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Exploring Virtual Reality as a Design Observation Training Tool for Engineering Students

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Exploring Virtual Reality as a Design Observation Training Tool for Engineering Students

Abstract

Direct observation of design contexts allows engineers to collect detailed data in ways that are not possible with other methods, and is therefore a key method in sociotechnical engineering design, especially during the front-end of design processes. The development of design observation skills for engineering students presents challenges, however, including the effort required to reach representative observation sites and the uncertainty involved in real-world design environments. Students have often struggled to demonstrate recommended practices in sociotechnical design activities such as observation, yet may need observation skills during design project opportunities including curricular and co-curricular design projects. In addition, skills development may be especially challenging and critical when design environments are difficult to access, such as those in sensitive or remote locations. Therefore, this study explored the efficacy of a prototype VR-based design observation training tool with four undergraduate students engaged in a co-curricular global health technology design program. Participants were first given classroom- and VR-based design observation training, then interviewed before and after real-world design observation practice to elicit perceptions of the advantages, limitations, and overall effectiveness of the VR training experience. Across approximately six hours of collected interview data, participants reported positive general perceptions of the VR tool, which was described as more engaging and realistic than classroom-based training. Participants also discussed the limits of VR in preparing them for real-world observation, and technical and usability limitations of the VR system; they also identified variables to consider for the design of future design observation tools. Overall, participants suggested that VR may be most valuable as a complementary tool to other training formats.

1. Introduction

Observation is an essential method used during human-focused engineering design approaches. Observations allow engineering designers to collect rich data on design problem environments and stakeholder behaviors in ways that are not always possible with other methods, as well as allow for the triangulation of data across methods [1]. Multiple tools and strategies exist to support quality data to be gained from observations. However, support for the development of skills necessary for effective design-focused observations that can inform design decisions is limited in engineering education. Additionally, educational settings may not be able to create authentic observation experiences that prepare students for the challenges of real-world observation, and therefore practical observation experience is often required at the cost of extra effort for students to reach observation locations outside the classroom. Students may also be confronted with high-pressure or sensitive observation environments like medical facilities in curricular, co-curricular and extracurricular design projects and internships, which are likely to be especially difficult to access for preparatory practice or to prepare for in a classroom setting. As observation often involves uncontrolled environments and the management of high levels of uncertainty, and because engineering students have been shown to struggle with these aspects of observations [2], increased support in observation skills would benefit engineering students.

Virtual reality (VR) technologies have been promoted as promising design training tools for their ability to provide controlled, yet immersive access to scenarios that are otherwise difficult to replicate in a classroom [3]. VR may offer a bridge between conventional education and learnings that are only possible through in-person experience. Though immersive virtual tools are increasing in accessibility and affordability within educational contexts [4], there is mixed empirical evidence of the benefits and drawbacks of VR-based training simulations in higher education [5] and no studies have characterized the use of VR for engineering design observation training. To explore the effectiveness of VR for supporting engineering design observation training, this preliminary study explored students' perceptions of a prototype VR-based design observation training tool. Four undergraduate engineering students were each interviewed twice: once directly after a VR design observation training experience and again 2-8 weeks following in-person design observation practice within a clinical setting during a co-curricular design program.

2. Background

2.1 Ethnographic design skills education

Scholars frequently advocate for engineering designers to identify, collect, and make use of diverse types of data, including sociotechnical sources, to meet the needs of industries and to serve society effectively [6]. Students must be prepared to practice design approaches that are tailored to the complex realities in engineering design practice not only to support innovative and profitable industries [7], but to support ethical, critical engineering design that considers societal needs [6]. Broad, high-quality sociotechnical data collection and analysis, frequently requiring the use of qualitative research methods, are especially critical during the front-end of design processes, which Atman [8] defines as activities like problem scoping, requirements definition, and concept selection, and that often determine the success or failure of design projects [8, 9].

Ethnographic data collection methods, which are defined by [11] as the systematic watching or recording of a person or thing to develop knowledge, are primary tools for designers to collect contextual and stakeholder data needed to support innovation and meet stakeholder needs. Among the ethnographic data collection methods that may be applied to design, it is critical that designers participate in the direct observation of people or things relevant to a design problem, in particular, as it is not possible to convey the full range of information available in an observation environment via a third-party observer. Such design observations help designers understand context, develop new concepts, and verify or refute assumptions in ways that are not necessarily possible with other data collection methods.

Despite the importance of observation skills in design, there has been a long-running need for improvements in the ways that observational data collection skills are taught to engineering students, as well as how students are taught to bridge quantitative and qualitative design criteria [12]. Compared to experienced design practitioners, engineering students often struggle to demonstrate recommended practices in their work during front-end design activities, in particular, such as engaging with stakeholders [12–14] and developing prototypes to support stakeholder engagement activities [15, 16]. Moreover, students have been found to undervalue activities like engaging with stakeholders [18]. Burleson et al. [19] also found that students value opportunities to observe the context of use for a potential design solution and expressed frustration when they were unable to spend time in that context. At the same time, students felt overwhelmed by the amount of data available during observation and were sometimes unsure where to focus their attention. Lai et al. [20] demonstrated that design ethnography skills training not only improved observation skills, but actually increased the value students placed on ethnography and developing an understanding of user environments. In addition, engineering faculty may need further support to teach unfamiliar qualitative methods [20].

Therefore, the emphasis on, and educational tools available to support design observation training need to be further developed.

2.2 Virtual reality in education

While systematic literature reviews of immersive virtual media tools in education have shown mixed, sometimes contradictory results with respect to their advantages and limitations [20, 21], the balance of studies have demonstrated benefits afforded by virtual learning tools over other methods. Mikropoulos & Natsis [21] found that more immersive learning experiences resulted in more positive outcomes in terms of both attitude and learning. A systematic review of studies on virtual educational tools by Bacca et al. [23] echoed these findings, naming motivational and learning gains, as well as improved student engagement and positive attitudes towards the subject matter as the main advantages over other media. Moreover, interactive digital technologies not only offered new communication and learning opportunities, but were shown to support intellectual performance and new ways of cognitive processing [24].

In addition, a systematic review by Radu [25] found that immersive virtual media may improve long term retention of topics, and that immersive virtual technology is often more effective than traditional video and screen-based educational media. In a separate review, Radu [26] expanded upon these findings by highlighting the likely limitations of interactions with a mouse, keyboard, and screen in conventional PC-based media, which cannot create the same sense of "presence" for students and therefore can make learning more difficult. Radu [26] also described potential complementary benefits of immersive virtual environments to other media, where the auditory, visual, and/or tactile stimuli provides individuals with a broader range of sensory inputs to support diverse learning styles. Parong and Mayer [4] experimentally compared the learning value of a VR versus desktop computer based college science lesson, demonstrating that VR provided "significantly" greater learning outcomes. The study by Parong and Mayer [4] built upon findings from Winn et al. [27], who created a similar experiment in a college science lesson where the authors found that a virtual environment was beneficial specifically for concepts that must be understood spatially in three dimensions.

New media technologies like VR do not automatically lead to improved educational opportunities, however, but require intentional curriculum design to leverage the advantages of those technologies [23, 27]. Researchers and designers of virtual reality systems have come to similar conclusions across a wide range of studies, according to a systematic review by Mikropoulos & Natsis [21]. Specifically, researchers have called for strategic, goal-based design for VR-based education [28, 29]. In a meta-analysis of studies on the use of immersive virtual environments in K12 and higher education, However, Merchant et al. [5] found that there was still a lack of clarity in recommendations for specific design features for virtual educational tools.

Recurring limitations to immersive virtual educational tools have also been identified in research. A systematic review by Akçayır & Akçayır [22] named usability of virtual systems as being a consistent issue, due to either the inexperience of the user or educator, or design problems with the system itself. Radu (2012) also found common obstacles related to educators being unfamiliar with immersive virtual technologies, how to use them, and potential educational benefits of virtual tools, in addition to usability difficulties with the technologies. Additionally, Radu reported that compared to other media, immersive virtual education experiences presented more information than students could absorb, which may be seen as more representative of real-world environments or as a limitation of virtual training tools. In the case of information overload in virtual environments, Mayer & Moreno [31] proposed that cognitive burdens must be managed by curriculum designers more intentionally than with other forms of media due to the greater availability of information to the user, and Jordan [2] demonstrated that there was a range in how, and how well, students handled uncertainty, which should be considered in curriculum design.

Though few studies on the use of VR in university-level engineering design education have been conducted, studies of the use of immersive virtual environments within engineering science and design more broadly have found similar advantages and limitations as those reported in the body of literature referenced above. Berni & Borgiani [32] reviewed 86 articles on the use of VR in engineering and product design, finding some conflicting results within the literature. The authors also found that VR presents distinct advantages during the early stages of design work and design training, as VR is able to evoke emotional dimensions for users that are not possible with other types of media. In a study of a VR-based tool in a physical science lesson, Fidan & Tuncel [33] found that VR improved retention, and that students reported greater usefulness of the lesson and interest in learning, albeit with an increased risk of physical discomfort (i.e., nausea) among some students. Similarly, in an analysis of the usability of VR in design education, Özgen et al. [3] reported that a treatment group reported significantly higher "intention to use" the learning tool and "perceived enjoyment" compared to a control group that received a paper-based activity. The authors described the VR tool as enabling greater problem-solving abilities, and as having promise as a complementary tool to other formats in design education, while at the same time being in need of additional development to reach its full potential.

3. Methods

The study design and research methods used, participant recruitment and demographic information, and guiding research questions are discussed below in section 3.1, followed by a description of the data analysis process in section 3.2.

3.1 Data collection

To investigate the potential for use of a VR design observation training tool in an engineering design education setting, a set of two semi-structured interviews were conducted using the following research questions as a guide:

- How do students perceive differences, including advantages and limitations, of pre-recorded VR video versus other design observation training modes?
- In what ways can pre-recorded VR design observations prepare students for in-person observation?

Participants were recruited from a cocurricular global health design program [34] at a large Midwestern university, which requires students to spend approximately 150 hours conducting design observations in a clinical setting to support the identification and definition of unmet needs for health technologies. Four undergraduate students out of a cohort of nine voluntarily elected to participate in this research. All four participants identified as women and were in their third or fourth year of study. Participants had no formal prior experience with design observation practice and while all four had some familiarity with VR systems, none owned or used one regularly.

This study consisted of a conventional classroom design observation training, a separate VR-based design observation training, a follow-up interview regarding the training, as well as a second follow-up interview after participants had practiced design observation in a clinical setting. Participants completed the classroom-based and VR-based training before or shortly after beginning real-world design observations. An overview of this training and interview schedule is shown in Figure 1, which is followed by descriptions of each aspect of the research.

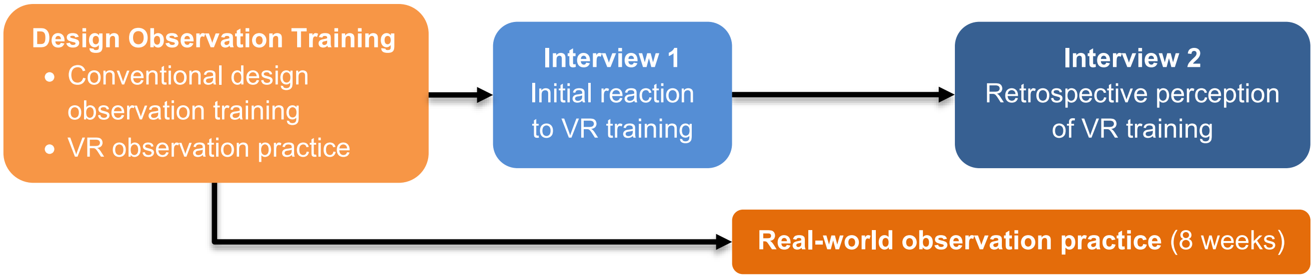

Figure 1. Flow diagram of design observation training and data collection activities

The classroom-based design observation training was facilitated by the research team for all students in the global health design program. Classroom instruction consisted of a 45 minute lecture and training session with practice observation, structured note-taking, and needs-finding activities based on two views of a two-minute clip of a video tour of a farmers market. A separate VR-based observation training was then conducted with the four students who opted to participate in this study. The training was facilitated by a researcher with one participant at a time in a private room. Participants were asked to watch a 360 degree video recorded from a single vantage point at a different farmers market for up to 20 minutes using an Oculus Quest 2 VR headset, which enabled participants to view the scene from all angles as they moved their heads. Participants were seated in a stationary swiveling chair to allow for ease of movement while minimizing the risk of disorientation or accidental movement towards objects in the room. Participants were again asked to take written notes on their observations. During the VR-based training, participants used a paper notebook that was visible beneath the VR headset, which did not seal around the nose and face. While this reduced the potential immersiveness of the observation experience, previous experiments by the research team found virtual writing tools that allowed for note-taking in the VR environment to be less effective.

A 45-minute interview was conducted with each participant within two weeks of the design observation training sessions. Upon the completion of the in-person clinical observations conducted as a part of the global health design program, a second, 45-minute interview was conducted with each participant (approximately two months after the first interview). In both protocols, follow-up questions were used regularly to probe students' perceptions and reasoning with respect to their responses, as is recommended by Patton [35]. Each interview protocol was also iteratively revised after piloting with two students who had previously experienced the VR training tool.

Questions in the first interview focused on expectations and perceptions of the VR training, as well as initial comparisons of the VR training to the lecture and 2D video-based practice done in the classroom. Example questions are given below:

- During your design observation in VR, was there anything that you felt like you wanted to observe, or observe more, but could not?

- Can you tell me what you found most *challenging* about the process of conducting observation in VR compared to the observation practice you did with a 2D video, if anything?
- Can you tell me what you found most *beneficial* about the process of conducting observation in VR compared to the observation practice you did with a 2D video, if anything?
- Has your impression of VR as a design observation training tool changed as a result of this VR observation experience? If so, in what ways?

In the second interview, participants were asked to describe the extent to which the classroom and VR-based training did or not prepare them for in-person observation, with questions such as:

- When observing in-person, in what ways did you feel prepared or unprepared to conduct design observations?
- Has your impression of VR as a design observation training tool changed as a result of your in-person observation experience? If so, in what ways?
- What questions or uncertainties do you still have about conducting design observations, if any?

The University of Michigan Institutional Review Board (IRB) reviewed and granted the study an exemption, and consent was obtained from each participant prior to participation.

3.2 Analysis

All interviews were audio recorded, transcribed, and de-identified. Then, these data were analyzed inductively, which is defined as the development of emergent patterns of meaning rather than the assignment of predefined themes [36]. Patterns were developed iteratively, as is suggested by Patton [35] to allow for the understanding of the data to evolve as transcripts are evaluated and revisited. Specific codes were assigned to relevant responses related to participants' perceptions of VR versus classroom design observation training, as well as responses related to how VR-based training prepared them for in-person design observation in a clinical environment. Coded excerpts were then organized into broader themes, which are discussed in the findings. As similar themes emerged from the first and second interviews, data from both interviews are presented together in the findings.

3.3. Researcher Positionality

The authors are White, from the United States, have professional expertise in the use and/or study of design observation and related techniques, and are at least 10 years removed from their undergraduate studies. As such, we acknowledge that our identities separate us from those of current undergraduate students both in terms of possible generational differences in relationships with technology, as well as from those who may not have had the privilege to access technologies including, but not limited to, VR during their upbringing and education. We aim to reflectively consider these differences during our research process.

4. Findings

Participants reported a variety of advantages and limitations of VR as a training tool compared to the two-dimensional (2D) video-based design observation practice they received as a part of their global health program training, as well as the in-person design observation practice they gained while working in clinical environments. Findings are organized below into 1) a comparison of VR and classroom-based design observation training, 2) a comparison of VR to in-person design observation practice, and 3) description of the effectiveness of VR as a training tool.

4.1 Advantages and limitations of VR compared to classroom-based design observation training modes

Compared to practicing the observation of a scene in a 2D video, participants described different advantages and limitations related to 1) the quantity of observable data, 2) enjoyment and engagement with the training, and 3) the novelty of VR systems. Participants described VR as a more challenging, realistic experience due in part to the increased amount of information available for observation. Unlike in a 2D video, when using VR for observations Participant 2 described being able to choose where in the scene to focus, and therefore which people or activities to focus on and which to ignore:

> I might have missed important things [in VR] because I was focusing in the wrong spot, but I think that's good to know and do because in a real situation, you have to figure out where it's important for you to focus at the moment, so that you try and make sure you're focusing on the important stuff.

Similarly, participants discussed observation and note-taking during VR as more difficult than with a 2D video, as there was more information available to observe and filter. Participant 4 described challenges not experienced while watching a 2D video:

> I felt a little more overwhelmed in that [VR] environment, just because there was more going on around me and [...] it felt like I needed to take in everything at once, because there was a time limit, and I was in this space, rather than [...] looking at [a static 2D screen] and writing a note.

Participants described VR as a more enjoyable training experience due to both the engaging nature of the VR environment and the novelty of the VR experience. With respect to engagement, Participant 4 reported that:

> It gave me that opportunity to feel like I was there.

Additionally, Participant 2 compared the difference in VR and 2D video to the difference between a remote and in-person lecture, saying that it was easier to focus on a VR video due to its proximity to an in-person activity:

> …it was so much harder to focus and watch [lectures online over Zoom] when it was just on the screen versus when you're sitting in the lecture hall, and I think the same principle [applies to VR].

Similarly, when asked how they would feel about practicing design observations on footage of the same scenario in VR or on a 2D screen for 20 minutes, Participant 3 responded that they would prefer VR because:

> …it might be challenging for attention span to just make yourself look at a screen. It's easy to start doodling on your paper while you're taking your observations, so I think that attention span element is different.

Regarding the role of novelty in participants' perceptions of VR experiences, while all participants had some level of prior familiarity with VR, none had used it regularly. Participants described curiosity or excitement around VR as influencing their attitude towards the training:

> I mean yeah, part of it was very exciting because it was new to me. (Participant 3)

> …it sounded like a neat idea and I was excited to try it out and get some more experience with, you know, ways of doing observation. (Participant 4)

Upon reflecting, Participant 3 also speculated that the novelty might wear off over time if she were to use VR regularly:

> If you've done [VR] a lot of times and it's not necessarily like a video game or something crazy fun, it might get a little dull…

4.2 Advantages and limitations of VR compared to in-person design observation practice

When comparing VR design observation practice to real-world design observation practice, participants described logistical advantages to VR, as well as the limitations of VR in simulating a real design environment. Specifically, participants discussed differences related to 1) the accessibility of practice environments, 2) social engagement with others, 3) the use of complementary design ethnography skills.

4.2.1 Accessibility differences in VR and real-world observation practice

Participants discussed differences in the effort required for, and accessibility of virtual and real-world design observation practice, expressing the relative ease of VR training compared to real-world observation:

> If I was working [in-person] in the farmers market I'd worry about parking, transportation, and so forth. (Participant 1)

> Standing up all day and walking around [...] can be pretty exhausting, and the longer that I stood, the more tired I became [and] the harder it was to really stay engaged and pay attention when I was observing. (Participant 4)

4.2.2 Differences in social engagements during virtual and real-world observation practice

In addition, all participants reported multiple differences in the social nuances of practicing design observation in VR versus real-world settings. In each case, participants described both the relative ease of VR observation due to the absence of constraints present in real-world observation, as well as the potential limitations of VR in preparing them for in-person observation. For example, Participants 2 and 4 described the awareness of one's own presence and related social considerations:

> The VR training experience doesn't necessarily do a great job preparing you for that because you don't really start thinking okay, well, I need to be aware of the physical space I'm taking up and even things like, if a doctor asks you "oh, can you get the light switch" [...]. And I think that's good to prepare students if they're going to have an in person observation, but not having that issue [in VR] would make things in a way, a more positive experience… (Participant 2)

> I like to kind of be a fly on the wall [in VR], rather than having to worry about am I freaking this person out by staring at what they're doing and writing down notes. (Participant 4)

Participants also reported the relative ease of focusing on the design environment and "a better ability to take in my surroundings" (Participant 1) in VR with fewer distractions compared to in-person observations. Participant 3 discussed the distraction caused by people in a real-world design environment questioning her presence or observation activities:

> …in VR you don't have people asking what you're doing and why you're taking notes. You can just do it in peace.

In addition, Participant 3 reflected on issues of consent and access in real-world design observation that were not present in the VR training tool:

> The social interaction of in-person… you have to ask what you can go see, you have to make sure you're doing it at the appropriate time. That's all eliminated when you're in VR because you already have the stuff to watch - the permission is there.

Participants also reflected on the effects of the presence of a human observer versus a camera in the design environment, with potential implications for the data collected during observation in different scenarios. Participants 2 and 3 discussed ways in which they noticed people behaving differently in the case of the farmers market video and real-world clinical observation, respectively:

> There were people who were aware of the camera sometimes as they were passing it [in the 360 degree farmers market video]. A person is a little bit more obstructive but also a little less novel [in a farmers market]. (Participant 2)
>
> Maybe, especially in topics of pain, if you're standing right there someone's maybe more likely to try to hide their pain or discomfort just because of social norms. So I think, maybe if there were a camera it'd be a more subtle way of capturing that experience, I think you might get more [...] natural behavior because I feel like people act differently on camera, but they also act differently if you're a person in front of them. (Participant 3)

Participant 4 also described ways in which a human observer or camera may have different access to different design environments; especially sensitive environments:

> In some ways, I think, having a camera there could allow you to be in situations where, otherwise it would be inappropriate for you to be there in the person. At the same time that might make people feel more uneasy because if you're capturing something digitally there's a greater likelihood of it being stored and recorded versus if someone's just standing there watching you it's not like they can post that somewhere. (Participant 4)

Finally, participants discussed the value of an emotional connection to their work that was present in real-world design observation practice, but absent in VR training:

> I think [real-world observation] adds an element of feeling like what you're doing is important when you're actually there versus just doing a VR experience. (Participant 3)

> I feel like it's kind of important as a designer or an observer to be interested in what you're doing and excited about what you're doing. [...] it feels strange and surprising that as an engineer I got to do [practice design observation in person] and it's very valuable and engages [me in a way] I don't think anything else could. And that's important too. (Participant 4)

4.2.3 Complementary design ethnography skills practice

When reflecting on the VR design observation practice after completing in-person clinical observations, participants discussed the absence of training on the complementary ethnographic design skills they found themselves using, formally or informally, in the real world. For example, Participant 1 discussed difficulties understanding how and when to informally question or interview the subjects of their observation:

> The ability to ask questions: when do I get the attention of a doctor or any kind of personnel or patients? I get to ask them questions and follow up on different things, whereas I wasn't able to do that in VR. (Participant 1)

Participant 4 reported similar difficulties in adapting formal research interview experience into informal, impromptu interviewing of subjects, especially when considering different relationships between the designer and subject:

> It would be nice to know what it's like to interview, the people who are the visitors in that space [...] or people who just aren't necessarily expecting to be interviewed because all of the doctors I spoke to were expecting to be interviewed […]. I have developed interviews where I've asked this person to interview, and then I can sit down and write down my list of questions ahead of time, but being able to come up with meaningful questions to ask when I just happen to notice something, and to ask me for questions about that… so I guess [I wish I had been taught] some improv interview skills. (Participant 4)

Participant 4 also described being surprised by the opportunities for, and value of methods that approximate participant observation and were not available as a part of her training. In this case she was asked to assist medical staff and as a result gained valuable insights that would not have come from pure observation:

> I actually got some really interesting observations about the [design problem] because I was asked to handle [medical equipment] and got hands on with that process [...]. That wasn't something that I was really expecting and I was kind of surprised that they let me do, but I think that it contributed a lot to me being immersed in that setting and understanding more about some of those problems. (Participant 4)

Notably, Participant 4 discussed immersion in this context as tactile and social forms of engagement in a real-world design problem context, as opposed to visual and auditory immersion of VR discussed in previous quotations (i.e., compared to classroom-based training).

4.3 Perceptions of the effectiveness of VR as a training tool

Separate from assessing the advantages and limitations of VR as a design observation training tool relative to other methods, at the conclusion of their global health design program, participants reflected on their perceptions of the overall effectiveness of the VR training provided in this study in preparing them for real-world design observations. Participants discussed 1) generally favorable impressions of the value of VR-based design observation training, 2) a unique benefit of VR-based training over other formats, and 3) issues related to a learning curve in using the VR system, as well as technical limitations.

Overall, participants described their VR training as "the next best thing" (Participant 2) to real-world practice for students who have little or no real-world design observation experience. Participant 4 reported that:

> …overall [VR is a] really clever and helpful way to kind of bring the observation experience to someone who has never done it before [...]. It's really helpful in comparison to even just a 2D video in terms of feeling immersive and being able to, you know, change perspectives and feel like you're in the environment [...]. I think it has the most usefulness from what I've seen as a training tool.

Additionally, Participant 2 described VR as a way to build confidence before observing in an environment with data that was meant to be used in real design work.

> I think again it's not going to be exactly the same as being there in person, but I don't think it necessarily has to match every single feature in order to be effective. So I think it was very helpful to be able to get that sense of trying to pay attention to different things, practicing a note taking method, seeing how that works without necessarily risking losing important observations because you're now in the clinical setting um. And so I think it was a good way of helping me practice and build a little bit more confidence. (Participant 2)

At the same time, participants consistently described VR-based training as a valuable complement to real-world experience, which they also found engaging. Participant 4 summarized this as follows:

> I think [that VR is] a really neat and helpful tool that has a lot of advantages, especially for observers who are just starting out and while I wouldn't say that it is the only training you'll ever need, that it should be combined with in person experience, I still think that it has a lot of merit and helps in a lot of ways.
>
> There are some ways in which I nerd out about VR tech that makes that portion interesting to me, but I think that [...] in many ways, I find in person observation to be fun and cool.

4.3.1 Unique training benefit of VR

Three of the four participants reported that VR training had the distinct advantage of encouraging them to observe elements of an environment longer and in more detail than they were able to do during in-person practice or other classroom-based practice. After completing her in-person clinical observations, Participant 2 described how the distractions present in real-world observations prevented her from developing this skill in the same way in the clinic:

> I was really trying to push myself to observe more of what's going on in the periphery, because I think that's really important especially. In our clinical observation contacts, because the truth is we aren't really there to focus on what the doctor is saying about the patient's condition that doesn't really translate to our needs. We want to focus on things like how is the room setup, how was the patient sitting, how is the doctor sitting, and so I liked that aspect of VR is it was much more on you to decide what your focus was going to be.

Participant 3 also described VR as motivating her to learn to observe more broadly and thoroughly than either practicing with a 2D video or real-world observation:

> I think [VR design observation training still] added value, because it was during the time that I was [conducting in-person] observation - it was very much a reminder of: make sure you're looking at everything [...], paying attention to all the senses and what's happening. So it's a good reminder to stay focused and I think [...] it reminded me of some stuff I should be looking for in person.

4.3.2 Learning curve and limitations related to the prototype VR tool

Participants discussed various limitations specific to the prototype VR tool used in this study, along with issues related to a learning curve as participants adjusted to a relatively unfamiliar VR system and the general challenges of using a VR headset, which was not necessarily comfortable or easily adjusted. All participants reported challenges related to both hardware and unfamiliarity with the system, as described by Participant 2:

> I did spend a little bit of time just adjusting to the VR itself and [...] being a little bit distracted by how cool it was.

> It was sort of hard for me to keep the VR properly on my head, I tried adjusting it and maybe I just didn't adjust it enough, but I felt like it kept sort of sliding down my nose.

In addition, all four participants described the audio quality as limiting. Participant 3 reported expecting to be able to understand the speech of people in the recording and include dialogue in her data collection, but she was unable to distinguish among the different conversations while wearing the VR headset:

> The audio makes it a bit difficult to really understand the conversations that were taking place [...] I remember trying to turn it up.

Similarly, participants struggled with note-taking due to limited visibility of their notebooks while wearing the VR headset:

> I think [the VR setup] made my note taking slower [...]. When I'm taking notes in the hospital, I can kind of start writing down some stuff and then it's kind of easier for me to see things in the periphery continuing to happen or to look up more. I felt like I had to take my gaze away from what I was observing more in VR to write down notes - it’s not a ton but the feeling was there. (Participant 4)

All four participants also discussed wanting to explore the farmers market from more than the single vantage point available in the VR footage, as they would have if they were at the market in person. Participant 2 described this as both a limitation, and (in hindsight) as a potential benefit in preparing for observation in a restricted, clinical setting:

> Initially, I felt like one drawback of the VR was that we were confined to only standing in one place, but then in the clinic I realized, even though I can technically move around, I don't have quite that same ability as maybe I was thinking originally when I was thinking [about] walking through a farmers market. … We usually only get one vantage point in the room [in the clinic].

5. Discussion

5.1 Advantages, limitations, and effectiveness of VR-based design observation training

Compared to 1) the design observation practice provided to participants with a 2D video in a classroom setting, and 2) the real-world design observation practiced by participants in clinical settings, participants described the prototype VR-based observation practice as adding value to both training formats, while also having limitations. Overall, VR observation practice was described as helping to build confidence and encourage broad, thorough observations in ways that were not intuitive in observation practice in-person or with a 2D video. Participants also reported logistical advantages to VR such as the reduced time, energy, and stress required to practice virtual design observation compared to physically going to an off-campus design observation site. These advantages are likely to be shared with other classroom-based training. Though improvements in VR-based training over practice with 2D video were often described as minimal compared to the gaps between real-world design observations and a simulated VR observation experience, participants consistently described VR as a more effective training media than a 2D video. Participants framed VR as offering more observable data than a 2D video at any given time, compelling them to prioritize their attention in ways that came closer to real-world observation as has been found in prior research [24, 30]. In addition, all participants reported enjoying the novelty and immersive nature of VR over other training formats as was also found by Akçayır & Akçayır [22]. Participants' attraction towards and engagement with VR training may hold significant educational value in and of itself [24]. That participants suggested numerous improvements and ideas for future VR training tool designs may also demonstrate their interest and engagement.

When comparing VR observation practice to real-world observation practice, participants listed numerous ways in which the VR environment lacked the nuances of real-world observation, which required awareness and consideration of one’s presence and relationships with others as a designer and observer. Participants described this difference as both a feature of VR, in that it allowed a low-stress, yet still valuable introduction to design observation without the pressure to manage the social factors present in real-world observation, as well as a limitation, in that the VR training experience did not fully prepare them for the uncertainty and complexity they encountered in a clinical environment. This comparison of real-world and VR observation experiences has not been described in previous studies, and helps to frame the unique value of VR as an observation training tool, as well as the meaningful gaps between VR and real-world experiences.

With these findings in mind, VR appears to offer evolutionary, rather than revolutionary advantages over the 2D video shown in the participants' classroom training. VR may be especially valuable as a complement to, rather than replacement for, other design observation practice approaches. The use of multiple, complementary observation practice modes may also encourage more holistic thinking about the advantages of different observation strategies in real-world observation, which is aligned with Özgen's [3] suggestion that VR may be best used when its distinct advantages and limitations are considered in a broader curriculum.

The learning curve and technical issues that limited the quality of participants' VR training experiences in this study match the findings of previous studies closely [21, 24]. Some of these issues will likely improve in the future as students and educators become more familiar with VR technologies and as available technologies are improved, while others may be inherent limitations of VR. For example, audio quality may be easily improved in future training tools with improved recording or speaker hardware, while simulating active engagement with stakeholders in a VR environment would require greater development resources and may still not be able to fully approximate an in-person experience in the near future with available technologies. As has been recommended for other immersive virtual educational tools [20, 28, 29], and taking the limitations of current VR systems into account, a VR design observation experience will likely be most effective when designed with intentionality to support specific aspects of students' design observation skills, and when other aspects of their training and/or prior experience are taken into account. It should also be noted that while design features to consider in the design of VR educational tools have been identified in this study and others, the costs and benefits associated with each deserve future exploration in specific educational contexts. It is not yet clear which types of VR tool designs are likely to be most effective, usable, easy to implement, etc. for a given educational goal [32]. This cost/benefit ratio may change over time as familiarity with VR systems increases, cost decreases, and students' perception of novelty decreases.

5.2 Study limitations and future research

Given the use of a prototype VR tool with a limited number of participants, these findings are meant to provide a starting point for the exploration of VR in design observation rather than generalizable results or definitive recommendations for the development VR-based curriculum. Future work may build on this study by evaluating various VR training tool designs, comparing VR tools to other training methods, assessing the costs and benefits of VR training versus other methods, and exploring the longevity of the novelty factor in creating student engagement with VR-based curriculum. Future research may also assess the effects of VR training on student design outcomes. In addition, this work may support the development of research characterizing the use of VR in other areas of design education, especially ethnographic design skills training.

5.3 Implications

These preliminary findings suggest a range of design features or variables that may be considered in the development of future VR-based design observation training tools, some of which have also been suggested by other researchers [4, 22]. Several considerations for future VR-based design observation training tools were noted by participants during both interviews when the technical limitations of the prototype VR tool were discussed, as well as elsewhere in the interviews. These potential design considerations are summarized below:

- **Team or individual observation:** Whether VR trainings and data synthesis are done in a team or individually
- **Synchronous or asynchronous collaboration:** Whether any collaboration on VR-based exercises is done synchronously or asynchronously
- **Interactivity of virtual environments:** Whether interaction with people or other elements of the environment is incorporated
- **Mobility within virtual environment:** Whether simulations enable continuous, discrete, or no movement of the position of the observer
- **Realism of virtual environments:** Whether real-world and/or computer generated content is used
- **Video replay:** Whether portions of a scene may be repeated or not
- **Quantity, frequency, and duration of training sessions:** How long, how often, and how many times training should be implemented, as well as time intervals between trainings
- **Variety in virtual design environments presented:** The quantity and characteristics of different design environments experienced (if multiple sessions are conducted)
- **Complementary training approaches/modes:** Whether VR design observation training procedures are used in concert with in-person practice, practice with 2D video content, lectures, and/or other formats

It is worth noting that while the narrative of advantages and limitations offered by VR-based educational tools discussed in this research are similar to those found by other researchers since the inception of VR systems, the advantages of VR may be especially relevant in preparation for design environments where comparable in-person practice is not feasible (e.g., medical settings, distant or international design environments, or other cases where stakeholders are otherwise vulnerable or sensitive to designers' presence). In these cases, the relative value of VR may be higher given the absence of opportunities for representative real-world practice, and therefore it may be more worthwhile for educators to invest in developing VR training tools.

6. Conclusion

This preliminary study found that participants reported two main advantages of practicing design observation in a VR environment over other classroom-based training modes: 1) the more immersive experience provided by VR more aptly represented a real design environment, which supported the development of skills and helped to build confidence before in-person design observations, and 2) VR was a novel and more engaging format than other classroom-based training modes, while also reducing time and effort compared to in-person design observation practice outside of the classroom. Students' interest in VR-based training may increase their engagement with design ethnography skills, as well as support learning and retention.

However, participants reported that VR-based training did not fully prepare them for the complex and social considerations present in real-world design observation. VR as a training mode was discussed as an incremental improvement over other classroom-based observation practice rather than a near approximation of a real-world experience. One exception to this finding appeared to be the ability of VR to encourage greater focus and thoroughness during observation, which was described as more difficult in less-immersive classroom training modes, as well as in more chaotic in-person environments. In summary, VR likely offers value as a complementary training tool for design observation skills and deserves additional evaluation with improved VR tools, as technology improves and students' and educators' familiarity with VR systems increases, and as a training mode for related design ethnography skills.

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