Applying a Constructivist Approach to Designing Virtual Reality Experiences that Facilitate Authentic Learning for Adolescents

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This article explores how constructivist learning theory can be applied to the design of virtual reality (VR) experiences aimed at fostering authentic learning opportunities for adolescents. As VR becomes more common in educational settings, it is beneficial for educators and instructional designers to carefully consider how learning theories and pedagogical strategies influence the learning process and outcomes. Moreover, understanding and integrating student *perspectives is necessary to ensure VR education is relevant and meaningful. To study student experiences in a VR-enhanced classroom built on constructivist pedagogy, a class of 28 eighth-grade students (ages 12 to 14) participated in two days of VR learning, which included authentic tasks, social interaction, and knowledge-creation activities using FrameVR and MultiBrushVR. Qualitative methods were employed using pair interviews, in which the students questioned each other about their personal experiences in learning, creating, and sharing VR artifacts. The findings revealed the VR environments provided substantial opportunities for adolescents to develop and practice skills such as collaboration, empathy, creativity, and problem-solving. The study contributes to the field of applied instructional design by demonstrating how constructivist principles can be applied in VR-enhanced classrooms to support authentic learning experiences for middle-school students.*

Introduction

Virtual reality (VR) is gaining momentum as a useful technology for facilitating authentic learning experiences which may not otherwise occur in traditional K to 12 classrooms due to limitations in resources, geographical constraints, and the inability to simulate real-life situations effectively (Araiza-Alba et al., 2021; Southgate, 2020; van der Meer et al., 2023). Often, the mandatory school curriculum prioritizes the acquisition of content knowledge and lacks the practical contexts necessary for authentic learning of school subjects and the practice of skills students need to thrive in life and future careers (Soares et al., 2017; USAID, 2019; Wats & Wats, 2009). VR offers an interactive platform for students to deeply engage with the subject matter to construct knowledge and practice essential skills like critical thinking, collaboration, empathy, creativity, and problem-solving (Bertrand et al., 2018; MacDowell, 2022; Thornhill-Miller & Dupont, 2016). The rising implementation of VR in educational contexts highlights its potential to surpass traditional classrooms' limitations, immersing students in authentic and hands-on learning experiences (Lowell & Tagare, 2023; Thompson et al., 2018). Integrating VR within the complexity of contemporary classroom settings, particularly with large and diverse student cohorts, must be guided by both theory and practice to leverage educational affordances and mitigate constraints. Existing research is dominated by small-scale lab studies or quantitative analyses, hence the need for studies with more in-depth pedagogical strategies to engage an entire class (Fowler, 2015; MacDowell & Lock, 2022; Southgate, 2020).

This article addresses this gap in the research literature by introducing a framework which connects constructivist learning theory with practical considerations for educators and instructional designers in developing VR-enhanced classrooms for middle-school students. It then presents grade 8 students' narratives of their VR experiences, segmented into four key sections of skill-based learning, including collaboration, empathy, creativity, and problem-solving skills. The students' rich and detailed qualitative data provides valuable insights into the complexities of VR learning in classroom settings, offering practical knowledge beyond the scope of controlled lab studies. Following this, the article discusses the study's limitations and provides recommendations for designing VR experiences to align with constructivist principles and student perspectives. The aim is to bridge the gap between theory and practice for skills-based learning within VR, emphasizing the development of essential human skills today's students need to thrive in school and beyond.

Designing Constructivist VR-Enhanced Experiences for Authentic Learning

Building on the research of Aiello et al. (2012) and Huang et al. (2010), which utilized a constructivist framework to harness the potential of VR technologies in school contexts, we explore how VR can engage adolescents in authentic and meaningful learning. Constructivist theory positions the learner as someone who elaborates upon and interprets information from their physical and social environments to construct knowledge using an active, effortful, and mindful process —beyond passively receiving content from their teacher (Driscoll, 2005; Ertmer & Newby, 2013). Pioneers such as John Dewey (1859-1952), Jean Piaget (1896-1980), Lev Vygotsky (1896-1934), Jerome Bruner (1915-2016), Ernst Von Glasersfeld (1917-2010), and Seymour Papert (1928-2016) were all instrumental in developing constructivism into the learning theory it is today. While historically dominated by male scholars, modern contributions by female scholars like Jacqueline Grennon Brooks (1999), Barbara Rogoff (1990), and Eleanor Duckworth (2006) have significantly advanced constructivist learning theory.

Traditionally, VR instruction has focused on skill acquisition through simulated training. However, constructivist approaches, which emphasize learning in context, can offer a more meaningful educational use of VR (Aiello et al., 2012; Huang et al., 2010). Dewey (1997/1933) believed learning should be authentic and applicable to daily life, viewing knowledge acquisition as an active process of being experimental and experiential in the learning environment. VR is particularly suited to providing authentic and relevant learning experiences due to its capacity for unique, first-person interactions (Lowell & Tagare, 2023; MacDowell, 2022; Southgate, 2020). The effectiveness of constructivist learning depends significantly on the context, and VR offers boundless opportunities for creating immersive teaching and learning environments accessible through head-mounted displays (HMD) and desktop applications. To facilitate authentic learning, educators and instructional designers using VR with adolescents should thoughtfully consider how VR experiences can be enhanced by applying the big ideas and core concepts of constructivist theory (e.g., Brooks, 1999; Bruner, 1966; Dewey, 1997/1933; Duckworth, 2006; Glasersfeld, 1984; Papert, 1980; Piaget, 1954; Rogoff, 1990; Vygotsky, 1978).

Synthesizing our extensive experience working with students in VR environments, we developed a constructivist VR framework to connect theory to practice. This framework, outlined in Table 1, identifies the key principles and practices which support constructivist learning. It contributes to an understanding of how adolescents construct knowledge within the dynamic and complex settings of VR-enhanced classrooms. By applying this guiding framework, educators and instructional designers can leverage VR's affordances to foster authentic and meaningful learning experiences for middle-school students.

Table 1

Constructivist Theorist’s Big Idea Applied to Designing VR Experiences for Authentic Learning

Constructivist Theorist’s Big Idea	Connecting Theory to Practice
John Dewey Inquiry and problem-based learning in rich contexts are ideal (Dewey, 1997/1933).	• VR scenarios should be designed to allow students to explore abstract ideas in meaningful ways which connect life experiences with the learning process. • Students can engage in VR scenarios which promote inquiry and serve as building blocks for the ongoing construction of knowledge.
Jean Piaget Cognitive development is an outcome of a student’s active cognitive construction process. New knowledge builds on previous knowledge as learning is refined through exploration and individual meaning construction (Piaget, 1954).	• VR should be designed or selected with awareness of students’ prior experiences. • VR content can be tailored to align with the student’s cognitive development stages, ensuring experiences are challenging yet scaffolded based on their existing knowledge.
Jerome Bruner Students create knowledge by categorizing and organizing information in	• VR can provide a scaffolded learning environment where teachers offer guidance when needed, but students

a self-discovered mental coding system. Students benefit from the help of more knowledgeable people or instructors (Bruner, 1966).	have the autonomy to explore and make decisions. • VR scenarios can be designed as progressive challenges which continue until the instructional content or problem has been mastered.
Lev Vygotsky Social interaction and communication are an integral part of learning, cognition, and the critical thinking process (Vygotsky, 1978).	• If appropriate to the learning objective, group activities within VR can foster shared understanding and collaborative problem-solving. • Social VR experiences can enhance collaboration and communication by allowing students to interact with each other in a virtual environment.
Seymour Papert Learning is most effective when the student is constructing something for others to see. Papert expanded upon constructivist theory to develop constructionism (Papert, 1980).	• VR can be designed as a playground for students to collaborate on meaningful VR projects to showcase their understanding. • Students can use VR to tinker, build, and complete projects aligned with their interests, fostering a sense of ownership and motivation.
Ernst Von Glasersfeld Cognition is responsible for every type or kind of structure a student comes to know (Glasersfeld, 1984).	• In VR, students can express their understanding by designing virtual artifacts, presentations, or simulations representing their knowledge and unique perspectives. • Students can use VR as a canvas or creative space to exhibit their cognitive processes (e.g., making decisions, understanding, and reasoning).
Barbara Rogoff Cognition is situated in specific contexts and learned through engagement in socio-cultural activities (Rogoff, 1990).	• Socially guided VR activities can mirror contexts in the physical world, promoting a deeper understanding of cultural influences. • VR should allow students to learn through observation and

	collaboration with peers, with technical support available.
Jacqueline Grennon Brooks Cognition is situated in specific contexts and learned through engagement in socio-cultural activities. Students construct knowledge by reformulating how they see the world (Brooks, 1999).	• VR environments can be designed to adapt to students' evolving understanding, provide dynamic feedback, and allow students to negotiate and make sense of their learning. • Reflection within VR can be facilitated to encourage students to reflect and make sense of their experiences and interactions.
Eleanor Duckworth Learning happens through critical exploration. Students must construct knowledge and assimilate new experiences in ways that make sense to them (Duckworth, 2006).	• VR projects can empower students to conduct independent research within the virtual environment, fostering critical thinking skills. • Hands-on VR activities can stimulate curiosity and prompt students to question and challenge their preconceptions and existing knowledge.

Research Design and Methods

This study's constructivist VR-enhanced learning experiences were designed to support authentic learning, social interactions, and knowledge-creation activities (Olson, 2023). The study participants included a class of grade 8 students (15 female and 13 male) aged 12 to 14 with varying levels of experience and skills in VR. To offer equitable learning experiences, every student participated in a fun and comprehensive 90-minute Meta Quest training session, which included instruction on how to use the controllers. Engaging in a 2-day VR workshop, they experienced teacher-guided field trips in AltspaceVR virtual worlds, including The Ocean, Plastic Mountain, Food Waste, and SDG Global Agenda. Unfortunately, Microsoft shut down AltspaceVR on 10 March 2023, so these educational worlds are no longer available to the public. The students completed team design challenges using FrameVR and MultiBrushVR, with the goal of teaching friends, family, and the local community about deforestation from a youth perspective. To achieve a manageable instructional size, the class was divided into two groups, alternating between team design challenges in FrameVR (using desktop computers in the university library) and MultiBrushVR (using Meta Quest HMDs). The grade 8 class was studying a unit on deforestation; the field trips and learning experiences for the 2-day VR workshop were carefully selected to align with the school curriculum. The schedule of team and whole group VR learning experiences and data collection activities is detailed in Table 2.

Table 2

Schedule of Team and Whole Group VR Learning Experiences and Data Collection Activities

Time	VR Learning: Team 1	VR Learning: Team 2
DAY 1		
9:00 – 10:00	• Introduction to Educational VR	
10:00 – 11:30	• HMD onboarding with Meta First Steps game; Teacher-guided field trips in AltspaceVR virtual worlds	• FrameVR team design challenge: begin project (desktop VR)
11:30 – 11:45	• Break	
11:45 – 12:15	• Pair interviews (iPads)	
12:15 – 1:00	• Group lunch; sanitize HMDs	
1:00 – 2:30	• FrameVR team design challenge: begin project (desktop VR)	• HMD onboarding with Meta First Steps game; Teacher-guided field trips in AltspaceVR virtual worlds
2:30 – 3:00	• Conclusion: Group debrief and sanitize HMDs	
DAY 2		
9:00 – 9:15	• Introduction	

9:15 – 10:45	• FrameVR team design challenge: complete project (desktop VR)	• MultiBrushVR team design challenge (HMDs)
10:45 – 11:00	• Break; sanitize HMDs	
11:00 – 12:15	• MultiBrushVR team design challenge • (HMDs)	• FrameVR team design challenge: complete project (desktop VR)
12:15 – 1:00	• Group lunch	
1:00 – 1:30	• Individual surveys completed on paper	
1:30 – 2:00	• Celebration and presentation of team design projects	
2:00 – 2:45	• Sharing circle and open reflection on the VR learning experiences	
2:45 – 3:00	• Conclusion: Clean up and sanitize HMDs	

The onboarding phase involved students connecting their HMDs to the Internet and ensuring they understood how to use the controllers by completing the First Steps game, a free tutorial designed by Meta for those new to VR (Figure 1). Once a basic level of familiarity was achieved with navigating in VR, the students were challenged to explore the creative features of FrameVR and MultiBrushVR. They were guided by an instructional manual we developed specifically for grade 8 students; two instructors were available to troubleshoot HMDs and ideation. The FrameVR team project focused on co-designing an immersive experience to educate friends, family, and the local community about the United Nations' Sustainable Development Goal (SDG) 15: Life on land. Leveraging FrameVR's capabilities, the adolescents showcased their learning by creating and sharing multimedia artifacts, including posters, poems, photos, and TikTok videos. The MultiBrushVR team design challenge aimed to convey a compelling message about deforestation from the perspectives of grade 8 students. The students collaborated in real-time 3D art creation and presented their work in a VR art gallery accessible to family and friends through HMDs, laptops, or cell phones.

Figure 1

Grade 8 Students Learning How to Use Meta Quest HMDs and Controllers

The study employed qualitative data collection methods, encompassing pair interviews and open-ended surveys (Creswell & Creswell, 2018). This research was conducted during two school days, between 9 am and 3 pm, for 12 hours of research and learning activities with the students. On the first day, students partnered up (or formed groups of three) and went outside (it was a beautiful sunny day) to conduct interviews based on their reflective questions and an interview guide about the VR workshop activities (Appendix A). Utilizing pair interviews generated highly detailed and descriptive feedback from the students who were invited to reflect on their VR learning experiences, with the least amount of influence from the researchers and in a relaxed outdoor setting (MacDowell, 2023; Olson, 2023). On the second day, students individually completed anonymous surveys, followed by a whole group sharing circle to gain additional insights from the adolescents. NVivo software was utilized to store and analyze all the qualitative data, facilitating an organized approach to coding and generating themes aligned with understanding the primary research question: How can constructivist VR approaches foster authentic learning of skills?

To ensure the rigor of the qualitative study with the grade 8 students, three researchers checked the transcripts to ensure the analysis included verbatim accounts and quotes from interviews and surveys for an authentic representation of the adolescents' perspective (Creswell & Creswell, 2018). In addition, different types of qualitative data were collected (e.g., pair interviews, observations, open-ended surveys, and artifact analysis of the team design challenges) to triangulate findings and strengthen the trustworthiness of the study results (Mathison, 1988). We practiced strong objectivity while collecting, analyzing, and interpreting data to report ethical and trustworthy findings that make sense of the adolescents' individual and collective experiences (MacDowell, 2023; Olson, 2023). The data analysis led to the identification of four interconnected skills developed by the students during the two days of VR learning:

1. Collaboration: Students' ability to work as a team to achieve learning outcomes (van der Meer et al., 2023).
2. Empathy: Students' ability to perceive the emotions of others and adopt different perspectives (Bertrand et al., 2018).
3. Creativity: Students' ability to conceptualize and generate original ideas (Thornhill-Miller & Dupont, 2016).
4. Problem-solving: Students' ability to identify challenges and devise flexible solutions (Araiza-Alba et al., 2021).

The following four sub-sections synthesize the study findings to explore how a constructivist VR approach can facilitate authentic learning opportunities for adolescents to practice and develop skills. These skills are commonly known as soft skills, power skills, or essential skills, encompassing a “broad set of cognitive, social, and emotional competencies that affect how children and youth interact with each other, solve problems, make decisions, and feel about themselves” (USAID, 2019, p. 1). These skills lay the foundation for adolescents to flourish in their personal lives, academic pursuits, and future workplace settings (Soares et al., 2017; Wats & Wats, 2009). By highlighting the participants’ reflections and insights, using their words and expressions, this study addresses the literature gap on underrepresented student perspectives on VR learning within classroom settings (Araiza-Alba et al., 2021; MacDowell, 2023; Olson, 2023). Pseudonyms are used for all research participants to ensure the students' confidentiality and anonymity.

Authentic Learning Opportunity 1: Adolescents Developing Collaboration Skills in VR

According to van der Meer et al. (2023), collaboration skills encompass the ability to work as a team and deal with conflict to achieve learning outcomes. Peer collaboration was an essential element of this study's constructivist VR learning environment, guided by Driscoll’s (2005) understanding that cognitive development is fostered through social interaction. Many students reported a noticeable improvement in collaboration skills from the VR learning experiences during the 2-day workshop. 56% of survey respondents identified MultiBrushVR collaborations as their preferred VR learning activity, demonstrating how the adolescents enjoyed co-creating virtual art. Katrina expressed her positive experience, “My favorite 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.” Savanah echoed similar thoughts, emphasizing the joy of collaborative art creation in MultiBrushVR: “It was very interesting. And you could work together, to make art with your classmates in like a virtual world.” Emma highlighted the synergy of collaboration in MultiBrushVR: “I’ve gotten better at teamwork because you’ll have to work together to make something that’s okay.”

The SDG world visited by the class in AltspaceVR incorporated playful interactive objects the students enjoyed while completing the scavenger hunt challenge. Learning about the SDGs is challenging and complex due to the vast scope of global issues they encompass (United Nations, n.d.). The SDG world facilitated a positive framing of this instructional topic, and the presence of others contributed to learning from different points of view. For example, Clara noticed how VR invites opportunities for discussing complex issues, “I would say that VR lightens the mood around heavy topics such as the SDGs and how badly it’s affecting people.” Similarly, Leonardo commented on the SDG world, “It was teaching about the effects of climate change. And there was a basketball hoop, and I got to play a round with my friends on that once we were done learning about it.” Several students appreciated the freedom to socially negotiate interactions in VR as a positive aspect of their learning experience (Thompson et al., 2018). Christopher felt a sense of adventure, “I felt I had more freedom to roam around … go places, talk to some people.” Kiera also discussed the unique communication opportunities: “You get to talk to different people, which is cool because I don’t think you see that often, you know? And I thought it was cool that I was able to communicate with my class.”

While the opportunity to socially negotiate learning (Driscoll, 2005) had transformative moments for some students, others became distracted, focusing on fun rather than learning. Kiera cautioned, “You have to make sure with the VR that it’s strictly used for education and everything in that world doesn’t get blown out of proportion.” Clara added a perspective on the maturity required, noting, “And a lot of people wouldn’t have the maturity to deal with this right now, which is why it might be a problem teaching other classes.” Our study revealed varying levels of focus during the class field trips, with one group seamlessly navigating virtual worlds while the other faced challenges due to distractions from all the exciting stimuli. There is a delicate balance in designing collaborative VR experiences, as some groups may need help prioritizing learning activities over recreational ones. Consequently, students may only sometimes be accurate or responsible in discerning their learning needs in constructivist VR settings (Aiello et al., 2012; Huang et al., 2010).

Authentic Learning Opportunity 2: Adolescents Developing Empathy Skills in VR

Empathy is a significant aspect of Bruner’s (1966) work on constructivism, stemming from his experience of being blind for the first two years of his life. His early visual impairment influenced him to have empathy and optimism for learners who are challenged at any stage of their development (Jari & Pekka, 2018). Empathy is the ability to perceive the emotions of others and adopt different perspectives (Bertrand et al., 2018); empathy resonated deeply in the grade 8 students’ reflections. They discussed VR’s capacity to immerse them in a virtual space and allow them to actively experience environmental and sustainability issues rather than passively learning facts and information typical in a traditional classroom setting (Soares et al., 2017; Wats & Wats, 2009). Lennon considered the critical role of immersion in fostering empathy, “Sometimes when you’re not in VR, you don’t really see what’s happening in front of you. But when you’re in VR, you’re able to see what people are actually going through and therefore … you care more.” Concordia added that physically embodying a space creates a more authentic learning experience, stating, “When you’re there and experiencing it, you’re automatically going to care because it’s triggering more in your physical self than just your mind, right? It’s triggering your heart and your emotions, and that affects you.”

Christopher provided insights into how VR can nurture empathy for marine life affected by ocean pollution. After a virtual swim with his classmates in an ocean filled with plastic debris, he exclaimed, “Sea creatures are dying because of that!” Concordia agreed, “When we go in VR, and we’re actually swimming in the ocean, filled with garbage, something you could never do in a classroom, it impacts how you feel about the environmental issue because you are experiencing it.” Savanah shared empathy for the marine mammals negatively impacted by pollution, stating, “I think in the ocean life, specifically, that world, seeing the animals caught up in the plastic. Yeah. That just really affected me.” In addition to empathizing with life in ocean environments, the adolescents described how VR facilitated empathy for life on land. Hailee explained, “It actually gives you a visual because if people are just telling you, trees are burning down and trees are getting cut down, you can’t really picture what the scene looks like.” Sabrina reflected, “Places that are strongly affected by like deforestation and stuff like that, and you actually go to that place, it makes you care much more about it than you would just looking at pictures or talking about it.”

Overall, the adolescents found the experience of navigating the SDG worlds in AltspaceVR to be authentic and meaningful learning (Thompson et al., 2018). Along with recognizing the impact of exploring different virtual worlds, they suggested that VR’s active involvement of students challenged them to change their perspectives and helped foster respect and connection with others (Aiello et al., 2012). Sabrina summarized this finding, “Moments that challenged me was actually seeing how much garbage there was in the ocean and actually seeing how people are affected by the flooding of houses or the flooding of the community and actually being there.” Similarly, Autumn expressed, “It’s a lot easier to learn about topics like that because you get to experience firsthand what it is about.”

Authentic Learning Opportunity 3: Adolescents Developing Creativity Skills in VR

Creativity is widely acknowledged as a fundamental human skill in personal expression, innovation, and the ability to adapt to an ever-changing world. Fostering creativity is a central focus in various domains of education and industry as it signifies the ability to conceptualize and generate original ideas (Thornhill-Miller & Dupont, 2016). Diverse responses evidenced how making art in MultiBrushVR (accessed through the HMDs) impacted the students’ creativity skills. The MultiBrushVR environment provided novel materials and tools, realistic and unrealistic, to spark adolescent creativity and unleash imagination. For example, an anonymous survey response reported, “I was able to tap into my artistic side. I never really knew I had.” Damien reflected on how his drawing skills changed, “I’ve really improved in drawing because I’m a really bad drawer.” Sabrina emphasizes the collaborative aspect of creating in MultiBrushVR with peers, “When we were just experimenting with the MultiBrush that was really fun, with my classmates, just experimenting and making artworks and stuff.” Autumn considered the novelty of the VR experience, “It was really, really cool to be able to use my hands or use my eyes instead of just writing stuff down, drawing stuff, with a pencil or pencil crayon.”

The adolescents appreciated the creative avenues in FrameVR for expressing their knowledge and understanding of environmental issues. Amelia shared her creative experience, stating, “FrameVR has that way of that creativity where you can create your own world and worlds.” Kiera added that in FrameVR, “We saw how you could create things and the whole new world you were in. It was really fun, and getting to also participate in the creation of that was a really cool experience.” Lana said she would give her friends the following advice, “I would tell them how creative you can be in virtual reality because it’s not real. You can do whatever you want pretty much.” Overall, the grade 8 students were motivated by the innovative ways to contribute to the class Frame VR project, appreciating the platform's scalability for students to design artifacts and immersive experiences that represented their ideas and visions of environmental issues and sustainable living (MacDowell, 2023; Olson, 2023). We observed how both desktop VR and HMD applications have distinct affordances and constraints for facilitating collaboration, social interaction, and ingenuity (see Table 2 for a breakdown of the desktop VR and HMD activities).

While VR enhanced the opportunities for unlimited creative freedom, instructors should keep the design challenges simple and specific at the beginning. The goal is to scaffold the learning so students can discover their creative direction and not be overwhelmed by the unlimited options VR affords (Aiello et al., 2012; Huang et al., 2010; Southgate, 2020). Additionally, offering relevant resources suitable for the age level (such as the MultiBrushVR and FrameVR manuals we designed for an adolescent audience) and low-stakes creative tasks to build VR design skills can better prepare students before they start creating a major VR project. This scaffolded approach will help to facilitate creative flow in individuals (Driscoll, 2005), leading to creative synergy within the group environment. Creative flow was evident in some of the adolescents' VR experiences. For example, Clara described how deeply engrossed she was in MultiBrushVR, sometimes losing her awareness that she was physically present in a classroom with her peers. Even though the students had virtual guardians in the HMDs and physical chairs to define their space, Clara's presence in the physical world was connected to her sense of creative flow in MultiBrushVR:

> *Everyone was bumping into each other. Well, I was bumping into everyone because I was just like so obsessed. I just needed to get all those brush strokes in, and I didn't realize that I could resize myself at the time. I was just going around my tree, and I was just like hitting everyone with my Oculus.*

Authentic Learning Opportunity 4: Adolescents Developing Problem-Solving Skills in VR

According to Vygotsky (1978), each problem encountered has different possible solutions, which must be assembled in the mind of the solver. Technology problem-solving was challenging for the students because VR placed them in learning environments they had never been in before (Southgate, 2020). Students needed to learn new technical skills ranging from navigating how to move around with hand controllers to connecting their HMD to the Internet and sanitizing it with the CleanBox (Araiza-Alba et al., 2021). Limited technical support was available, with two instructors guiding 28 students. Classmates were responsible for their learning and supporting each other. Getting started on the VR was challenging for some, as anonymous survey responses reported: "Learning how to use the headset was difficult at first, but I got the hang of it fairly quick" and "The only challenging part was just learning how to actually use the device and how it operates as you learn." Similarly, Autumn admitted, "I found getting on the different apps challenging," and Lennon reflected, "It took a little bit to get the hang of it. Just moving around and like getting used to the hands and stuff."

Despite the learning curve that comes from using VR, the adolescents were able to solve the technical problems that arose (Aiello et al., 2012; Huang et al., 2010). The students identified how their improved troubleshooting and problem-solving skills could benefit their future careers. Concordia commented on her improvement, “Well, I know how to work technology better. This experience was really helpful. I learned how to move my hands so that I could control the headset.” In addition to problem-solving issues with physical VR hardware, the students were able to develop skills within VR applications and platforms. Nyomi reflected, “I’ve also developed life skills in VR because I’d never used it before. I mean now I’m like pretty comfortable in Altspace.” Clara notes how she has improved her technology skills: “I can just put on a VR headset and just know what to do right now. And that’s gonna be useful skills in the future, considering how fast like technology is advancing.” Clara added later how she can see these VR technical skills as valuable for her future career. She commented, “If we were ever to apply to a job and like say we have this experience that puts us on the hot seat.”

During the final whole group interview, the students discussed the opportunities VR offers for a regular grade 8 class which would be impossible otherwise due to the time requirement, expense, and safety concerns (Fowler, 2015; MacDowell & Lock, 2023). Leonardo identified how VR is a practical solution for learning about the world, “I got to visit the places that were affected by the main SDG that we were focusing on … because I don’t see it a lot in the city.” Christopher shared that he would be more comfortable learning in VR when the weather is extreme, “When it’s a cold winter day, I would say being able to go do VR stuff instead of being outside in the cold.” Despite the advantages of VR for experiential and place-based learning without leaving the classroom, some students had concerns about inclusion and equity issues due to the high cost of HMDs. Emma said, “I assume that it uses some pretty expensive technology that probably isn’t very available.” Clara has similar thoughts, “It’s a reality that not a lot of classrooms have these things, or they’re able to access VR headsets and stuff or even the Internet sometimes.” These concerns about inclusion and equity need to be addressed, considering school divisions often struggle to adjust their budget to meet the diverse needs of students and teachers (Soares et al., 2017; USAID, 2019).

Instructional Design Considerations for Facilitating Authentic Learning in VR

In the previous four sections, the participants’ perspectives were synthesized to describe the authentic learning which can occur in a constructivist VR-enhanced classroom. By applying constructivism learning theory and drawing insights from adolescents, this article aims to bridge the gap between theory and practice for skills-based learning in VR, including the development of essential human skills that today’s students need to flourish in their lives, classrooms, communities, and future workplaces (Soares et al., 2017; USAID, 2019; Wats & Wats, 2009). While the findings are promising, they should be considered carefully as an exploratory study with one grade 8 class is limited in terms of validity, generalization, and reliability (Creswell & Creswell, 2018). We are continuing our study with another class to enhance the quality and applicability of the findings and encourage other researchers and practitioners to study VR teaching and learning in classroom settings. Detailed qualitative feedback from adolescents is uncommon in academic research involving educational VR (Olson, 2023; Southgate, 2020), positioning this study as a distinctive and valuable contribution to applied instructional design. We advocate for including, interpreting, and considering adolescent perspectives to ensure their narratives can be heard and shape curriculum, instruction, and educational policy (MacDowell, 2023).

To guide educators and instructional designers who want to integrate VR to facilitate better ways for adolescents to learn, we offer recommendations and reflective questions aligned with five core elements of constructivism defined by Driscoll (2005), who suggests constructivist learning is characterized by these core elements rather than a single unified theory. First, we recommend situating learning within complex, realistic, and relevant VR environments; students and instructors can modify pre-designed environments by integrating contextualized and localized content. For example, classes could customize existing FrameVR templates to better suit their specific educational needs instead of building from the ground up. This approach saves time and enhances the learning experience by making it more directly applicable and relatable to students. Adding this layer of personalization encourages deeper engagement and a stronger connection to the material.

Secondly, our approach underscores VR's potential to facilitate positive social interactions, particularly when learning requires social negotiation as an integral part of the process. For example, VR can make complex instructional content like the SDGs more accessible and engaging by allowing students to explore and discuss various perspectives on global issues. This approach deepens understanding and encourages active participation and dialogue among peers.

Thirdly, fostering a sense of ownership in the learning journey can be achieved in VR by enabling students to progress at their own pace and personalize their projects, both individually and as teams. For example, by presenting students with open-ended design challenges aligned with the learning outcomes, they are empowered to choose how they demonstrate their knowledge and understanding. This approach gives them creative freedom in designing their artworks and virtual worlds, which increases engagement and encourages deeper comprehension of the subject matter.

Fourthly, multiple perspectives and modes of representation can be supported by offering VR learning across various devices (e.g., HMDs, mobile, and desktop), accommodating learner preferences, and addressing the potential discomfort and nausea associated with using HMDs. Ensuring students can share their VR creations with broader audiences (e.g., friends and family), including those without HMD access or apps which require a paid subscription, is an important consideration when deciding which VR platforms to use.

Fifthly, promoting students' self-awareness of their learning and knowledge construction process can be achieved through pair interviews and open-ended surveys with questions which require reflective thinking. While these metacognitive activities can be situated within VR settings, the grade 8 participants chose to conduct their peer interviews outdoors using iPads. They assumed the role of interviewer and selected their preferred outdoor location for the interview setting. In a VR-enhanced classroom, learning is not confined to HMDs. Educators should use VR purposefully, as some activities may be more effective in the physical world. For instance, while VR excursions can supplement physical field trips, they should not replace the irreplaceable insights gained from being in natural land-based environments. These in-person field trips, however, are not always an option due to logistical constraints, costs, weather conditions, or other factors. These limitations may indicate a VR field trip would be a better choice to offer an experiential learning opportunity (Fowler, 2015; MacDowell & Lock, 2023). Table 3 summarizes five constructivist principles from Driscoll's (2005) work, offering reflective questions to consider and instructional design recommendations.

Table 3

Instructional Design Recommendations for Facilitating Authentic Learning in VR

Constructivism Principles (Driscoll, 2005)	Questions to Consider	Instructional Design Recommendations
Relevant Setting Learning is embedded in complex, realistic, and relevant environments.	• Does this environment, device, and application have transferable relevance for students?	• Customize pre-existing VR environments to enhance personalization, visualization, and interaction. • Evaluate the VR environment's relevance, appropriateness, and usability in practical situations.
Social Negotiation Learning provides for social negotiation as an integral part of the process.	• Does this VR application offer collaboration tools? • Can collaboration be designed outside of the HMD?	• Select tasks and environments encourage students to develop and build knowledge in collaboration with peers. • Foster a collaborative learning environment so peers can help address technical issues, thus reducing instructor workload.
Ownership Students are encouraged to be self-directed and take	• How can I allow students to learn outside the designated instructional time?	• Offer students a non-limiting time frame for their progress and process.

more ownership of their learning.	• How can I promote inclusivity in learning?	• Invite students to create virtual worlds. Allow options for students to represent their knowledge and understanding.
Viewpoints Multiple perspectives and modes of representation are supported.	• Which VR applications offer students meaningful opportunities to contribute to their learning tasks outside the HMD?	• Consider collaborative VR software compatible with an HMD. It is also possible to work in 2D mode on a desktop.
Metacognition Self-awareness of the knowledge construction process.	• Can students be directed to question their thinking in the virtual environment? • How can metacognition be promoted outside of the VR environment?	• Embed metacognition prompts directly into the learning environment. • Before VR learning, students could predict their performance and later compare it to their actual performance. • Students provide summaries of their learning after the experience.

Conclusion

This article strategically aligns constructivist learning theory with designing VR experiences tailored for adolescents, offering a framework and practical guidelines to foster authentic learning in VR-enhanced classrooms. Often, standard curricula lack real-life contexts crucial for facilitating a genuine understanding of academic subjects. By adopting a constructivist VR approach, teachers and students can overcome conventional classroom settings' typical physical and intellectual limitations. The recommendations presented in this study are drawn from an innovative learning environment and a specific cohort of students; hence, the findings should be carefully considered, and they may need to be adapted to meet the needs of different educational contexts or demographics.

In today's educational landscape, it is clear adolescents need more than mastery of content knowledge. As artificial intelligence (AI) increasingly performs more cognitive tasks, students require authentic opportunities to practice and develop human skills that AI cannot replicate, preparing them to thrive in a rapidly changing world. This article illustrates how VR, as a pedagogical tool, can support educators and instructional designers to enrich adolescent learning of essential human skills (e.g., collaboration, empathy, creativity, and problem-solving skills). The study also highlights the importance of including student perspectives in curricular and instructional decisions which affect their learning environments. The aim is to facilitate learning experiences which are not only authentic and relevant but also motivating and responsive to students' interests and aspirations, thereby enriching their educational journey.

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Ethics Approval

The methodology and research instruments for this study were approved by the Behavioural Research Ethics Board at the University of Saskatchewan (Application 3023) and the Greater Saskatoon Catholic Schools (GSCS). Parental consent and participant assent were obtained from all participants in this study.

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Appendix A: Guiding Interview Questions

1. What was your favorite VR experience?
    - Why was this experience better than others?
    - Who would you recommend this experience to?
2. List some decisions you made about your VR project.
    - Why did you make these decisions?
3. If you had more time, what you add or change to your VR project?
4. What would you tell a family member or friend about your VR project?
5. Were there any moments in the VR learning that challenged you? What were they, if any?
6. Have you improved because of your experience in VR? Please explain a little bit.
    - How might you use this improvement in the future?
7. How comfortable were you in the VR headset?
    - Did you experience any dizziness or nausea?
8. Do you have any concluding thoughts about VR for learning?