A Case Study on Student Experiences of Social VR in a Remote STEM Classroom

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ABSTRACT

Extended reality (XR) technologies continue gaining traction in multiple higher education contexts. As XR becomes more commercially accessible to students and universities, its convenience for educational purposes presents a renewed potential for exploration. Due to Covid-19 restrictions, there is also a growing interest in cross-platform, socially orientated software for remote educational practices. However, the precise role of XR technologies and how they contribute to student experiences of remote learning, particularly the unique affordances of social virtual reality (VR) for evoking an embodied sense of presence, is relatively unknown. Based on real-world experiences, we present a case study on a social VR intervention in a remote higher education classroom to inspire Human-Computer Interaction (HCI) researchers to investigate further the issues that arise from our practice-based research. Our motivations were to report, analyze, and summarize everyday virtual learning environment (VLE) challenges, identify design considerations for VLE technologies, and comment on social VR's utility in delivering Science, Technology, Engineering, and Mathematics (STEM) subjects in a remote setting. We apply a practical approach to investigate and identify potential HCI problems, capture the unique experiences of STEM students during the lockdown, and explore the effects of tutorial activities that give students agency in constructing VLEs. The findings of this student-focused case study draw attention to the design of social VR activities that support conventional, web browser-based VLEs.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**; *User studies*; Empirical studies in collaborative and social computing.

KEYWORDS

Higher Education, Social VR, Virtual Learning Environments

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1 INTRODUCTION

What will higher education (HE) look like in the future? This broad and open question challenges scholars across multiple disciplines to re-imagine and apply creative thinking to future digital classroom experiences. Because of their ability to transition users between the physical and digital worlds, extended reality (XR) technologies have attracted much attention for supplementing the modern classroom experience. XR refers to a group of evolving digital platforms, such as augmented and virtual reality (AR/VR), that can render spatially accurate 3D models and virtual simulations across both physically real and digital worlds. In this way, XR mediates the merging of the physical and digital somewhere along a *"virtuality continuum,"* reaching from real to virtual, commonly referred to as mixed reality (MR) [24]. XR in educational practices has also received an increase in attention since the recent resurgence and general commercial availability of these technologies for public use [12]. XR can also enhance the quality of communication among geographically dispersed teams, positively influencing knowledge transfer and efficiency of industrial processes[5].

The current XR market is expanding, with AR and VR's total value predicted to reach $60 billion in 2020 [3, 33]. Moreover, despite the manufacturing challenges faced during the pandemic, the VR market continued to grow. With an increase in spending during Covid-19 to just over US$1.8bn, VR generated US$615mn in revenue in 2020 and is expected to grow to US$1.4bn by 2025 [34]. With the continued investment and prevalence of this technology in cultural heritage [29, 31, 44], using XR can substantially change and challenge how students and teachers perceive the physical boundaries of the classroom and potentially provide new approaches to the creation of innovative learning material that can give immersion and presence a more dominant role in the delivery of educational content. As a result, emergent XR platforms will transform notions of immersion in the classroom and facilitate remote presence.

XR technologies have already entered the educational and cultural heritage mainstream [6, 16, 30, 31], and their evaluation has become prominent in human-computer interaction (HCI) research [3, 15]. However, establishing them within an educational context will require more practical and empirical assessments executed *"in the wild"* to develop best practices and design guidelines for integrating them seamlessly into existing curricula. Here, the phrase *"in the wild"* refers to specific methodological approaches to HCI investigations and accounts for user experience phenomena that contextually differ from those derived from lab-based techniques [36]. Furthermore, many of these technologies are steeped in a deep history of technological revolutions that have primarily been explored in controlled laboratory settings. Therefore, new approaches to immersive learning now require traditional HCI research and situated case studies which involves context-specific analyses in multiple learning environments.

Remote learning during the Covid-19 pandemic has drastically changed the HE landscape for teachers and students. This impact was particularly felt for technology-focused academic disciplines, as access to laboratory equipment was severely limited. Furthermore, additional pressure was placed upon lecturers to provide extensive online materials via conventional web-browser-based virtual learning environments (VLEs) that would have previously been presented in the physical university, with the VLE acting in a more supplementary role. Traditional VLEs of this type, such as learning management systems (LMS), have been present in HE since the late 90s and offer many features, including managing courses, users, & roles; synchronous & asynchronous learning; online assessments & customized testing; learning analytics & student progress reports; and student & teacher forums.

2 BACKGROUND

There are many challenging opportunities and potential benefits of harnessing XR technologies in the STEM classroom, and recommendations and implications for future applications have been explored and presented [41, 43, 45]. With the Covid-19 pandemic extending well into 2021/22, learning institutions of all sizes are seriously considering incorporating XR experiences in the classroom [19]. By implementing XR social systems, questioning how students feel about using them, and the design considerations that can be learned from direct classroom observations, we can gain insight and new direction into how self-guided exploration and collegial collaboration can benefit the HE classroom of the future [25]. In this way, social VR platforms allow users to share virtual spaces and digital media content.

Multimodality [35], the feelings of presence [28], immersion [8], and empathy [42] offer clear advantages for users of this technology in remote learning contexts. Moreover, via 2D screens or other real-time video-based telepresence systems, social VR platforms can enable users to experience the virtual self as the actual self [2]. Therefore, adapting educational content for remote learning and conceiving new ways of delivering STEM materials in innovative learning contexts that incorporate embodied experiences may provide considerable growth potential.

From a technological perspective, social VR applications have been around as long as VR systems; for example, see the *"reality built for two"* designed and built by VPL in the late 1980s [4]. The popularity of this technology has been in a state of flux ever since [17]. However, with the rapid growth of consumer VR equipment in the 2010s [12], there are many social VR platforms that present users with various design choices around avatar customization, interactive environments, and collaborative social event planning and attendance tools [16, 23, 40]. Using virtual avatars, the immersive nature of social VR systems creates a shared collaborative environment that is distinctly different from video, text, and audio-based communications alone. Thus, avatars incorporating physical body-tracked avatar responses to user input can mimic physical body language, with rules and styles inherited from real-world social situations [39]. These physically expressive capabilities result in more natural and effective communication [32].

While there is a core set of standard functionalities across social VR applications, several distinctions exist. Many have cross-platform capabilities, so non-VR users can connect from a laptop or mobile device during multi-user collaboration sessions. Experiments with these different platforms have identified shared and platform-specific usability problems and highlighted design-specific issues and new challenges for telepresent human-computer interaction in social VR [21]. Previous research has also shown that students respond positively to small group interactions in social VR [14]. Furthermore, small group interactions via social VR do not interfere with learning outcomes, are inappropriate for more significant (+25 students) meetings, and can be no more time-consuming to set up than video conferencing [11].

The presented case study explored the effects of using a cross-platform social VR application called AltspaceVR (ASVR) in a remote HE classroom scenario. For this purpose, an MSc module of a large university was utilized to explore the application of course content inspired by the concept of *"Virtual Field Trips"* [3, 43]. As such, via remote lectures, structured remote tutorial sessions, and ASVR, we empowered students with the necessary knowledge and skills to conduct experimental practices for co-constructive world-building. The main guiding question for this practical exercise was: *What are students' perceptions of using social VR as a teaching intervention during lectures in remote learning HE context?* Henceforth, in executing this practical case study we explore the following practice-based HCI issues associated with remote teaching and learning in HE:

- **Problem 1:** The perceived usability and the hedonic and pragmatic student experiences of traditional VLEs and social VR platforms will present with varying impacts.
- **Problem 2:** Learning tasks and remote classroom encounters with these platforms will invariably embellish the experiences of HE from the student's perspective.
- **Problem 3:** The combined effects of Issue 1 and Issue 2 will impact student perspectives on the future design and use of social VR and VLEs in HE.

3 METHODOLOGY

During the second term (*"Hilary"*) of the academic year, our students began foundational work for their dissertation and immersed themselves in further specialist modules of their chosen strand. The AR module was devised to equip students from multiple disciplines with a solid foundation in emergent XR technologies, and the students also learned how to develop interactive applications for both PC and mobile devices. Due to the Covid-19 lockdown, the entire semester was delivered online using Blackboard (see Figure 2) and the social VR platform *"AltspaceVR"* (see Figure 3). The case study methodology was structured to focus specifically on technology-in-use; therefore, the pedagogical approach and methods for student interaction were that of a formal online lecture. The lecturer delivered an organized, pre-constructed academic presentation. Following this, an interactive class was given outlining the 3D content workflow (Figure 1). This lecture type works well for teaching large groups of students and has been popularized more recently in massive open online courses (MOOCs).

By tightening the scope of our work on applied social VR systems in HE, moving out of the laboratory to more ecologically valid

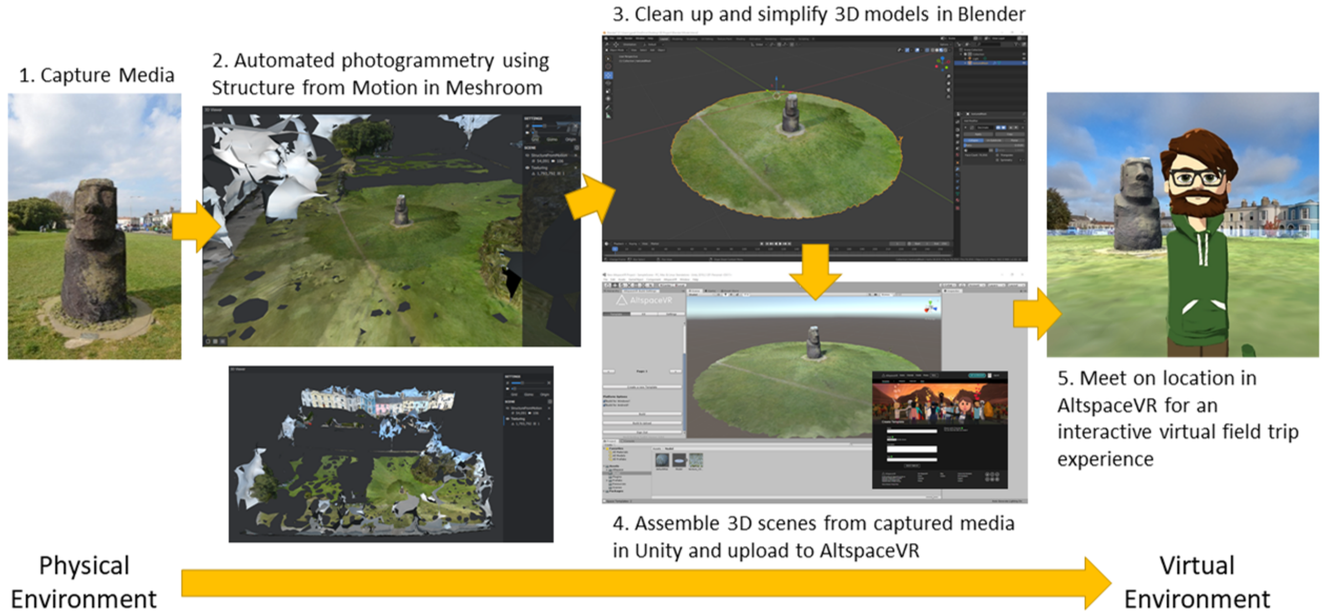

Figure 1: The ASVR 3D content creation workflow [10]

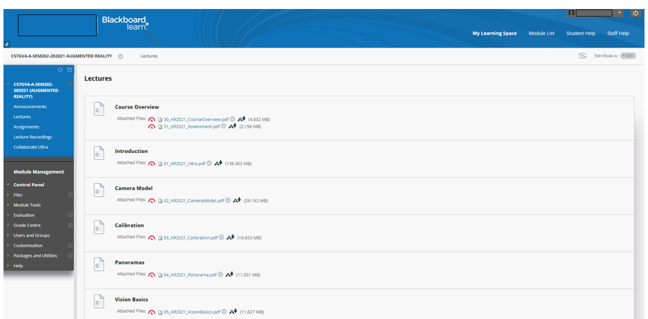

Figure 2: Blackboard Learn.

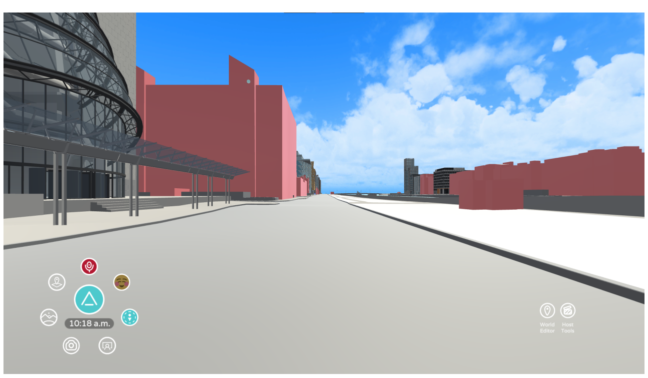

Figure 3: AltspaceVR.

"in the wild" situations, a methodology is presented to study a HE class using both traditional VLEs and social VR for extended periods when completing remote tutorials. The following case study follows a mixed-method research design to establish student perceptions of a social VR classroom intervention. Thus, students were engaged in several remotely delivered lectures and practical tutorials that focused on applying visual computing theories. The tutorials followed a five-step content creation methodology specifically designed for *"AltspaceVR."* Dawkins and Young have previously validated this co-creative 3D content creation approach, wherein research was undertaken to establish an open-access process and study small user-group interactions when creating content for ASVR [9, 10].

At the end of the semester, the students were asked to complete an anonymous online questionnaire. The questionnaire first captured student demographic data, followed by the self-reported ability to use digital technology, current knowledge of VLE systems, and their practical expertise using these platforms for remote learning on fully labeled 6-point Likert scales [26]. Next, the questionnaire was divided into two sections, student experiences of traditional VLEs (Blackboard Learn, Microsoft Teams, etc.) and social VR (AltspaceVR, etc.). For each section, a Usability Metric for User Experience questionnaire (UMUX-Lite) was used to measure the general usability of the VLE system on fully labeled 7-point Likert scales [13, 20]. The UMUX-Lite was expanded with a simple *"Why?"* statement to unpack subjective sentiments toward platform usability. Next, a User Experience Questionnaire (UEQ) was used to record the students' experience of each system on 26-item seven-stage scales [18, 38]. Finally, the students were allowed to report their final impressions of these VLEs freely. Three open-ended questions operationalized this last section as follows: What previous knowledge or experiences have you had with VLEs in the remote learning classroom?; "What benefits or problems do you see arising from the use of VLEs in the remote learning classroom, generally?"; "What do you think you would need from future VLE technologies in the remote learning classroom?".

A total of 46 students were invited to voluntarily provide anonymous feedback on the technologies used in the remote classroom via the online questionnaire, of which 24 responded ($RR = 52.17\%$) with an average time to complete of 12 : 56 minutes ($SD = 06:42$). For comparative studies of this type, where statically significant findings are being sought, a group size of $8-25$ participants is typically valid, with $10-12$ participants being a sensible baseline range [22]. The average cohort age was 24.42 ($SD = 4.78$), with a gender balance of 14 male and 10 female respondents. The average self-evaluated ability to use digital technology was *"Very Good"* ($M = 5.21$; $SD = 0.87$). The participants described themselves as being *"Familiar"* ($M = 4.83$; $SD = 0.99$) with VLE systems with *"Slightly Above Average"* ($M = 4.5$; $SD = 0.87$) practical expertise in using VLEs in a HE context.

4 RESULTS

4.1 Usability

First, students described their usability experiences of traditional VLEs and social VR in the remote learning HE classroom, see Table 1. As such, the cohort reported traditional VLEs having a mean usability score of 60.42 ($SD = 20.59$). The UMUX-Lite result was then converted to a raw System Usability Score (SUS) to help benchmark the collected data ($M = 62.17$; $SD = 13.38$). The percentile rank for the raw SUS score was calculated as 35% for traditional VLEs, or *"below average,"* where a percentile below 50% is, by definition, below average [37]. On the other hand, the UMUX-Lite for social VR was believed to be equally usable as the traditional VLEs ($M = 60.17$; $SD = 17.72$), with no meaningful differences in perceived usability. When converting this score to SUS ($M = 62.17$; $SD = 11.52$) and calculating the percentile rank for the raw SUS score (35%), it was seen that social VR was also considered *"below average"* for remote learning practices. Although the median score on the UMUX-Lite scale decreased from Traditional VLEs ($Md = 66.67$) to social VR ($Md = 58.33$), both platforms could be considered below average for use in the remote HE classroom. A Wilcoxon Signed Rank Test revealed no statistically significant impact between these interventions on the students' perceived usability scores, $z = -0.627$, $p = 0.53$, with a small effect size ($r = 0.13$).

The students identified several shortcomings when asked *"why?"* they scored each VLE this way. Some students expressed that they preferred in-person teaching, but with the circumstances of the pandemic lockdown, they understood the current reliance on VLEs; for example, it was reported that: "I prefer in-person teaching, but given the circumstances, it was a fun and informative module." Traditional VLEs were considered *"accessible and intuitive"* to use to some extent, as video stream and chat functionalities all served their purpose and allowed for suitable communication in and out of the virtual classroom. These materials were considered more convenient than the physical creation of classroom materials via note-taking and handouts, for example, *"Quite accessible and intuitive to use. More convenient than physical delivery of paperwork."*

Table 1: Usability Measures

	Traditional VLE		Social VR	
Scale	**Mean**	**SD**	**Mean**	**SD**
UMUX-Lite	60.42	20.59	60.17	17.72
Raw SUS	62.17	13.38	62.17	8.43
SUS Rank (%)	35		35	

However, some students experienced occasional connectivity issues, and when compared to working in the physical lab, they felt it was hard to get instant feedback from their peers. Furthermore, *"no reality attached to the learning experience"* was supposed, and students lost concentration more quickly due to long back-to-back classes with little opportunity to move. Additionally, it was suggested that traditional VLEs hid some of their functionality, such as tutorials and class materials, etc., behind counterintuitive multi-level menus that were often frustrating to use. Although the video conferencing software used within the VLE was thought to be much easier to use, some students identified that they had had prior experience using different platforms of this type. For example:

> "Blackboard hides functionality, such as recordings, behind unintuitive menus and generally is annoying to use. Microsoft's Teams is much easier, but I also had prior experience using it."

Exploring the usability of social VR, the students identified that although traditional VLEs were not the *"favorite"* software for online teaching, they were still somewhat adequate for use in the remote classroom. On a technical note, although students felt that social VR was, to some extent, intuitive to use, it was also considered less accessible due to intensive GPU hardware usage and *"lack of detail"* in some 3D environments. Furthermore, the user interface was not designed for computer scientists or developers, and the entry-level was thought of as being lower in terms of content difficulty as *"less technical content [was] covered"* and *"The user interface of AltspaceVR is not friendly for a developer"*

Joining the specified learning events was considered a less than seamless experience; however, the advantages of social VR were in the interactions with *"real"* people and the environment. Although the initial steps were somewhat complicated, the platform was effortless and impressive in practical activities and the setup and loading of different scenes. In this case, there seemed to be extra complications for some of the students trying the software for the first time, but others could use the controls more effectively. The students also felt directly involved in the class, and they could use the interfaces intuitively, for example:

> "Initial few steps were hard, the setup and the scene loading. Apart from that, I felt everything was smooth and amazing to use. Kept me involved in the class"

Many of these factors were explained due to previous experiences with 3D games. Overall, most students reported that social VR was *"entertaining," "instructive,"* and *"pioneering"* to use in the classroom, for example, *"It was fun and learning at the same time is innovative."*

4.2 Student Experiences

The UEQ captured the attractiveness and hedonic (stimulation and novelty) and pragmatic (efficiency, perspicuity, and dependability) experiences of traditional VLEs and social VR (see Table 2 and Figure 4). Thus, the hedonic qualities define non-task-related quality items, and the pragmatic quality scales describe the task-related quality.

A Wilcoxon Signed Rank Test evaluated traditional and social VR VLE interventions on the students' experiential scores. For these tests, we chose 0.05 for the significance level. The tests revealed no significant differences between VLE systems on pragmatic scales,

Table 2: User Experience Measures

	Traditional VLE				Social VR				
Scale	**Mean**	**SD**	**Conf**	α^*	**Mean**	**SD**	**Conf**	α^*	**Sig.****
Attractiveness	0.32	1.30	0.52	0.93	1.17	1.22	0.49	0.96	0.02
Perspicuity	0.56	1.12	0.45	0.77	1.01	1.02	0.41	0.87	0.05
Efficiency	0.76	1.17	0.47	0.77	0.72	1.14	0.45	0.78	0.59
Dependability	0.58	1.28	0.51	0.82	0.64	1.26	0.51	0.87	0.43
Stimulation	0.11	1.38	0.55	0.85	1.16	1.41	0.56	0.96	0.01
Novelty	-0.29	1.19	0.48	0.76	1.25	1.04	0.42	0.80	0.00

Notes: $*$ An Alpha-Coefficient of 0.7 was considered sufficiently consistent [7].
$**$ Wilcoxon Signed Ranks Test.

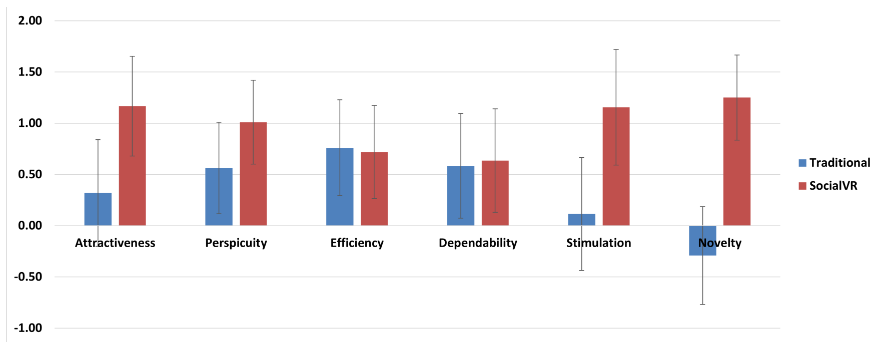

Figure 4: Mean UEQ results for traditional vs. social VR.

Table 3: What are students' perceptions of social VR as a teaching intervention during lectures in remote learning HE contexts?

	Knowledge & Experience	**Current Problems**	**Future Requirements**
Themes	• Minimal pre-Covid experiences	• Not human-to-human	• Engaging and friendly
	• Limited to HE experiences	• Lonely & demotivating	• Streamlined environments
	• Multiple courses in one place	• Internet connectivity & hardware	• Enhanced user experiences
	• Course administration	• Lack of creativity & immersion	• Accessibile by design
	• Too many features to list	• Absence of student networking	• Multimodal
	• Face-to-face was preferred	• Slow to get feedback	• Multiplatform
Example Answers	*"Not much, just for supportive material or submitting work."*	*"I like not being in a physical space, but it can be alienating."*	*"More interaction, to keep the students engaged."*
	"I've used Blackboard before, and had a negative experience."	*"As with all online learning, it relies on stable connection."*	*"Tackling problems and conversing about solutions in the same room."*
	"The main issues came down to consistency between modules."	*"I feel less involved in the course or answerable to a higher authority."*	*"More fluid experiences for practical lab work."*
	"Due to remote learning, Blackboard is more widely used."	*"Demotivated to engage, getting up and walking away."*	*"Simulators that can help you to connect with mobile phone."*

with $p < 0.05$ for efficiency, perspicuity, and dependability. However, the test revealed significant differences between VLE systems for attractiveness and hedonic qualities (stimulation and novelty). The attractiveness of the VLEs measured $z = -2.26$, $p = 0.02$, with a medium effect size ($r = 0.46$). The median score on the Attractiveness Scale decreased from social VR ($Md = 1$) to traditional VLE ($Md = 0.58$). Similarly, when considering stimulation, the traditional VLE ($Md = 0.13$) was again scored significantly lower than social VR ($Md = 0.13$), $z = -2.68$, $p = 0.01$, with a medium effect size ($r = 0.55$). Finally, the novelty of the traditional VLE ($Md = -0.25$) scored significantly much lower than social VR ($Md = 1.13$), $z = -3.9$, $p < 0.01$, with a large effect size ($r = 0.8$).

The analyses of the open-ended questionnaire answers took a thematic approach guided by the frequency and fundamentality of the issues raised by the students [1, 27]. This approach frequently emphasized occurring problems and deemed fundamental importance to the students, see Table 3.

4.2.1 Previous Knowledge & Experience: Many students expressed prior knowledge or experiences in HE, with minimal hands-on experience with VLEs reported before the Covid-19 lockdown. Where students had used VLEs before, they had used them in HE to access supporting materials or submit coursework. However, some students were somewhat more familiar and had used Skype, Zoom, or Microsoft Teams, but not as a social VR and VLE combined.

The main issues concerned consistency between modules, where some lecturers would use VLE platforms extensively, using many advanced features. Other lectures would use them minimally or not at all. This variation in use meant that module information had no consistent location or format for the students to access and use. However, due to remote learning in 2020/2021, Blackboard became much more widely used in the university for sharing information across modules and, for some students, presented as a more attractive solution for course administration. It was also stated that not everything should be done through Blackboard and face-to-face meetings were still preferable.

4.2.2 Current Problems. For remote learning specifically, the students were concerned with addressing engagement issues, such as *"complete lack of focus on the lesson," "being demotivated to engage,"* and *"getting up and walking away during [class]."* Moreover, students said they lost interest or concentration if they accidentally skipped any portion of the class materials, so contingency measures must be taken to avoid this issue. When using social VR for remote learning, similar concerns were echoed as *"I'm unsure how technology would translate to complete lessons"* and:

> "I feel that Teams, etc., are better suited to serious [learning] situations, and the virtual environments are more geared towards a bit of fun."

Students suggested that physical classrooms should be made available for social VR classes because not everyone had access to a space that was conducive to learning, for example:

> "When I had my sessions, there was a lot of street noise which would hinder the advantages of learning in AltspaceVR."

Ultimately, modern VLEs need powerful/modern hardware to run embodied systems. Furthermore, as with any online learning scenario, these platforms rely on a stable internet connection. Any delay in audiovisual feedback was considered anathema as students required instant responses to input with little or no wait. Therefore, any goal toward a completely accessible service will require some investment in infrastructure.

4.2.3 Future Requirements. When asked what students would demand from future VLEs, the cohort reported several features currently lacking or missing from existing VLEs. In a more general sense, the students commented on the constancy and *"friendliness"* of user experiences within VLEs. For example, they required accessibility features or adaptability for different types of learning within the same VLE and more intuitive interface designs. Specific feature requirements focused on student-student interactions and engaging with lecturers to keep the students grounded, involved, and connected to the learning experience. As students found it hard to stare at a computer screen for hours – *"without somewhat zoning out"* – it was also suggested that VLEs should be accessible via multiple platforms, such as seamless connectivity between location-specific and mobile devices. Multiplatform access also raised issues with ease of access to computational power and fluid transitions from academic lectures to practical laboratory-based work. In this context, instant feedback on coursework, coding, or progress reports from both professors and peers were hindered when switching chat rooms or sharing screens, expressed as such:

> "[It] isn't as attractive as tackling problems in the same room and conversing with other students or TAs about solutions."

General interactivity would also require balancing with course-specific topics, where access to course materials, bespoke software, and high-powered hardware facilitate the use of other technologies; for example, *"using a laptop without a VR headset makes the technology feel like a bit of a gimmick."* When balancing previous knowledge, user requirements, and ideas for future VLE designs, the students identified several gains and shortcomings for VLEs in remote learning contexts. Fundamentally, the benefits of remote learning require balancing with more *"human"* or experiential factors.

It was suggested that enhanced interaction and creative expression within a learner group could be facilitated and improved through avatars, creating a safe classroom environment with a more immersive feel. Socializing with peers was highlighted as deficient within a traditional remote learning context, although some students preferred remote learning to in-person, as attending on-campus required additional effort. It was also raised that remote learning was less interactive for inter-student relations, reducing networking and open discussions around new or innovative ideas. The students also emphasized that poorly designed VR environments for learning could cause cybersickness issues for some, which might cause further accessibility concerns in the future.

5 DISCUSSION

In the presented research, we have gathered self-assessments on experiences of a social VR teaching intervention in a STEM classroom and applied a mixed methods approach to data gathering. With the rapid paradigm shift in teaching and learning approaches, moving physical classroom materials to online repositories, the students acknowledged that teaching and learning had only shifted in response to the global pandemic and required further HCI developments to make it more attractive and less problematic in the future. Upon reflection, it was felt that the *"liveness"* of the online lectures and ASVR tutorials worked well, but the VLEs made demonstrating bugs or issues with code require more effort than having someone *"looking over their shoulder,"* so students were much less likely to seek help. Furthermore, students reported that it was not always clear how the various tests, questionnaires, and exams would behave when submitted on Blackboard. For example, with multiple attempt quiz submissions, starting a second attempt seemed to delete the original; although a genuine student concern, it must be noted that this did not occur during the class.

Concerning our exploration of **Problem 1**, the usability testing, the effectiveness, efficiency, and satisfaction with which students achieved their goals within each VLE, there were no significant differences between traditional and social VR systems. However, of particular interest to the HCI community, statistical differences were reported between the non-task-related quality items, each uniquely adding and detracting from usability experiences. For example, when using traditional VLEs, the students said that accessing the learning materials was relatively easy, but the experience lacked a sense of embodiment within the virtual classroom and that interaction with peers was disjointed and lagged considerably compared to the actual classroom. On the other hand, the social VR platform provided real-time embodied interactions with learning materials but required specific hardware and connectivity bandwidth, and the user interface was not considered *"developer-friendly"* for more technically minded students. These findings were also observed in the UEQ results, where the pragmatic qualities of the two systems were scored similarly.

To address our interests in **Problem 2**, the students' user experience questionnaire and qualitative responses allowed for further insight into the hedonic attributes of each approach to remote learning. In their open-ended answers, the cohort revealed several insights into the appeal of VLEs, their uniqueness in a remote learning context, and the group's motivations for using these systems. Overall, the attractiveness of the social VR platform was rated higher than traditional VLEs. Likewise, the hedonic qualities of stimulation and novelty scored much higher for social VR.

The participants expressed that they had had relatively few interactions with VLEs before the lockdown. Therefore, the novelty and stimulation they provided the students could be considered as displaying internal validity between traditional VLEs and social VR. In terms of needs and requirements, each system presented bespoke advantages and disadvantages; however, the overall experience of remote learning was highlighted as lacking in traditional VLE platforms. Therefore, a more stimulating, communicative, or social element was required from VLEs to address the lacuna between technology and remote learning experiences; suggesting further HCI studies to expand (**Problem 3**). In the future, more accessibility options are needed, where online content could be accessed from within the university infrastructure and remote locations outside. This approach would work towards more inclusive, engaging, and social experiences. However, virtual field trips must be tailored to specific learning outcomes [43] to balance with the approach to pedagogical and instructional designs of the course.

6 CONSTRAINTS AND FUTURE WORK

The presented case study points to several areas of interest for the future of HCI in HE. This future will introduce HE systems that allow institutes to reach students locally, globally, and online, where learning can occur at home and in the community. Our case study demonstrates how acquiring and applying knowledge can contribute to future instructional systems design (ISD) focusing on immersive technology. Our results represent the data-gathering element of the ADDIE model for ISD. These systems' interfaces will require further streamlining to ensure the seamless integration of new immersive worlds with both online and offline learning environments. To obtain accurate outcomes, all students must provide appropriate feedback, which is impractical in real-life situations. This unique learning paradigm must be responsive to the student's individual needs, adaptable for novice and advanced users, and have cross-platform mobility.

Before the lockdown, students expressed relatively few interactions with VLEs as the primary learning environment — this knowledge and experiential factor place all responses into a *"novelty effect"* for human-computer performance. The novelty effect presents a tendency for participants to express a more vigorous response. Over time, the novelty effect will fade, and users' reactions to some issues may decrease. Nevertheless, the cohort's reports can be extrapolated, as nearly all students have felt this shift to online learning platforms in 2020/2021. Although many changes will be required for seamless remote learning and VLEs, students also praised some aspects. These included beneficial access to recorded lectures, not relying solely on note-taking skills, and watching classes that were unavoidably missed. Other advantages pointed to time-saving benefits, easy access, and exploring different topics simultaneously.

7 CONCLUSION

XR technology is increasingly being applied in the HE classroom. These platforms can potentially alter the HE landscape by harnessing the immersive nature of this technology and the feelings of presence it can imbue upon the students and teachers that use them. In a remote learning context, these factors have been shown to directly influence the experiential quality of the virtual classroom by providing a qualitatively different approach to VLE design. In this exploratory case study, we report on the experiences of a student cohort in a remote HE STEM classroom. These results indicate that social VR can potentially address the shortcomings of existing VLE platforms and provide insight into how these systems can address future classroom scenarios. Therefore, further in-depth reflection is needed on how pedagogical approaches and methods are implemented to fully use VR technology effectively, to investigate the impact of these technologies *"in the wild"*, and how they can further facilitate ISD for remote classroom experiences.

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