Customizing Design Thinking for Social Aware Virtual Reality: Exploring Immersive Empathizing in Co-Design

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Abstract

Despite the growing prominence of VR in education, research has largely focused on evaluating learning outcomes rather than on developing VR-specific design frameworks that leverage the medium's unique affordances and actively involve students as co-designers. This study proposes the Immersive Empathy-Driven Design (IEDD) framework, as an adaptation of Design Thinking (DT), that introduces immersive empathizing with the VR medium and repositions collaborative scenario co-creation as the central organizing principle of the design process. To explore the applicability of this framework, in a half-day workshop, university students designed VR scenarios on environmental challenges, starting with experiencing a VR simulation unrelated to the topic to familiarize themselves with perspective-taking and emotional engagement. Participants then progressed through traditional DT stages and co-designed their scenarios in teams. The outcomes of this feasibility study indicated that preliminary VR exposure influenced scenario design, by encouraging perspective shifts and emotional intentionality. Participants also indicated a clear preference for positioning the immersive empathizing stage for VR familiarization at the beginning of the design process. Furthermore, preliminary VR exposure enhanced empathy and perspective-taking, while collaborative design activities promoted soft skills such as teamwork skills. Taken together, the workshop not only supported effective scenario design but also promoted the intended learning outcomes, demonstrating the potential of immersive empathizing and scenario-centered co-design in the VR design process.

Keywords

Design Thinking, Social Aware Virtual Reality, Immersive Empathizing, Empathy, Perspective-taking

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1. Introduction

Despite the growing maturity of Virtual Reality (VR) technologies and their application across various fields, such as education [1, 2], healthcare [3], tourism [4] and more, the methodological foundations of VR application design remain under-explored [5]. Several VR systems have been designed by adapting desktop computer interface frameworks rather than following an established VR-based design framework [6]. This methodological gap is particularly evident in educational VR applications, where immersive environments are often designed relying on principles derived from traditional 2D interface paradigms. However, these principles are insufficient for 3D immersive learning experiences, highlighting the need for the establishment of VR-specific design principles that unlock the capabilities of immersive technologies, while maximizing user experience, learning engagement, emotional response and satisfaction [6].

Addressing this gap, the present study proposes a customized Design Thinking (DT) based framework tailored for the design of educational VR environments. DT is a human-centered methodology that integrates empathy, out-of-the-box thinking, creativity, experimentation and iteration to develop solu-

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tions that are aligned to users' needs and challenges [7, 8]. DT is also an interdisciplinary approach [8], making it a strong foundation for the design of educational VR applications, which requires collaboration across multiple disciplines and domain-specific experts. However, although DT shows strong potential as a design methodology, its application within educational VR design remains insufficiently examined in existing research.

This feasibility study explores the potential of a customized DT-based approach, within the framework of a workshop, in which university students had to collaboratively co-design VR scenarios addressing environmental challenges. As an initial step of the design process, an immersive empathizing phase was introduced before the core stages of DT, aiming to familiarize the participants with the VR affordances. To minimize bias, a VR application unrelated to environmental challenges was selected, which focused on raising awareness of workplace challenges faced by individuals with visual impairments, promoting inclusivity and reasonable accommodation. This stage was introduced to familiarize the participants with the VR medium itself and deepen their understanding of core VR elements, including perspective-taking, navigation, and emotional engagement. The research goal of the workshop was to explore whether the introduction of this preliminary immersive empathizing stage before the DT process influenced how participants integrated core VR elements into their subsequent scenario designs.

1.1. Problem statement

VR has gained increasing attention in educational research over the past decade. However, the vast majority of existing studies focus on evaluating learning outcomes or comparing VR with other media, rather than systematically exploring how educational VR applications should be designed from a methodological and pedagogical perspective [9, 10]. Moreover, there is a notable gap in research exploring how students themselves as stakeholders are actively involved as co-designers of VR learning environments [11, 12, 13]. Given these circumstances, it is unsurprising that existing literature reveals a lack of robust, evidence-based design frameworks tailored specifically for VR learning environments. In response to this gap, DT has been argued as a promising approach that can be implemented in educational VR to develop interactive and captivating learning environments that cater to the needs and interests of the learners [14]. However, empirical studies integrating DT into educational VR are still scarce, and the few existing ones largely position VR as a medium to enhance DT skills and practices [15, 16], rather than applying DT as a methodological framework to design the VR experience.

One possible explanation for this limited integration lies in the origins of DT itself. While DT is a well-established and widely adopted methodology [17], it was not originally conceived for immersive VR environments. As a result, its transferability to VR design may overlook the medium's unique affordances and experiential qualities. Additionally, previous efforts to apply traditional DT methodology to storyboard design for VR experiences produced outcomes that while meaningful, did not incorporate VR elements, such as perspective shifts, or were not successful in eliciting end-users' emotional engagement. This limitation could be attributed to participants' unfamiliarity with VR. In these earlier attempts, participants were exposed to VR mainly through slides rather than hands-on VR experience, limiting their ability to envision scenarios that incorporated elements such as perspective shifts.

Therefore, adapting and customizing DT is necessary to provide a systematic and structured framework for the design and development of VR educational applications. Such customization is essential to address users' unfamiliarity with the VR medium and to integrate core experiential dimensions, such as embodiment, perspective-taking, and sense of presence, that are central to effective VR experiences. Furthermore, first-hand VR experiences are crucial for enabling users to understand the strengths and constraints of this technology before engaging in VR design activities, allowing them to contribute meaningfully to the design process.

1.2. Conceptual foundations for adapting DT to VR

The current work explores the potential of adapting the traditional DT approach as a foundation for developing the Immersive Empathy-Driven Design (IEDD) framework for designing more user-centered

VR learning experiences. The proposed approach is built around two core features. The first core feature is immersive empathizing with the medium of VR itself. In traditional DT methodology, which formed the basis of the proposed approach, empathizing refers to understanding in depth end-users, their needs, challenges, and context [17]. However, in participatory VR design contexts, the individuals involved are not only end-users but also act as co-designers. This dual role is especially significant considering that many participants lack prior VR knowledge and an in-depth understanding of the technologies' strengths and constraints [18, 19, 20, 21], which may make it challenging to fully grasp concepts such as embodiment, perspective-taking, sense of presence, and interaction. This limited familiarity may, in turn, influence the extent to which they can meaningfully contribute to the co-creation of VR experiences. This work, therefore, extends the traditional empathize phase by introducing immersive empathizing, which shifts the focus from understanding users' experiences to developing an experiential understanding of VR as a medium before engaging in co-design activities.

The second key feature introduces a scenario-driven co-design dimension that positions collaborative scenario construction at the core of the design process. While traditional DT employs tools such as personas and user journeys to support empathy and ideation, these tools typically function as auxiliary mechanisms within a broader problem-solving cycle. Drawing on principles of scenario-based design, where scenarios are used to envisage and develop new technology-based systems by representing real situations enriched with social and technical constraints [22], the proposed approach elevates scenario co-creation to a primary structuring element guiding the development of VR learning experiences. Although scenario-based design has been increasingly adopted in technology design, scenarios are often used as evaluation tools rather than as generative means for defining interaction requirements and are typically authored by designers rather than collaboratively constructed [23]. In immersive VR contexts, however, scenarios act as experiential blueprints that shape spatial interaction, perspective-taking, and emotional engagement. By involving students in the co-creation of immersive scenarios from the outset, the framework repositions scenario-based design as a participatory and generative strategy, aligning pedagogical goals with the embodied and narrative affordances of VR.

Taken together, the novelty of this work lies in the customization of the DT methodology for VR-based design through two complementary methodological extensions. First, the IEDD framework introduces immersive empathizing with the medium of VR itself as an initial stage of the design process. The goal at this stage is not to enhance users' empathy skills in general, but to allow them to experience firsthand how VR functions as an "empathy machine" [24, 25], enabling understanding of perspective-taking [25] and emotional engagement [26]. By positioning users in a hands-on VR experience before co-design activities, the proposed framework aims to address the critical gap in existing VR design methodologies that refers to users' lack of familiarity with immersive environments. Second, the framework repositions scenario construction as the central organizing principle of the co-design process. Rather than treating scenarios as auxiliary artifacts, the approach foregrounds collaborative scenario co-creation as a generative mechanism for defining immersive VR learning experiences.

To the best of our knowledge, no existing design framework places immersive empathizing with VR as an initial stage in the design process. The remainder of the paper presents the concept of DT and its application in the design of VR environments within the context of environmental education, the proposed methodological framework, findings from an initial pilot test, followed by discussion and conclusions.

2. State-of-the-art

2.1. Designing for empathy and perspective-taking in VR

VR has been described as the "ultimate empathy machine" [25] because it enables users to experience alternative viewpoints. Unlike traditional role-playing, where users are given predefined scenarios, are aware of their own body and must mentally adopt another person's role, in VR users are located in a virtual body, referred to as an avatar, and have the ability to swap virtual bodies [25, 27, 28] and even enter non-human body representations [29]. Slater's research [30] highlighted that users can feel strong body ownership, perceiving a virtual body as their own, when viewing it from a first-person perspective. Stavroulia and Lanitis [2] also demonstrated that perspective shifts, placing teachers in their students' position, enhanced empathy and understanding of students' challenges. Perspective shifts within the VR experience enable users to experience alternative viewpoints enhancing empathy and understanding of others [2, 25, 29, 31], improving understanding towards minorities [32], reducing stereotypes [33], or raising awareness of gender-based harassment [34].

Despite VR's potential as an educational tool [35] and its effectiveness on the cultivation of soft skills such as empathy and perspective-taking [2, 29, 32, 33, 34], most VR applications are not designed based on a well-established framework. Additionally, users' unfamiliarity with the VR medium may result in learning scenarios that do not fully leverage the medium's capabilities. Building on these insights, the present study proposes a customized DT-based framework for VR educational applications that introduces immersive empathizing as an initial stage of the design method, alongside a scenario-driven co-design approach that foregrounds collaborative construction of immersive learning experiences. For this work, "immersive empathizing" is defined as the initial stage of the design process, in which users experience VR to become familiar with the medium and its capabilities, enhancing their ability to co-design meaningful scenarios that take full advantage of VR, while remaining aligned with specific learning objectives.

2.2. Design thinking approaches for VR design

There is a growing interest in applying DT methodology to educational VR design, yet this is still an emerging field. DT is "an idea, a strategy, a method, and a way of seeing the world... a way to solve problems through creativity" [36]. It is more than a process; it is a human-centered design toolkit, a systematic framework with a "multidisciplinary character", that can be adapted and customized to align with different contexts, including VR [36, 37, 38, 15, 16, 39, 40].

The DT framework has been used to some extent in VR design, yet its systematic use remains limited. While many studies investigate the use of VR to enhance DT skills [15, 16], little research explores how DT can be applied as a methodological framework to guide the design and development of VR learning environments. The limited existing results indicate the potential of this approach in the design and development of VR applications, but further research is required to define the impact of this approach [40]. Velasquez [41] explored, for instance, 360° VR for pre-ideation empathizing of designers with the problem spaces. While the results indicated the promising use of VR compared to traditional methods, it did not outperform them, and no customized DT framework was developed. In another case [42], DT was applied to design and develop a VR application for students with disabilities. While the results highlighted the significance of the iterative process for the production of a meaningful VR application aligned with users' needs, the VR experience was not a prerequisite to the DT process. Aiming to address these gaps, this feasibility study explores the customization of DT methodology in VR design by introducing immersive empathizing as the initial step of the empathize phase to familiarize users with the VR medium before contributing to scenario co-design. The following section describes the methodological framework and procedures implemented to guide this research.

3. Methodological approach

3.1. Methodological overview

This work is based on the five-stage DT model proposed by the Hasso Plattner Institute of Design at Stanford (the d.school) [17] as presented in Table 1. The empathy-driven nature of DT allows designers to understand in-depth end-users, ensuring the successful fulfilment of user requirements and expectations [17, 36, 37]. The proposed approach, as presented in Table 1 (right column), builds on the d.school DT approach and introduces immersive empathizing as a new initial stage before user empathizing, enabling end-users to first empathize with the VR medium. The proposed methodological framework was explored through a co-design workshop to investigate its applicability and added value in the context of a scenario-centered co-design activity for a VR learning environment. More specifically, the research goal of this study is to investigate the extent to which prior immersive exposure to VR influences participants' ability to co-design learning scenarios that effectively leverage VR's empathetic, perspective-taking, and emotional engagement affordances.

Table 1
d.school's DT stages (left column) versus DT stages of the proposed approach (right column)

d.school	Proposed Approach
Stage 1. Empathize / Understand users and their needs	Stage 1. Immersive empathizing with the VR medium
Stage 2. Define / Synthesize insights to craft a meaningful point-of-view	Stage 2. Empathizing with end-users
Stage 3. Ideate / Generate a wide range of ideas and potential solutions	Stage 3. Define the needs and learning objectives
Stage 4. Prototype / Build tangible solutions	Stage 4. Ideate VR learning scenarios
Stage 5. Test / Evaluate the prototypes with users and iterate based on the insights	Stage 5. Prototype VR scenario storyboards
	Stage 6. Test and refine the VR scenarios

3.2. Educational contexts

To explore the feasibility of the proposed DT-based framework, a workshop was implemented involving university students in co-designing VR scenarios focused on environmental challenges. This approach responds to calls within environmental VR research to move beyond media comparison studies and to examine how participatory and design-oriented methodologies may influence engagement with environmental content [43]. By integrating immersive empathizing alongside a scenario-driven co-design process, the workshop aimed to investigate how hands-on VR exposure affected participants' understanding of the medium's affordances and their design of immersive learning scenarios.

3.3. Participants

Twenty-two (n=22) undergraduate students at a public university participated in the workshop. Participants included 13 men (59%) and 9 women (41%), ranging from 19 to 22 years. None of the participants had prior experience with VR or DT. Participants were recruited through convenience sampling, as the workshop was embedded within the undergraduate course "Introduction to Human-Centered Design".

3.4. Workshop design and implementation

The workshop was structured as a half-day session and followed a clear sequence of activities aligned with the stages of the proposed DT-based framework. Facilitated by the three authors who served as trainers, the workshop began with a welcoming, obtaining informed consent and introduction to set expectations and workshop goals. During the first stage of the workshop, an immersive empathizing activity was conducted.

To familiarize participants with VR, an application unrelated to environmental challenges was selected to avoid bias towards the topic. The application used was developed under the Erasmus+ project InclusiVR@Work (https://inclusivr-project.eu/) which aims to enhance empathy of Human Resource (HR) managers and Vocational Education and Training (VET) professionals towards people with vision impairments such as diabetic retinopathy and macular degeneration. In the VR experience, participants take on the role of an employee with visual impairments who must evacuate the office space during a fire emergency. The simulated vision impairments make this task challenging, increasing participants' understanding and fostering empathy towards people with disabilities as well as awareness of reasonable accommodation in the workplace. The VR experience allowed participants to understand core VR concepts, such as perspective-taking, presence, emotional responses, and eye gaze interaction to navigate, deepening their understanding of the medium. Participants first experienced the VR scenario individually, and afterwards, they worked in small groups (of 4-5 members) and collaboratively reflected on the VR experience, answering some questions focused on the medium's affordances, rather than the content of the scenario.

In the second stage, each group focused on empathizing with users regarding environmental challenges, exploring how university students perceive those issues. More specifically, within each team, one student acted as the interviewer, collecting insights from the other members of the group. These insights were used to create a draft empathy map highlighting key themes. To ensure consistency across the groups, a set of predetermined questions was provided, given time constraints, but also to ensure that all groups gathered comparable data.

Building on the empathizing activities, the define phase guided participants to identify higher education students as the main target audience and craft point-of-view (POV) statements that reflected higher education students' key needs, motivations, and challenges. For example, one of the groups formulated the following POV statement: "University students need an interactive VR application to help them understand the consequences of environmental indifference. While they witness pollution and environmental degradation in their daily life, they often do not know how to contribute meaningfully to large-scale change".

During the brainstorming phase, each group generated four to five ideas without detailed analysis. After discussion, each group selected a single idea to further develop in the prototype phase. In the prototype phase, the teams had to develop the content of their VR scenarios. Each group developed a scene-by-scene outline of the scenario and then used AI tools to generate a visual storyboard that reflects this scenario.

During the final phase, each group prepared a one-minute pitch to present their VR scenario to the other group. The presentations were intended to generate feedback and provide insights that could inform future iterations; however, due to time constraints, discussion and iterative refinement were not conducted within the workshop.

Finally, following general closing remarks, all participants were asked to complete an individual reflection diary, providing their personal reflections on the overall workshop experience. All aspects of the study, including the co-design workshop and data collection procedures, were reviewed and approved by the Cyprus National Bioethics Committee (EEBK EP 2026.01.29) to ensure compliance with ethical standards.

4. Preliminary results

4.1. Impact of VR exposure

Immediately following the immersive VR experience, participants were asked to evaluate the VR experience in their groups, in terms of the experience and not of the scenario regarding vision impairments. The results revealed that the participants emphasized the enhancement of perspective-taking and empathy. For example, one of the groups described the VR experience as *"an action and adrenaline experience"*, as a *"life-like experience that put us in the shoes of a person with this (vision) problem"*. All student groups reported that the VR experience enabled them to *"enter the shoes of people with disabilities"* and raise their awareness of the challenges they face. Moreover, a second trend was that the participants found the experience realistic and immersive, associated with strong emotional engagement and a sense of challenge. These preliminary results indicate that the immersive empathizing stage was successfully introduced, allowing participating students to familiarize themselves with the VR medium as part of the DT process.

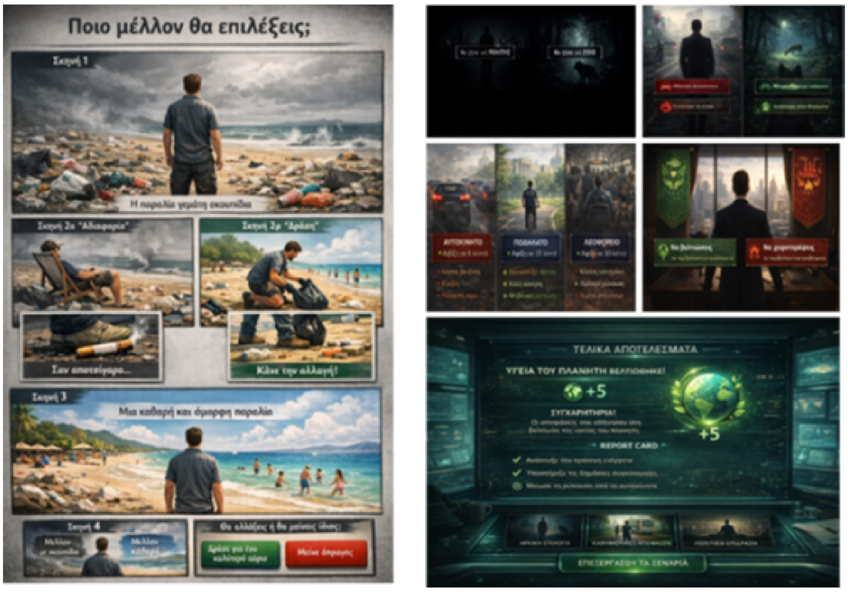

Figure 1: Indicative co-designed VR learning scenarios illustrating embodied (left side) and systemic (right side) perspective-taking.

4.2. Analysis of co-designed VR learning scenarios

The analysis of the co-designed scenarios provides also supporting evidence of how the proposed VR-adapted DT framework shaped students' understanding of empathy and perspective-taking as central design mechanisms. More specifically, rather than approaching educational VR as a medium for content presentation, students structured their experiences around embodied role shifts, moral decision points, and experiential consequences. The analysis of students' scenarios revealed that immersive empathizing was not treated as a preliminary activity but became internalized as a generative design logic. Perspective was not added superficially. Instead, it functioned as the organizing principle of narrative development and interaction design. Due to space limitations, the discussion below focuses in depth on two indicative scenarios to shed light on these patterns.

For instance, in the first scenario, which focused on environmental pollution on a beach, students co-designed an experience structured around emotional contrast and moral agency (Figure 1, left side). According to this scenario, the user initially inhabits a polluted environment characterized by sensory discomfort (grey sky, unpleasant atmosphere, visible waste), before encountering a decisive immersive shift: becoming a discarded cigarette butt that is stepped on and ignored. As the students explained, *"the user steps into the position of the cigarette"*, which in turn allows adopting the *"perspective of the thrown-away cigarette butt".* This transformation from a human observer to an "invisible" object signals a move beyond cognitive awareness toward embodied empathy. Next, the subsequent juxtaposition of two possible futures, a polluted beach versus a clean one, culminates in a frozen moment of choice, positioning the user as an active agent responsible for shaping environmental outcomes. Taken together, the design demonstrates an understanding of VR's affordance for identity transformation and affective immersion, suggesting that the participating students had appropriated the idea of VR as an "empathy machine" and translated it into narrative structure.

Likewise, the second scenario extends this logic by operationalizing perspective-taking at a systemic level (Figure 1, right side). According to this scenario, users navigate multiple points of view within a VR gamified app, initially choosing to experience the world as a citizen or as an animal affected by environmental degradation. As the students explained, participants would be invited to *"live as a citizen or as an animal"* in order to *"have this specific point of view"*, emphasizing experiential immersion rather than observational learning. The scenario then introduces a further role shift, positioning the user as a politician capable of influencing structural change, allowing according to the students *"the average user to experience what possibilities a politician has".* Moreover, through real-time feedback on everyday decisions, such as transportation choices and their environmental consequences, the scenario visualizes causal relationships between individual behavior, ecological impact, and political responsibility. This layered movement across roles indicates a more complex understanding of empathy as relational and multi-scalar, linking personal agency to institutional power. Therefore, perspective-taking becomes not only an emotional device but also a mechanism for modelling interconnected systems.

In conclusion, across both scenarios, perspective shifts, consequence visualization, and decision-based interaction function as the backbone of experiential design. The emphasis on role transformation, temporal comparison of alternative futures, and explicit moral choice points suggest that students internalized the embodied and narrative affordances of VR during the immersive empathizing stage. In addition, the centrality of collaborative scenario construction enabled them to translate these affordances into structured learning experiences. Taken together, these findings support the claim that the proposed methodological adaptation fosters an empathy-driven VR-based DT approach, moving participants beyond abstract awareness toward the deliberate construction of embodied and consequential learning experiences.

4.3. Findings from reflective diaries

After the end of the workshop, the participants were asked to write a reflection diary answering a set of questions related to the overall experience of the design process and to the VR exposure at the outset of the DT process. Participants' responses indicate a strong consensus that the VR exposure was beneficial, it placed them *"in the process of thinking, imagining a virtual world and bringing it to reality as we enter someone else's thoughts and mind"*. VR exposure helped them understand concepts such as human-centered design and prepared them for subsequent activities. Most participants reported that the VR exposure, as the initial stage of the process, was appropriate and effective, helping them understand tasks and key concepts early on. Participants also indicated that VR exposure *"would not have the same preparatory benefit"* if introduced at a later stage.

Additionally, participants were intrigued by the hands-on and collaborative aspects of the workshop. The VR experience, the creative process of designing the VR scenarios, and teamwork were identified as the most valuable elements promoting students' engagement and a deeper understanding of key concepts. Another interesting outcome is that participants felt surprised by the emotional impact of the VR experience, discussing *"how strongly a VR experience can affect emotions"*, which enhanced their empathy and contributed to a deeper understanding of others' challenges. Many also reported that this creative design process and teamwork inspired them.

Overall, throughout the workshop, participants experienced mostly positive emotions, including interest, excitement, curiosity, and enjoyment. Moreover, many highlighted empathy, concern, and reflection when engaging with the difficulties experienced by others. Furthermore, most participants felt that the workshop was a positive experience, and no major changes are needed.

5. Discussion and implications

Limited research has explored how DT can be adapted to intentionally design for the social and emotional affordances of immersive learning environments [44]. As VR technologies increasingly enable forms of social augmentations, such as enhanced perspective-taking [2, 31, 32], embodied role-shifting [30, 28, 29, 32, 33, 34], and affective engagement [26], there is a need for frameworks that translate these possibilities into structured design practices. By foregrounding immersive empathizing and scenario-driven co-design, the present study contributes to the development of the Immersive Empathy-Driven Design (IEDD) framework, as a novel framework for intentionally designing socially enriched VR learning scenarios, aligning with emerging discussions on empathy, engagement, and social interaction in XR. To explore the potential of the IEDD framework, a workshop was conducted with university students focusing on environmental challenges.

The results indicated that the immersive empathizing step achieved its intended impact. Participants reported that the initial VR exposure helped them understand VR, which in turn informed and influenced the design of their scenarios. Importantly, participants also highlighted that the timing of the VR experience (i.e., at the beginning of the workshop) was appropriate and should be maintained, as a later exposure would likely have reduced its effectiveness. It is also noteworthy that, although the trainers primarily focused on familiarizing participants with the VR medium rather than explicitly fostering empathy, most participants reflected on the experience's impact on understanding the perspectives of individuals with disabilities. This increase in empathy and perspective-taking informed the co-designed scenarios, as students incorporated perspective shifts into their designs.

Taken together, these findings suggest that VR environments can function not merely as representational tools, but as structured empathy-building interventions within design processes. The effectiveness of the immersive empathizing phase, particularly when positioned at the beginning of the DT process, highlights the importance of timing in activating affective and cognitive engagement. This also supports the argument that immersive experiences should be deliberately scaffolded within DT frameworks to prime perspective-taking and inform subsequent ideation. In this sense, the IEDD framework advances DT by operationalizing immersive empathy as a structured and pedagogically intentional design phase rather than an incidental by-product of VR exposure.

Equally significant is the fact that the workshop was mutually beneficial. For the students, it facilitated new knowledge about VR, the DT process, and environmental challenges, while also fostering essential soft skills such as empathy and teamwork. For the trainers, the session provided useful insights into the impact of VR exposure on design outcomes and highlighted the need for greater customization during the design process. Toward this end, this feasibility study suggests that the IEDD framework has potential for adapting the DT methodology to achieve the design of more effective VR educational scenarios. Collectively, our findings suggest that the IEDD framework shows promise for extension beyond a single project, offering a scalable and adaptable approach for future VR initiatives across diverse contexts. Future work could expand its use to multi-user co-design settings and more diverse participant groups, while longitudinal studies could assess whether immersive empathizing leads to sustained creativity and long-term social awareness. Furthermore, involving participants with varying VR experience may further clarify the framework's long-term impact and broader applicability.

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Declaration on Generative AI

During the preparation of this work, the authors used GPT-4 for grammar and spelling check.

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