Witnessing the Last Tropical Glaciers: Student Use of Virtual Reality Technology to Learn about Climate Change and Protecting Endangered Environments

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ABSTRACT

Climate change and global warming have huge impacts on the most fragile ecosystems on Earth. With temperatures rising, most of the tropical glaciers on Earth, found near the Equator, will be gone before the end of the century. These far-removed natural areas are obscure and difficult for students to visit or learn from directly. Educating students in non-traditional, more experience-based settings is crucial for them to better understand current issues the world is facing, like glacial shrinkage, loss of sea ice, and accelerated sea level rise. This study found that virtual reality 360-degree video technology (VR-360), by providing close to real-life experiences and engaging storytelling, has the ability to engage students and provide them with meaningful information and experiences about climate change. In Phase 1 of this study, 65 students reported that VR can be beneficial for educational purposes to learn about global climate change. In Phase 2, with 227 students from around the globe, path analysis supported the need for VR-360 video producers to consider the importance of spatial presence, in the form of possible action and self-location, as critical elements of their videos to encourage people to use VR technology to learn about extreme environments and climate change.

INTRODUCTION

At a time when the world itself is facing a range of significant challenges—such as rises in air temperature and record heat waves, floods in some places, droughts in others leading to wildfires, ice shelves melting and collapsing in Antarctica and Greenland—a relatively new technology in education can help inform people of current issues that may not be close to them but, nevertheless, can have a significant impact on their future. The evolution of technology has brought tremendous change. Virtual Reality (VR), including 360-degree video, now has the cost-effective potential to bring far-distant environments to students because it can provide close to real-life experiences. VR has the potential to inspire students to reconnect with nature and to give them both a human perspective on climate change and a sense of respect for people fighting to preserve such fragile ecosystems.

Climate Change and Tropical Glaciers

Typically, climate change and global warming impact areas of the globe that are distant from population centers. These far-removed natural areas are obscure and difficult for students to visit or learn from directly. Educating students in non-traditional, more experience-based settings is therefore crucial for them to better understand current issues the world is facing, like glacial shrinkage, loss of sea ice, and accelerated sea level rise. This study investigated whether VR technology has the ability to engage students as well as provide them with meaningful information and experiences about climate change.

For this study, a VR-360 video educational experience of one of the last tropical glaciers in Colombia was created in order to investigate students' intention to use this modern technology. Do glaciers really exist in the tropics?! The word tropics is typically associated with sandy beaches, rainforests, and hot humid weather near the equator. Rarely are the tropics associated with snow, glaciers, or high mountains, but glaciers can be found in most of the highest mountains in the world—even in the tropics. Inherited from the last Ice Age, today about 3,000 glaciers are still holding onto their elevated summits between the Tropics of Cancer and Capricorn. These tropical glaciers, mostly found in Andes mountains of South America, but also in East Africa and the Pacific islands of Papua New Guinea (Kaser & Osmaston, 2002), are the last of their kind and are disappearing fast, directly impacted by increasing air temperatures and changing weather patterns.

Tropical glaciers archive important information about the climate, and at the same time, provide a water resource for humans, in addition to the local flora and fauna. Unfortunately, according to Enslin (2017), the glaciers in Peru have deteriorated considerably. Over the last 50 years their surfaces have reduced by half, with increasing global air temperatures, El Niño effects, and volcanic eruptions all playing a role in their recession. Ceballos et al. (2006) reported that glacial retreat has also been taking place over recent decades in the highest mountains of Colombia. According to Rabatel et al. (2018), for example, the surface of the Colombian glacier Nevado Santa Isabel in Los Nevados National Park reduces by 3 percent per year. Colombian glaciers have gone from 374 km^2 at their peak to 37 km^2 in 2017; hence, Colombia has lost over 90% of its glacial area in the last 170 years (IDEAM, 2017). Scientists caution that within a few decades, all the world's tropical glaciers will vanish (Whitfield, 2001). This will impact many millions of people who rely almost entirely on water from glaciers for drinking, agriculture, irrigation, hydroelectricity generation, and other purposes.

Virtual Reality

VR is often loosely used synonymously with 360-video, augmented reality (AR), extended reality (XR), mixed reality (MR), and others. For our purposes, VR is defined as a three-dimensional space learning environment, where learners can be in a fully digital environment encompassed in the virtual world, such as a 360-video cave projection (Moore, 2019). VR refers to the technology conceptually, as well as the hardware required for the technology.

A key element to VR, that differentiates VR from other technologies, is the concept of spatial presence, which is a heuristic and perceptive experience that often emanates from VR (Wirth et al., 2007). Biocca (1997) described spatial presence as the idiosyncratic conscious impression of “being there,” even when the actual user is situated in a different place and knows they are not “there.” When immersion triggers this presence, which commonly happens in VR or 360-video, the user will behave within the virtual environment instead of the real setting (Slater & Wilbur, 1997; Slater, 2009). Slater and Sanchez-Vives (2016) wrote that the brain’s perceptual system treats the virtual environment as if it were the participant’s actual surroundings. For example, spatial presence related to VR in education about extreme environments would allow students to experience things like high mountain glaciers without the discomforts of exposure to extreme conditions like lack of oxygen, cold temperatures, and increased exposure to other risks (Linxweiler & Maude, 2017).

VR in Climate Education

The affordability and ubiquity of educational technology drastically revolutionizes the ways learners interact with educators and gain information about the world at an accelerating rate (Dunleavy et al., 2008; Huang et al., 2019). In the case of VR, Huang et al. (2019) showed that both AR and VR environments improve knowledge retention because of spatial presence, which resulted in both psychological and cognitive reactions. Winn (1993) reported that VR helps to create first person, non-symbolic experiences that better assist students to retain educational materials. Quieroz, Fauville, Abeles, Levett, and Bailenson (2023) have reported that as people used VR in museums, they perceived climate risks as more severe and were more motivated to engage in pro-environment activities. Similarly, Thoma, Hartmann, Christen, Mayer, Mast, and Weibel (2023) and Nelson, Anggraini, and Schluter (2020) found that VR experiences helped to increase environmental awareness and encourage pro-environment behavior.

Education does not occur only in the classroom. Many different projects and organizations around the globe have a mission to educate students and young people on the science of climate change to help empower them to take action. Identifying technologies that will help with both curricular and extracurricular education will be important for these efforts. The most endangered areas—for example, polar regions, high mountains, oceans—are at vast distances from most populated locations. Travel for firsthand learning opportunities is often too difficult or too expensive for schools to provide or for individuals to access. However, technology has the capacity to enhance the quality of academic courses on climate change when field classes are impossible. Therefore, for many students, the only way to see tropical mountain areas will be through technology and distance learning. As Atkins, Charles, and Adjanin (2020) suggested, “If we are not able to take students to see specific environment, we believe that education delivered through the use of 360VR can ‘bring’ these remote areas to the students.”

Some have studied specifically the value of incorporating technology, such as VR, in climate education. For example, Gold et. al. (2015) reported that incorporating technology, like student-produced videos about climate change, improved learning among middle and high school students. Dailidienė et al. (2019) found that graduate students strongly agreed that environmental change management is only possible through the integration of a new technology in education—to understand current issues and advocate for the future. VR may present a solution to expose students to challenging learning environments that are inaccessible due to weather, difficult terrain, political issues, distance, or human mobility. For example, Yu et al. (2018) suggested that VR can be an option for individuals with limited mobility to approach remote regions that would previously be inaccessible to them to gain an environmental experience. Riva (2020) showed the possibility for VR technology to be used as an environmental conservation tool, to help people visualize and conceptualize ocean acidification. Guttentag (2010) and Tussyadiah (2016) claimed that the tourism industry can benefit financially by helping people create memories in places to which they cannot typically travel. Cho and Park (2023) reported that because immersive VR gives students realistic experiences, it can help them become aware of and solve problems related to the environment.

Theoretical Framework

Davis (1986) introduced the Technology Acceptance Model (TAM) to evaluate technology—particularly users' intention to use various office and educational technology. TAM focuses on users' acceptance or rejection of innovative technology and can be used to explain how and why people decide to adopt different technologies (Davis, 1986; Davis & Venkatesh, 1996). Using TAM as a framework can help us learn how VR can be successfully deployed as an educational technology. Therefore, based on the suggestion from Chen et al. (2012), TAM is the model used for this VR study to examine the factors driving college students' use of VR to better understand climate change and its impact on tropical glaciers. It has also shown promise in studying the acceptance of technologies in outdoor and extreme environments (Nikou & Economides, 2016).

TAM implies that intention to use technology is considered the major predictor of actual usage behavior. In TAM, the user's attitude toward, acceptance of, and intention to use technology can be explained by two primary beliefs: perceived usefulness and perceived ease of use. Perceived usefulness (PU) is a subjective belief that represents "the degree to which a person believes that using a particular system would enhance his or her job" (Davis 1989, p. 320). PU addresses how strongly respondents believe that VR could enhance their performance, effectiveness, and productivity. Perceived ease of use (PEU) is defined as "the degree to which a person believes that using a particular system would be free of effort" (Davis 1989, p. 320). PEU is concerned with beliefs about users' control, freedom, and ease in using technology. The key factors of TAM for education are the beliefs that technology, like VR, will support students' learning and that using VR is easy for students and teachers (Davis, 1989; Davis et al., 1989). These beliefs then lead to a more positive attitude toward technology which leads to a stronger intention to use it.

According to Davis and Venkatesh (1996), it is important to emphasize external factors that will affect the intention to use each different type of technology. Because the literature has suggested that spatial presence is a critical construct for VR technology (Tichon, 2007), spatial presence has been incorporated into the model. Literature has suggested that spatial presence may predict both perceived usefulness and attitude toward use. Hence, the modified TAM model designed for this study (called VR-TAM) will contain two constructs added from Hartmann et al. (2016): possible action and self-location. Self-location refers to users' feeling of "being there" and possible action refers to users' "subjective impression that they would be able to carry out actions in the environment" (Hartmann et al., 2016, p. 5). That is, students using VR on tropical glaciers should have the impression that they are standing on the ice or walking through vegetation of the tropical mountain region. Therefore, the VR-TAM model adds these variables (identified in blue) to the core TAM variables (yellow) in Figure 1.

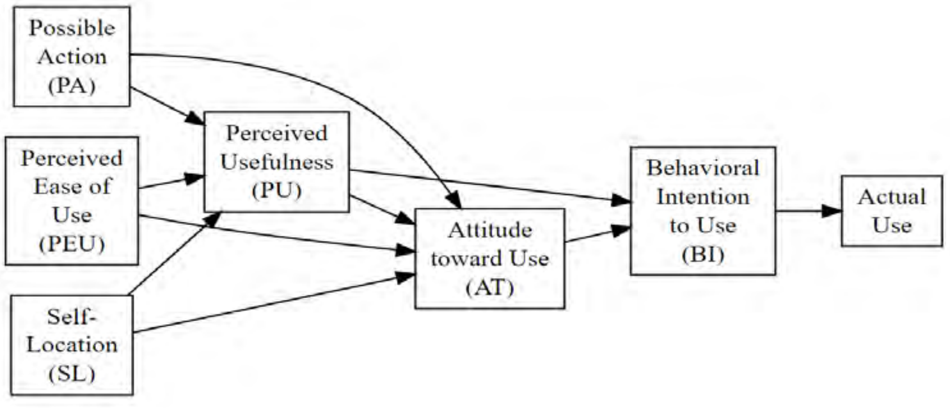

Figure 1. Initial VR-TAM Model

PURPOSE OF THE STUDY

Atkins, Charles, and Adjanin (2020) wrote that faculty must continue to explore the use of new technologies as ways to deliver instruction. The purpose of the study specifically addressed their charge to see where college students would embrace 360-degree VR to learn about climate change and tropical regions. Further, another purpose is to identify variables that may help determine whether young adults would use VR for lifelong learning about important environmental topics. Before climate agencies and non-profits begin to create such VR-360 videos, it will be useful to identify how likely young adults will be to use the technology to learn about climate change and extreme environments, as well as what are the important predictors of VR use.

The use of VR technology in climate education was studied using TAM as a framework to study the value of VR technology to climate education. Davis's (1986) TAM model has been shown to predict students' behavioral intention to accept and use VR in a college setting. In particular, predictors were identified that impact students' acceptance of VR as a learning device to better understand climate change in tropical mountain regions. Two research phases were used to answer the research questions for the study. Results from Phase 1 guided the execution of Phase 2. In Phase 2, students were exposed to an educational activity, about which students responded to an online survey.

PHASE 1: ELICITATION STUDY

The guiding research question for the Phase 1 Elicitation Study was: Do college students think the use of technology as VR will impact students' learning outcomes related to climate change and tropical glaciers? The goal was to determine the core salient beliefs students had about the use of VR to experience a previously unexplored natural environment for educational purposes. These beliefs were focused on normative referents and control factors regarding the use of VR technology in education.

After obtaining IRB approval, purposeful sampling was used through email and social media platforms to recruit students who were familiar with VR technology used in education. A total of 110 students were invited to participate in this phase and 62 provided useful information. The participants were all college students, 56.5% male and 43.5% female, from 9 different universities around the globe. The majority of students (79%) who participated in this phase were from a midwestern American university, with most of the remaining 21% from European universities. Ages ranged from 20-52 years old, with a mean age of 31 years. Over half, 59.7%, of students reported having previous experience with VR.

Participants were asked to provide demographic information and to answer questions about the use of VR technology. Data were collected using open-ended survey questions in Qualtrics that were adapted from previous elicitation studies (Ajzen, 2013; Ajzen & Fishbein, 1980). The questions were designed to understand the students' behavior and normative beliefs related to VR technology and to obtain their perceptions of what constitutes the strengths and weaknesses of utilizing VR in educational settings.

Phase 1 Results

The results from the Phase 1 Elicitation Study showed that a majority of the students surveyed in this phase would use VR if they had the opportunity to use it to learn about climate change and the impact of global warming. Among these students, 95.2% agreed completely that VR can be beneficial for educational purposes to learn about climate change. In particular, 38.7% of participants revealed that they intend to use VR for environmental education, 27.4% expressed the usefulness of VR as a device for virtual travel, and other participants indicated that they would use VR for fun, for gaming, and for new ways of exploring different subjects.

The participants suggested that VR can be a unique teaching tool to provide experiences for educational topics being studied at a great distance, such as touring a polar environment or a new kind of scientific field trip. Many students agreed that VR can be a unique way to engage a diverse community in learning, especially when the settings are located in a challenging physical or geographical context. Participants believed that by using VR they could acquire a more authentic experience exploring other cultures and environments globally, to which they may not be able to travel. VR can be used to show the progression of the life of a glacier over time to help students learn about the impact of climate change.

Students identified several advantages of using VR in an education setting. They recognized VR as a device to experience environmental issues and travel in a safe way. That is, because some travel may require specific technical skills or is overly risky, VR allows everyone access to a realistic, authentic experience without being exposed to dangers, such as high altitudes or freezing temperatures. Many of the participants also revealed that the use of VR in education, especially in learning about climate change, can change the students' perspective and help them develop empathy for the environment.

Students, however, also identified some disadvantages that VR might have, such as the high price, lack of availability of VR devices, and specific applications that are necessary for using VR. VR could possibly lead to lost human interaction and decreased communication with peers and in the classroom. Some of the students shared that they had experienced motion sickness or cybersickness while using VR. Concern regarding how to operate the devices was one of the main disadvantages that students expressed. Finally, a current lack of quality educational content for VR devices may pose difficulties for using VR in education: "The content is important. If the VR does not provide real settings or meaningful content, I would not want to use it."

PHASE 2: FINAL STUDY

The findings of the Phase 1 Elicitation Study and recommendations from the literature helped guide the development of the instrument used in the second phase of the study. As suggested for using the TAM model (Davis, 1986), in addition to using TAM variables, the model was modified by adding external variables identified in the literature and obtained from the elicitation study. External variables were Self-Location (SL) and Possible Action (PA), measured by the Spatial Presence Experience Scale (SPES, Hartmann et al., 2016). In this study of VR, SL and PA are hypothesized to help explain PU and AT. The theoretical model studied was named VR-TAM (see Figure 1). The primary research question that guided the research in Phase 2 was: Does the VR-TAM predict an intention to use VR among college students for their future learning and understanding environmental subjects such as climate change in tropical regions? The question will be answered based on a path analysis of the VR-TAM model, testing the paths of the model and the overall amount of variation explained in Behavioral Intention to use (BI) technology for learning about climate change and tropical glaciers. In addition to SL and PA, the predictors in the VR-TAM model are: Perceived usefulness (PU), Perceived ease of use (PEU), and Attitude toward using VR (AT).

Participants

Participants in this Phase 2 study were both undergraduate and graduate students from 51 different universities and 35 different home countries around the globe, including Ohio University, University Centre in Svalbard, University of Alicante Spain, National University of Colombia, and others. Recruitment for the study occurred through social media platforms (e.g., LinkedIn, Facebook, and Viber) and also through faculty who were known to share an interest in new educational technologies. Faculty acquaintances at other universities received detailed guidelines on how to provide VR headsets to students, as well as directions on how to access the online platform Oculus/YouTube. In total, 25 Oculus Go VR headsets were sent to these faculty assistants for the study. Ultimately, 271 participants were recruited, and they provided 227 useful questionnaires (32 did not go beyond the consent form and 12 did not complete enough sections of the questionnaire).

The majority of participants were female (52%), with 41.4 % male and 5.7% self-identified as another gender. Graduate students (master's or doctoral) comprised 63% of the sample and undergraduate students represented 37%. About 74% of participants said they had some experience with VR (all others indicated this was their first VR experience). Most students used the Oculus headset (27.3%) or Smartphone-VR (52.4%) to participate in this study, while some students used computers to access the video. In regard to climate change, about 81% of students expressed an interest in learning about climate change. Not many students had previous knowledge about tropical glaciers: about 60% of students said they had no previous knowledge and 20.7% were not sure.

Educational Activity

A VR-360 experience was created that was set in one of the fastest-disappearing environments on Earth: the Santa Isabel Mountain, Nevados National Park in Colombia, home to one of the last tropical glaciers of South America and myriad endemic species. The narrative lecture in the video was provided by Dr. Heïdi Sevestre, the winner of the inaugural Shackleton Medal for the Protection of the Polar Regions, who is a glaciologist and pioneering climate activist. Dr. Sevestre tells the story of the last tropical glaciers in Colombia, while also educating the user to understand that glaciers in the tropical regions are rare and unique, as well as what can potentially be done to preserve them from extinction. The video was an 8-minute VR lecture that was a 360-degree projection of the glacier located at a height of 17,000 feet in Colombia. The 360-video was created with Premier Pro software with footage that was collected in the fall of 2019 in Colombia. A 360 One X camera and a Zoom H 4 audio recorder were used to assemble the video and audio material.

The "Last Tropical Glacier" video was provided through the Oculus and YouTube-VR online platforms. Every participant confirmed informed consent prior to watching the video and filling out the questionnaire. Participants watched the video using a VR headset. Some participants had access to Oculus Go VR headsets through faculty associates at the universities, however, most participants used their own devices (e.g., computer, smartphone, Smartphone Cardboard). Participants were monitored locally or through internet support from the researcher.

Instrumentation

After receiving IRB approval for Phase 2, data were collected using the Qualtrics online platform. The questionnaire comprised the following sections: basic demographics, VR ownership, VR experience, the four subscales of the TAM instrument, and the two subscales of the SPES. Subscale scores were created as mean item scores for each of the variables. The TAM instrument comprises 15 items that represent the four different constructs, each measured on a 5-point Likert scale, from 1 (totally disagree) to 5 (totally agree). The TAM scales have been studied for validity and reliability many times and the subscales have typically provided reliability estimates above .90 (see Table 1 for current study reliability). Table 1 also contains descriptive information for the two spatial presence variables, SL and PA (Hartmann et al., 2016), which are both on the same scale as the TAM scales and were added to the VR-TAM model in order to explain spatial presence as predictors of VR technology use.

Table 1. Descriptive Statistics for VR-TAM Variables

	Mean	SD	Cronbach's alpha	Items
Behavioral Intention (BI)	4.56	0.66	.82	3
Attitude toward Use (AT)	4.33	0.68	.76	4
Perceived Ease of Use (PEU)	4.18	0.65	.84	4
Perceived Usefulness (PU)	4.69	0.52	.91	4
Possible Action (PA)	4.28	0.72	.85	4
Self-Location (SL)	4.28	0.74	.88	4

Phase 2 Results

The data acquired from the online questionnaire were exported from Qualtrics to IBM SPSS and R for analysis. The mean for BI was *M* = 4.56 (*SD* = 0.66). The means for PEU was *M* = 4.18 (*SD* = 0.65), for PU was *M* = 4.69 (*SD* = 0.52), for AT was *M* = 4.33 (*SD* = 0.68), for PA was *M* = 4.28 (*SD* = 0.72), and for SL was *M* = 4.28 (*SD* = 0.74). Correlations among variables are presented in Table 2.

Table 2. Correlations among VR-TAM Variables

	AT	PEU	PU	PA	SL[1]
Behavioral Intention (BI)	.57**	.43**	.64**	.42**	.47**
Attitude toward Use (AT)		.31**	.57**	.58**	.57**
Perceived Ease of Use (PEU)			.54**	.33**	.32**
Perceived Usefulness (PU)				.57**	.59**
Possible Action (PA)					.85**

** = $p < .001$

[1] *SL is abbreviation for Self-Location*

Because means were greater than 4 for all variables, there may be ceiling effects for the variables, perhaps due in part to social desirability or acquiescence response sets. The ceiling effect may impact normality and may reduce variability which in turn may impact statistical power and correlations between variables. To confirm there was no violation of the assumptions, variables were tested and examined. A small number of outliers were identified using Mahalanobis distance but were included in the analyses because they were legitimate scores and did not appear to impact the conclusions.

In order to observe the potentially mediated relationships among variables hypothesized by the VR-TAM, path analysis was used to analyze complex relationships among variables. The initial path model chi-square $\chi^2(4)$ = 9.121, *p*= .058. The chi-square statistic was not statistically significant indicating that the model fit the data adequately. Other useful model fit statistics were also calculated: GFI = 0.982, CFI = .988, TLI = .963, and SRMR = .021. The RMSEA was .075, with a 90% confidence interval of [.000, .141] and, for the null hypothesis RMSEA <= 0.05, p = .210.

Despite the reasonable fit of the initial VR-TAM path model (see Figure 1), it contained two nonsignificant paths (SL predicting AT and PEU predicting AT). Both nonsignificant paths were consequently removed from the analysis. The final path model (see Figure 2) explained 47.3% of the variation in BI, 48.9% of the variation in PU, and 42.0% of the variation in AT. All three predictors of PU were statistically significant: SL (β = 0.31, p = .001), PA (β = 0.18, p = .046), and PEU (β = 0.38, p < .001). Both PA (β = 0.38, p < .001) and PU (β = 0.35, p < .001) were statistically significant predictors of AT. Finally, both PU (β = 0.48, p < .001) and AT (β = 0.30, p < .001) were statistically significant predictors of BI.

The final path model chi-square $\chi^2(4)$ = 9.123, *p*= .104. The chi-square statistic was not statistically significant indicating that the model fit the data adequately. Other useful model fit statistics were also calculated: GFI = 0.990, CFI = .993, TLI = .976, and SRMR = .021. The RMSEA was .060, with a 90% confidence interval of [.000, .121] and, for the null hypothesis RMSEA <= 0.05, p = .328.

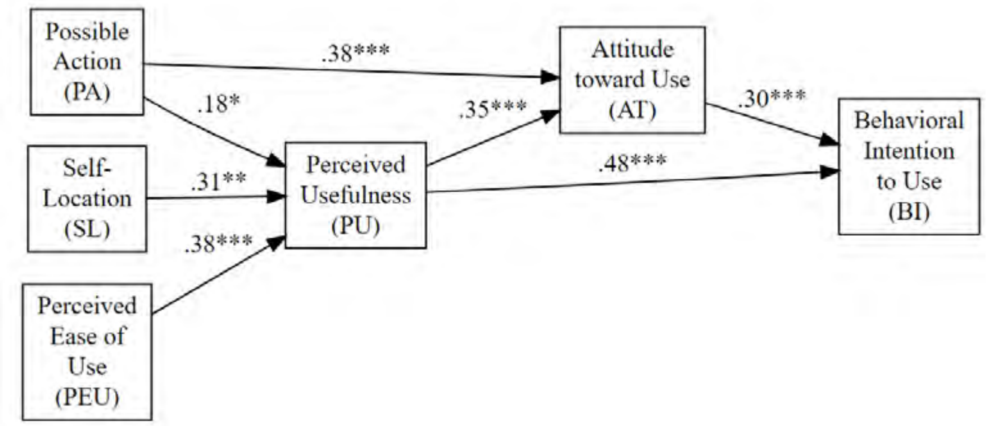

Figure 2. Final model Path Analysis results (*= p <.05; **p < .01; ***= p < .001)

VR Device Type

To use VR content, it is necessary to use VR hardware. That is, the hardware plays an essential role in the VR experience. Therefore, a supplemental analysis compared variables across the type of VR device used by students. One-way ANOVA was conducted to compare the pseudo-experimental differences in the type of technology device that was used for watching the 360-video. Smartphone and Smartphone Cardboard users were combined into a single group and both desktop and laptop computer users were combined into a single group, making three groups with the Oculus Go group included (see Table 3). The ANOVA across devices for all VR-TAM variables was statistically significant using the Welch ANOVA F test: BI yielded a Welch $F(2, 80.87) = 15.23$, $p < .001$; for PA, Welch $F(2, 73.49) = 45.25$, $p < .001$; for SL, Welch $F(2, 76.08) = 56.63$, $p < .001$; for PU, Welch $F(2, 75.49) = 17.27$, $p < .001$; for PEU, Welch $F(2, 76.85) = 7.48$, $p = .001$; and for PEU, Welch $F(2, 74.80) = 32.95$, $p < .001$. Post hoc comparisons were performed using the Games-Howell procedure with a Bonferroni-adjusted alpha of .0083 for testing hypotheses for the six dependent variables. For BI, PA, SL, PU, and AT, the Games-Howell multiple comparisons showed that Oculus differed from both other groups (i.e., Smartphones and Computers) at the adjusted alpha level of significance; however, Computers and Smartphones did not differ statistically significantly for any of those five variables. On the other hand, Oculus differed statistically significantly from only Smartphones for the variable PEU, with the other comparisons both nonsignificant.

Table 3. Means and Standard Deviations for different types of VR

	Computer (N = 31)		Oculus (N = 62)		Smartphone (N = 131)	
Variable	Mean	SD	Mean	SD	Mean	SD
Behavioral Intention (BI)	4.40	0.59	4.84	0.36	4.46	0.75
Possible Action (PA)	3.81	0.92	4.78	0.33	4.16	0.68
Self-Location (SL)	3.92	0.77	4.85	0.36	4.10	0.72
Perceived Usefulness (PU)	4.57	0.53	4.92	0.22	4.61	0.59
Perceived Ease of Use (PEU)	4.20	0.74	3.96	0.38	4.26	0.71
Attitude toward Use (AT)	4.15	0.78	4.74	0.31	4.19	0.70

CONCLUSIONS

In this study, virtual reality (VR) was investigated as an educational technology with the potential to be used in educational settings for learning about climate change and the impending disappearance of tropical glaciers. Juxtaposed between insufficient education resources and knowledge about climate change and tropical high mountain regions, VR education could serve as the fulcrum which balances the needs to learn, understand, and preserve natural sources that are losing the battle against global warming.

The TAM model was expanded to work with virtual reality by adding spatial presence ("being there") as explanatory variables for perceived usefulness. In the Phase 2 path analysis, both self-location and possible action, along with perceived ease of use, were found to be statistically significant predictors of perceived usefulness, which was the strongest predictor of behavioral intention to use VR. Possible action was also predictive of attitude, however, interestingly, self-location was not statistically significant predictor of attitude. These results suggest the importance of the VR video experience itself in terms of spatial presence, which points to the need to pay careful attention to the design of the virtual environment and the storytelling used for educational purposes.

The one-way ANOVA showed that Oculus Go VR equipment provided the highest spatial presence, perceived usefulness, attitude, intention to use VR, but it was considered the most difficult to use. Conversely, while smartphones and computers may be easier to use, they do not yet match Oculus headwear for the critical spatial presence aspect of VR. Because possible action was a significant predictor of attitude, this may mean that paying attention to the available equipment may matter for creating educational content for VR.

Unexpectedly, based on the TAM literature, perceived ease of use did not explain variation in attitude toward VR use in the presence of the possible action predictor. This result could be due to the difficulty some participants had in using the VR hardware. Similar results have been found in the literature for VR technology. For example, Markowitz, Laha, Perone, Pea, and Bailenson (2018) reported that parts of the VR learning experience may be difficult for the user to manipulate.

VR in Climate Change Education

When considering VR technology from an educational standpoint, the concern is that students have experiences that reach similar outcomes as if they would have if they had gone on a field trip. Among other advantages and disadvantages suggested by students reported above, they indicated that the cost of owning a high-quality VR device (like Oculus Go) and instructions for use were two of the main concerns about implementation of VR for education. The VR-TAM model was strong for all devices, but further study could show that because the devices matter for spatial presence, prices may need to drop further before VR can truly become integral to education. These disadvantages fit with concerns like installation of the VR applications and cyber-sickness mentioned by others (e.g., Dirin, 2020).

VR technology has the ability to change education about climate change in a positive way. Getting young adults to gain experience in distant environments that are not easily accessible is essential so that educators can influence them in the right direction to act, conserve, and love our environment. Utilizing VR in education can create immersive and interactive learning experiences accessible to all. VR has the potential to revolutionize the way people teach, learn, and bridge the knowledge-action gap on climate change. Technology has sometimes been a destructive force in the world, but at the same time it can be a powerful force in solving and educating about the current existential crises that humanity is facing.

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