Seeing Through Users' Eyes: Teaching Human-Centric Software Engineering Through Immersive VR

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Abstract—Human-centric software engineering (HCSE) approaches are increasingly gaining prominence in Software Engineering (SE) education to prepare students to understand and respond to real-world human needs, contexts, and requirements of end-users throughout the development process. Many software projects continue to encounter usability and adoption issues due to insufficient attention to human needs, and students often find it difficult to understand the aspects of HCSE through traditional teaching methods alone. Virtual Reality (VR) with its immersive, first-person point of view digital simulations, offers a way to expose learners to the lived experiences, constraints and challenges faced by diverse end-users. Despite this potential, VR remains underutilized in SE curricula, and limited research has examined how HCSE educators might integrate it in SE curriculum to support students' understanding of HCSE approaches. Our study examines how educators experience a VR simulation first-hand and how this exposure informs their thinking about integrating VR into HCSE teaching. We engaged 15 HCSE educators in a VR simulation of a scenario depicting real-world challenges faced by a person with disability, using head-mounted displays, followed by semi-structured interviews to reflect on their experience and ideate curriculum-cases. Qualitative thematic analysis identified four experiential aspects shaping their impressions: (a) emotion evocation, (b) sense of VR immersion, (c) health, comfort, and accessibility considerations, and (d) the need for VR orientation. Educators identified ten curriculum-cases such as empathy-building, AI-avatar interviews, VR-based requirements elicitation and inclusive VR prototypes, that align with key phases of HCSE processes, from understanding user needs through to ideation, evaluation, and iterative refinement. Our findings illustrate how VR exposure broadens educators' awareness of experiential learning opportunities and presents curriculum-cases where VR may strengthen students' understanding of users, contexts and design implications in HCSE.

Keywords–Virtual Reality, Educators' perspectives, Human-centric software engineering, VR Experiential Learning

1 Introduction

Across higher education, many disciplines rely on understanding the perspectives and experiences of people, different from themselves, to ensure that their work serves the needs of the end-users. For example, in health sciences, students must develop sensitivity to patients from diverse cultural and socio-economic contexts [1], education students need to adapt teaching strategies to learners with varying abilities and prior knowledge [2] and business management students benefit from understanding consumer behavior in different markets. In Software Engineering (SE) education, teaching students human-centric approaches to develop software considering the end-users' perspectives, experiences and challenges is increasingly important [3]. This ensures students' prioritize end-users' needs and challenges, and learn to create effective, inclusive human-centric software engineering (HCSE) solutions that truly meets end users' needs and expectations [3], [4]. This suggests that understanding and applying real-world user needs is critical for professional effectiveness across higher education disciplines.

Yet, many educators in higher education encounter challenges when trying to emphasize these human-centric perspectives [5]. For example, getting access to *real* users and their usage environments [6], particularly the vulnerable population groups, such as young children [7], people with disabilities or elderly people, is often very challenging [6]. Even if educators were successful in organizing user research opportunities, large class sizes [8] and a packed curriculum make it challenging to scale learning activities that involve direct end-user interaction to understand their needs and challenges. In the absence of direct interaction with end-users, methods such as academic research, surveys, mock interviews, or role-playing offer proxies. However, these are not as effective at helping students appreciate end-user perspectives, which often differ significantly from their own in age, physical, cognitive abilities, and other factors [9].

Virtual Reality (VR) in education offers potential to help educators use realistic simulations of end-users [10], through which students can gain first-hand insights into the physical, cognitive, or emotional challenges faced by people, issues that might be difficult to understand from a purely theoretical standpoint [11], [12]. These simulations can also replicate environments, such as kindergartens, shops, or retirement village settings, which are typically difficult for students to access [12]. The use of VR in disciplines such as healthcare [13], teacher training [2] and engineering [14] is gaining traction due to its potential to immerse users in real-life like situations, that can also help SE students assess the impact of design decisions [15], foster empathy [16] and design accessible technology [17]. However, its applications within HCSE education [3] and similar human-centric design disciplines [18], [19] so far remain relatively under-explored and less understood. Therefore, SE, particularly HCSE, serves as the primary disciplinary focus for this investigation.

VR research highlights the essential role of educators in effective technology integration in VR integration [20], [21] and notes that most prior work has centered on students rather than incorporating educators' perspectives in the design and use of VR learning environments [22]. Yet, several studies [23], [24] draw attention to the lack of educators' perspectives in the development, design and use of VR technology in education. There is a lack of understanding and guidance on how educators can effectively integrate VR into SE and computing curricula [20], leaving many uncertain about its role and application in enhancing student learning [22], [25]. This paper therefore addresses this gap through the following two key research questions (RQs):

- **RQ1 How do HCSE educators' describe their first-hand impressions of using a VR simulation?** We want to have a number of university educators experience a VR simulation and reflect on it to consider how such immersive experiences might support students' understanding of HCSE concepts.
- **RQ2 What areas within HCSE course curriculum do educators believe would most benefit from VR integration?** Leveraging this VR immersion, we aim to identify concrete curriculum-cases in HCSE that educators believe could benefit from VR integration.

We are using the term curriculum-case to refer to a *specific, actionable instructional scenario in which VR simulations can meaningfully support an HCSE process related teaching activity or objective, according to educators' perspectives*.

Through a qualitative examination of the educators' responses, this study: a) advances the understanding of how VR simulations are experienced by HCSE educators; and b) it presents curriculum-cases that offer new directions for SE educators looking to leverage VR-based experiential learning to teach HCSE design approaches.

2 Background and Related work

2.1 Human-Centric Approaches across Higher Education

Human-centric approaches are being widely being applied to various education disciplines such as medical education [1], engineering [14], teacher education [26]. Likewise, Software engineering is increasingly prioritizing human-centricity through practices such as early user involvement, iterative prototyping, and usability testing [6]. This is due to several reasons: it can enhance usability and user experiences of the software products [3], reduce error rates and risks and foster user engagement and well-being with the developed software and systems [4].

2.2 Challenges in Human-Centric SE Education

Incorporating human-centric focus in SE education presents several challenges. Recruiting the 'right' users, or finding real-world users who may be interested and available to engage with SE students [4] through field work interviews and site visits, is time-consuming, costly, resource-intensive and often contingent on educational institution's processes and regulations [27]. There are ethical or often legal considerations in accessing vulnerable participants, such as young children [7], people with differing mental abilities, and elderly people for educational and research purposes [6].

Even if SE educators are successful in organizing these real-world user research experiences for students despite the hurdles, there are additional time and cost challenges involved in scaling up these user research experiences for large classes with packed curriculum [8]. Methods like conducting academic research, running surveys with peers or mock interviews with tutors (or others pretending to be end-users) offer proxies, however, these are not as effective in getting the students to consider the perspectives of end users who are often quite different to the students due to age, physical and cognitive abilities and other factors [9].

2.3 Virtual Reality & its Use across Higher Education

VR has been described as a "mosaic of technologies that support the creation of synthetic, highly interactive three dimensional (3D) spatial environments that represent real or non-real situations" [10]. There exists a considerable body of literature [28], [29] that discusses VR's unique features such as immersion, interactivity and sense of presence [30] that makes the users experiencing VR feel like they are actually inside the virtual environments i.e. 'being there' and embodying the characters in the VR simulations [29].

In fields like medical education, VR enables students to learn from simulations of medical procedures and patient interactions, providing invaluable opportunities for hands-on experience with surgical training and patient interaction skills in diverse controlled environments [13]. In engineering education, VR allows students to create prototypes or conduct experiments in virtual labs without the need for expensive equipment or hazardous material [14]. In teacher education, VR, through real-world classroom simulations, allows educators to enhance their teaching skills and confidence in classroom management and student interactions by providing a safe, controlled environment where they can practice and refine their approaches without real-world consequences [2]. Similarly, through digital simulations of courtrooms and forensic scenesor geographical environments [31], VR offers safe, repeatable and scalable learning opportunities for law education [32], and environmental studies [31]. These immersive experiences enable students to learn and acquire knowledge and skills in a safe, lower-risk environments, while offering a scalable and flexible approach to education.

2.4 Virtual Reality and its Promise for HCSE Education

VR offers the potential to enable SE students to experience first-person point of view simulations of (target) end-users and physical environments that would otherwise by inaccessible to them [11], and better understand users' needs and behaviors which may be quite different to their own [17]. This is important as it has been found that most current software engineering research and practices still tend to be function without paying much attention to the human-centric issues such as accessibility, usability, emotions, personality, age, gender, and culture, leading to the misaligned software [3].

The VR approach is especially relevant as SE educators face challenges in providing students with direct interaction with end users due to budget constraints, large class sizes, ethical and oftentimes legal considerations, and resource limitations [5], [8], [27], and proxy methods such as academic research, surveys and mock interviews with peers lack the immersive, real-world context essential for understanding users' perspectives and need [6].

VR's digital simulations can provide real-world like environments that are costly, time-consuming, counterproductive, or ethically challenging [12], such as retirement villages or kindergartens. VR through its first-person point of view allows the illusion of embodiment [29], [30] that may help students empathize and better understand the experience of others, regardless of their own 'temporal, cultural, demographic or spatial context, leading to more effective software design [33].

2.5 Uses of VR in HCSE Education

The context of 3D games and worlds has garnered interest such as the use of multi-player online SE educational games in 3D virtual world Second Life were found to be useful teaching aides for teaching students, principles of software development and software specification processes [34]. Rodriguez et al. [35] tested an educational virtual world called Virtual Scrum that simulated a Scrum-based team room for a 45-student capstone project and student feedback indicated it as a viable tool for performing Scrum process activities. It is also evident that while there has been experimentation with games and 3D worlds, the use of VR in in SE education remains relatively limited. In terms of VR, educators' have trialled VR-based simulations to aid in requirements engineering, particularly for app users with ADHD [17], learning software processes [19], and simulated analysis and modelling [36]. Advances in SE education include SENEM, a novel SE-enabled metaverse for learning [37] and examination of ethical use of avatars and VR in education [38].

Despite the promising potential of immersive technologies, a recent systematic review on extended reality in higher education found limited use of VR in teaching and assessments, and highlighted the need for clearer guidelines for its effective integration in computing education [39]. Within SE, the call for VR adoption to enhance educational outcomes has been echoed by [40], yet its applications remains underexplored.

2.6 SE Educators' Perspectives on Using VR in Teaching

VR researchers have drawn attention to the crucial role of educators in the VR integration process for education [20] and the need to incorporate their perspectives for it to be utilised effectively to enhance educational outcomes [21]. A recent review on VR in computer science education found that most previous works had focused on students' perspectives and not enough attention has been given to educators' perspective in the development of VR learning environments [22]. The review recommends future research to address requirements, potential issues, and curriculum use cases from the educator's perspective in order for VR to be integrated into the curriculum and become a part of the classroom experience [20].

Additionally, another systematic review on HMD VR in higher education, highlights that not many papers described how VR-based teaching can be adopted in the teaching curriculum [41]. The need for 'guidelines for instructors that want to introduce these technologies in their classrooms' has also been identified by [25]. The importance of recognising educators' experiences with teaching in VR and recommendation for future studies to focus on this aspect for VR technology to be fully integrated in school curricula has also been made by [23]. This indicates that a significant gap exists in our understanding of educators' experiences with VR and how educators can meaningfully integrate VR into their course curriculum and practices, which motivates our RQ1 and RQ2.

3 Method

3.1 Study Procedure and Interview Questions

Following an ethics approval from our institution's ethics review board , our study recruited educators as participants and engaged them in: a) filling in a short questionnaire to collect demographic and previous VR use information, b) engaging in a VR immersion where they put on a VR HMD to experience a VR simulation of a person with disability, followed by c) a semi-structured interview session to address RQ1 and RQ2 .

The short questionnaire included questions on participants' age-range, gender, experience in higher education teaching and/or learning design of SE courses, previous experience with VR and use in teaching (results in Section 3-C).

The semi-structured interview included questions related to RQ1 and RQ2. For RQ1, we asked:

> *Could you describe your simulation experience, particularly what emotions you felt?*
> *Which aspects of the VR scenario in your view enhanced or broke the immersion of the VR simulation?*
> *Did you feel any health or comfort related issues when experiencing VR?*

For RQ2, we asked:

> *Which curriculum areas or topics would be most beneficial for VR integration?*
> *Could you describe the curriculum-case with VR?*
> *How would the curriculum-case complement your course curriculum?*

We placed no limits on the number of curriculum-cases proposed, and each 30-40 minute session was conducted individually to capture participants' personal VR experiences.

3.2 Participants Recruitment

We used a purposeful sampling approach for data collection [42] to recruit educators and learning designers with university teaching and/or curriculum design experience in SE courses with a human-centric focus (e.g., game design, user interface design, accessibility, and web design). We identified potential participants through publicly available information on university websites and professional contacts, and sent email invites and recruited 15 educators (12 teachers and 3 learning designers) who consented to participate. Interviews were scheduled progressively as expressions of interest were received. All participants were briefed on the study's purpose and procedures, and informed of their right to withdraw at any time without explanation. We assigned letter-number codes (e.g., P1, P2) to each educator and analyzed and reported their quotes in a de-identified form to preserve confidentiality.

3.3 Participant Demographics

Most of our participants (n=7) were in the age range of 25 to 34 years. Six educators were in the age range of 35-44 years and one educator each in the age range of 45-54 years and 55-64 years, respectively. Eight educators identified themselves as men, six as women and one educator as non-binary/gender diverse. Over half the participants (n=8) had more than 7 years of teaching and/or learning design experience in higher education, while 3 had 2–4 years and 4 had 1-2 years, reflecting varied levels of experience. In terms of previous experience with VR, 12 educators had some limited exposure to VR through playing games, cinema or research studies, however, they had no experience using VR in their teaching.

3.4 Study Setup, VR Equipment, VR Scenario and Context

All interviews were conducted and audio-video recorded in person in a booked room at the host university. VR equipment included an HTC Vive headset with handheld controllers, and the room also had recording equipment, and seating for participants. Before VR immersion, educators were provided the following scenario context:

> Let's consider a scenario where students will be tasked with designing a software application intended to support individuals with early-stage memory loss, particularly with the challenge of reducing their likelihood of wandering or getting lost when navigating independently in public spaces.

This task will be grounded in human-centric SE approach, focusing on understanding users' needs, challenges and the environment where the system will be used. To facilitate this, the class will first engage in a VR simulation by putting on a HMD, followed by a discussion to help students reflect on their observations, identify user challenges and how would they integrate their needs into software design process.

Our participants then experienced a 3-minute, 20-second 360° immersive VR simulation titled *A Walk Through Dementia*[1], developed by Alzheimer's Research UK. This first-person simulation portrays the experience of a person with dementia navigating physical and cognitive challenges in public space, en-route home. A publicly available YouTube-VR simulation was used for low cost, easy and open-access compared to custom-built simulations. Although centred on dementia which could come across as a non-traditional theme for computing, it was selected to offer a perspective-taking scenario for end-users whose needs differ significantly from their own. Participants could choose to experience the VR simulation either seated or standing, using head and body movements to engage with the scenario via the HMD. They were informed they could pause or stop the simulation at any time or request assistance from the researcher.

3.5 Data Analysis

We used NVivo 12.0 for thematic analysis and followed Braun and Clarke's inductive, reflexive thematic analysis approach [43], [44], adopting a latent, interpretive approach, following the steps from data familiarisation, coding, theme development and reviewing and reporting. The primary coder (first-author) began the analysis process by transcribing the audio recordings verbatim using an automatic transcription service and cross-checked them against the recordings for accuracy. Once verified, our team of three researchers read the transcripts multiple times to familiarise with the data.

The primary coder then conducted inductive and iterative coding, identifying segments of data (codes) relevant to RQ1 and RQ2, and participant quotes. Our team met regularly to review and refine the coding structure, contributing multidisciplinary perspectives, while final analytic decisions remained grounded in the primary analyst's reflexive approach.

After coding seven transcripts (nearly half of the dataset) and achieving coding stability, we conducted inter-rater reliability testing and obtained Cohen's weighted kappa as 0.748 for the first test and 0.91 for the second, indicating substantial to almost perfect agreement [45]. We only used this metric as a diagnostic aid as the coding differences sparked interpretive discussions, strengthened our reflexivity and guided the primary analyst's refinement of the latent themes. We also analysed the themes and their inter-relationships collaboratively with ongoing critical reflection to ensure analytic rigour.

For RQ1, we developed 4 latent themes: 1) emotional evocation, 2) sense of immersion, 3) health, comfort and accessibility, and 4) VR orientation, comprising 11 codes in total (see Figure 1). We interpreted how educators made meaning of the experience in relation to teaching, empathy, and curriculum design. For example, codes in Table I such as *empathy*, *willingness to help* and *curiosity* capture educators' emotional engagement with user challenges, while immersion-enhancing and immersion-breaking codes (Table II) reflect

[1]The Youtube link to the study VR experience: https://youtu.be/R-Rcbj_qR4g?si=0EtQMdtkBrSoGncu

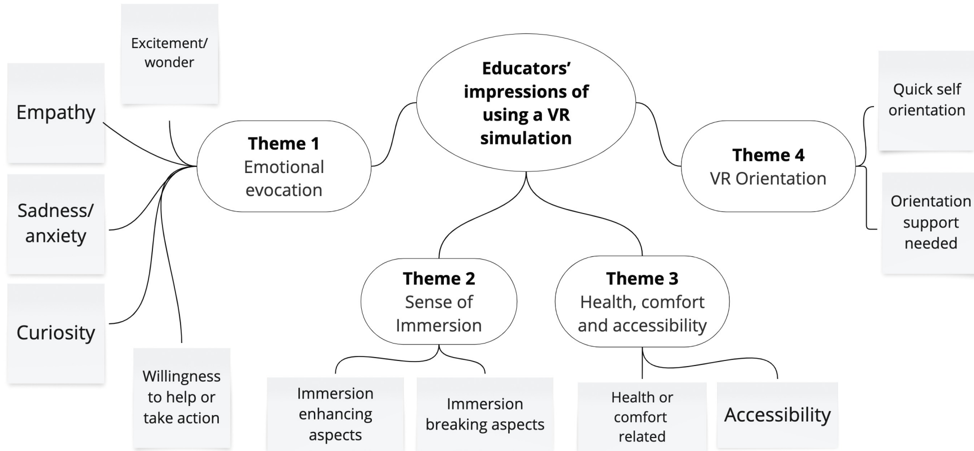

Figure 1. Educators' impressions of VR simulation: Themes & codes

how design features shape presence and connection within the simulation.

For RQ2, educators' suggested curriculum applications were grouped into conceptually similar areas, resulting in ten HCSE curriculum-cases for VR integration (Table V). The final coding schemas and anonymized participant data, including demographic information and interview transcripts, are retained by the research team in aggregate form to protect participant privacy.

3.6 Researcher Positionality

The three researchers in the team have backgrounds in human-centered computing, data science, and software engineering, which informed how we interpreted and coded the data using Braun and Clarke's reflexive thematic analysis [44]. Our extensive experience teaching HCSE courses helped understand educators perspectives however, our relative newness to VR encouraged attention to new avenues for curriculum integration. Ongoing reflexive discussions helped our team examine how our assumptions and disciplinary perspectives influenced the analysis.

4 Results

The generated themes and codes for RQ1 and RQ2 are discussed in the following section, along with example illustrative educator quotes. We refer to the entire sample of study participants as 'educators' unless divergent views were expressed, in which case we discuss teachers and learning designers as separate groups. Also, we report simple frequency counts (n) as additional descriptive indicator to enhance transparency and contextualize how many educators raised particular points. However, these do not determine theme significance, which was guided by depth, meaning, and relevance in line with reflexive thematic analysis [44].

4.1 RQ1 – Educators' first-hand impressions of VR simulation

Our thematic analysis revealed 4 main themes and 11 codes in total: Theme 1) emotion evocation (with 5 codes), Theme 2) sense of immersion (with 2 codes), Theme 3) health, comfort and accessibility (with 2 codes), and Theme 4) VR orientation (with 2 codes), as shown in Figure 1.

Theme 1 Emotional Evocation

The VR experience evoked a range of emotions such as empathy, excitement, sadness or anxiety, willingness to help and curiosity in participants. (see Table **I** for the list of codes and example illustrative quotes). The most commonly reported reaction was empathy as all educators (n=15) expressed feeling empathetic to user challenges demonstrated in the VR experience. Educators described it as *'being in the shoes of'* the VR character [P3, P11]. P15 expressed: *'I'm a mental health expert, I have the theoretical orientation...This is for the first time I have actually felt...virtual reality is kind of like giving you that connection, the feeling, the way I reacted just after this exercise, I felt the pain of a person...I think the difference is empathy, which will come from the virtual'*[P15]. Seven educators related their empathic reactions to VR's potential to help build understanding of diverse users and challenges, summarized by P7 as: *'I do think it has the potential to make visible some of the challenges that people should be thinking about*'.

The initial reactions of many educators (n=12) related to excitement and wonder related to how '*cool*' the experience was when they removed the head-mounted display. P1 said,' *It was really cool to actually get that sense of what a person with dementia would feel.*' P14 and P15 expressed excitement on their exposure to VR technology and its capabilities. P14 called it a *'cool technology*' and added,' *just being able to know what new things can be done, what these things offer...I never used VR before but I was excited.*' P15 remarked,'*It's*

TABLE I

THEME 1 (T1) EMOTIONAL EVOCATION: CODES & QUOTE(S)

T1.1 Empathy:
'I think it is quite enlightening, it's very hard to understand what people with certain disabilities may go through and lets you put your feet into their shoes' [P11]
T1.2 Excitement or wonder:
'it's my first time being in like a real environment...I haven't seen something like this so that's cool.' [P9]
T1.3 Sadness or anxiety:
'that's really sad' [P9]
'The emotion was very real...confused, panicked, anxious and I could connect to that was really good' [P15]
T1.4 Willingness to help or take action:
'you can hear them sort of panicking and breathing faster, you kind of go, oh, I want to help this person.' [P3]
'in my head, I'm already planning what kind of solution or help could be developed?' [P4]
T1.5 Curiosity:
'I was actually interested in what's going on now...what would be next? How was that? Or how they represent that?' [P4]
'I want to do another one & see what happens to old lady' [P12]

a new intervention, VR in classroom is not a very common scenario...never seems like people are using it in the class'.

Twelve educators reported feeling connected to the scenario's confusion and anxiety, which evoked sadness or anxiety in them. P12 described it as follows, *'the heartbeat was going and I actually did feel my anxiety coming up, and I would take a breath...I've got to calm myself down because I'm emotionally reacting to what's the environment around me'*. In some educators (n=3), the experience evoked the willingness to help and problem-solve, as P4 expressed: *'in my head, I'm already planning what kind of solution or help could be developed?'*. Furthermore, three educators felt curious to know more about the scenario: *'what would be next?'* [P4] and *'I want to do another one [VR scenario] and see what happens to the old lady...'* [P12].

Theme 2 Sense of Immersion

Educators (n=12) commented on the realism features such as hearing the heartbeat [P7], blurriness of vision [P11], first person point of view [P12] and realistic environment much like real-world [P13] contributing to their sense of immersion. For example, P7 commented: *'hearing the heartbeat and the anxiety style vision gives you a bit of a sense of embodying that state of mind'* and P11 said,' *their fast heart beating, it makes you feel what the other person is going through...then you know, the blurriness and all, that it makes it quite realistic*'. Comparing the immersion level in a video, P13 remarked,*'Oh, this is really, really realistic. While I was in it, there was definitely a difference when you come out of it that, and I'd say that would have been different to if I just watched it on a video, perhaps'*. Educators (n=10) also identified aspects that broke their sense of immersion such as lack of personalisation with voice and gender of the avatar [P4], cultural context of language or environment [P8, P15],

TABLE II

THEME 2 (T2) SENSE OF IMMERSION: CODES & QUOTE(S)

T2.1 Immersion-enhancing aspects:
'hearing the heartbeat and the anxiety style vision gives you a bit of a sense of embodying that state of mind.' [P7]
'I'm seeing it through her eyes...Ifelt like her & not myself.' [P9]
T2.2 Immersion-breaking aspects:
'If it was my own voice, I'd probably feel more immersed.' [P4]
'I was physically stationary while seeing motion.' [P7]
'some of the different effects of the blurriness felt a bit sudden and a bit unpredictable, that probably broke the immersion there...' [P10]

being stationary while experiencing motion [P7] and sudden changes in graphics [P10] . For example, P4 said,'*I didn't have a full immersive experience simply...because her voice wasn't male as well. It was a woman. So there was this disconnect*' and suggested,*'If it was my own voice, I would probably feel more immersed.'*. P7 commented on the motion issue,'*I was physically stationary while seeing motion*' and P10 commented on the sudden changes that broke sense of immersion,*'some of the different effects of the blurriness felt a bit sudden, and a bit unpredictable. That probably broke the immersion there a little bit as well*'. P15 talked about the importance of *'cultural adaptation of virtual reality*' and having experiences that match the viewers' cultural backgrounds for better connection. See Table **II** for the list of codes and example illustrative quotes corresponding to this theme.

Theme 3 Health, Comfort and Accessibility

Nine educators identified VR-related health and comfort issues such as motion sickness [P7], disorientation [P9], loss of balance due to sudden visual changes [P10] and feeling of suffocation [P15]. P1 mentioned '*I had a little bit of a headache because of motion sickness*' and P9 said, '*I did feel a bit disoriented, when the vision blurred*'. Issues such as head fitment and use of vision glasses, that hinder accessibility were also raised by two educators - P8 commented, '*I have a big head [for VR headset]*' and asked if they needed to take their glasses off to put on the headset. P13 remarked,*'pop them on with your glasses on? It was natural for me to take them off, I don't like it'*. The remaining educators (n=6) reported no notable health or comfort issues related to VR use. See **Table III** for the list of codes and example illustrative quotes corresponding to this theme.

Theme 4 VR Orientation

Several educators (n=7) commented that it took them **time to orient themselves**. P5 said,*'it took me some time to understand that I'm that person who has got that memory loss'*. P12 commented '*it took me a second to to realise that the voice was me*' and suggested that a walkthrough of the VR experience to familiarize and orient them would be useful. In contrast, only one educator [P] found that it did not

TABLE III
THEME 3 (T3) HEALTH, COMFORT & ACCESSIBILITY: CODES

T3.1 Health or comfort related:
'I had a little bit of a headache because of motion sickness' [P1]
'I did feel a bit disoriented, when the vision blurred.' [P9]
'definitely messing with my balance the shaky cam' [P10]
'I was feeling like I'm very suffocated.' [P15]
T3.2 Accessibility:
'I have a big head [for the size of VR headset].' [P8]
'pop them on with your glasses on? It was natural for me to take them off, I don't like it.' [P13]

take them very long and they could **orient quickly** to the VR simulation. P7 recalled the simulation content, '*I had a little bit of difficulty telling the difference between whether they were just thinking something or whether they were saying it. That may be because maybe they were saying things out loud the whole time? I'm not sure.*', indicating the confusion they felt in identifying whether the spoken content in VR was the character's thoughts being talked out loud or them actually saying it. See **Table IV** for the list of codes and example illustrative quotes corresponding to this theme.

TABLE IV
THEME 4 (T4) VR ORIENTATION: CODES & QUOTES

T4.1 Quick self orientation:
'it didn't take me very long at all to kind of get kind of oriented. And that was good.' [P8]
T4.2 Orientation support needed:
'So it took me a second to to realize that the voice was me...I could have done a walkthrough that have been useful.' [P12]

4.2 **RQ2 – SE Curriculum cases for VR Integration**

Our educators identified ten HCSE curriculum cases (Table V) for VR integration.It is worth noting the frequency of educators who proposed a potentially suitable curriculum area does not necessarily imply the its perceived value or priority.

All fifteen educators suggested using VR simulations to build empathy in SE students by helping them understand the needs and challenges of diverse users, such as those who are neurodivergent or elderly. For example - P7 quoted, *'they [students] need to have some regular opportunities to think about a broader set of human experiences'*.

Six educators suggested use of an AI avatar (of the target software user) within a VR simulated environment that students could interview to elicit requirements for design scenarios and prototypes. P13 explained it as *'avatar AI kind of domain, where they can actually ask questions off a virtual person'*.

Eleven educators (through curriculum cases 3, 5 and 8) discussed using VR to simulate real-world environments that are distant, inaccessible, or challenging to visit, to better understand the context in which software prototypes would be used - *'where the interface could be placed, and the environment and the space and choosing what kind of different hardware to have'*, as P1 suggested. Educators also identified prototype evaluation within VR environments, either by designers (n=5) or end-users (n=2), as a valuable application for understanding interface behaviour in realistic contexts.

The use of students as VR content creators as a part of SE projects was suggested by three educators: *'produce 3D worlds'* [P7] or *'different applications for VR'* [P14]. Five educators recommended extending the topic of accessibility to VR products, interfaces and experiences for future software engineers to explore. This includes understanding *'students, those who have disabilities, maybe they can experience it differently'* or making it more inclusive [P15] and thinking about design of headsets, controllers or other VR equipment for people with varying motor skills [P10].

Some educators (n=3) pointed out that requirements engineering using a VR environment might require different methods and techniques than doing so from interviews. P5 remarked *'[students] they're not going to use the same extraction method [from VR] as they do for reading the transcript'* therefore, they suggested it as a potential curriculum area within HCSE education and research. Two educators, including P6, noted they would consider using VR to prompt students to think about emerging and future technologies, using it for creative exercises involving innovative input methods such as gesture and motion control; as P6 explained in Curriculum case 10 (Table V).

5 Discussion and Implications

We discuss findings for our two RQs and their implications for practice in SE education and higher education more broadly:

5.1 **Educators' Impressions of VR Immersion (RQ1)**

Regarding the theme related to empathy and emotional engagement to drive human-centric thinking in education, our study revealed that educators experienced a range of emotions during their VR immersions, including empathy, excitement, sadness, anxiety, curiosity, and a willingness to help. Recent studies [16], [17], [33] suggest VR as a promising tool for building empathy, described as an *emotional response to another person's feelings, helping people understand others' situations and build meaningful connections* [33], and the educators' empathic responses further support VR's effectiveness in evoking empathy. The emotions such as sadness or anxiety might appear negative however, further reinforces the emotional impact VR affords.

The curiosity and willingness evoked by the VR simulation could potentially influence students in HCSE education to learn more about users and create purposeful software to solve user challenges. From a broader education perspective, the VR simulations could foster empathy and context awareness, giving students and educators insights into marginalized or vulnerable populations - opportunities limited due to budget, large class sizes, ethical or legal constraints, and resource limitations [5], [6], [8]. It could deepen understanding of theoretical concepts, cultural contexts, and social interactions in fields like business and social sciences.

TABLE V
HCSE CURRICULUM CASES FOR VR INTEGRATION (C1-10)

C1. Building empathy for end users' needs:
'they [students] need to have some regular opportunities to think about a broader set of human experiences' [P7] ;
'great activity if we want to actually design to help students understand about people with disabilities and not just dementia...how would you design with seemingly different accessibility provisions?' [P12]
C2. Improving interview skills using AI-avatars in VR environments:
'oh, imagine if in a VR experience, you could go up to somebody, and then you could literally ask them anything...I'm gonna ask you a question. You're responding in that role. So that's what they [students] do' [P12]
'avatar AI kind of domain, where they can actually ask questions off a virtual person, and then get the responses back ' [P13]
C3. Evaluating prototype designs [in VR environments]:
'if some user is from non technical, or say, older people who are not familiar with technology, they may not also like technology...rather than just describing the look and feel or the features of a new application or software, I think if they can visualize in their own experience using VR. So I think that can help them to understand what the new technology can offer in their life in practical.' [P14]
C4. Investigating Accessibility in VR:
'some people don't have the motor controls they need for typical controller, they might need a different controller, or they might need an adaptive controller where you can actually customize the different buttons and joysticks and that sort of stuff.' [P10]
'inclusive VR...like VR should be inclusive to all communities' [P15]
C5. Building socio-cultural understanding using VR environments:
'...where the interface could be placed, and the environment and the space and choosing what kind of different hardware to have...' [P1]
'VR is excellent for [understanding] location because the way we naturally navigate around environments' [P12]
C6. Designing VR prototypes -Students as creators:
'students are supposed to produce 3D worlds' [P7]'looking at someone using that VR, what things can go wrong when they're looking at someone using that VR. So they can start critically thinking about different applications of VR, maybe as a part of project or real life applications.' [P14]
C7. Eliciting requirements from VR simulations:
'It's very important for information gathering where you don't have [user] access...using VR to gather information in a way that you can actually process this information and use it for a design' [P6]
C8. Showcasing prototype designs in VR environments:
'whatever they [students] are prototyping, developing, whatever they've learned, if they're able to showcase that using the VR to show their peers in the classroom...using the VR headset...that would be cool.' [P9]
C9. Representing problem scenarios through VR simulations:
'And it could also be used for differentiated learning as well, if there was a video or written component, but also the option for VR for people who might find that more useful for actually understanding the problems, or whatever the topic is for that week.' [P10]
C10. Simulating future technology designs, roles and interactions:
'the goal of the unit was designed for the future, we say, future technology designer...a big room for VR to actually bring those things to life.' [P6]

Regarding the theme related to immersion in VR, a first-person perspective, a realistic looking environment, and awareness of physiological reactions enhanced educators' sense of presence within the VR scenario. Previous research [46] indicates design strategies in VR impact immersion and task engagement. In contrast, aspects such as motion misalignment, avatar representation, voice mismatches tend to put educators' off. Thus, the immersion enhancing and breaking aspects identified by the educators might be useful to inform the design of instructional VR scenarios and metaverse creation [37] across diverse higher education contexts.

Regarding accessibility for effective VR use in teaching, while motion sickness, disorientation and headache identified by educators are commonly associated with VR [47], these health and comfort aspects are important to ensure effective use of VR in educational settings. Additionally, the accessibility of VR seem to be an important practical area identified by educators, an area that remains under-explored, particularly for people with disabilities [48]. The health, safety, and accessibility concerns raised imply that appropriate briefings and disclosures should precede VR activities. This enables students across diverse disciplines to assess their emotional readiness and allows educators to ensure psychological support is available, facilitating more effective and responsible VR integration into higher education courses.

5.2 Curriculum Cases for VR integration (RQ2)

All educators recommended VR for empathy building based on their immersion experiences. Empathy i.e. *perspective-taking* with *potential end-users* has been identified critical skill for software engineers [16], [33] and ongoing research is exploring VR's potential to foster empathy and promote inclusivity in SE [17]. Given the strong interest from educators, this represents a meaningful area for VR integration in HCSE education to design for diverse user needs.

Another educators' suggestion was to immerse students in a simulation to interview an AI avatar to strengthen interviewing and SE requirement elicitation skills. This aligns with recent work such as Barambones et al. [27]'s exploration of ChatGPT-simulated users as training material for persona creation, and examining the role of avatars in VR interactions [38]. This reinforces that effective interviewing skills are important for software engineers to elicit current ways of work and requirements for system design from the target users.

Curriculum cases related to VR accessibility, include the proposal by educators to train SE students to to make VR more inclusive for users with different physical, motor or cognitive needs also make for an important area. This is especially so given that research efforts are underway to explore inclusive design for older adults [49], train students with cognitive differences such as autism spectrum disorder [50]. Aligned with this, training SE students to design and create experiences for VR headsets and environments [51], educational metaverse [37], or explore it as a medium for futuristic interaction styles also emerged as other useful areas for HCSE teaching.

VR applications that simulate authentic environments warrant exploration in HCSE, where understanding *where* (location, culture) and *how* (work practices) software will be used may be essential. The applications of this also extends to showcasing, monitoring or evaluating VR avatar and design prototypes in simulated environments. Our educators also highlighted the importance of assessment tasks and analytics and behavior tracking within simulated environments as a useful feature to assess students' learning in VR.

The proposed curriculum-cases appear to align with phases of HCSE lifecycle, suggesting that VR-based experiential learning may lend itself to teaching in potentially broad range of human-centric software engineering processes [3], [4].

Empathy-building curriculum-case (C1) and socio-cultural contextual exploration (C5) align with early problem framing and understanding user needs [6]. AI-avatar interview practice (C2) and VR-based requirements elicitation (C7) curriculum-cases support user research and requirements gathering [52]. Prototype evaluation (C3), showcasing designs (C8) and representing problem scenarios (C9) correspond to iterative refinement and design evaluation [6]. VR prototypes (C6) and future-oriented design exploration (C10) extends into inclusivity and accessibility considerations [49] in software design.

5.3 Implications for Teaching

For teaching, the curriculum cases [C1-C10] contribute practical curriculum areas to leverage VR for experiential HCSE teaching. Building on this study, we are investigating a curriculum-integration study employing curriculum case C1 as a follow-on to this, and plan to share findings and resources from its in-class implementations. We also encourage and recommend other SE educators to implement these curriculum-cases and share their insights. From a broader curriculum development perspective, the suggested curriculum-cases such as using simulations to foster empathy, communication, and interviewing skills are practical competencies valued across many disciplines, as discussed in Sections 1 and 2-A. Therefore, we encourage educators across disciplines to implement these curriculum-cases in their own classrooms and share their insights to help advance broader adoption and innovation in experiential education.

5.4 Implications for Research

For research, it is imperative that VR developers and researchers address immersion-breaking aspects and other design features (Table II) affecting VR experiences identified by educators to ensure effective pedagogical use. Accessibility is a critical area [17], [48], [53], and our findings highlight the importance of designing VR for educational stakeholders with varying abilities. Our findings also reinforce the need to involve educators, students and people with lived experiences in the co-design, use, and evaluation of VR experiences [20], [22], [54]. Moreover, HCSE educators' positive perceptions of VR following direct exposure suggest that immersive simulations may also offer an approach to inspire educators in other disciplines to envision new teaching approaches and curriculum-cases while addressing the gap in prior studies around incorporating educator perspectives [23], [41].

6 Limitations and Future work

This study has several limitations. First, the small sample of 15 educators limits generalizability, although it was not our goal. Our aim was to explore how SE educators experience VR to inform its use for HCSE teaching, and the diversity of participants across SE sub-disciplines provided rich insights. Second, the study focused solely on educators' VR immersion experiences and did not examine how demographic factors (e.g., age, gender, teaching experience) may shape emotional responses, which future work could investigate. Third, the curriculum-cases generated are not exhaustive, however, offer valuable areas for exploration. Another limitation is that this study did not examine the enactment of the proposed VR curriculum cases in authentic classroom settings. Although emerging work [20] has begun to identify these practical constraints, comprehensive classroom-based investigations are still needed to understand issues such as feasibility, assessment integration, and the real-world learning impact of these curriculum cases. more comprehensive classroom-based investigations are needed to understand practical constraints, assessment integration, and real-world learning impact of these potential curriculum applications.

We also acknowledge that educators' own VR immersion experience may have influenced the types of curriculum-cases they proposed, particularly those centered on empathy building. Additionally, participants' prior interest in VR may have contributed to more favorable perceptions than those held by more sceptical educators, therefore, future studies should include educators with varying levels of interest to compare perspectives. Future research should also extend beyond educators by examining VR integration with students and other educational stakeholders, such as VR administrators and designers, to capture a more holistic view of implementation challenges and opportunities.

7 Conclusion

This study captures the first-hand impressions of 15 HCSE educators who experienced a VR simulation with a head-mounted display and reflected on its potential curriculum applications. The VR sessions evoked emotions including empathy, anxiety, curiosity, and excitement. Educators cited realism as a key factor for immersion, while the lack of voice, gender, and cultural personalization disrupted it. Health and accessibility concerns (e.g., motion sickness, use of glasses, orientation needs) were also noted. Ten educator-curated HCSE curriculum-cases such as empathy building, AI-avatar interviews, virtual prototype evaluation and accessibility highlight how VR integration can meaningfully enhance HCSE teaching across SE lifecycle, from understanding user needs through to ideation, evaluation, and iterative refinement.

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The authors have no competing interests to declare that are relevant to the content of this article.

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