How Will VR Enter University Classrooms? Multi-stakeholders Investigation of VR in Higher Education

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ABSTRACT

VR has received increased attention as an educational tool and many argue it is destined to influence educational practices, especially with the emergence of the Metaverse. Most prior research on educational VR reports on applications or systems designed for specified educational or training objectives. However, it is also crucial to understand current practices and attitudes across disciplines, having a holistic view to extend the body of knowledge in terms of VR adoption in an authentic setting. Taking a higher-level perception of people in different roles, we conducted a qualitative analysis based on 23 interviews with major stakeholders and a series of participatory design workshops with instructors and students. We identified the stakeholders who need to be considered for using VR in higher education, and highlighted the challenges and opportunities critical for VR current and potential practices in the university classroom. Finally, we discussed the design implications based on our findings. This study contributes a detailed description of current perceptions and considerations from a multi-stakeholder perspective, providing new empirical insights for designing novel VR and HCI technologies in higher education.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**.

KEYWORDS

Virtual Reality, higher education, multi-stakeholder, educational VR, collaboration, social VR

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1 INTRODUCTION

With Virtual Reality (VR) becoming more accessible in recent years[37], the potential of VR to revolutionize education has been widely discussed in the academic community [16, 42]. There already exists a range of educational activities and training processes based on VR for higher education with various disciplines (e.g., geoscience [15], climatology [29, 68], psychology [31], art [6] and construction management [49]). Using VR as an educational tool provides new forms and methods of visualization and presentation ([86, 87]), motivates students' learning and stimulates their interest [64, 75, 87], and enhances students' learning and comprehensive by providing a learning context that is hard to replicate or accessible in real life [7]. Learning in VR also has a theoretical root in constructivism learning theory [117], which advocates constructing knowledge based on students' real experiences[99] because "VR promotes the best and probably only strategy that allows students to learn from non-symbolic first-person experience."[117]

As there are many advantages for using VR in education [87], showing great potential for educators, it is crucial to understand the benefits and challenges in integrating VR into the actual classroom as a standard and practical educational tool around the world. Many prior works in HCI have studied specific applications or systems to achieve individual learning goals or explored specific problems conducted in the lab environments [42]. However, only a few studies (e.g., [3, 13]) provided an empirical overview of the VR integration in situ. The emergence of the Metaverse [84] and the availability of more advanced VR equipment has opened new opportunities for people to understand how VR might be better integrated into the real classroom as a commonly used instructional tool. Similarly, a more holistic and up-to-date investigation of VR adoption in higher education is needed. First, as VR technology continues to improve, adding a new level of immersion and reducing the entry barriers, public acceptability and functional capacity of technology have changed [62]. Prior studies might have less connection to the ongoing state of the technology [56]. Second, it is worth noting that higher education setting is a complex ecosystem [50]. A large number of variables and stakeholders involved in and influenced the strategic planning process regarding a new technology adoption [27]. Many prior studies identified the barriers and challenges seen in classrooms or educational activities as separate entities, ignoring the potential support or conflict caused by other stakeholders in the educational community. Taking a higher level perception of people in different roles could improve current educational VR systems and produces new design opportunities in adopting new technologies in higher education for future work.

Therefore, it is necessary to understand who are the stakeholders we should consider and connect to better adopt VR in universities, and what kinds of concerns and rationale they have regarding VR's use from a holistic perspective. In this paper, we were interested in understanding the multi-stakeholders perspective of using VR in a university ecosystem beyond the courses or disciplines differences, figuring out what excites instructors and students about VR, and what barriers hindered VR's educational adoption. In particular, we paid more attention to the immersive VR (i.e., head-mounted devices (HMDs)) since it's commercial accessibility and natural immersion and imagination possibility [38]. We conducted two rounds of semi-structured interviews and participatory design workshops with multiple stakeholders from a midwest university of United States to answer the following research questions:

- **(RQ1)** Who are the stakeholders we need to consider for using VR in the classroom?
- **(RQ2)** Based on the stakeholders' perspective, what is the rationale for VR use in higher education?
- **(RQ3)** What challenges do major stakeholders face in using VR technology in educational activities?

Our study contributes to the HCI community in three unique ways. First, we provide new empirical insights from multiple stakeholders' perspectives regarding applying VR into higher education. We focus on the real context of higher education where VR learning occurs, identifying stakeholders with different responsibilities and investigating how they are currently or potentially connecting and collaborating with instructors to facilitate VR's adoption as an instructional tool. Second, we provide a synthesis of rationales and challenges faced by stakeholders, illustrating the common reason and barriers for adopting VR in higher education. Third, we contribute to a discussion of design implications and propose solutions from HCI and educational VR areas, providing insights for novel technologies to motivate future work in the field.

In the following sections, we first clarify the theoretical foundation of VR-based learning, then summarize the existing literature on virtual reality environments and VR designs for higher education. We further describe the methods and procedures of our semi-structured interview and workshops, followed by the findings clustered by research questions. Finally, we reflect on our methodology and present three design implications: 1) inequity in VR use may be a deal beaker to its adoption; 2) collaborative social experiences are key to VR's success in the class; 3) institutional support for management, deployment and content creation is critical for VR adoption.

2 RELATED WORK

Our work is informed by learning theories related to VR, educational VR environments and prior VR explorations on higher education.

2.1 Learning Theories Relevant to VR-Based Education

Understanding the educational theory foundations behind VR's implementation is an important step to create the best learning and teaching practice in higher education. As William Winn says, "the chances are that VR would be little more than another educational gimmick were it not for the fact that the theory that directs the design and use of technology-based educational systems is currently undergoing a radical revision" [117]. There are a number of learning theories related to VR [72]. Each theory provides a different lens and insight on the educational goals and outcomes, the process of knowledge motivation and transformation, the role of instructional tools and emotions, and implications for the teachers [92].

Based on *a conceptual basis for educational applications of virtual reality* [117], constructivism theory [11] provides the best basis for developing VR educational applications. In constructivism, VR allows learners to build their knowledge so they may "construct their own reality, or at least interpret it based on their perceptions of experiences" [44], even if they learn via distance education. Therefore, learning with instructional VR tools fits the constructivist learning design [99]. Social constructivism [1] takes this idea further to say that students live in a social context that guides their perspective, learning in the context of their lived experiences in society. Similarly, experiential learning theory [52, 72] adopts the constructivist's perspective to some extent, where teachers motivate students' learning from their personal experience. It newly represents learning as a four-stage cycle of experiential stages: concrete experience, reflective observation, abstract conceptualization and active experimentation [52].

More recently, social presence theory [19, 46, 110] has been offered as a theoretical foundation of educational VR. Social presence is defined as "the extent to which other beings (living or synthetic) also exist in the virtual environment" [96] and it is considered one of the key factors that influences VR learning experiences [66]. Since VR supports first-person experience and a sense of presence [42], which can increase the sense of social presence. For example, through a shared virtual environment, enhancing social presence can lead to deeper cognitive processing and better learning outcomes [71]. According to social presence theory, the amount of social cues allowed in media can increase the degree of social presence in VR.

Of course, literature has identified many other theories to analysis of VR in higher education, including motivational theory [2], connectivism [23, 100], behaviorism [97], social cognitive theory and motor learning theory [39], and embodied learning [58, 93]. These theories offer intrinsic motivation for the rationale of using VR in education. We conducted a qualitative work that can provide a basis for associated technologies, which also put the results of learning theories to practical use and which in turn furnishes other educational research with new stakeholders, data or problems for investigation.

2.2 VR Environments for Education

Virtual reality is defined in [18] as "a medium composed of interactive computer simulations … giving the feeling of being immersed in the simulation". Similarly, according to [9], VR is defined as an environment created by computers or other media in which people can feel present. Although there are many other definitions about what constitutes VR [105], most of them highlight the immersive view by replicating or simulating an environment.

Based on the level of immersion, VR falls into three major categories [7]: **Non-immersive VR** is where users can view the 3D environment on a screen or stereo glasses and interact with the environment through a keyboard, mouse or other input devices. Non-immersive VR is sometimes referred to as the desktop VR or fish tank VR and some educational applications of non-immersive VR are 3D modeling software (e.g., Blender [10]) and 3D design applications (e.g., SketchUp [101]). Next, **semi-immersive VR** is where users are surrounded by screens with projections of the virtual environment based on their viewport. A classic example of Semi-immersive VR is CAVE (Cave Automatic Virtual Environment) [67]. This type of VR is particularly suitable for collaborative educational activities [4, 21] because different people share the same experience at the same time. However, creating such a VR experience requires a large space for the screens and expensive projections. So CAVEs are often used for more professional purposes [118]. Finally, **immersive VR** uses head-mounted display (HMD) with a tracking system, controller input, and other hardware, giving users the most immersion among the three types. Nowadays many HMDs are commercially available, including the more sophisticated devices like Oculus [111, 121] and more portable and low-cost devices integrated with screens of mobile phones (e.g. classes used Google Cardboard [55, 107]). Definitions of extended reality (XR) [94] and mixed reality (MR) [105] may also come into play with VR when discussing other forms of immersive media.

Contemporary immersive VR technology typically acknowledges HMDs as the most common form of VR [105, 118]. More advanced immersive VR systems can offer synthetic and immersive stimuli to support instructional goals potentially such as spatialized sound [81, 83], gesture control [43, 76], and force or tactile feedback [8, 28, 51]. The recent release of wireless and fully stand-alone VR systems like Oculus Quest 2 and Sony PlayStation VR are not required to connect to a high-graphics computer with lower price. However, although we seemed to have more mature VR environments, using VR in higher education is still in the experimental stages [12] - prototyping and testing with students rather than applying VR in regular teaching activities. As current pedagogical application in immersive VR has not kept pace with technological developments, it is important to examine up-to-date reasons and on-site methods to use VR for learning and teaching and extract technology opportunities for future design. In this paper, we focus on the use of immersive VR in educational activities - because it provides the highest level of immersion and gives unique opportunities for educators, and contribute design directions for VR technology from the real educational contexts.

2.3 VR Explorations of Higher Education

Previous studies have reviewed VR designs for higher education [74, 85], indicating that there is interest in the use of immersive VR technologies in many different fields. A systematic review of immersive VR applications for higher education [47] noted that engineering, computer science and astronomy were the most popular application areas. Other categories like biology, geography, art, chemistry were also the higher education application domains. In some areas (e.g., fire safety, surgery, nursing, and astronomy), VR seemed to be mature enough to be used for teaching procedural knowledge, practical knowledge and declarative knowledge. In these cases, professional VR applications were appropriate for learning in higher education. However, VR maturity level remains a barrier for its adoption in regular teaching activities [12, 16, 47]. Beyond a substantial body of research that has investigated VR on specific areas of education, or reported customized systems with their impact on targeting educational or training goals, it is especially crucial to understand current practices across disciplines [47] and have a holistic view to extend the body of knowledge in terms of VR adoption in an authentic settings [35, 42].

Although most educational VR articles did not report experiences with or challenges faced from applying VR in the real university classroom, some studies provided empirical insights about adopting VR in regular educational contexts. One study [13] connecting teachers' pedagogical practices and learning theories identified three significant challenges (cost, equipment, usability, fear of technology) of using VR in educational settings. Another qualitative study [3] examined instructors of Information Technology faculty's perceptions towards VR integration through questionnaires in a University in the Middle East. Results revealed the instructors' willingness to adopt VR systems as a teaching aid and discuss the barriers to technology use. In [35], seven participants who used VR as a pedagogical tool were interviewed to understand the attitudes and perceptions of higher education instructors. Using a qualitative methodology, authors identified experiential learning as a key benefit, while financial backing, institutional support and self-efficacy were common barriers. Other research has either focused on students attitudes [70] or teachers-in-training [17]. Prior explorations facilitated VR's applied use in the classroom by identifying and understanding attitudes and experiences from instructors or students - a single stakeholder's perspective.

However, for larger organizations or complex contexts such as universities, there is usually more than one type of stakeholder who works together to guide the technology's adoption decisions. For example, one work has identified a group of stakeholders (e.g., instructors, financial staff and administrators) in higher education who will interact with each other to affect the strategies and decisions of the university [27]. Several HCI research [16, 54, 102, 108] offered insights on tensions between multi-stakeholders perspectives and motivations. Researchers and institutions were able to have a more comprehensive lens for those unnoticed factors when focusing on individual stakeholders. Particularly, to our knowledge, current practices, reasons and challenges of using VR in higher education has not yet been investigated from a multi-stakeholder perspective. Our study sees the university as an interconnected ecosystem. We first assume the instructor and student as the major stakeholders, then further identify other stakeholders related to higher education through a multi-method and finally, explore VR's opportunities and activities for education and its corresponding challenges.

3 METHODS

In order to get a more holistic view to answer the research questions, find the tensions among different stakeholders and identify values and design opportunities that exist in VR-supported education, this study applied a multi-method approach with semi-structured interviews followed by two participatory workshops with university students and instructors. We followed up with semi-structured interviews with other major stakeholders identified by participants in the workshops. In this section, we describe our recruitment, participants, procedure, and analysis techniques.

3.1 Recruitment and Participants

We recruited 18 participants (nine students and nine instructors) through a community mailing list, and five other stakeholders (two academic technology support services staff, two teaching support staff, and one IT staff) provided by university service or connected through community networks in an Upper Midwestern university of the United States. We stopped recruiting instructors and students when we reached data saturation, which means we began to keep hearing the same comments in interviews. We recruited additional stakeholders identified from an ideation workshop in two ways. First, we distributed a recruiting message through a community mailing list, from which we screened and recruited two teaching support staff. Second, we reached the administrators of related school services centers. Through communication, they helped to contact the most suitable professionals in their center. We kept recruiting until all centers confirmed that the people we had recruited could fully represent centers' responsibilities when adopting VR in the class. A total of two academic technology support service staff and one IT staff were recruited during this process.

A total of nine participating instructors (3 females, 6 males, *M = 43.56 years old, SD = 182.28*) and nine students (4 females, 5 males, *M = 25.67 years old, SD = 8*) were self-identified by their role and came from 16 different departments or colleges. Four instructors and three students had prior educational VR experience, and seven out of nine instructors and all students used VR before. We recruited two instructors (I2 and I3) who didn't use VR before in order to understand the reason they are interested in educational VR and the considerations they may have regarding VR used in higher education. After the interview, we asked each participant's willingness to join the participatory design workshops. In order to have a diverse participant pool, we finally selected eight participants (four instructors and four students) who volunteered to participate in the workshops based on their backgrounds (e.g., involving participants with different majors and knowledge of VR in the same group). In other words, we maximize the diversity of departments, VR expertise, and educational VR experience to reduce potential bias in both interview and workshop sessions. The workshop attendants are divided into two groups. Each group has two instructors and two students. Detailed information of their departments, prior VR knowledge, educational VR experience, and workshop attendance is shown in Table 1. Participants were compensated for the study by Amazon gift cards, with $30 for each instructor and $20 for the student in the interview session. $100 was compensated for instructors and $60 for students if they participated in the workshop.

As our workshops identified a number of additional stakeholders, we conducted a follow-up set of interviews with relevant campus professionals who had experience rating from several years up to multiple decades. Three of these stakeholders viewed sharing their expertise on this topic to be an element of their professional responsibilities (and thus refused compensation for their participation). Two other stakeholders were recruited from the community mailing list were compensated by a $30 amazon gift card for the interview.

3.2 Procedure

The procedure for the data collection consisted of two rounds of interviews and participatory design workshops (See Figure 1). We first conducted semi-structured interviews for instructors and students to understand their perceptions of educational VR technologies at an interdisciplinary level. Then, we conducted two separate ninety-minute workshops (Technical Possibilities Workshop and Ideation Workshop) for each group (two groups in total) that took place over two weeks. While not all participants had VR-supported educational activities, we provided headsets for every participant who joined workshops in advance to allow them to be exposed to current VR applications. We used the data collected from the interview to prepare for and guide the content of the workshop. Finally, based on other critical stakeholders identified from workshops, we had further semi-structured interviews with those persons to get more values and other invisible aspects behind the higher education classroom.

3.2.1 First Round Interview: Student and Instructor Interviews. We used first-round interviews to understand instructors' and students' needs, considerations, and challenges in educational activities to answer our research questions. We focused on three main parts: understand the role of technology currently played in classrooms, talk about participants' past experience or knowledge of using VR, and discuss the potential and future of using VR in educational activities. Specifically, we asked instructors about their strategies for facilitating technologies and educational activities (including VR if any) in the class. We also asked participants to identify any other stakeholders that should be included and why they were important. These stakeholders were discussed and ranked based on their importance during the workshop. All interviews in this study were done individually over Zoom, lasting from 30 minutes to 1 hour. After the interview, we invited each participant to join the participatory design workshop. Based on their willingness and background, we selected eight people to participate in the workshop.

3.2.2 Student and Instructor Participatory Design Workshop. A total of eight participants, who were separated into two groups (each group included two instructors and two students), attended the workshops. We conducted two workshops for each participating group for the purpose of 1) identifying stakeholders' priorities and giving insights to second-round interviews (expert staff interviews);

Table 1: Demographics of Participated Instructors and Students. We had two workshop participating groups, * and + marked participants in different group. The department has been slightly modified for university anonymity.

Participant ID	Department	Knowledge of VR	Have used VR for higher education?
I1+	Retail Merchandising	Knowledgeable	Yes
I2*	Molecular, Cellular, Developmental Biology, and Genetics	Passing Knowledge	No
I3*	Agronomy and Plant Genetics	No Knowledge	No
I4+	Food Systems	Knowledgeable	Yes
I5	Computer Science	Expert	Yes
I6	Aerospace Studies	Passing Knowledge	No
I7	Psychological Foundations of Education	Knowledgeable	Yes
I8	Chemistry	Passing Knowledge	No
I9	Chinese	Passing Knowledge	No
S1	Mechanical Engineering	Passing Knowledge	No
S2+	Scientific and Technical Communications	Knowledgeable	Yes
S3+	Mass Communication	Passing Knowledge	No
S4	Computer Science	Expert	Yes
S5*	Pharmaceutics	Passing Knowledge	No
S6	Evolution, Ecology, and Behavior	Passing Knowledge	No
S7	Psychological Foundation of Education	No Knowledge	No
S8*	Bioproducts and Biosystems Engineering	Knowledgeable	No
S9	Orthodontics	Knowledgeable	Yes

Table 2: Demographics of Participated Expert Staff

Participant ID	Job role	Knowledge of VR	Have used VR for higher education?
O1	Extension Professor in Forestry	Knowledgeable	Yes
O2	Teaching and Research Support Faculty in Engineering	Passing Knowledge	No
O3	Academia Support (Media Creation)	Passing Knowledge	-
O4	Academia Support (Accessibility)	Knowledgeable	-
O5	IT Support Staff	Expert	-

2) having a deeper discussion of the themes raised in the prior interviews based on the role (instructor or student); 3) understanding the contemporary VR technologies and characterizing future opportunities. The workshops were important for enlisting participants to get more technical possibilities of VR and further helping them as inventors, especially for those participants who lacked educational VR experiences before. The Technical Possibilities Workshop focuses on experiencing and discussing the educational VR activities, followed by an ideation workshop, which focuses on brainstorming ideas of ideal educational VR design and identifying the importance of other stakeholders.

Technical Possibilities Workshop: We led two sessions for technical possibilities workshop: pre-workshop session and workshop session. During the pre-workshop session, we shipped an Oculus Quest I headset to each participant. We asked them to get familiar with Miro [112] and try a list of VR applications that can be used for educational purposes and presented their reflection during the workshop:

- ***Engage*** [26]. Engage is an online teaching platform that allows instructors to meet students virtually in a variety of classroom environments and provides tons of 3d models for different subjects. This is the state-of-art teaching platform on the market to our knowledge.
- ***Spatial*** [104]. Spatial is a cross-platform, online multi-user meeting platform that supports real-time interaction, handwriting notes, and uploading multimedia elements such as images, videos, slides, and 3D models.
- ***Wander*** [113]. Wander provides 360-images from all over the world using the database from Google Map and supports single-user and multi-user functions. We mark Wander as one of the prototypes of a virtual field trip experience.

During the workshop session, we meet over Spatial for around 30 minutes to let participants have a hands-on experience using an online meeting platform in VR. Then participants met over Zoom and formed into an instructor group and a student group to discuss the potential VR classroom settings and activities based on their roles. Following group discussion, each group presented their boards in Miro [112]. At the end of the workshop, each participant shared the experiences of using educational VR applications.

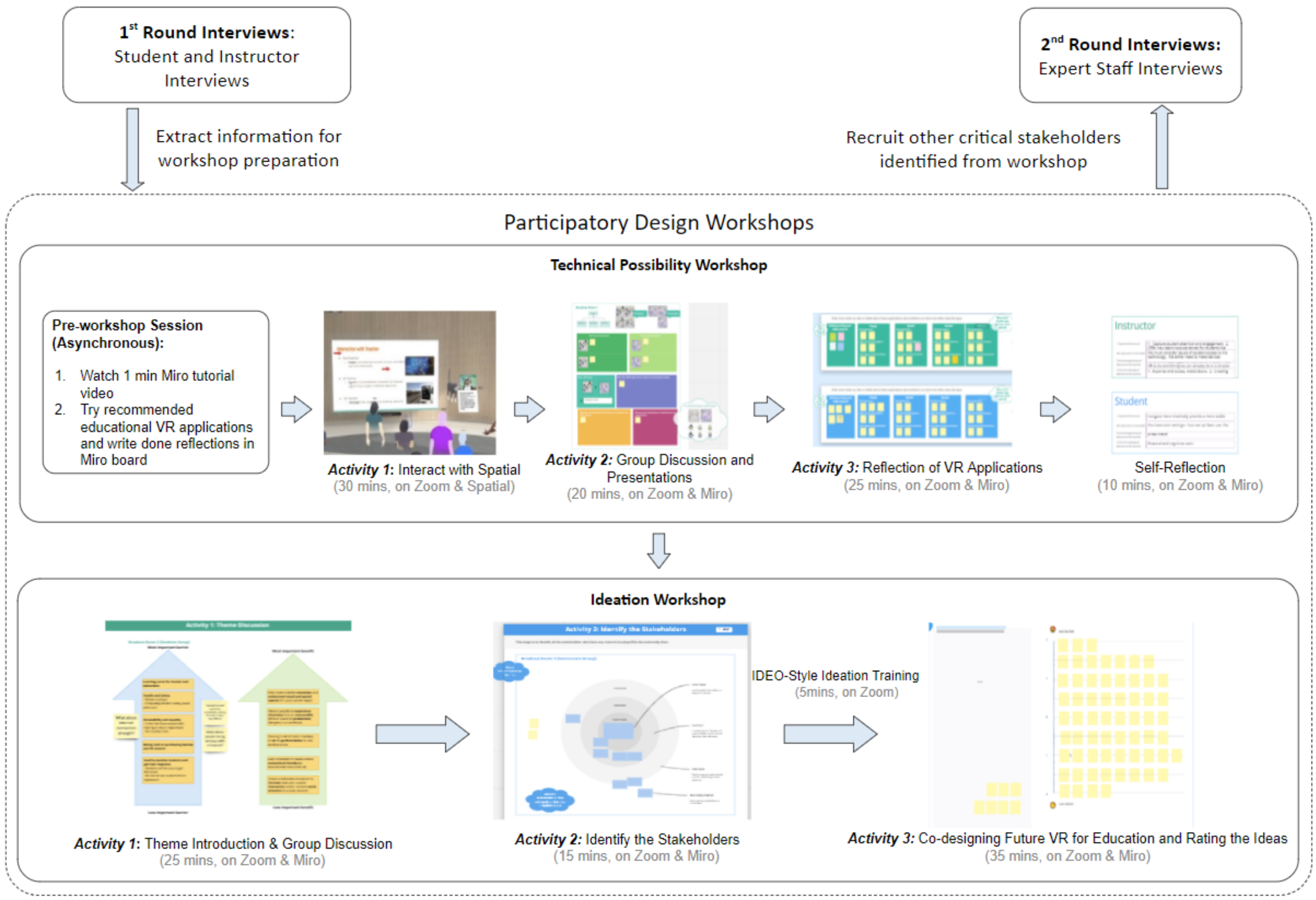

Figure 1: Overview of the study procedure

Ideation Workshop: We concluded themes (e.g., benefits and challenges of using VR in higher education) of educational VR from first-round interviews. During the ideation workshop, participants first formed small groups of instructors and students and discussed the themes which are similar to our themes mentioned in the results sections. In the next activity, each group was asked to prioritize the importance of themes and brainstorm new stakeholders if any, then classify the stakeholders into the core, involved, informed and irrelevant groups which were defined as follows in a bull's eye diagram:

- *Core group*: includes the most important stakeholders in using VR in the class.
- *Involved group*: provides input or helps to VR-supported class, but this kind of class is not their sole focus.
- *Informed group*: wants to stay up to date and will provide feedback/input when necessary.
- *Irrelevant group*: doesn't need to be considered as stakeholders.

After the group discussion, all participants had a five minutes IDEO-style ideation [77] training session held by one researcher. Then they worked together to brainstorm around 70 ideas of their ideal VR support tool for teaching or studying. The ideas varied in many different topics including hardware design, software functionality and interaction methods. In the end, participants were asked to work individually to rate each idea. A higher score meant "more expected features or ideas" (rates ranged from 0 to 4).

3.2.3 Second Round Interview: Expert Staff Interviews. We recruited and ran second-round interviews for those stakeholders identified as core or involved stakeholders. They were asked to provide general descriptions of their responsibilities in facilitating VR-supported activities. We also asked about considerations or challenges from their perspective in order to better understand the ecological relationship among those stakeholders. All interviews in this study were done individually over Zoom or phone calls, lasting from 20 minutes to 1 hour.

3.3 Qualitative Content Analysis

To analyze the qualitative data generated from the interviews and workshops (including participant notes, discussions and ideas), we converted all data into a textual format and used data-driven thematic analysis (following the grounded-theory inspired process described in [80]) to code the text and find meaningful patterns within the codes. We chose to follow an entirely data-driven process rather than combining inductive and deductive analysis due to the lack of prior multi-stakeholder work in the field and a lack of existing relevant taxonomies or frameworks available for application to this data set. The two lead authors began by reading, memoing, and generating open codes of the textual data. The first three interviews were completed together to calibrate the process and then the other data was open coded independently by each of these two authors. This process generated more than 1700[1] open codes from the first round interviews, and about 300 open codes from the second round interviews (many of these codes were overlapping as no clustering or culling is recommended at this stage of the analysis). The analysis of data from the workshops followed the similar open codes process. There are about 500 additional open codes including 126 ideas generated from this process. The two lead authors then worked together to cluster these codes from interviews and workshops into themes using constant comparison. Each code was discussed and a placement on the affinity map was proposed by one of the authors. Contentions and disagreements were resolved through discussion, bringing in a third author as necessary. As higher-level themes began emerging, the entire author team contributed to the discussion of the significance and novelty of these themes to focus our presentation on the most salient and relevant findings to the CHI research community. We present overarching themes that emerged through this process in the next section.

4 RESULTS

4.1 RQ1: Who are the Stakeholders We Need to Consider for Using VR in the Classroom?

We initially identified instructors and students as major stakeholders, as the core process of teaching is usually understood to be the actions between the teacher and students. Through our first round of interviews, it became apparent that there are more people, beyond instructors and students, that we should consider as stakeholders when integrating VR in higher education.The university can be seen as an educational ecosystem, where instructors may be collaborating with other types of experts or services to facilitate their courses. Stakeholders identified by our participants under university systems includes co-teaching instructors, TAs, teaching support staff (e.g., experts who provide training for professors or help instructors prepare the class), school or department administrators, classroom designers, IT staff, digital accessibility support staff and the research teams involved in specific classes. There were also some stakeholders beyond the campus, including VR content creators/developers, funding providers, students' parents, and industrial companies.

In each ideation workshop, an instructor group and student group separately discussed the importance of the stakeholders, dividing them into the core, involved, informed and irrelevant groups. All groups put instructors (including co-teaching instructors) into the core team. It became obvious that instructors were viewed as the most important stakeholders because they needed to make everything ready before using it. Co-teaching instructors are also important as they ***"would need to know as much as an instructor" (I, IW1[2])***. Besides these roles, students, TAs and IT support staff were the stakeholders most frequently mentioned in the core team. Students were viewed as playing crucial roles as they provided feedback and input during class. However, one student group indicated students should be placed in the involved team instead of the core team because ***"they don't have to be very advanced in the VR settings or be familiar with the headsets in the very highest level. So they can just be involved." (S, IW2)*** In addition, TAs needed to help students out with potential VR problems but ***"it all depends on course arrangement" (S, IW1)***. Moreover, ***"having IT support that is professional as part of our core team was really helpful." (I, IW2)*** One instructor group considered VR content creators/developers as part of the core team: ***"if you needed something very specific in application design, then they'd have to be part of your core team. "(I, IW1)***

Besides the stakeholders mentioned above, the involved team included digital accessibility staff (e.g., ***"they'll be in a good position to inform students what is going on and make accommodations or alternatives" (I, IW1)***) and teaching support staff (e.g., ***"they might not particularly care about the exact content, but if they're responsible for helping to facilitate the class." (S, IW1)***) All other stakeholders fell into the informed team, while two groups think students' parents cannot be the stakeholders since ***"they don't really know what students are doing in courses, even if they may provide the funding for students" (I, IW2)***. As a result, we recruited and interviewed those stakeholders identified as core and involved stakeholders from the university system. Because two of our prior participants already talked about the considerations from a TA's perspective, we didn't recruit for this role in the second-round interviews.

In this second round of interviews, professional experts reclaimed their responsibility as the stakeholders when VR was used in the classroom. We summarized their background and responsibility as follows:

- ***Teaching support staff O1*** is an extension professor, who provides VR and 3D model training and lectures for forestry instructors, woodland owners or volunteers. She is not responsible for a typical university class with undergraduate or graduate students;
- ***Teaching support staff O2*** helps maintain the engineering lab and interact with students to ensure students are working on their projects. He didn't teach class but was involved in discussions with faculty and committees and curriculum development;
- ***Content producer O3*** mainly works on instructional support for video content creation. He helps to record, edit and distribute videos, going through the instructional design process to see whether video elements are needed. Although O3 has not provided any VR content before, he can give instructors consultations of 360 video creation;
- ***Digital accessibility staff O4*** provides consultations for faculty and staff about technology tools with a lens on how to create an accessible and inclusive learning environment;

[1]We generated 919 codes from students and 836 codes from instructors.

[2]Ideation workshop for the first group

- ***IT support staff O5*** is working with the IT Service Desk as a tech specialist, helping to distribute and manage the VR headsets for the Computer Science Department.

4.2 RQ2: Based on the stakeholders' perspective, what is the rationale for VR use in higher education?

4.2.1 Increasing Social Presence. Three students(S1, S3, S4) and two instructors (I2, I8) mentioned the importance of social presence as a key benefit for VR, especially in remote learning, as it allows a more natural social environment more similar to that of an in-person class. Compared with traditional online classes, VR provides a more believable simulation of a real social experience and has the potential to increase natural interactions. Two other students (S5, S6) mentioned VR can be used to stimulate students' group work by giving the experience of being in the classroom. Using VR can also support instructor-student interactions and help instructors get feedback from their students in the online class, ***"it will be really helpful if you can meet in VR, as instructors can know whether we are paying attention and engaging in the class."(S3)***

VR's authentic social environments can also serve various instructional goals. Instructors described various situations in which VR can support knowledge and skills acquisition by creating a certain social environment, including teaching skills (S7), language skills (I7), leadership skills (I6), communication and presentation skills (I3, I5), and for ethics learning (e.g., sexual harassment) (I6).

Participants were excited about using virtual avatars to improve the social presence. Virtual avatars made it easy to get social cues, from facial expressions to body language (S4), without worrying about privacy leaking like showing surroundings in the background on video (I4). 11 ideas were raised in the ideation workshop related to social VR besides the idea of supporting realistic avatars and social interactions mentioned in the interviews, which also included protecting privacy and having social agents as learning partners.

4.2.2 Accessing Otherwise Inaccessible Learning Contexts . Learning contexts can be accessed using VR no matter the geographic location, the distance, or the time. Three participants and five instructors expressed their interest in VR's ability to help students experience different parts of the world (e.g. virtual trips) that cannot be replicated using traditional tools such as Zoom or equipment that needs to be accessed physically. When describing learning in a VR lab, students mentioned that they didn't have to ***"access the lab equipment with social distance during the pandemic" (S5)*** or ***"watching over someone's shoulder in crowds" (S8, IW2).*** One instructor described the potential benefits of taking a VR trip to learn about Indian food production in agronomy class: ***"we can use VR to see how people in India are growing crops there and students can understand the complexity and the realities that other growers or farmers throughout the world are facing."*** In addition, VR field trips can happen at any moment in time. For example, one expert mentioned VR can be helpful when having a winter field trip because ***"flowers and leafs and plants, they're not like literally are not going to see for months because the world is dormant." (O1)***

In addition, VR provides a safe replacement for dangerous or unethical activities in the real world. For example, S5 mentioned the chemical experiments which are too dangerous to actually conduct in classes, ***"if we have VR, we don't have to experience the potential danger, but we do have experience about how we process this experiment".(S5)*** The realistic environment that VR can provide can also reduce potential ethical issues in certain situations. For example, S7, worried that she may make mistakes when teaching children. ***"It will be more dangerous if we harm children socially and psychologically, but VR can give me a safe place to practice without causing harm."(S7)*** I6 also mentioned that VR can be used to simulate a stressful situation for his students to practice leadership skills.

A total of 14 ideas raised in the ideation workshops were coded to support functionalities regarding learning in inaccessible or problematic situations (the ratings shown in Table 3). Several functionalities aimed to support students to access the different learning contexts inaccessible in real life; for example, having virtual field trips in VR just like the cartoon "Magic School Bus". Thus, many disciplines and activities can be supported by VR's ability to more easily access the learning contexts which are problematic or inaccessible.

4.2.3 Understanding and Remembering Visual and Spatial Knowledge. Compared with other traditional teaching-supporting technology (e.g. text, image, or video), VR can help learners better understand and remember visual and spatial aspects by providing an immersive and interactive 3D environment. Seven out of nine students and five out of nine instructors in the interviews described one of the benefits of using VR in classes as the ability to visualize concepts in scalable 3D models, which brings more vividness and awareness of the spatial aspect compared to plain 2D materials. For example, one teacher stated, ***"it is cool if it puts you inside of a cell and you can see all the organelles..., it can help you get a better sense of dynamic and complex situations that are hard to distill down into an individual image or a textbook."(I2)*** Particularly, the ability to rescale scenes in VR is beneficial for students' learning. For example, ***"teeth are so small, VR is able to blow teeth up and look at them on a large scale".(S9)***

15 ideas raised in the ideation Workshops were identified to support functionalities that talked about using VR to support spatial demonstrations or interactions to better understand or remember the knowledge (Table 3). Participants also highlighted the importance of interacting with spatial objects; for example, viewing complex molecular processes in 3D and being able to fast-forward/rewind a 3D animation.

4.2.4 Supporting Embodied Learning . Embodied learning theory advocates an education method that not only offers an intellectual way of teaching but also involves the whole body [58], including vision, touch, proprioception, interoception, motor control, and vestibular sensations [69]. Our participants described that embodied learning can be promoted through the unique sensory integration possibility of VR to allow higher motoric engagement: ***"learning experiences take advantage of the body-centric learning because you have the ability to simulate multiple senses. . . . like transforming yourself into a molecule that feels forces and***

Table 3: Prevalence (i.e. number of ideas) and popularity (i.e. ratings shown in boxplots) of participant ideations organized by themes. Data were collected from the ideation workshop where each group conducts a IDEO style ideation and rated each idea of their most expected features of educational VR. For the ratings, we first calculated the mean of each idea from the same group, and then extracted statistical features for each idea clusters according to themes (a few ideas are counted more than once if the idea can fit into different themes).

Theme Addressed	# of Ideas	Ratings (Range from 0 to 4)	Example Ideas from Data
Increasing Social Presence	11	2.4 2.8 3.1	Very wide avatar creation possibilities to support self-exploration and role playing.
Accessing Otherwise Inaccessible Learning Contexts	14	1.4 2.2 2.7	VR simulate different states of mind, like drunk goggles.
Understanding and Remembering Visual and Spatial Knowledge	15	1.1 2.2 2.9	View complex molecular processes in 3D and be able to fast-forward/rewind a 3D animation.
Supporting Embodied Learning	14	2.0 2.6 3.5	Getting rid of the controller and use hands to control.
Attracting Students through Novelty	4	1.8 2.3 2.6	Using a unique setting to spur creativity, like a space station for aerospace concepting.
Course Design Investment	22	1.2 2.8 3.7	AI hear what you say and transcribe it for note-taking.
Financial Consideration	4	1.8 3.1 3.8	Cheaper headsets.
Healthy Concerns	24	1.5 2.6 3.4	Have a function to massage your eyes.
Learning Curve	9	0.8 2.9 3.3	Unified across-apps controller layout, so don't need to learn every app separately.
Technology Management	12	1.8 2.4 3.1	Synchronized Updates. Maybe a constant wireless connection to your computer.

sees forces, which can draw upon embodied cognition and a multi-channel way to learn."(I5)

Moreover, by replacing the real-world training process with a believable simulated virtual environment, VR can help students ***"have hands-on experience"(S5)*** and ***"is able to be a visual and tactile learner over verbal and written."(I8)*** However, although most of the participants expressed positive expectations about virtual embodied learning experiences, instructors were worried about the capacity of embodiment simulation in the current VR system. For example, ***"holding the Oculus quest handset controllers is not the same as holding lab equipment,... actions like chopping a plant will have a different feeling. You'll get a sense for like, what steps are involved but it won't be normally the same as really doing it."(I2, Technical Possibility Workshop)*** Similarly, another participant I8 was concerned that using simulated training settings in VR may lead to losing the ability to handle the accident, emphasizing that ***"these accident need to be experienced by students and trainees before going into a professional chemist setting."(I8)*** Therefore, the final learning performance relies on the degree of the embodiment.

14 ideas related to having embodied features in the VR (Table 3), including multi-sensory functionalities (e.g., touch, taste, smell) and better hardware design to support more embodied interactions. For example, one idea talked about upgrading the controller: ***"Develop the sticker that can be attached on hands rather than using the two handles"***.

4.2.5 Attracting Students through Novelty. Intrigued by its novelty, most participants (five out of nine students and all instructors) mentioned that VR can engage students and stimulate their interest, promoting interest-driven learning. This is an especially important benefit of VR because it can ***"increase motivation to learn.".(I7)*** S4 used a theory in the advertisement field to explain the positive effect of VR as a novel technology: ***"people will notice the novel part of a subject when you are playing an advertisement. (S3)"*** Similarly, two instructors (I7 and I8) also mentioned that VR can ***"rein students' attention because the new experience is much more engaging".(I7)*** Another potential benefit reported by four students (S3, S4, S7, S9) and two instructors (I4 and I9) were that utilizing novel technology like VR may increase students' enrollment because instructors ***"try to create the engagement"(I4)***.

During the ideation workshops, instructors and students echoed this result and described the engagement as ***"a prime reason for using VR in class"(I4)***. Only four ideas were explicitly designed for attracting students' interest and attention (e.g., improve the immersion through noise canceling), that is because this theme is mainly based on its novelty nature.

4.3 RQ3: What Challenges do Major Stakeholders Face in Using VR Technology in Educational Activities?

4.3.1 Course Design Investment. Instructors face trade-offs between the possible benefits of VR and the substantial course design investment required to integrate VR into a course. As I9 said, ***"it can take me a lot of time and effort to really build that (VR-supported) class".(I9)*** However, it might be not worth it if the current routine or other technologies had been able to achieve the instructional goals, while VR adds extra workloads for students: ***"We already got a lot of stuff going on (in the class)..., if you're going to replace something or if it's going to somehow be crammed into the vast amount of materials, that's maybe put unnecessary pressure on students."(I2)***

Since commercial VR is more often used for entertainment, one big challenge for instructors is that current VR systems only have limited educational functionalities and resources. Although there exist lots of systems supporting educational activities, those techniques are not widely available for the public or are hard to meet the needs to support various classes or activities. For example, three students (S1, S2, S3) mentioned reviewing in VR would be challenging, because ***"going back to notes or videos are easy, but if you want to go back and find a thing in VR, the operation would be more difficult and complex."(S2)*** In another example, I7 talked about his prior experience of using VR in an in-person class: ***"Students were just working individually in their headsets and it was really hard to facilitate collaboration that promotes meaningful learning."(I7)*** So current technological VR options for supporting higher education do not sufficiently capture all instructional activities and teaching needs.

Creating VR resources is also challenging. Participants described methods for creating learning content. The most common method is working with tech experts. For example, a student S5 talked about a VR class aimed to teach prosthodontics in dental school. In this class, the instructor worked with a collaborative development team to create the VR application. For instructors who didn't have such developing resources or technical background, they might directly find some open resources online (e.g., 360-degree videos, images, or VR applications) or get help from university technical experts like O1 to get related training or technical support. However, the latter option also has its own problem. Basically, technical experts don't provide customized application development and mainly focus on multimedia creation, or consultation, which has ***"limitation of the level of creativity."(O1)*** Thus, there exists a gap for creating the VR learning content easily, especially for those non-technical background instructors.

There is no one-size-fits-all VR setting, which brings another challenge: instructors need to carefully consider the appropriate VR-facilitated situations to maximize VR's power. Taking pedagogical types in Engage as an example, instructors can interact with students in real-time directly or use pre-recorded 3D videos, or simply leave instructional cues (e.g., text, image, audio) to achieve teaching goals. The three different settings were extensively discussed during the technical possibilities workshop and participants showed great interest in all settings. Real-time interaction is preferred by most participants as it's more interactive and flexible, but it also requires instructors to ***"make the class in a very good mood"(I1, TW1[3])*** and act perfectly. The pre-recorded videos were described as ***"(3D videos in Engage is) definitely better than just watching somebody talk on a YouTube video."(S8, TW2)*** but were still less preferred than the real-time interaction. The instructional cues allow instructors to bring outside information to students, but students may ***"stop paying attention and just absorb what they feel like to absorb".(S2, TW1)*** Therefore, instructors need further investigations and research to figure out the best practice for their classes.

In the ideation workshop, a total of 22 ideas fall into this theme. 12 ideas out of 24 talked about the potential of VR to support general educational activities like taking notes, doing evaluations, collaborating with others. For example, ***"having shared viewing experience with people who use the 2D screen, to help conversations."*** 10 ideas were functionalities that allowed instructors to create VR content or modify an existing system to match the course. One of the high score ideas is ***"to incorporate the camera into a VR headset to generate video and capture images of the user within the environment"***.

4.3.2 Financial Consideration. The consideration of financial cost is inevitable when applying new technologies into classes. Even though VR has become more commercially available and less pricey compared to years ago, students and instructors still raised concerns about purchasing those devices. Six out of nine students expressed their worries similar to ***"if VR were to land on the students, tuition would be going up".(S1)*** In general, instructors were pressed for getting enough budgets for purchasing large amounts of devices: ***"the department might sponsor one or two sets of equipment for us but not a lot."(I9)*** In the ideation workshop, instructors also highlighted the importance of overcoming the cost challenge: ***"if we can't overcome the cost hurdle, nothing else matters".(I2)***

Besides headsets investment, participants also identified VR content, applications and other peripheries may be costly. For example, instructors may need to purchase extra equipment to create VR content such as the 360 video cameras. However, some participants had a positive attitude to this challenge, because VR has a great potential to create an economical-friendly lab as a supplement to the real lab, allowing ***"practicing over and over again without utilizing any expensive physical materials"".(S9)***

[3]Technical possibilities workshop for the first group

Participants also came up with other solutions during the theme discussion. Examples included creating low-cost hardware or using phone-based VR and applying suitable class settings to avoid the large cost in headsets(e.g. share the device in the group). A total of 4 ideas aimed to reduce the hardware cost, mostly focusing on using some lower-cost methods such as Google Cardboard and more widely available devices such as mobile phones for VR to reduce the cost.

4.3.3 Health Concerns. Health issues are one of the most important challenges and it's relatable to all disciplines. Motion sickness or cybersickness, eye strain and headache were the most frequently mentioned health concerns in the interviews. Four students and three instructors have experienced motion sickness or cybersickness from using VR. Even though some participants did not have such issues, they still raised concerns as other students may suffer from this issue. In addition, most participants (7S, 2I) mentioned that current VR headsets are too heavy and not comfortable to wear. Current VR headsets, especially the more sophisticated ones with better display and rendering capacity, are too heavy to wear for a long time. After the Spatial activity in the workshop, two students (S5, S8) reported eye strain and headaches after a long time in VR.

Besides that, instructors need to pay more attention to the students who are disabled (e.g. low vision, motor disability or physical disability, cognitive disability, etc) because ***"they're not your standard students that can just throw on the headset and use it like any able-bodied person...I think of even for me, I'm trying to like jam glasses into my headset while I'm wearing it, which is never great."(S2)*** Thus, in order to create a more inclusive class, O4, accessibility support staff, gave the following strategies. First, for students who have motion or light sensitivity (e.g., seizures, vertigo), VR tools used in the class should ***"make sure their screen is not refreshing too fast and make the person wearing the headset not move too fast, because the virtual reality could trigger something unexpected for a client."(O4)*** Then, while VR headset is a physical piece rendered images digitally, both the accessibility of physical and digital control should be considered. Third, instructors could claim the technology usage clearly in the course syllabus, ***"in case someone doesn't have the means to pay for it. They might not register for the course."(I3)***

During the ideation process, 24 ideas were generated to address the health concerns for VR, including lighter and more customized headsets, and better motion sickness or cybersickness treatment. There are 9 ideas related to promoting accessible capacity of VR, including the compatibility with other devices or 2D platforms, descriptive audio, scalable text, and higher resolution to support low-visual students.

4.3.4 Learning Curve. Applying a novel technology in class means both students and instructors need to get familiar with it before it can actually start to promote meaningful learning. The steep learning curve of VR mainly comes from the completely different interactive pattern compared with other tools like mobile phones. During the interview, S3 talked about her initial struggle with VR: ***"You're in a different world and everything is 3D, and how to click buttons, ...it's a really difficult experience when I first started."(S3).*** Compared with students, instructors may get more pressure. Some instructors were not tech-savvy but were pressured to be familiar with new technologies used in the class: ***"I expect my instructor to explain clearly about how to use the devices".(S7)*** Yet, while all students and four instructors mentioned the learning curve when discussing concerns for using VR, most of them had positive attitudes towards the learning curve and believed that the learning curve would be acceptable by providing a simple tutorial.

A total of 9 ideas aimed to reduce the difficulties of using VR, including having a more user-friendly interface, providing tutorials, and making it easier to get technical help in VR. Participants highlighted the idea of making the interaction paradigm unified across different applications to reduce the learning effort.

4.3.5 Technology Management. Technology management involves but is not limited to storage, maintenance, distribution, and in-class management. One instructor indicated that managing and sustaining the headset would be challenging because ***"it becomes administratively burdensome""*** and that they hope to get help from ***"somebody who could sustain it facilitated".(I6)*** O5 provided the headsets management strategy for the computer science department stating, ***"we have an inventory system for 20 at the low end and like 40 or 60 on the high end. We keep track of it, and maintain the checkouts and, you know, clean the equipment, make sure it gets ready for the next person to use."***

Facilitating any technical and safety issues that may happen during classes is challenging for instructors. Most participants mentioned their concerns about meeting technical issues during classes that may affect the course progress. To address this, instructors tried to ***"overcome that technical hurdle, while still not losing students' attention"(S2)*** and ***"have a backup plan".(S7)*** Another example shows the logistical concerns about using VR in a large class: ***"I have not yet brought VR into like the undergraduate course, which now has about 120 students each semester. I'm a little scared to do that because making that work for 120 students each semester, each with their own individual headset, is kind of a logistical challenge."(I5)*** Besides that, VR itself is also a more demanding technology in terms of space, power, network, screen projection, or computational performance. I7 mentioned another management challenge when he applied VR in his science class as ***"I made sure that everything was charging. If I didn't keep putting them back on the chargers each time, they would die by the end of the day.""(I7)*** Thus, instructors need to spend extra effort on classroom management for VR to work more smoothly and effectively. Furthermore, complete immersion in the virtual world blocks people's perception of their real surroundings, which may cause safety problems such as falling to the ground (S4), striking objects (S2, S6) or hitting neighbors in the classroom (S5). Therefore, extra protection and caution are needed when managing the real class. For most of the technical management issues mentioned above, participants expected to have IT support staff to help them overcome those problems. IT support staff O5 responded to this expectation, were willing to offering technical support during the lab session or out-class consultation. O5 also noted that in current practice, computer science or engineering professors tended to create their "class-only" tutorials for students to use VR, but other professors, especially those who are not specialized in technical areas, could potentially take advantages of these training resources if they can be shared and accessed in a public platform.

From the ideation workshop, participants raised 12 ideas related to better managing the headset, updates, and remotely-controlled devices, including ideas that involve constant wireless connection to desktops to facilitate management over devices, and designing safe zones. One of the highly rated ideas suggests having inter-headset location communication to avoid hitting one another.

5 DISCUSSION

Our findings illustrated the current and potential practice of adopting VR in higher education. In this section, we reflect on our methodology and provide three design implications for designing better VR technologies in the future.

5.1 Methodological Reflections

In this study, we utilized a multi-method approach consisting of interrelated interviews and participatory design workshops to identify stakeholders, rationale and challenges faced in educational VR. In this way, we were able to gather information from previous sections and then guided and facilitated the following sessions. For instance, from our first-round interviews, we found that some of our participants had no educational VR experience even though they used VR before and it was hard for them to brainstorm novel technologies in this context. Therefore, we conducted a technical possibility workshop to concertize the potential of VR, providing social VR experiences in Spatial. After trying several educational VR applications, they could keep their favorite features in mind and reflect on the ideation process allowing nuanced interpretations of certain concepts. Then, in the ideation stage, they came up with a series of meaningful designs in our context, weeding out nonsensical ideas that had nothing to do with educational VR. Otherwise, if we only conducted the study without the technical possibility workshop, it would have been difficult for us to obtain a good focus and deeper reflection.

In addition, we also identified some methodological challenges with conducting online participatory design workshops (especially using VR as a meeting platform) because of the COVID-19 pandemic. For most of the workshop activities, we used online meetings and collaborative platforms, e.g., Zoom and Miro. However, when it came to a hybrid setting (using Zoom and Spatial) in the technical possibility workshop, the transition and management between the tools became challenging. For example, at the first technical possibility workshop, platform transition was time-consuming because both researchers were facilitating the Spatial room and didn't pay enough attention to the messages participants sent in Zoom. We had a better practice in the next workshop with one researcher facilitating the Spatial room and the other researcher staying in the original Zoom room to make sure everyone could enter the Spatial. Therefore, if a hybrid-platform or novel application is used in an online workshop, researchers should pay more attention to the management, both in hardware (e.g., remind every participant to get their headset fully powered before the workshop) and software (e.g., let participants know clearly about every step in the transitional process and prepare a backup plan).

5.2 Implications for Design of Educational VR

5.2.1 *Inequity in VR Use May Be a Deal Breaker to Its Adoption.*

Our study identified several challenges of using VR in higher education. The optimistic predictions about introducing immersive VR into the classroom are based on the fact that the hardware is now much better and cheaper. Our findings demonstrate that no matter how excited people are about using immersive VR in the classroom now, in most situations instructors can only include this as a small optional experience because of fundamental barriers to equity. Unlike other challenges of VR, equity becomes a major obstacle that prevents adoption. For example, if one student experienced a severe sickness, most instructors in our study would choose to no longer use VR.

Several factors have been identified to influence the inclusive experience in the virtual environment. For example, earlier studies have shown that an advantage of men over women with regards to cybersickness [63, 98, 106] and sense of presence [30, 82] in virtual reality. A prior systematic review [42] also indicated that bring-your-own-device(BYOD) philosophy and personal traits for head-mounted VR would influence the learning experiences, and therefore raise questions of equity. Our study emphasized equity issues and identified that they came from multiple aspects. As illustrated in our results section, participants noted that financial, health, and learning curve concerns all lead to accessibility and equity challenges. Students who are disabled or identified as "tech uncomfortable", or have severe motion sickness or cybersickness, or cannot afford the potential cost of VR, may cause equity concerns for the class. More importantly, when these issues are not randomly distributed in the population (such as gender and age [34]), the situation will become more serious. Take gender differences as an example, we can imagine how using VR will hurt gender equity, especially in those already male-dominated fields such as computer science [57, 103].

In light of this, future VR educational technologies should pay more attention to inclusive design for equity and see it as the crucial step when designing it for use in real classrooms. Technology should not only consider the diversity of demographic characteristics, such as gender, personal ability, financial condition, age and ethnicity, but also to make sure that the educational context is designed to avoid or mitigate physical discomfort. In order to achieve this, educational VR technology needs to be guided by open standards and specifications that could be compatible with a range of more accessible equipment and provide multiple paths for use during the class. For example, considering the sense of immersion [79, 88] and incidence of cybersickness [120] varies in different displays and input methods [91], it is helpful to have a framework that will allow bridging 3D and 2D dimensions platforms [60] or an automatic porting tool for scaffolding the development process. Although there is no agreement on the cause of cybersickness, one study [106] noted that gender differences in cybersickness might be related to whether the VR display can be fit to the interpupillary distance (IPD). So redesigning VR displays to have a wider IPD adjustable range may mitigate the cybersickness experienced by females. Another potential approach to minimizing physical discomfort in a virtual environment is using appropriate system design, e.g. user's role type [73], perspective[109] and narrative way [115] all related to the incidence of cybersickness.

Moreover, technology should determine whether it needs to make changes for those learners who are blind or have low vision, deaf or hard of hearing, and students who with physical disability, cognitive disabilities or other general accessibility issues, considering the needs of the disabled community. For example, the game accessibility guidelines recommend that including features like key remapping, text size, colorblindness, and subtitle presentation as the quick ideas to start with [24]. In the context of educational VR, systems could consider similar strategies as the first step to support inclusive experiences. Technology could further integrate multi-sensory cues beyond visual (e.g. [22, 45]) and advocates embodied learning (e.g. [119]) to accommodate a wide range of abilities.

5.2.2 Collaborative Social Experiences are Key to VR's Success in the Classroom. Our work points out the importance of collaborative social experiences that VR can achieve in students' learning processes. In our results, most participants identified the ability to create a realistic social environment that supports collaboration as one key benefit of VR. Theoretical foundations like social presence theory [65] and computer-mediated collaborative learning [114] supports that the sense of presence and collaborative environment can lead to a positive learning outcome. Accordingly, previous VR studies and practice also provide evidence of values from collaborative, multi-participant, immersive social experiences in education [40, 54, 59, 61, 89]. Compared with some other benefits of VR, such as the engagement and interest that are brought by its novelty and would eventually fade away, the social presence is a long-lasting benefit because it is derived from the nature of virtual reality. This also aligns closely with social constructivism [1] and social presence theory [33] mentioned in the first section of related work.

In order to have a spontaneous collaborative social environment in VR, users should be able to interact with people or VR content naturally using gestures, speech, haptic touch or other forms of interaction. There are multiple ideas on how to improve social presence raised from our workshop, such as creating more realistic avatars and better mimicking the real classroom. Although some VR applications already support creating avatars based on users' photos (e.g. Spatial [104]), those avatars are not authentic enough to create enough sense of social presence and one participant commented on the avatars as "good but a little scary". This can be explained by the uncanny effect: when the avatar imperfectly resembles the real human, it increases the fear of the observers [78]. Thus, future work should focus on understanding the social impact of avatars and be cautious about the fidelity of avatars (one example is [90]). Mimicking the real classroom environment was also highlighted during the workshops, especially for online classes where it's harder for students' to get social interaction with classmates. In person classes, on the other hand, may have different requirements of social presence when creating the virtual classroom for it [48], since the students are already within the same location physically and can have social interaction without VR. For example, learners sitting in the back positions of the virtual classroom may be difficult to extract information during the lecture [32]. Allowing students to have both private and public discussions is another noteworthy design raised in the workshop. Having private-channel discussions between students means they can concentrate more on their topics, while making the discussion public, same as the real world, may help students get inspiration from other groups. Therefore, when studying and designing the virtual environment to mimic classrooms, researchers should pay attention to the use case and consider providing different mechanisms that support various learning scenarios, from online to in-person class and small discussion group to classroom-size education (one example [95] supports various training settings in liver anatomy education).

Finally, our findings showed that collaboration among students is also an important part of a class. Unlike students who may get more learning benefits from the immersive, first-person perspective social presence, instructors hold different responsibilities and could potentially gain advantages from the omniscient perspective or the third person perspective even through external display, to help them have a better overview of the class [25]. Of course, this does not mean that instructors should not have the first-person perspective: instructors may also benefit from a shared first-person view when performing collaborations with students [109]. There are also revealing opportunities for technologies to explore different perspectives and collaboration scaffolding for instructors to achieve the collaborative purpose (e.g., assistance, discussion, sketching, presentation, object manipulation) and optimize collaborative social experience in VR class. As one exploration in this area, CollaboVR [36] investigated three custom layouts (integrate, mirrored, and projective) to fit different purposes of creative collaboration, such as whiteboarding, demonstration, and lectures with a presentation.

5.2.3 Institutional Support for Management, Deployment, and Content Creation is Critical for VR Adoption. Although in current practices, teaching might be siloed into different disciplinary schools or departments (or even courses). We found that different stakeholders at a higher education institution have the power to accelerate the integration of VR technology into traditional classrooms and influence financial decision making which can define an institution's long-term future. Our results echoed the recommendation from prior work [3, 27]: administrative support should be considered as an essential way to reduce faculty members' load while implementing new educational strategies.

Most notably, our result indicated the significance and usefulness of involving other stakeholders from the university community for VR adoption. Institutional support can promote sustainability and maximize efficiency in many aspects in the long term, including but not limited to management, deployment and content creation. Several instructors in our study expressed their need for management support, technical consultation and training resources. However, that causes the emergent need of funding for virtual application development or customization and additional time allocation for related staff during the management and deployment [20]. Considering this, technology that helps administrative staff collect specific needs and feedback from instructors could be helpful (e.g. crowdsourcing or online communities [53]). Also, designing technology platforms for tracking and managing headsets, human resources or other contextual resources are also helpful for scaffolding this process. For in-class management, VR tools should be provided by intuition to ease the stress of technology management by offering straightforward ways such as forming teams, releasing notice, sharing resources or doing other common educational activities. Although models based on existing VR conference platform like Spatial [104] and Mozilla Hubs [14] supports basic requirement for class collaboration, they still need to be customized based on the course design.

Institutional support can also help instructors to transit their courses from ordinary classes to VR medium classrooms (also suggested in [3]). Besides connecting professional technicians, university provides a community network for instructors and faculty to communicate and share their pedagogical insights and VR resources to enhance their educational strategies. It is worth remarking as well that involved other stakeholders like accessibility centers helps instructors shape more inclusive teaching content. Similarly, previous literature highlighted that professional VR creators benefit from having collaborative creation with people interdisciplinary [41, 54]. Future technology should make it easier for core stakeholders to connect with others to build a more sustainable collaborative network. In addition, to better work with professional developers, institutions should create learning opportunities for instructors (or even students [116]) without any technical background. [5] discussed three potential technology directions to solve the AR/VR authoring-related issue for a broader creation community: supporting early-to-middle-stage AR/VR prototyping, personalizing AR/VR authoring tools based on expertise and integrating access to learning resources within implementation workflows. In the educational context, similar strategies can be used to support instructors as VR application creator, by providing VR prototype or template tools, customizing tools based on their specialty and incorporating learning materials or features where users can find institutional support quickly.

5.3 Limitations and Future Work

The recruiting and screening process of our interview and workshop may have attracted students and instructors that were more interested in using VR or novel technologies, leading to a potentially biased participant group towards VR. It's hard for us to evaluate from the perspectives of students or instructors who have to passively accept VR in the class or have a negative attitude towards using VR in classes. We tried to maintain diversity by recruiting participants from different colleges or departments, but all participants were recruited from the same large public Midwestern university. Our confidence in these findings may be increased with future replication and triangulation studies in other contexts. Future research should seek to expand the participants to a more diverse group and seek further investigation into specific areas and disciplines that are not covered in our study. As a qualitative study, we also experience perspective bias from both the participants and researchers. Future research should run other qualitative work on a different set of participants to understand how our results are representative of the broader population.

Although we discussed different types of VR in the workshop, our main focus is immersive VR, and this may limit participants' experience and discussion since most of our participants did not have experience with other VR formats such as the Cave VR. Future research should include more diverse VR formats and explore the potential of other types of VR in higher education, as well as their corresponding challenges and concerns for different stakeholders and different educational activities. In addition, in order to get more focused and deeper insights, we only invited eight participants to the workshop. The ratings of the idea cluster's popularity only can be suggestive because of the small sample size. The replication study and a larger sample can enhance the confidence of these findings. Besides these limitations, we believe that our study still provides a key complement for the current study from an empirical view.

6 CONCLUSION

Introducing VR as an educational tool into the classroom is based on the trade-off between its benefits and barriers. It should be more cautious when adopting VR into a real classroom. In this paper, we viewed the university as a connecting body of relationships among various stakeholders, carried out a qualitative investigation that combined two rounds of interviews and a participatory design workshop to identify the stakeholders, rationales and challenges of using VR in higher education. This paper is an essential supplement to the construction of accessible and effective VR classrooms under the university system. Compared with previous studies done in the educational VR areas, we provide new empirical insights in its real usage context no matter the course, classroom settings and disciplines from a multi-stakeholder perspective. We further contribute implications for designing better VR technologies in higher education and method reflections for other HCI researchers in this context.

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