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Preservice Teachers' Acceptance of Virtual Reality to Plan Science Instruction

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ABSTRACT
To improve understanding of preservice teacher acceptance and integration of virtual reality into science, this study examined individual concerns to integrate virtual reality into science instruction before and after a hands-on intervention with virtual reality. Framed by the Concerns-Based Adoption Model using a mixed-method design, preservice teachers were exposed to a 5-week intervention to integrate and expand on existing VR tours and construct a personalized VR tour. Pre and post analysis of the stages of concern questionnaire show four of five preservice teachers remained focused on their personal concerns (stage 2, unsure of VR teaching demands). The fifth advanced to stage 3, management, and was interested in learning ways to implement virtual reality in the classroom. Open-ended data (survey items, science journals, focus group) illuminated concerns about the technical aspects of VR, learning engagement/satisfaction, and generation of lesson plan ideas, which influenced preservice teachers' intention to use VR. For four of five preservice teachers, this experience increased their likelihood to use VR in the classroom, with adoption dependent on using VR with their students. Implications for teacher educators, educational researchers, administrators, and digital designers address the integration of VR, instructional planning, and usability considerations.

Keywords: Curriculum design, Pedagogy, Science, Technology acceptance, Virtual reality

1. Introduction

Higher education students use digital technology most frequently for personal and informal reasons, to communicate socially with one another (Echenique et al., 2015; Gasaymeh, 2018). A synthesis of a special issue on virtual reality (VR) in learning revealed vivid and enhanced ways that students can learn with "virtual and augmented reality modes;" however, the synthesis stated that this shift would require "extensive research on content and context design" (Lytras et al., 2016, p. 878). Ioannou and Ioannou (2020) identified academic gains and positive perceptions when middle-schoolers' used VR to go on a virtual tour of Archaic kingdoms, but more research is needed at the intersection of technology, design, and pedagogy when integrating VR.

Other integration factors such as school leadership and modeling of the innovation influence whether a technology is adopted for use (Hall, 2010). To contribute to the complexity, the successful implementation of a technological innovation, such as VR in the classroom, also hinges on a teacher's ability to move through their stages of concern (SoC) related to the innovation (Loucks & Hall, 1979). An individual's initial concerns focus on personal issues, (stage 2 of 6 on a 7-point Likert scale), primarily related to "time, planning, and instructional practices" (Donovan et al., 2007, p. 274).

Preservice teachers (PSTs) require explicit strategies to integrate VR into primary and secondary classrooms (Ferdig et al., 2018). Students who produced a written summary of the lesson after each VR segment outperformed those who did not pause to document their learning (Parong & Mayer, 2018). Lee and Shea (2020) found that introducing PSTs to VR with the intent to develop curriculum increased PSTs self-efficacy, and PSTs' intention to use VR in their future classroom. However, not all PSTs are convinced they should integrate VR into their teaching. Unlike Donovan et al., (2007) measure of teachers' initial SoC, more research is needed to explore an individual's change in concern following the implementation of a new technology. To address the need for an in-depth understanding of "content and context design" (Lytras et al., 2016, p. 878) when using VR, the purpose of this study is to examine PSTs acceptance to use VR to plan science instruction. This research seeks to inform how teacher educators, school administrators, and digital designers can acknowledge and respond to individual teacher concerns to help schools more effectively integrate VR technology to support teaching and learning in the classroom.

1.1. VR in education

The term "virtual reality" has been used since the 1960's, but differences between immersive and non-immersive VR require clarification. Ferdig et al., (2018) define non-immersive VR as a computer-based environment or simulation (e.g., iPad, laptop, desktop computer), whereas immersive VR is when an individual perceives him or herself inside the proposed setting (e.g., head-mounted viewer). Our study aligns with the immersive VR definition, which we hereafter refer to as VR.

VR as an instructional tool is a relatively new concept that holds considerable promise for the educational technology community because it offers potential for growth in student learning (Hutchison, 2018) and can help students understand abstract models (Chen et al., 2020). Though there is a paucity of research on VR in teacher preparation, the study of VR is noted within some education settings. For example, middle-school social studies students in economically disadvantaged rural school districts were introduced to VR to measure differences in motivation and student achievement (Bowen, 2018). Similar, but using augmented reality, 51 elementary students used augmented reality to engage in hands-on science learning (Wang, 2020). Although Wang (2020) found no statistical significance between using augmented reality and e-books, qualitative data indicates the bright colors offered by multimedia was an affordance that increased student discussion.

In higher education, undergraduate medical students used VR to help learn about the structure of the human body, and results also found that immersion and imagination features of VR-mediated course content positively impacted perceived usefulness and perceived ease of use (Huang et al., 2016). Harron et al. (2017) also explored the design of a museum learning experience using virtual reality and mobile devices. To contribute to students' understanding of science concepts, a classroom of elementary learners used VR to access the View-Master National Geographic Wildlife app (Hutchison, 2018). Similarly, in another example, VR devices helped deliver instruction to students in remote locations to transform social interaction via behavior and context (Bailenson et al., 2008). Additionally, computer-based VR using a researcher-designed software known as Topo-Pano Explorer helped teach the concept of contour mapping by displaying immersive 360° images of real-world environments (Park et al., 2008). Though exploring VR implementation in the classroom is essential to determine strategies for using VR, aligning VR to standards-based instruction needs to be a curricular imperative.

VR is an effective mechanism to increase student engagement (Bowen, 2018; Ferdig et al., 2018; Merchant et al., 2014). Most recently, Bowen (2018) realized gains in student achievement and engagement when VR was implemented in a rural middle school to teach social studies. Merchant et al., (2014) examined 29 studies on virtual worlds in K-12 and higher education and concluded that, overall, virtual worlds positively affected student outcomes. VR-based instruction may also benefit English learners' language development (Craddock, 2018) and students with cognitive or psychological disorders (Horn, 2016). Despite some evidence to suggest that VR may benefit learning and increase student engagement, we still know little about how a teacher perceives and intends to use VR in the classroom.

1.1.1. Immersive virtual reality

Since 2016, low-cost VR devices and curriculum resources such as Google Cardboard head-mounted viewers and the Google Expeditions app ("Expeditions") have become widely available and accessible (Churchill, 2017). Google Cardboard is a VR head-mounted viewer intended to be used with a smartphone or small tablet (Google Cardboard, n.d.). Similar viewing devices are readily available from other manufacturers, but since Google introduced Google Cardboard for $15 USD, this viewer has garnered the attention of classroom teachers (Horn, 2016). Teachers can create their own immersive VR classroom kit for as little as $150 and download a variety of free apps (Long & Eutsler, 2020).

The Expeditions app is designed to support learning in K-12 classrooms (Dutton, 2016). Each expedition is a virtual tour of a location viewable by students with a VR head-mounted viewer. Locations include sites from outer space, the inside of an atom, and the caldera of a volcano. The teacher utilizes a tablet to direct students to specific points and can observe where students are focusing their attention within the tour (Google Expeditions, n.d.). Expeditions boasts over 900 virtual tours available for open access and use to allow students to see around the world from the safety of their desks (Ullman, 2016). Twenty-four elementary students attended a 2-week social studies camp, and results showed that after using the Expeditions app to engage in immersive VR learning, student motivation improved, coupled with a diminishment of test anxiety (Cheng & Tsai, 2019). Companies who sell VR, such as RobotLab, are developing VR Expeditions 2.0 in partner with Britannica, slated to be introduced in late 2021 (Galvis, 2020). As VR in education affordances continue to evolve, more research is needed to examine how to plan instructional experiences with VR.

2. Concerns-based adoption model

The concerns-based adoption model (CBAM) is a technology adoption model that identifies an individual's concerns about an innovation (Hall, 1976), such as new technology. This model offers an in-depth measure of an individual's concerns, as opposed to the diffusion of innovation theory (Rogers, 2003) which analyzes innovation acceptance over time. CBAM is comprised of three dimensions to understand technology acceptance: SoC, levels of use, and innovation configuration. When integrating a new technology, these concerns are influenced by the individual's background experiences, self-efficacy related to the technological innovation, and the intended purpose for introducing the target technology. When we implement the CBAM model and focus on the SoC dimension, it allows for the exploration of potential adopters perceived needs and perceptions relative to the innovation. Figure 1 displays the SoC about the innovation, measured on a seven-point scale that ranges from zero to six: awareness (0), informational (1), personal (2), management (3), consequence (4), collaboration (5), and refocusing (6). The CBAM acts as a guiding framework to help illuminate concerns that accompany PSTs perceptions and intentions to use VR. These illuminated concerns make it possible to tailor technology integration strategies and teacher professional development.

IMPACT	6	Refocusing	The individual focuses on exploring ways to reap more universal benefits from the innovation, including the possibility of making major changes to it or replacing it with a more powerful alternative.
	5	Collaboration	The individual focuses on coordinating and cooperating with others regarding use of the innovation.
	4	Consequence	The individual focuses on the innovation's impact on students in his or her immediate sphere of influence. Considerations include the relevance of the innovation for students; the evaluation of student outcomes, including performance and competencies; and the changes needed to improve student outcomes.
TASK	3	Management	The individual focuses on the processes and tasks of using the innovation and the best use of information and resources. Issues related to efficiency, organizing, managing, and scheduling dominate.
SELF	2	Personal	The individual is uncertain about the demands of the innovation, his or her adequacy to meet those demands, and/or his or her role with the innovation. The individual is analyzing his or her relationship to the reward structure of the organization, determining his or her part in decision making, and considering potential conflicts with existing structures or personal commitment. Concerns also might involve the financial or status implications of the program for the individual and his or her colleagues.
	1	Informational	The individual indicates a general awareness of the innovation and interest in learning more details about it. The individual does not seem to be worried about himself or herself in relation to the innovation. Any interest is in impersonal, substantive aspects of the innovation, such as its general characteristics, effects, and requirements for use.
	0	Unconcerned	The individual indicates little concern about or involvement with the innovation.

Figure 1. Stages of concern (SoC) about the innovation (George et al., 2006)

Adapted to the context of this study are examples of each SoC. An example of a concern at the awareness stage could be an individual admitting they have never used VR. Informational constitutes the information seeking stage where an individual may ponder what apps and VR tours are compatible with the VR hardware. In the next stage, personal, the concern might center on how VR influences an individual personally, which could include questioning if immersive VR might lead to dizziness or another unpleasant feeling. During the management level, the user might focus on integrating VR into lesson planning (e.g., selecting the appropriate app, VR tour, scaffolding with supportive learning activities) in addition to expressing concerns about how to maintain the VR viewers and smartphone devices (e.g., charging the devices, updating software, downloading VR tours). At the consequence stage, the teacher might inquire about how VR can influence student motivation, engagement, and achievement. Within the collaboration stage, concerns might focus on wondering how others are using VR compared to how the individual uses the innovation in their own classroom. The final stage, refocusing, occurs when the teacher seeks out new ways to improve the teaching and learning experience, which could entail searching for new and improved software (e.g., VR apps) and higher quality hardware.

Similar to other technology innovations, implementation barriers can stem from an individual's beliefs about technology, self-efficacy, reaction to change, availability of technology resources, lack of professional development, and inability to manage the tool (Hall, 1976). Despite the promise of VR's ability to improve student motivation and learning, few teachers integrate VR into their classrooms. With access to more affordable head-mounted viewers, it is important to investigate PSTs' attitudes, perceptions, and intentions to use VR in the classroom so teacher preparation programs can address and prepare for perceived barriers that might otherwise inhibit technology acceptance and use.

2.1. Research questions

- How do PSTs' SoC before the introduction of VR compare to their SoC following a hands-on intervention with the innovation?
- Relying on open-ended data sources (e.g., survey items, science journals, focus group), what appear to be the underlying reasons to explain each PSTs' concerns when using VR to plan science instruction?

3. Method

This mixed-method research study (Creswell & Creswell, 2018) provides empirical and explained perceptions to compare each participant profile with the innovation before and after exposure to VR. This method was most appropriate to help closely examine the sample size of five PSTs from the same undergraduate classroom. Multiple data sources provide triangulation to answer the study's research question. We implemented a pre and post design of the Stages of Concern Questionnaire (SoCQ), which contains 35 Likert-scale response items, to which we added one open-ended response item (George et al., 2006). Although the SoCQ reports quantitative data, the questionnaire produces qualitative descriptions based on the quantitative measures obtained. Other qualitative data sources include PSTs' individual science journals, individual surveys following each VR experience, and a focus group meeting to conclude the study.

3.1. Participants, context, and procedures

Data were collected in fall 2018 within an undergraduate science methods course at a large, public, Hispanic-serving and minority-serving institution, comprised of more than 38,000 students in the southwestern United States, with approximately half first-generation college students. PSTs enrolled in the course as part of their degree requirement toward becoming middle-school science teachers. Participants included Amber, Ava, Carla, Chuck, and Frieda (pseudonyms). Chuck and Frieda were student teaching full-time in grades five and seven, respectively; Amber, Ava, and Carla were observing in middle-grade classrooms twice a week as part of their teacher preparation. Three of the five participants came from diverse backgrounds; Table 1 displays the study participants reported gender, ethnicity, and age.

Table 1. Demographic makeup of study participants

Participant	Gender	Ethnicity	Age
Amber	Female	Caucasian	25
Ava	Female	Hispanic	24
Carla	Female	Hispanic	21
Chuck	Male	Caucasian	25
Frieda	Female	Asian	27

This study was introduced to PSTs as an opportunity to engage and explore with VR to innovate science learning. Participation had no impact on their course grade, and informed consent was obtained from each participant. The consent outlined the risks involved, including the potential for "loss of spatial awareness, dizziness and disorientation, seizures (e.g., anyone who is epileptic or is prone to seizures should not be considered as a candidate for VR), nausea, and eye soreness."

Four of the five VR sessions were conducted in a science education laboratory classroom. The classroom, equipped with high top laboratory tables with four swivel laboratory chairs at each table also contained sinks, and most equipment typically found within a middle-school science lab. One intervention session was held at the university's environmental education center. The environmental education center contains indoor and outdoor areas designed for informal learning. The outdoor learning area includes two paleontology/archaeology dig boxes, a Texas geologic history walk, and a pond suitable for practicing environmental monitoring and collection of macroinvertebrates.

The VR equipment used in this study was a commercially available classroom set containing 20 headset viewers, a teacher tablet, 360-degree camera, and LAN router. The viewers consisted of a hard-plastic shell with magnifying lenses that allowed for viewing VR content displayed on the included smartphone. Unlike the more affordable cardboard viewers, these viewers are sturdier and include a focus adjustment. The viewers did not come with a head strap, which required students to hold the viewer when experiencing the VR lesson.

3.2. Data collection

This study was conducted over five consecutive weeks. Before PSTs were introduced to VR, they completed the SoCQ, which contained the standard 35 items and demographic items. One additional open-ended response item concluded the survey, "Please share anything else you would like to tell us about your experience/opinions regarding technology." Other qualitative data sources included individual science journals, individual surveys following each VR experience (n = 5), and a focus group meeting at the end of the study.

The SoCQ questionnaire "was designed for and is intended to be used strictly for diagnostic purposes for personnel involved in the 'adoption' of a process or product innovation" (Hall et al., 1977, p. 57). The questionnaire contains 35 statements, with each focused on a specific concern in connection to the innovation. Respondents indicate the degree to which each concern is true for them by selecting from a 0–6 Likert-scale. High numbers indicate high concern, low numbers are associated with low concern, and 0 indicates very low concern or irrelevant items (George et al., 2006, p. 26). Sample items include: "I am concerned about students' attitudes toward the innovation," "I have a very limited knowledge of the innovation," and "I would like to know how the innovation is better than what we have now."

Details of the intervention illuminate PSTs depth of involvement with the VR. Each 90-minute session built on the previous experience to move at a pace dictated by the participants (Pearson et al., 2019), with lessons intended to help PSTs' envision VR in their science classrooms.

We introduced the study and PSTs completed the SoCQ (Hall et al., 1977). To administer the survey, we loaded the original questionnaire items into Qualtrics and PSTs completed the electronic survey on their personal laptops. Following the survey, we unboxed the VR and provided basic instructions on how to power on and handle the equipment. The learning objective during session one was for PSTs to become familiar with the VR device. To accomplish this goal, we directed PSTs to the functions of the hardware and took them on a VR tour, using the Expeditions app. For the second VR experience, PSTs compared Expeditions tours designed by different developers intended to teach life science. Though most VR tours are silent and only include on-screen text, PSTs went on an Expedition tour that was equipped with audio features, audible through the teacher tablet. We integrated individual science journals that contained guiding instructional questions to support and encourage responses and reflective thinking, which were adapted from the Expeditions curriculum.

Within the third VR experience, PSTs' aligned science-learning standards with VR videos, while continuing to integrate science-learning journals. To accomplish this, PSTs explored the Discovery VR and roller coaster apps and brainstormed how these immersive videos might influence students' personalized learning experience and understanding of the standard. Additional apps explored were Titans of Space Cardboard VR, SciVR, Share the Science: STEM, and Water Cycle VR. By the fourth VR session, we perceived PSTs were ready to create their own VR tour. Using a Ricoh Theta SC 360° camera, they took turns taking photos of an outdoor science center located on the university campus. Some of the photographed settings included a fossil dig, pond, nature trail, waterfall, and life-size reconstructions of extinct animals. Photos from the 360° camera were transferred to a desktop computer using Google Poly, a free VR tour creator software. The self-made VR tour was made publicly available online at [link available upon acceptance]. Each PST typed the web address into the browser on their VR smartphone device, placed the phone into their head-mounted viewer, and immersed themselves into the VR tour they had created. Again, PSTs responded to question prompts and documented their thinking in their science journals. At the completion of the study, PSTs completed the SoCQ for the second time.

3.3. Data analysis

The SoCQ was analyzed in accordance with the guidelines outlined in the questionnaire manual (George et al., 2006). The scores for each of the SoCQ stages were averaged and the resulting means were multiplied by five to produce a raw score. The raw score for each stage was converted into a percentile score utilizing the tables derived by George et al., (2006). As illustrated in the graphs, the resulting percentile scores were graphed with a description to produce an individual profile for each participant. Each PSTs result was matched to one of these profiles to form the basis for the descriptions of their SoCs.

Guided by Braun and Clarke (2006), we engaged in a seven-phase deductive thematic analysis of open-ended data (science journals, pre and post SoCQ open-ended item, surveys, focus group). During phase one, we individually read the complete qualitative dataset, documenting impressions, thoughts, and preliminary interpretations. Following our initial readings, phase two consisted of rereading all open-ended responses to deductively align data in accordance with each CBAM SoC level (Hall, 1976). This deductive process allowed for a deeper understanding to compare each participant's SoC at the beginning and end of the study. In phase three, we collaborated, compared, and contrasted our sorting of open-ended data to align with each SoC, to deepen our understanding of each participant's experience. Phase four involved individually delving back into the dataset to determine whether all data fit within the deductive SoC domains, ascertain whether data were sorted accurately, and distinguish if new domains were needed. After sorting the data, our fifth and final phase served to ensure a shared understanding of each theme.

To ensure inter-rater reliability, the data was independently analyzed by both authors and discussions were held until consensus was reached. To address issues of validity, we employed member checking by returning the data and our interpretations to the participants to allow PSTs to support, explain, corroborate, or clarify their responses. To further address validity, we divulge the role of the researchers. Both researchers were involved in the design, implementation, and analysis of the present study. The primary researcher was an experienced educational technology user, but had never used VR head-mounted viewers prior to this study. The co-researcher has a background in computer science, was the science methods professor, and had previously used VR to access Google Expeditions in his 8th-grade classroom.

4. Results and discussion

Given the potential benefits of using immersive VR to support learning, such as increased student engagement (Bowen, 2018; Ferdig et al., 2018; Merchant et al., 2014) and opportunities for inclusion (Craddock, 2018; Horn, 2016), it is important to understand what barriers to implementation are perceived by teachers who consider incorporating VR into their instruction. Since implementation of VR in the classroom may represent a large investment of teachers' and school districts' budget allocation, it is important for schools and districts to understand barriers that could otherwise hinder a valuable return on their investment. As outlined in George et al., (2006) SoCQ manual, findings are organized and discussed by each participant's individual peak stage score interpretation before and after the study, and relative to their individual profile interpretation description.

4.1. Individual peak stage score interpretation

Peak stage score interpretation is the simplest form of SoCQ data analysis. To perform this analysis, we charted the percentile scores and identified the highest stage of concern. In cases where another stage was within one or two points, both stages were identified as the highest stage of concern. It is important to note that percentiles are not interpreted as absolute scores; rather, they are viewed as relative to the other stages. Individual second highest scores were also examined to identify a secondary SoC.

4.1.1. Before the VR experience

Table 2 shows the individual peak scores for each participant prior to the study. Stage 0 (unconcerned) was the peak score for both Amber and Carla, indicating that teaching and learning with VR was not necessarily a high priority. Interestingly, unique to both Amber and Carla, their second highest SoC was stage 1 (informational) suggesting that while not a high priority for them, they were interested in learning about VR.

For Ava and Frieda, their highest SoC was stage 2 (personal), which suggests they were unsure about the demands of implementing VR in science. Akin to Amber and Carla, both Ava and Frieda shared Stage 1 as their second highest score, which indicates that although they had concerns about using VR to support instruction, they were interested in learning more about the innovation.

Chuck's individual peak scores in stages 1 and 2 are nearly identical, indicating a profile similar to Ava and Frieda. However, he also has a relatively high score in Stage 0, which invites a comparison to Amber and Carla. It is interesting to note that there appear to be two subgroups, Amber–Carla and Ava–Frieda, with Chuck being a hybrid of both groups.

Table 2. Individual peak stage score interpretation pre

Participant	S0	S1	S2	S3	S4	S5	S6
Amber	99	*80*	48	39	69	16	5
Ava	31	*80*	83	56	24	28	17
Carla	99	*95*	89	60	43	76	34
Chuck	81	*96*	97	34	82	93	42
Frieda	31	*54*	59	30	11	10	17

Note. Peak scores are underlined.

4.1.2. After the VR experience

Table 3 displays the individual peak scores after the study ended. Several interesting observations appeared when analyzing the post-study scores. For one, the mini-cohort of Amber and Carla showed progress. While they both maintained Stage 0 as their primary SoC, their second highest SoC shifted upward on the model's trajectory. Amber moved from the information stage into Stage 3 (management), which indicates she is contemplating how to implement VR in her classroom. Carla shifted from Stage 1 to Stage 2, suggesting that she learned about the innovation but is now concerned with her ability to implement VR in the classroom.

The mini-cohort of Ava and Frieda indicated stagnant change. Both showed Stage 0 among their primary SoC with stages 1 and 2 nearly as prominent. This profile shows that they are still struggling with their self-efficacy, and the idea of implementing technology is no longer a high priority.

Chuck, who shared similarities with both mini-cohorts, had the most dramatic change in peak scores. Chuck's post-study peak score is at Stage 5 (collaboration), which indicates that he is focused on connecting with others to use the technology in more innovative ways. Chuck's second highest peak scores were noted in stages 1 and 2, indicating his concern with personal implementation and a desire to learn more.

Table 3. Individual peak stage score interpretation post

Participant	S0	S1	S2	S3	S4	S5	S6
Amber	99	45	7	*80*	5	5	11
Ava	*81*	80	83	60	16	40	38
Carla	98	*84*	92	73	43	59	57
Chuck	31	91	*92*	43	22	97	26
Frieda	81	*60*	57	52	19	22	30

Note. Peak scores are underlined.

4.2. Individual profile interpretation

The richest method for interpretation of the SoCQ occurs through individual profile analysis (George et al., 2006). Profile analysis is accomplished by graphing the SoC percentile scores for each participant. Ideally, peaks in the profile should move from left to right as the participant progresses into higher stages of acceptance. This movement was only noted among some of the study participants. To facilitate discussion of the individual profile interpretations, each student profile is presented as a separate figure. A frequency of the highest stage of concern is displayed to show collective concerns before (Table 4) and after the study (Table 5).

Table 4. Frequency of highest concerns stage for the individuals pre							
Participant	S0	S1	S2	S3	S4	S5	S6
Number of participants	2	1	3	0	0	0	0
Percent of participants	33	17	50	0	0	0	0

Table 5. Frequency of highest concerns stage for the individuals post							
Participant	S0	S1	S2	S3	S4	S5	S6
Number of participants	4	0	1	0	0	1	0
Percent of participants	67	0	17	0	0	17	0

4.2.1. Ava

Figure 2 displays the profile for Ava before and after the VR experience. Both pre and post lines of Ava's profile closely resembles what George et al., (2006) describe as a typical non-user profile. This profile suggests that while Ava is interested in learning more about the innovation, she is not overly concerned with other stages, such as management and collaboration. Although both lines adhere to the non-user profile, the increase in stage 5 and 6 (refocusing) scores indicate that Ava has become more involved in thinking about collaborating and/or is refocusing with competing ideas. The difference in the Stage 0 score is not as important in this profile configuration as are the stage 1 and 2 scores, because earlier conclusions have shown that "variations in stage 0 do not seem to be as important as variations in stage 1 and 2" (George et al., 2006, p. 38).

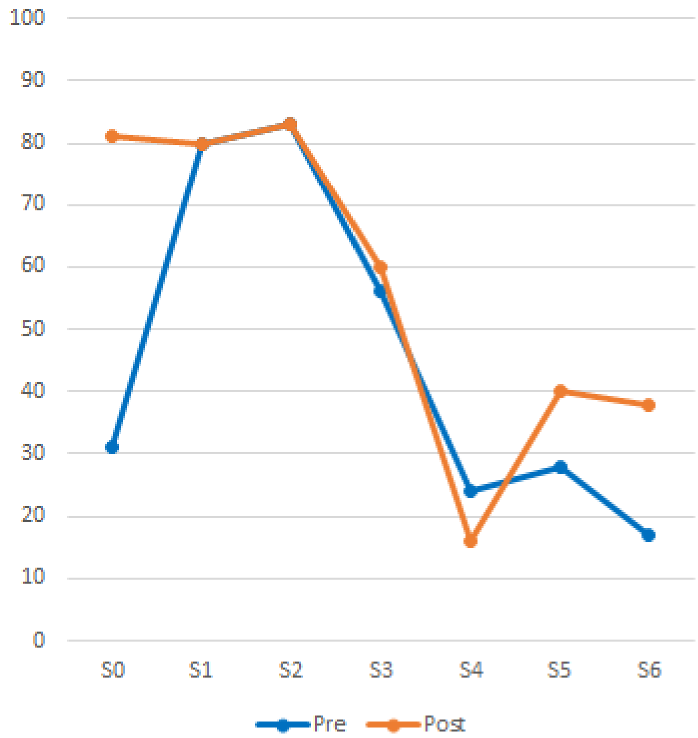

Figure 2. Ava's pre and post experience profile

4.2.2 Frieda

Figure 3 shows Frieda's pre and post experience profiles. Frieda exhibited a variation on the typical non-user profile, described by George et al., (2006) as a negative one-two split with tailing up at stage 6. A negative one-two split occurs when stage 2 is markedly higher than stage 1. In Ava's case, stage 2 was higher but only by a couple of points so it would not classify as a negative split. A negative one-two split indicates potential resistance to the use of VR in the classroom due to elevated personal concerns to use the technology. Users with this profile will not typically move toward adoption until stage 2 concerns are addressed (George et al., 2006). Frieda's post profile line removes the negative one-two split, and although the later stage of concerns are elevated, this implies that Frieda has started to move toward the adoption of VR. The increase in stage 1 indicates that she likely wants to learn more before exploring the innovation further.

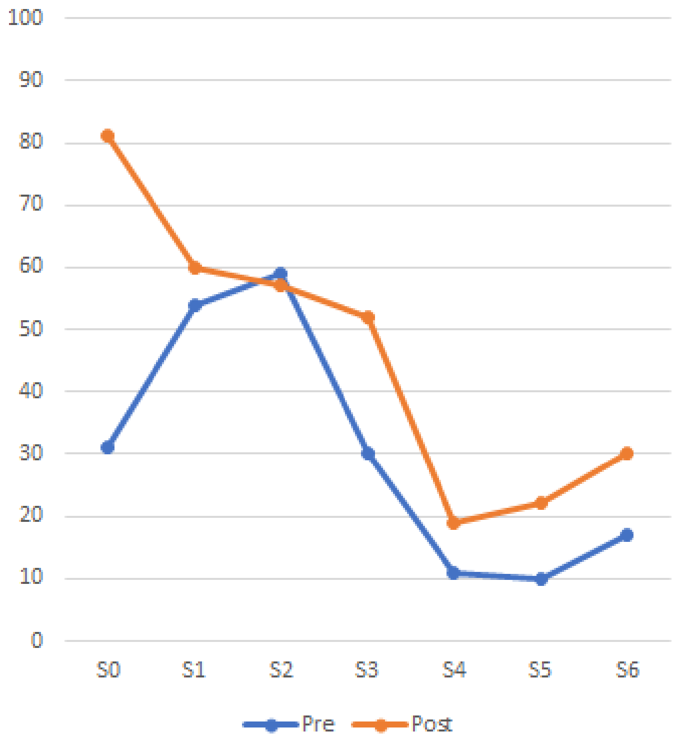

Figure 3. Frieda's pre and post experience profile

4.2.3. Chuck

Chuck's profile (Figure 4) also shows signs of a typical non-user but with the added characteristics of a high collaboration and consequence concerns profile. The high score in both stage 4 and 5 show that Chuck was initially concerned with how implementing VR would impact his students, but he was also interested in collaborating with others to use the technology. The drastic drop in stage 4 after the VR experiences indicates that Chuck is confident that his students would benefit from VR. However, Chuck still has concerns associated with the non-user profile, which indicates he would like to seek additional information.

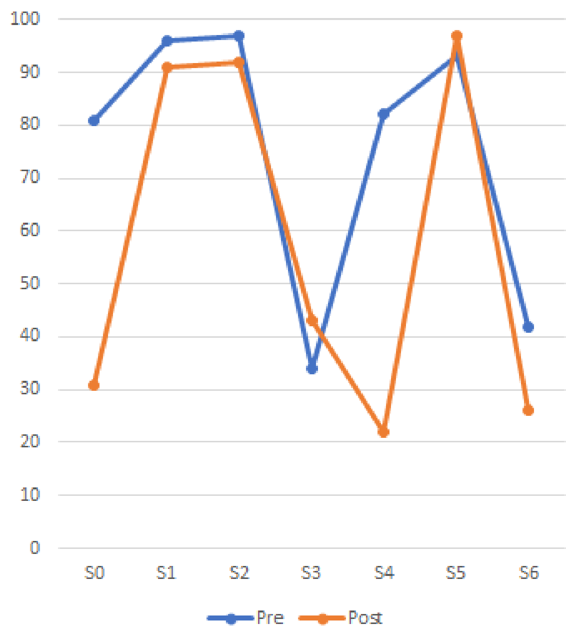

Figure 4. Chuck's pre and post experience profile

4.2.4. Carla

Figure 5 exhibits Carla's pre and post profiles. Carla began the VR experience as a typical non-user profile as described by George et al., (2006). At first glance, it may not seem like much change from pre to post; however, a closer examination reveals a negative one-two split similar to that portrayed in Frieda's pre-experience. This indicates that Carla's concerns about how to implement VR affects her personally, which now overrides her desire to learn more about the topic. It is interesting to note the reduction in Carla's stage 5 concern. This reduction suggests that she is more confident in collaborating with colleagues to use VR in the classroom. A stage 6 increase suggests she may be exploring a more powerful alternative and/or different ways to use the tool.

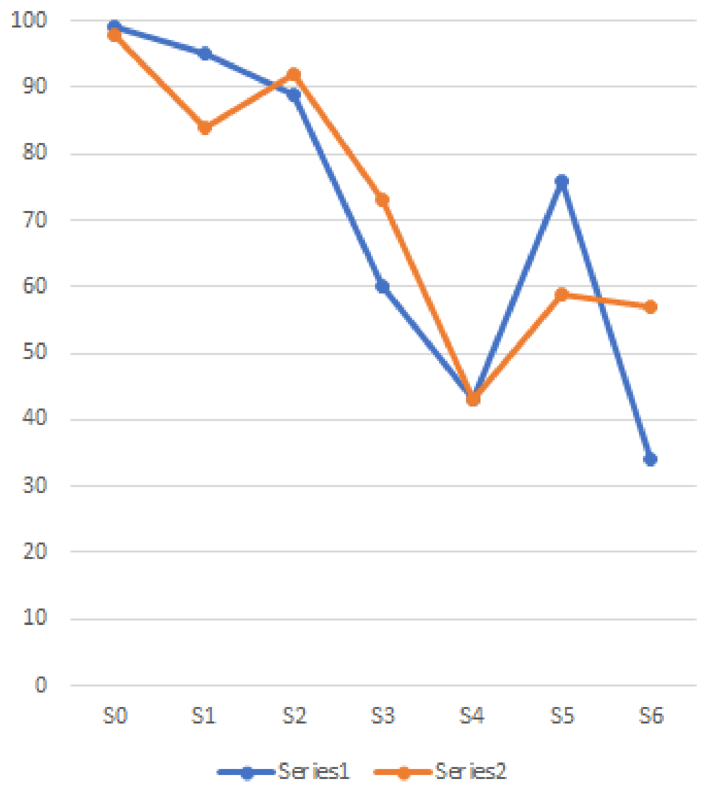

Figure 5. Carla's pre and post experience profile

4.2.5. Amber

Amber's pre and post profiles are depicted in Figure 6. Amber's initial profile indicates a high interest in stage 1 and a secondary concern in stage 4, suggesting that she is curious about VR but has reservations about what it means for her students. Amber's post experience profile shows that she has possibly lost enthusiasm for the innovation. The high stage 3 score could imply that she thinks the implementation of VR would require too much commitment in terms of time, logistics, and/or management.

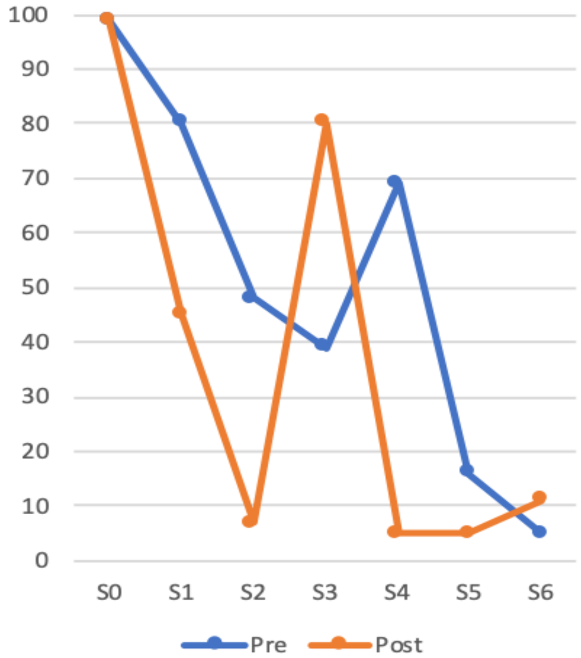

Figure 6. Amber's pre and post experience profile

4.3. Collective reflection of PSTs VR concerns

After unpacking PSTs concerns, open-ended response data revealed four additional themes: emphasis on the technical aspects of VR, learning engagement/satisfaction, generation of lesson plan ideas, and PSTs intention to use VR.

4.3.1. Emphasis on the technical aspects

Considering the technical properties of the VR headset, PSTs judged device quality and proposed suggestions. Four explained the clarity of the VR headsets was a problem. Carla said her main concern was quality and that it "would be great if the quality was better...that is my main concern." Chuck wished "there was some more clarity on the images." Frieda offered a suggestion to "try looking into if the blurriness came from goggles or the device," and explained that "you would have to have a better-performing device/cellphone than the provided Nokia," because "the Nokia was blurry and without finding a hot-spot, it would not be seen in good quality." Amber elaborated on the eyepiece and explained a possible solution to reduce motion sickness while wearing the VR headset, because "resolution is blurry possibly because of the eyepiece. This may help with reduction of motion sickness."
Ava noticed a difference among the quality of images and how they vary from one VR tour developer to another. For example,

I felt like the Life in the Deep Ocean expedition lost my attention because the images were fake and I could tell and I feel as though that would be the time to just pull images up on the board and have the students look versus using VR because it's not 'real' like the other images were.

Chuck offered a possible explanation for the differences among the image quality, saying that "the illustrations were okay- I understand that its purpose being that those images are harder to capture, and that some things must be illustrated for VR." Chuck added the importance of using a high-quality smartphone, "once the quality of the phone was changed (to Samsung™ Galaxy S7), I was really amazed at how great the experience became!" explaining, "I know I was being tough on it, but I'm just putting myself in the minds of my students and thinking what they would think."

Two students suggested head straps. Carla said that she felt she would "need straps to wear around my head" and Chuck said, "I wish there were straps on the headsets so I wouldn't have to hold up the goggles the whole time." Those who wore glasses faced another challenge. Carla noted "it's a little hard to use the equipment with glasses but because I can still see without my glasses, I'm fine. I would be concerned about students who cannot see too well without their glasses though."

There was mention of the time it took to prepare the VR headsets for use. Frieda said that "creating our own VR tour helped us to understand how time consuming it is to set up everything." Frieda went on to speak about connectivity issues, saying that it was "easier to use and follow along as long as the Wi-Fi is properly working. It would be easier without technological conflicts." Another shared an idea that could make the experience more realistic. Ava said, "I wish we could record videos or switch the view to 1st person like in a go pro that way it really feels like you're there."

4.3.2. Learning engagement/satisfaction

Four PSTs said they enjoyed the experience of using VR. Chuck admitted that he "really enjoyed this experience. I think it is awesome that we got to go to different continents to see the different volcanoes." Frieda reminisced about being able to ride on a roller coaster, an otherwise unimaginable experience. She explained, "I also tried the Discovery app, the roller-coaster video in thrills and adventure. That was a good experience: it actually felt like being in a roller-coaster." Carla relayed that VR can give students an opportunity to visit places they would never get to see otherwise. "I think it was great, especially because the deep ocean is an environment that students would probably never see in real life." Carla also found it "impressive that we can make our own [VR tours]." Ava, though she liked the VR, felt that the VR research detracted from her teacher preparation experience.

I enjoyed this experience overall. Although I do feel a little like it took away from the methods class and us actually learning things that are pertainable [sic] to learning methods content I enjoyed it. It made class a little more fun in being able to mess around with the VR technology.

PSTs also liked the variety among the VR tours available. Frieda said, "Using the different expedition types gives it variety and different perspectives." Chuck enjoyed going to "different continents to see the different volcanoes," while Ava "loved the persevered oceans." Two other PSTs emphasized how realistic the experience felt for them. Ava admitted she "really enjoyed having the sound even if it was only from the teacher's device. I feel like that does add to the expedition and makes it more realistic." Frieda provided an example of realism, "between the Discovery VR app and the YouTube® video, the YouTube video made a difference visually and in audio." Frieda also noticed "having realistic scenes will allow students to experience an outside classroom experience."

Issues of equity and access arose in regard to the importance of taking future students to places they may not be able to afford to travel. Ava admitted for herself that money was an impeding factor, because "both places we visited are places I have wanted to go in real life but just don't have the money for yet." Carla seemed relieved that VR allowed for some travel adventure, "I think it was great, especially because the deep ocean is an environment that students would probably never see in real life." Frieda echoed, "The illustration allows students to see what they cannot experience as there are places where people can't visit."

4.3.3. Generation of lesson plan ideas

Regarding science lesson plan ideas, PSTs had multiple recommendations for how to incorporate VR into learning. Frieda proffered, a

field experience involving different terrains and areas dealing with succession. Life Science involves the outside world so an explanation of microhabitats and biodiversity could make a great experience. Areas such as creeks and forests could make a good lesson with the VR tour.

Some PSTs were inspired by the Elm Fork VR tour they created. Amber envisioned how "you could take a 360 photo of a specific biome and have the students list all the biotic and abiotic factors that they see." Carla had an idea to take "a picture of an area where we have all these factors and then make students list out the different factors" and then ask students to consider how those factors could "affect the relationships that organisms have with their environment." Ava adapted the idea to make it here own,

one VR tour I could do would be similar to the elm fork where I could go to a nature reserve or park and use that over a lesson about organisms and the environment. Another VR tour I could do would be to make a trip out to the different ecoregions of Texas and take pictures so students can have an experience learning about the effects of weathering, erosion and deposition of the earth.

Chuck shared many different science lesson plan ideas, one involving students who might otherwise be unable to attend a field trip. He reflected, "I could use VR to simulate my trip for the students who didn't go so they don't totally miss out on the experience." Additionally, Chuck came up with lesson plans to explore the solar system, different volcanoes, as well as parts of a cell for biology. Carla also had an idea to create a VR lesson plan for her students following a storm or natural disaster. She explained how this would be helpful, "so that we can learn about natural disasters or certain events. I liked creating our own experiences so I think students would definitely enjoy it too."

4.3.4. Intention to use VR

In line with PSTs who were satisfied with the VR experience, four PSTs intend to use VR in their classroom because they were positively impacted by the experience. Frieda reflected, "it's a great way to have students experience their surroundings especially if there are students that have not experienced a 360 POV. It's really a good idea to use VR as a classroom experience." Mindful of the limitations of available technology in schools, Chuck said, "I'd use VR in my classroom if I had it! I think VR experiences can be a powerful thing for teachers and students." Chuck also admitted the need for additional professional development, "I would like to do VR experiences with my students one day, given a little more training to master the technology." Carla added that, "it's also cool to think that teachers can create their own experiences for their classes." Ava appeared impressed with the ability to make her own VR tour, "it's cool to see the finished piece of what we did last week." Carla believed that by using VR, "it would engage students to be able to create their own VR experiences."

Both Frieda and Carla explained how the experience could help engage their students and improve their lesson plans. Frieda said, "I think it would be great to use in the classroom and making our own with experience we want to share with our students could further better our lessons." Ava believed VR would be helpful because "students would really enjoy going out and taking the pictures and then being able to see it through a different lens."

4.4. Reflection of the intervention experience

To inform future research, we share lessons learned from this intervention experience. Logistics pertain to selection, planning, and implementation. First, it is essential to identify the usability experience. Decide on the desired VR interface, whether students will use a desktop computer, laptop, tablet, or head-mounted viewer. Next, consider when and how the devices will be utilized during instruction because device options vary in quality and movability. For example, the Oculus Rift® is high quality but requires a wired connection, whereas the smartphone and head mounted viewer setup is wireless. A wireless education kit typically comes equipped with a secure and padded carrying case, 10 headset viewers, 10 smartphones, charging ports, and a router, but it is costlier. A third option is to create a set of five for a classroom for about $150, which might contain the head-mounted viewers with a strap, gently used but higher quality smartphones, with an option for teacher-led instruction using a tablet and router. Add a 360° camera to help students create their own VR experiences. Device selection is important because it involves careful consideration of intended use, budget, and subsequently, quality.

With devices in hand, device exploration is foundational to using apps and aligning with instruction. Just as teachers need to preview the curriculum before designing a lesson, it is essential to practice device setup. Spend time locating or designing VR tours to support instruction. Prepare to introduce the innovation to students. Thus, adapt classroom management techniques, emphasize safety procedures, and provide students with a laminated printout with access, use, charging, and cleaning instructions. Finally, obtain student feedback to adapt instruction, brainstorm new ways to engage with VR, and challenge students to design their own VR tours.

4.5. Limitations

We acknowledge that this study contains limitations. First, the sample size of five participants is small, and therefore cannot be generalized to other contexts. Nonetheless, the rich dataset is triangulated by open-ended response items, and the SoCQ provides descriptive behaviors to explain acceptance to a technological innovation. Another limitation is that data from the SoCQ and open-ended responses are self-reported, which may include social desirability bias (Edwards, 1957), where participants' could portray themselves as a more positive or confident user than is true.

5. Implications and future research

Implications of this research first indicate the need to extract an individual's concerns before implementing a technology, because an awareness of an individual's SoC could reduce barriers toward the acceptance of an innovation. Our findings also demonstrate the importance of providing PSTs with hands-on technology experiences, which is essential for an individual to conceptualize and actualize themselves using a new technology and is a necessary process that supports PSTs becoming classroom teachers. In our study, we noticed that all PSTs perceived and responded differently to using VR to support learning, in addition to how they envisioned using technology in their future classrooms. Although each PST had a unique profile, three subgroups emerged in the data, which suggests that professional development should align with a user's individual SoC profile. Therefore, we recommend additional research examines how larger subgroups of PSTs demand unique supports as they move through their SoCs.

A longitudinal and more expansive approach similar to this research design could help distinguish the amount of time required by the individual to reach the two highest stages of concern, collaboration and refocusing. With regard to in-service teachers, researchers might consider investigating how these practicing teachers perceive the usefulness of using immersive VR in the science classroom over the long-term. This research could also focus on improving our understanding of K-12 teachers' willingness to integrate VR and how their students perceive and perform when learning with VR. To expand our understanding of how to help teachers use VR in the classroom, case studies might investigate teachers who are unfamiliar with VR and exhibit resistance toward adopting the technology. With comprehensive data collection via a large-scale research design, this could lead to the inception of a technology integration preparation manual for administrators, teachers, and teacher educators implementing VR.

To contribute to research on K-12 student achievement when learning with VR, we recommend researchers conduct a quasi-experimental study to measure the use of VR in the classroom on students' learning outcomes. We also encourage a study on the use of VR to measure students' self-efficacy in science before and after integrating VR as a tool to support learning. Finally, we urge researchers to explore the possibilities of VR in special education, to identify ways VR could support students with disabilities, such as taking them to locations that would otherwise be inaccessible.

6. Conclusion

The purpose of this study was to further examine the intersection of technology, design and pedagogy (Ioannou & Ioannou, 2020) when using VR. Therefore, by exposing PSTs to VR (Long & Eutsler, 2020) with the intention of expanding on the science curriculum and content (Lytras et al., 2018), we measured PSTs concerns to integrate VR when planning science instruction. Framed by the CBAM (Hall, 1976), we measured the SoC using the SoCQ before and after a 5-session hands-on exposure to the innovation. During these sessions, PSTs became familiar with the hardware, available VR apps, and brainstormed ways to connect science content to the experience of using and designing VR tours. An analysis of PSTs SoC shows that while four out of five participants intend to use VR within their future science classrooms, they desire more professional development and an opportunity to use VR with middle-grades students before they would implement VR with their own students. Open-ended data also found that PSTs focused on improving the technical aspects of VR, most were satisfied and enjoyed designing instruction and learning with VR, and these hands-on experiences of creating their own tour and engaging with VR led to the generation of multiple lesson plan ideas. This study provides a beginning model to introduce VR within teacher preparation programs and with middle-grades science teachers. Future research might replicate and expand this research design to include the investigation of in-service teachers and middle-grades students using VR to support science instruction.

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