VR Let My Creativity Out: Youth Creating with Immersive Learning Technologies

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Abstract

With a greater demand for ingenuity and innovation in today's creative economy, educators need to be creative practitioners inasmuch as students must be, learn, and grow creatively. This qualitative study explores the affordances and constraints of youth creating with immersive learning technologies at a *Youth VR Research Camp.* A class of 28 students in grade 8, ages 13 and 14, were invited to participate as the co-researchers. The data collection methods included artifact analysis, student-led pair interviews, sharing circles, surveys, and observation. The process of research-creation involved MultibrushVR and FrameVR design challenges focussed on pro-social and environmental change. Findings revealed that the immersive experiences provided flexible learning pathways for the youth to take creative risks, exercise autonomy over their learning, and co-design with peers in novel ways. Although a few co-researchers reported discomforts, such as dizziness or nausea, from using the Meta Quest headsets, a significant 94% expressed interest in further learning through VR. Furthermore, 78% concurred that VR facilitated creative self-expression, while 88% acknowledged having the freedom to make decisions about their learning in VR. These findings indicate that immersive education, when effectively designed, can be a viable strategy for teachers striving to nurture creative learning and creative thinking in their classrooms. The data collected in this study serves as a foundation for future research on the role of immersive education in augmenting creativity and facilitating self-directed learning.

Keywords: *autonomy, creativity, immersive education, learning, virtual reality, youth*

1. Introduction

Creativity helps youth understand and express themselves, broaden their perspectives, evaluate ideas, and develop resilience and resourcefulness. Developing creativity and creative thinking prepares youth to adapt and respond to the ever-evolving circumstances they encounter at home, school, work, in their communities, and in their roles as global citizens. In a world where creativity is widely recognized as a valuable power skill or essential human skill (Boyles, 2022; Csikszentmihalyi, 2013; Resnick, 2007), it is disheartening that our current educational systems often stifle the development of creativity capacities by prioritizing rote learning and shallow knowledge (e.g., emphasizing right or wrong answers) over more exploratory and divergent thinking processes. Regrettably, the ripple effects are a generation of learners who are hesitant to fail or take risks and struggle with knowledge-building activities that lead to deeper understandings. Consequently, students become experts at consuming knowledge (e.g., focusing on products and outcomes) rather than being empowered as knowledge creators (e.g., focusing on process and growth) (Brennan, 2015).

Educators should prioritize creativity in their classrooms to adequately prepare students for an unpredictable future and a new era with artificial intelligence (AI), automation, and virtual realities. However, actively supporting creativity and fostering creative problem-

solving is difficult within the constraints of standardized core curriculum and quantifying assessments that suppress creativity and conform learners to rigid thought processes (Sawyer, 2019). Resnick (2007) explains that schools are not typically designed to facilitate the growth of students as creative thinkers, even though "creative-thinking skills are critical to success and satisfaction in today's society" (p. 1). In this article, I advocate for a shift in formal education practices to foster learning environments that inspire curiosity and instill joy in learning, where students are encouraged to think creatively, experiment with new ideas, fail, learn from failure, and try again.

This study investigated the affordances and constraints of youth learning by creating with immersive learning technologies at a Youth VR Research Camp held at the University of Saskatchewan in Saskatoon, Canada. We invited a class of 28 students in grade 8 to participate as co-researchers, giving them a significant role in planning and leading the research activities (Figure 1). They were challenged to use FrameVR and MultibrushVR to co-design immersive learning experiences that teach their friends, family, and school community about the Sustainable Development Goal (SDG) 15: Life on Land (United Nations, n.d.). We carefully designed the research setting to position the co-researchers as SDG changemakers, thereby visualizing complex global issues from their unique lenses of understanding and concerns. The findings have been synthesized and organized into three sections: possibility, flexibility, and capability. These sections include a narrative analysis of the co-researchers' experiences as immersive learning creators. Practical insights and pedagogical strategies are offered as guidance for educators who want to experiment with using immersive technologies to ignite creativity within their classrooms— and thereby play a part in a grander vision to reimagine formal education for a world transformed by the Metaverse and AI.

Figure 1. The Co-Researchers Learning, Thinking, and Creating with VR.

2. Theoretical Perspectives

Creative thinking is regarded as an essential life and career skill in our AI-powered world, where automation and machines are increasingly performing routine tasks and labour. The latest advancements in generative AI open up a new world of creative possibilities for learners across

the lifespan, with new applications and chatbots released weekly. The online encyclopedia Futurepedia (2023) lists over 4000 AI tools and ChatGPT plugins organized into 54 categories, including productivity, image generation, video editing, copywriting, and research. Student-AI co-creation is now possible, where a synergy of human and artificial intelligence can generate original ideas and solve real-world problems together (MacDowell & Korchinski, 2023). Etemadi & Dede (2021) warn that students need to learn more than the skills and knowledge AI has mastered: "Instead, we need to target capacities that are uniquely human and cannot be easily replicated by machines" (p. 2).

Educators and scholars are starting to question if we are setting students on a path toward redundancy if they lack the confidence and capability to create with AI. Those who can use AI effectively will likely have advantages in terms of enhanced creativity, productivity, and extended capabilities (Zhang & Aslan, 2021). Peeters et al. (2021) reflect on recent developments in our human-AI society: we are witnessing an explosion of creative output as humans are no longer the exclusive creators, and intelligence is now hybrid (e.g., a collective of human and artificial agents). Our traditional understanding of creativity, once rooted in human experiences, is being challenged and transformed by machine-generated content produced on a massive scale. Hence, nurturing creativity in schools is crucial to prepare students for a future shaped by AI, automation, and the shared virtual spaces in the Metaverse, which many believe is the next iteration of the Internet (Hwang & Chien, 2022; Tlil et al., 2022).

Emerging technologies (e.g., Generative AI and VR creation tools) are rapidly evolving, so it is a priority for the research community to understand how these technologies can contribute to a better future for humanity or hinder our progress (Pedró et al., 2019). In a reflective piece that I wrote for the *Virtual World Society,* I invited educators to reimagine their classrooms "without conceptual walls and physical barriers to limit creativity and imagination, where students get transported to environments that spark their curiosity and learn by exploring virtual worlds suited to their self-determination" MacDowell (2023, p. 19). Immersive education is a relatively new pedagogical approach that offers embodied interaction, learner autonomy, and creative learning opportunities (Southgate, 2020). Educators experiment with immersive learning activities and assignments that complement the existing curriculum and unleash student creativity. I am well aware, however, of the institutional barriers that educators encounter in establishing classrooms that support creative thinking skills (MacDowell, 2023):

> Unfortunately, K-12 and higher education systems are often criticized for not encouraging students to think creatively or use their imagination. People use phrases like "schools kill creativity," "crisis of imagination," "cookie-cutter education," "outdated, irrelevant curriculum," "teaching to the test," and "memorizing and regurgitating" to describe the current state of affairs in schools. Many students feel anxious, overwhelmed, and under pressure to do well academically, which can further stifle their ability to be creative and imaginative. (p. 19)

Educators learned from the COVID-19 pandemic that maintaining the status quo as the world changes is a risky position for educational institutions. Today's students are well-informed learners and want flexibility, choice, and personally relevant education. In addition to knowledge comprehension, students seek opportunities to develop emotional intelligence and essential life skills such as creativity, empathy, integrity, leadership, resilience, decision-making, and time

management (Sawyer, 2019). This landscape necessitates reimagining formal education systems (see Table 1 for meaningful possibilities), including experiential learning through immersive technologies. The use of virtual worlds and Metaverse platforms is grounded in extensive learning science research that evidences how experiential learning is a powerful teacher (e.g., Hwang & Chien, 2022; Makransky & Mayer, 2022; Petersen et al., 2020; Tlil et al., 2022). Southgate (2020) suggests that no-code and low-code content creation tools have democratized the creation of immersive learning experiences, making it possible for students and teachers of varying expertise to be VR creators and worldbuilders.

Dengel et al. (2022) propose that integrating immersive learning and teaching within everyday classrooms is on the horizon. However, ongoing challenges with immersive education at the micro-level (learner-specific factors), meso-level (teacher and classroom-specific factors), and macro-level (institutional and governmental factors) are seldom observed in lab settings (Dengel et al., 2022). These persistent issues include device management, adequate professional development for teachers, harvesting of biometric data, and protection of student privacy. Hence the need for empirical research on immersive education in actual classroom settings. This study builds on the understanding that teachers can deliver better outcomes for the students they serve by offering personalized and flexible learning pathways within engaging and creative immersive environments. While this study focuses on youth learners, I have applied a similar approach using immersive technologies to support creativity and imaginative thinking in my graduate-level courses with adult learners (e.g., MacDowell, 2022).

Table 1. Reimagining Formal Education for a World Transformed by the Metaverse and AI.

Formal Education in the Past	Formal Education in the Future
▪ Fixed curriculum (e.g., teaching from the textbook)	▪ Experiential learning through immersive technologies (flexible learning pathways)
▪ Teacher centered (grade driven)	▪ Learner centered (motivation driven)
▪ Traditional assessment (recall of facts and information on multiple-choice tests, writing standard essays)	▪ Authentic assessment (application of knowledge in group projects, debates, worldbuilding assignments)
▪ Mastery of content knowledge	▪ Mastery of content knowledge and power skills (e.g., creativity, problem-solving)
▪ One-size fits all approach	▪ Differentiated instruction (Human teachers and AI tutors in the classroom)

3. Research Design

3.1 Research Problem and Questions

This study further underscores a concern I have brought forth in previous research: "Despite the growing global problems of unsustainable consumption and environmental

degradation, which threaten the health of the planet and our survival, many students and teachers are not taking action for sustainable living" (MacDowell, 2021, p. 111). While the SDGs are urgent goals to achieve, effectively teaching them in traditional classroom settings remains a challenge, such that students understand and care about how their actions affect other people and our planet (MacDowell, 2021, 2022). Due to the interdisciplinary nature of the SDGs, they are a challenge for teachers to integrate into a standardized school curriculum, which is traditionally split into distinct subjects, each with specific learning objectives and outcomes. Students need to understand how the SDGs are interconnected, their relevance across various subjects, and that empathy is required to create solutions for complex global problems. Adapting educational approaches to facilitate such understanding is a significant task for today's classroom teachers.

A growing body of research indicates that engaging students in immersive learning activities can serve as a holistic, contextualized, and cost-effective approach for teaching about challenging SDG topics such as climate disruption, ocean acidification, and deforestation, while simultaneously enhancing understanding and empathy towards the conservation and protection earth's resources (e.g., Fauville et al., 2020; Huang et al., 2020; Makransky & Mayer, 2022; Markowitz & Bailenson, 2021; Petersen et al., 2020). This study aimed to contribute empirical evidence about how youth learn by co-designing immersive learning experiences with a special focus on environmental and sustainability education (ESE) and engaged citizenship. This project contributes to the research ecosystem by building capacity for mobilizing youth voices on global issues concerning their lives and learning circumstances.

Three guiding research questions frame the study:

- How do youth describe their experiences as immersive learning creators working collaboratively with peers?
- What are the affordances and constraints of using immersive technologies to motivate youth learning about pro-social and environmental change?
- How can teachers foster student creativity with immersive technologies, including knowing how and why to use them?

3.2 Research Setting

The participants included 28 eighth-grade students (ages 13 and 14, mixed gender, and varied experience levels) from a culturally diverse elementary school located in Saskatoon, Canada. The class (and their two teachers) visited the College of Education at the University of Saskatchewan for a *Youth VR Research Camp* consisting of guided immersive adventures to explore and learn about the SDGs (Table 2), team design challenges, and research activities. The youth were invited to join the research team as co-researchers and were collaborators in designing and leading this study which occurred over two school days in May 2022. Indoor activities included lab work, demonstrations, sharing circles, and lunch. Most co-researchers conducted their interviews outdoors in nature, a few preferred interviewing in a quiet space in the Education Library. We adhered to all the COVID-19 protocols required by the university administration, including wearing face masks and

cleaning our hands often with sanitizer.

The goal was to promote agency and teamwork, so the co-researchers were involved in all technical aspects of connecting their Meta Quest head-mounted displays (HMD) to the Internet, installing application updates, and sanitizing the HMDs using CleanBox technology. The co-researchers were guided and supported in designing with user-friendly VR creation tools (e.g., FrameVR and MultibrushVR) to teach their friends and family about how we can work together to achieve the SDGs. We selected multi-platform creation tools to increase participation and engagement by ensuring people could access the immersive learning experiences using various devices, including personal computers and laptops, mobile phones, tablets, and HMDs.

The co-researchers had access to a spacious classroom equipped with large LED video screens on each wall, a feature which was advantageous for VR demonstrations via screencasting. The resources at their disposal included 15 Meta Quest HMDs, a cart of iPads, and a cart with 30 Dell Latitude laptops (designed to also function as tablets). To accommodate the use of HMDs, they formed two teams and alternated usage of the HMDs for various research purposes. The research and design activities were open invitations to contribute; voluntary participation helped to ensure engagement was driven by interest and willingness. The research team aimed to be inclusive and respectful of traditional knowledge. For example, Indigenous youth were encouraged to utilize immersive storytelling techniques as a means to help express their visions and ideas about a sustainable future. The gentle encouragement was about integrating their views and valuing and acknowledging the richness of their cultural heritage in shaping future narratives.

Table 2. Guided Immersive Adventures in Educational Virtual Worlds.

Description of the Guided Immersive Adventures	Educational Virtual World
"The Ocean" The co-researchers dove into a heavily polluted ocean to swim alongside abandoned human trash and accumulated litter. Group discussions focused on how to prevent and reduce marine pollution.	
"Plastic Mountain" The co-researchers experienced and discussed the hazardous effects of toxic plastic waste and microplastics on the planet, wildlife, fish, and human health.	

"Food Waste" The co-researchers explored the planet's unsustainable cycle of food production, consumption, and waste in our world's unindustrialized and industrialized production regions.	
"The Boreal Forest" The co-researchers were assigned a scavenger hunt to learn about the Taiga Biome ecosystem, including plants, animals, and climate. Myrtle O'Brien, a Traditional Knowledge Keeper, shared her wisdom and teachings.	
"SDGs 2030 Global Agenda" The co-researchers were assigned fun activities and challenging questions to provoke reflection and critical thinking about the well-being of all people and the planet.	

4. Research Methods

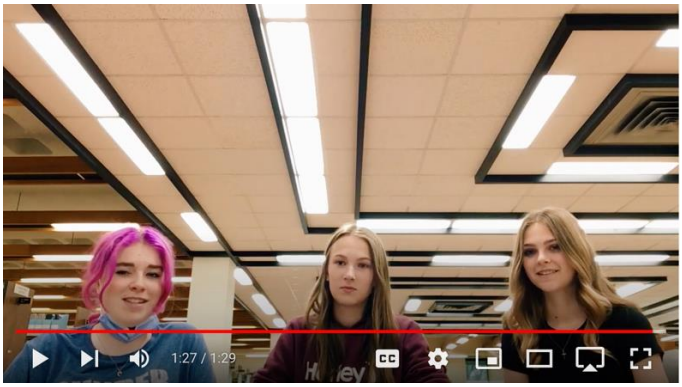
This study employed design-based research methods emphasizing collaborative design (or co-design) to collect a range of qualitative data focusing on how the youth are learning and creating with immersive technologies. The co-researchers faced two design challenges: 1) co-create a compelling message about deforestation using MultibrushVR, and 2) co-create an immersive learning experience concerning SDG #15: Life on Land using FrameVR. The co-researchers worked together to ideate solutions to these challenges and offered technical expertise when needed, fostering a lively and collaborative learning environment.

As a form of participatory research, we selected the co-design approach for its effectiveness in promoting shared ownership and responsibility while ensuring the inclusion of diverse perspectives, knowledge, and values. Co-design helped to cultivate a team-based strategy for generating creative solutions to complex issues like the SDGs, which demand teamwork and collective intelligence to identify and implement positive change (MacDowell, 2021, 2022). As part of the large group activities, we engaged in discussion around Resnick's (2007) kindergarten approach to creative thinking, encompassing a spiraling cycle of imagining, creating, playing, sharing, reflecting, and back to imagining. These conversations aimed to foster a supportive environment for risk-taking, encourage autonomy, and make it clear that creativity is an iterative process requiring effort. The objective was to empower youth voices and highlight their stories, practical solutions, and visions for how we can achieve the SDGs locally and globally.

The data collection methods included student-led pair interviews, sharing circles, surveys, artifact analysis, and direct observation. After we collaborated to finalize the interview guide, the co-researchers used iPads to interview each other, providing them with another leadership opportunity. This peer-to-peer interview approach mitigated potential bias

stemming from interactions with adult authority figures and facilitated the generation of a large dataset in an efficient and timely fashion. Video 1 demonstrates three co-researchers reflecting on the question, “How have you improved because of your collaborations in VR?” They discuss what they learned about deforestation as well as the usefulness and value of developing advanced technology and creative skills.

At the end of the Youth VR Research Camp, the co-researchers individually completed a survey and then participated in a one-hour sharing circle with the entire team to reflect on their learning and creating experiences using immersive technologies. All data were transcribed and stored securely in my DATASTORE account at the University of Saskatchewan. An analysis of all data sources (e.g., interviews, surveys, artifacts, and observations) was completed using NVivo12 to facilitate discovery and further investigation of the data collected with respect to the research questions and problem preidentified.



https://youtu.be/maA2JiKSAb4

Video 1. Three Co-Researchers Interviewing Each Other on Their VR Learning Experiences.

4.1 Research Limitations

The Youth VR Research Camp represents a small-scale, exploratory study that provided a unique educational opportunity for a class of 28 students to create and learn with immersive technologies. Participant bias may have influenced the learning outcomes described by the co-researchers, who may have reported socially acceptable answers rather than what they truly experienced. Due to the subjective and exploratory nature of qualitative research, I cannot claim that the results of this study are universally representative of all eighth-grade students, thereby limiting the data generalizability.

In this article, the author has endeavoured to avoid researcher bias and report the results as authentically as possible. To ensure the validity and reliability of research findings, the research team carefully designed every stage of the study to minimize bias. The reason for choosing a qualitative approach was to generate an open-ended and creative dataset, thereby contributing deep insights not typically collected through quantitative methods. Acknowledging privilege in this research-creation project is necessary, considering the significant number of children and youth worldwide who lack access to immersive learning

environments and basic, reliable Internet connectivity.

5. Results

The approach of the researcher to qualitative data analysis (QDA) was guided by Seidel's (1998) simple and elegant framework for the complex and rigorous practice of QDA. His inductive approach includes an iterative process of "noticing, collecting, and thinking about interesting things" (Seidel, 1998. p. 1). After repeatedly engaging and re-engaging with the dataset, the author thoughtfully selected and organized the findings into three interrelated sections: possibility, flexibility, and capability. Narrative analysis techniques were used to interpret the data to generate meaningful insights and draw broader implications for educators and researchers. The focus was to understand the co-researchers' experiences, perspectives, and understandings of creating using immersive learning technologies, within the context of *Youth VR Research Camp.*

5.1 Possibility

When asked the question, "What would you tell a friend or family member about learning in VR?" the responses of the co-researchers offer a vivid description of the possibilities for immersive learning in classroom settings. Autumn shared her experience by emphasizing the active engagement of senses in the learning process, as opposed to passive learning methods like note-taking, stating, "You can use your hands and eyes for learning instead of just writing stuff down." Christopher underscored the creative possibilities offered by VR, "I would tell them about the creativity that happened there because there are so many different forms of media that we chose to represent" (for examples, see Figure 2). Lana touched upon VR's affordances for perspective-taking while describing the class FrameVR project on SDG 15: Life on Land. She said, "it's really cool cuz you get to look around and see what everyone's perspective on deforestation is." Victor reflected on how VR could help to draw unmotivated students into a subject they are less interested in. He appreciated the diverse possibilities for students to complete assignments and demonstrate knowledge, "In VR, you can express yourself in ways in which you can't in real life." Lastly, Concordia offered her positive endorsement of VR by recommending, "It will make you look at learning in a completely different way. Other teachers need to try it."

Figure 2. Four Artifacts: Public Service Announcement (TikTok video), Forest of Forgotten Secrets (essay), Deforestation (poem), and 8 Fun Facts about Deforestation (infographic).

The survey results in Figure 3 evidence that most of the co-researchers (specifically 88%) agreed or strongly agreed with the statement, "When in VR, I enjoyed being with other classmates." A small percentage (6%) took a neutral stance, while another 6% expressed disagreement, with nobody strongly disagreeing. Similar findings resulted from the statement, "My group was inspiring to work with in MultibrushVR." Most of the co-researchers (specifically 76%) agreed or strongly agreed. 18% maintained neutrality, with the remaining 6% disagreeing and nobody strongly disagreeing.

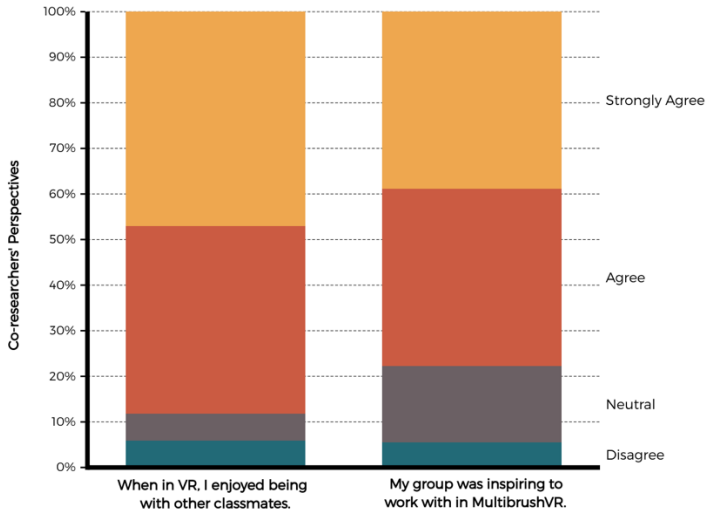


Figure 3. The Co-Researchers' Level of Enjoyment for Learning with Their Classmates in VR.

The survey results can be explained and given context by the co-researchers' reflections on the unique possibilities of teamwork and working with classmates in VR. Savanah reported her enjoyment in MultibrushVR with her peers: "It was very interesting. And you could work together, to make art with your classmates in like a virtual world." Emma highlighted the necessity of teamwork to achieve a quality final product, noting, "I've gotten better at teamwork because you have to work together to make something that's okay." Cassidy echoed a similar reflection about collaborative creativity, "I was able to express myself and create art with my classmates." Lily cherished the bonding time with friends in VR, "I think my favourite part about the VR learning was when I got to connect with my friends through the VR, and we were able to share our learning experiences together." Nadia was fascinated with the team aspect of MultibrushVR, "I loved getting to create art that was 3D and being able to collaborate with my classmates." Leonardo appreciated the collaborative possibilities of VR, remarking, "I liked how you could collaborate with other people. You could just be in the same room and just play around with it. It was a great opportunity, and I'm glad I got to do it."

5.2 Flexibility

The survey results in Figure 4 evidence that most co-researchers (specifically 88%) agreed or strongly agreed with the statement, "I had freedom to make decisions about my learning in VR." A small percentage (6%) took a neutral stance, while another 6% expressed disagreement, with nobody strongly disagreeing. Similar findings resulted from the statement, "VR helped me to express myself creatively." Most co-researchers (specifically 76%) agreed or strongly agreed. 18% maintained neutrality, with the remaining 6% disagreeing and nobody strongly disagreeing.

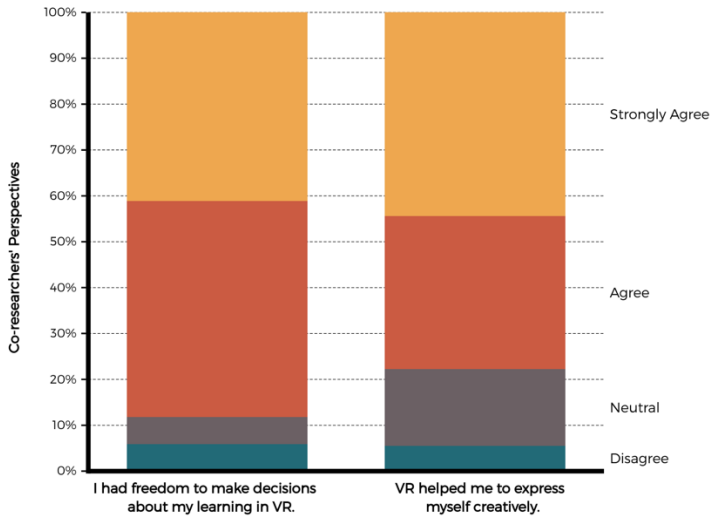


Figure 4. The Co-Researchers' Experiences of Flexible and Creative Learning in VR.

The survey results can be explained in depth by the co-researchers' reflective responses to the open-ended question, "What was your favourite experience with VR for learning? Everdeen valued the freedom to learn by exploring in VR, "I enjoyed going on the field trips to the ocean as well as the forest where we were really small. It was really cool going to these places because in real life we would not be able to." Nadia beautifully expressed her thoughts about VR, "just looking out different worlds and seeing how our world is connected through it." Zion shared a memorable takeaway from a virtual dive, "When we dove into the ocean. I was able to see how our waste affects the fish and marine life." Similarly, Jack noted the affordances for contextualized and experiential learning in VR, "My favourite experience was creating and being in an environment where you could not go in a normal classroom." Clara envisioned a bright future for immersive education, "I believe that if other classrooms were given this opportunity, then it could be good for them to see what we saw in the different VR field trips." Quandale remarked on his embodied interactions and VR superpowers, "Being able to experience things I couldn't do in real life like touching whales and flying." Finally, Leonardo highlighted the ease and depth of learning in VR,

> I'd say that in VR field trips, the few that we did, they were a lot easier to move around there and learn about the area because there are really no limits. If you have a field trip in real life to learn about sustainability, you have certain limits that you don't have in VR. You can learn faster in VR and just absorb things better in there because of the environment that it is.

Video 2 gives insight into the lively and active experiences of the co-researchers while they collaborated on their design challenge in MultibrushVR. Janet appreciated the autonomy offered by learning in VR, "you have a lot of freedom, and it really was all up to you, and you get to decide what you want to do." Lily explained how VR helped her to express herself creatively, "Painting with Multibrush changed the way I experienced art, mostly because I could create whatever I want in 3D." Turtle voiced his appreciation for self-directed learning, noting, "With the VR learning, my favourite experience was the fact that we had the freedom to roam around freely and being able to express yourself in ways in which you can't in real life." Greg reflected on the flexible and creative learning opportunities afforded by MultibrushVR, "My favourite part was probably getting to create art while learning at the same time." Evan emphasized the limitless potential of VR as a learning tool, stating,

> VR only opens doors. It doesn't really close any doors. And it's a great way to learn, not only about your ecosystem, but about every ecosystem on the planet and off the planet. I really hope that soon every class or school will have a set of the VR headsets. So, everybody can experience what we have experienced.

https://youtu.be/H3zpqW6Jn3g

Video 2. The Co-Researchers Co-Designing in MultibrushVR with Their Classmates.

5.3 Capability

The survey results in Figure 5 evidence that a significant majority of the co-researchers (specifically 94%) agreed or strongly agreed with the statement, "I would like to learn more about the SDGs in VR." A small percentage (6%) took a neutral stance, with nobody disagreeing or strongly disagreeing. Similar findings resulted from the statement, "I consider VR learning useful to my future." Most of the co-researchers (specifically 76%) agreed or strongly agreed. 18% maintained neutrality, with the remaining 6% disagreeing and nobody strongly disagreeing.

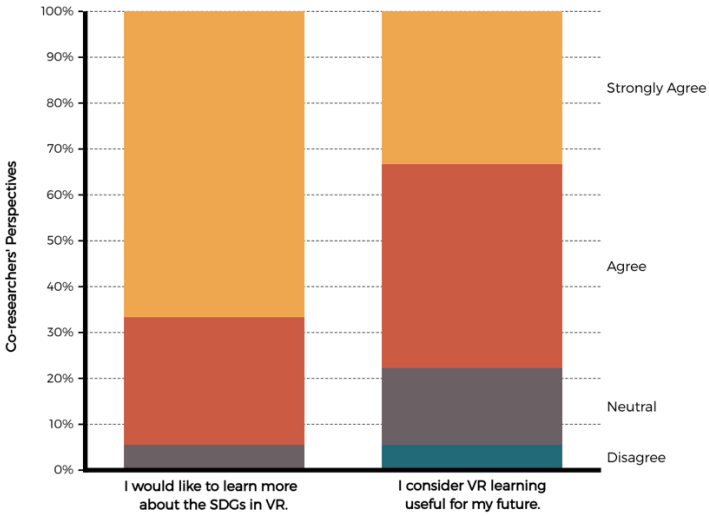


Figure 5. The Co-Researchers' Level of Interest in Future VR Learning.

The co-researchers' responses to the question "What was your least favourite experience with VR for learning?" indicate two primary challenges for immersive learning in classroom settings:

technical challenges and the experience of dizziness in the HMDs. Cooper mentioned there were no major issues, but a minor problem was connecting the HMD to the Internet, "It was logging into the WiFi lol, actually nothing." Greg voiced similar reflections on minor technical issues, "My least favourite part was trying to figure out how to use the remotes." Bery experienced hardware problems, "My headset wasn't working, but other than that nothing." On the topic of physical discomfort, Amelia stated, "My least favourite part was that after a while, it kind of hurt my eyes, and I started feeling a bit uneasy." Nadia experienced vertigo, "After a while, I got really dizzy but it was great other than that." Victor had a similar experience with vertigo, "I did get a little dizzy at the very end, but I think that was just due to the time that I was in the VR." Leonardo faced slight discomfort due to a long session in VR without taking any breaks, "In the VR headset, my head only started to hurt a little because I'd been looking at it for like an hour and a half, but other than that, it was fine."

When asked, "Were there any moments in the VR learning that challenged you?" The co-researchers offered thought-provoking responses that differed from technical issues or dizziness in the HMDs. Their reflections describe the enhanced capabilities that immersive learning experiences can foster. For example, Sabrina provided an insightful perspective on how immersive learning can deepen students' understanding of environmental issues, noting,

> Moments that challenged me were actually seeing how much garbage there was in the ocean and actually seeing how people are affected by like the flooding of houses or like the flooding of the community, and actually being there and seeing how much it is affecting people in the environment.

The VR experience appears to have pushed Sabrina to engage with the SDGs in a more critical and personal way. It seems to have bridged the gap between her theoretical understanding of environmental crises and lived experience, which can be a powerful catalyst for learning and action. Clara further analyzed the capability of VR as a pedagogical tool for teaching complex, multidimensional problems like the SDGs, which require empathy and understanding of other points of view. Clara reflected,

> VR makes you relate to sustainability issues. Like it's hard to empathize with situations that are so far away, like across the world, but when you're in VR you feel like you're really there. So, it's easy to connect with the issues. VR would definitely help citizens become aware and empathize with other people.

Thinking critically, Leonardo began to analyze the costs of immersive learning, "VR is good for raising awareness about environmental issues and teaching about sustainability, but there must be some sort of environmental cost for the materials that make a VR headset." Christopher commented on the capabilities of VR for teaching about the SDGs, reporting, "VR gave a close-up view of what's happening. One time Dr. Paula took us to the ocean where there's lots of plastic and sea creatures are dying because of that. We were able to learn all that through VR." Autumn offered insights into how VR can aid sustainability efforts, explaining,

> We got to see beautiful forests in FrameVR, and we got to see how it used to be. And then we came back into reality or out of FrameVR, and we saw the difference of the beautiful natural forests. So, it [FrameVR] could really support sustainability because it can show us what we're missing out on and what we can do to help deforestation.

Figures 6 and 7 display screenshots of the co-researchers' FrameVR world to demonstrate their creative engagement with SDG 15: Life on Land. This immersive experience is accessible at https://framevr.io/ecojustice, allowing others to view the co-researchers' learning artifacts and understand their environmental perspectives.

Figure 6. The SDG 15 Immersive Learning Experience, Co-Designed in FrameVR (View 1).

Figure 7. The SDG 15 Immersive Learning Experience, Co-Designed in FrameVR (View 2).

6. Next Steps for Immersive Education in the Classroom

The insights gathered from the co-researchers contribute to an understanding of the affordances and constraints of immersive education. Given this knowledge, researchers propose five pathways to improve and integrate immersive learning in classroom settings. By collaboratively addressing these next steps, so that educators can shape a future where VR can augment the classroom experience, opening up new possibilities for self-directed learning and creative thinking.

6.1 Promote Creative Problem-Solving

The experiences shared by the co-researchers emphasize the value of VR in fostering collaboration and creative problem-solving skills. Teachers can leverage immersive technologies to foster creativity in their classrooms by assigning students to co-design VR projects with peers that address tangible, real-world challenges like the SDGs. The co-researchers noted how VR made them think critically and creatively about the complexities of global issues like deforestation. Their interest in learning more about the SDGs through VR signals a promising path for using immersive technologies to cultivate global citizenship. Furthermore, teachers can also create immersive learning experiences, allowing students to explore and interact with the material at their own pace, thus fostering an environment conducive to self-directed learning.

6.2 Enhance Usability and Physical Comfort

The two main issues that emerged from the co-researchers' experiences were technical difficulties and physical discomfort. To mitigate these issues in classroom settings, it would be helpful to streamline the technical setup and provide clear instructions during the virtual onboarding. I recommend that educators schedule frequent breaks in VR learning sessions; all students must remove their HMDs during this time. While this may temporarily disrupt the flow of learning, it will help ensure student wellness and minimize the dizziness and vertigo that happens from prolonged usage. These breaks present a good opportunity to check that students have adjusted their HMD for optimal fit. Additionally, VR companies and manufacturers should prioritize the comfort and ergonomics of their HMDs and develop user-friendly VR devices suitable for the needs of young learners, including the secure handling of biometric data and preventing its misuse.

6.3 Increase Access to Immersive Learning Technologies

While most co-researchers expressed a high level of enthusiasm for future VR learning, its widespread integration into broader educational contexts is restricted by the cost of VR educational applications and the limited availability of HMDs. Productive partnerships between educational institutions and tech companies could help to develop cost-effective solutions, thereby expanding access to immersive technologies in schools. Cleanbox sanitation technology has made it safe to share HMDs, so a single set of headsets could benefit an entire school. I want to acknowledge leading-edge companies like FrameVR, which offers a generous free trial plan, enabling students and teachers to experiment with immersive technologies. FrameVR lowers the entry barrier as HMDs are not required. At the same time, there is a high ceiling for students to build immersive environments and demonstrate their knowledge in new ways (e.g., beyond writing essays or making slide presentations).

6.4 Provide Teacher Professional Development and Ongoing Support

Meaningful immersive education in classrooms is contingent on effective teacher training and support. Pre-service teachers need opportunities to create and explore immersive technologies in Teacher Education Programs, where they can learn how to integrate immersive experiences into

their teaching practices. In-service teachers need professional development and ongoing technical and pedagogical support. We need supportive networks dedicated to K-12 and higher education instructors from diverse backgrounds and countries. These online communities can provide opportunities for practitioners to discuss their experiences, collaborate on projects, report best practices (e.g., lesson plans, assignments, and assessment strategies), and share their resources for world-building (e.g., 3D models, textures, and assets).

6.5 Continue Research in Classroom Settings

To validate the benefits and impacts of immersive learning, ongoing research should be conducted to assess student learning outcomes and transfer of knowledge. This research should involve qualitative and quantitative studies in both controlled laboratory and real-world classroom settings. Longitudinal research is needed to understand the immediate effects of immersive education and the longer-term impacts on students' understanding, engagement, creative thinking skills, and attitudes toward learning. Further research should investigate how educators can adapt immersive education to diverse academic disciplines and age groups, with a clear intention of addressing specific learning challenges within the classroom (e.g., the application of immersive learning should always be driven by a clear purpose).

6. Conclusion

Overall, results from this study indicate that youth enjoy co-designing immersive learning experiences and show a keen interest in learning more about the SDGs in VR contexts. This finding corresponds with the growing body of literature evidencing immersive education's positive influence in enhancing learner engagement, fostering empathy, promoting embodied interaction, and developing learner autonomy. A logical next step is expanding this research to include a more diverse range of classes from schools worldwide. I recommend future studies adopt a participatory co-design approach, emphasizing the creation of immersive learning environments designed by youth, for youth, and as a result, resonate more profoundly with adolescent learners. The goal is not to create the most visually stunning and awe-inspiring virtual worlds but to foster authentic, student-driven learning opportunities. We need to make the SDGs more tangible and relatable to children and youth, enabling them to engage with the global goals on their terms, in their ways, and from their unique perspectives.

Accelerating progress on the SDGs demands new strategies and creative ideas. Future solutions will come from today's students who have been encouraged to be creative thinkers and have received an education that motivates them to address environmental and sustainability issues in collaboration with other citizens. Scalable projects, such as the one featured in this study, demonstrate how youth can leverage immersive tools to contribute to creating a more equitable and sustainable world. Moreover, fostering creativity holds inherent value for human flourishing and well-being. Cultivating creative abilities and mindsets can enhance the quality of life for students and unleash their potential— as one of the co-researchers exclaimed, "VR let my creativity out!" This study is a testament to the meaningful learning opportunities that exist at the intersection of immersive technologies, creative thinking, and sustainability education.

Data Availability Statement

The datasets generated and analyzed in this article are not publicly available due to confidentiality agreements with participants. Requests to access the datasets should be directed to the corresponding author: paula.macdowell@usask.ca

Ethics Statement

The University of Saskatchewan Behavioural Research Ethics Board reviewed and approved this study involving human participants. Application ID: 3023. Approval date: 9 December 2021. The Greater Saskatoon Catholic Schools (GSCS) school division reviewed and approved the study on April 2022. Written informed consent to participate in this study was provided by the participants (assent) and their legal guardian/next of kin (consent).

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