provided by the VR tour. Therefore, we argue that these features made the participants think of the place as "real-looking" even without wearing an HMD.

To verify this quantitatively, Gorini *et al.*'s (2011) aggregation and scaling methods were approximated to compare their results with those of the present study. The former research showed low levels of EV in their two groups (i.e. 47.95 in the high immersive group and 43.33 in the low immersive group). The present study, however, had higher levels of EV in both groups (i.e. 78.66 in the high immersive group and 72.28 in the low immersive group).

Conclusion: implications for distance education

The study attempted to address the gap characterized by the absence or lack of research investigating the influence of immersive capability and spatial presence on SI, IF and learning outcomes. More specifically, findings from the experimental study provided

Source(s): Plate courtesy of Gorinni *et al.* 2011

Plate 2.
A screenshot of a VR-based application from the study of Gorini *et al.* (2011)

empirical evidence of the positive influence of immersive capability on spatial presence in the context of an online educational VR photo-based tour.

Moreover, findings provided empirical evidence of the magnitude of correlation among spatial presence, SI, IF and learning gain. In contrast, synthesizing findings gave rise to new hypotheses that could potentially update the theory of multimedia learning. This gives a concrete basis for instructional designers and teachers to incorporate VR photo-based tours in their online courses, with implications for ODE institutions and practitioners.

Firstly, ODE institutions conducting similar initiatives and thinking about investing in VR equipment-like HMDs is that they should consider whether their learning goal line up with maximizing spatial presence. Purchasing HMDs or mandating their use can be a wise investment if improving spatial presence is the goal. Secondly, these institutions may also consider whether immersive experiences are necessary. If the courses are built around sound instructional design principles, non-immersive versions of VR photo-based tours can still keep students interested and improve learning results. Institutions should consider carefully whether immersive experiences are necessary to meet their educational objectives or if non-immersive alternatives are adequate. Thirdly, the favorable associations among spatial presence, situational interest, one's IF and learning gain demonstrated by the study's empirical findings may give teachers and instructional designers a guide for deciding on when to include VR photo-based tours in their online lessons. Institutions can improve student engagement, interest and learning results by utilizing VR technologies. Lastly, the actual tour presented in the study can be freely used by other educators under the Creative Commons Attribution License version 4.0.

The study findings also have significant implications for future research. Besides new hypotheses that may be used to improve the theory of multimedia learning in VR-based learning contexts, another theoretical contribution of this study is the empirical supported-inclusion of the IF as a motivational variable in a theoretical framework for the VR-based learning research. Furthermore, the validated instruments used in the study would be able to address the methodological issues reported in recent literature review articles (Di Natale *et al.*, 2020; Hamilton *et al.*, 2021 and Radianti *et al.*, 2020) and can be used by ODE researchers who would like to test similar interventions for their courses.

However, one of the study limitations is the number of participants. Structural equation modeling, which requires more participants, may help extend the findings from mere associations to directional relationships. More longitudinal studies may also be useful for observing motivational fluctuations that could confirm or debunk the existence of the novelty effect.

> The world is a book and those who do not travel read only one page.
>
> – Saint Augustine

The quote above encapsulates what inspired the idea behind this whole research journey. The researcher experienced traveling abroad after college graduation for the first time and realized how much he did not know about life and the world. The more he traveled, the more he learned and realized how ignorant and prejudiced he was about people and many aspects of life.

Living in a country where most of the population might not even have the chance to leave their place of birth burdened him. Hence, he tried to look for ways to share this joy of wonder and discovery with others through other means. When *Google Cardboard* started to gain popularity in the Philippines, he led a small outreach project with his parents to enable children in the neighborhood to experience going to different places abroad through VR.

The results, albeit anecdotal, were exciting. The participants were brimming with joy. They wanted to see more and learn more. It was then that the desire to learn more about this phenomenon of 'learning by VR' burst aflame in his heart. This flame, however, was doused gradually by the daily grind of work. Hence, the chance of a scholarship abroad to conduct four studies and, in the process, to learn and share more about this phenomenon has been extremely rewarding. It is, therefore, his hope that despite being imperfect, the humble contributions of this research endeavor could help expand possibilities for the underprivileged to *read more pages of this wonderful book* we live in.

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