A Comprehensive Review of Extended Reality Literature and Projects:

Empowering Indigenous Education

A Myera Group/BU CARES Report

BRANDON UNIVERSITY

Project Overview

Our Challenging Question - *Given that the average age of traditional Indigenous harvesters of fish, wild rice and traditional food and medicines is 60-70, how can we support youth to preserve and restore cultural ways of managing foods systems? What role can advanced manufacturing, machine learning and AI play in helping to create a new generation of Indigenous innovators? Can the benefit of these innovative technologies create enough value and be employed in rural and northern communities, further inspiring youth to stay in community?*

The Myera Project is a joint collaboration between Myera, Inc., Brandon University Centre for Applied Research in Indigenous, Rural and Remote Education Settings (BU CARES) and the Rural Development Institute (RDI). The intention of this collaboration is to explore the opportunities to develop culturally-relevant STEM curriculum and education initiatives that may leverage extended reality technologies to promote community development, wellness, and food sovereignty in Indigenous communities. The following report seeks to identify recommendations for utilizing extended reality technologies in education.

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Technology-based Learning in Education and Corporate Training

The implementation of tech-based learning in education and corporate training spans a plethora of subject matter and contexts. Using technology like virtual reality has been implemented in hands on training like flight simulation or surgical procedures (Oberhauser et al., 2018; Zhao, et al., 2020); used to expose learners to spaces and concepts impossible or too dangerous to share otherwise, such as historical scenes or fire safety (Smith & Ericson, 2009; Wallis & Ross, 2021); as well as used to improve intellectual skills, motor skills, cognitive strategies, attitudes, and overall skills (Wu, et al., 2020; Yu & Xu, 2022). Virtual reality experiences, like the immersive reality Residential School, have also been designed to respond to the Truth and Reconciliation Commission of Canada's 94 Calls to Action (Woolford et al., 2022). Overall, the literature highlights a variety of applications and positive effects of technology-based learning outcomes at a variety of educational levels and settings.

Leveraging technology-based learning has allowed educators to create virtual classrooms that are accessible anytime and anywhere that the resources are available (Yu & Xu, 2022).

When implemented skillfully, technology serves as a powerful catalyst for both teaching and learning (Wu et al., 2020). However, when employed inadequately or without due consideration, its potential can be hindered, leading to adverse consequences (Chudaeva, 2021). Educators and practitioners must be aware of special considerations in deciding how and when to integrate digital modalities into their programming.

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>
> (Wu et al., 2020)

Technological Resources

Definitions

Definitions adapted from Moro et al., 2020:

Virtual reality (VR): Virtual reality involves creating a simulated environment that completely immerses the user. This immersive experience is achieved through the use of advanced technology, such as high-resolution headsets, headphones, and motion-tracking systems, which provide sensory stimuli to mimic a real-world experience. Examples: Oculus Rift, HTC Vive, Playstation 4.

Augmented reality (AR): Augmented reality overlays digital content onto the real-world using devices like smartphones or tablets equipped with cameras and screens. This allows users to interact with both the physical environment and digital elements that are superimposed onto it. Examples: Google Cardboard, MagicBook.

Mixed reality (MR): Mixed reality goes beyond augmented reality by adding an extra layer of interactivity. MR devices present holographic renderings of images that appear to be anchored in the real world. Users can interact with these digital objects as if they were physical objects in their surroundings.

Extended reality (XR): Extended reality is a term used to encompass virtual reality, augmented reality, and mixed reality collectively. It refers to the spatially immersive ecosystem created by these technologies, enabling users to have immersive learning experiences.

Non-Immersive Technologies: Non-immersive educational technology that can only present models and objects in a 2D format. These methods do not offer the immersive and interactive experiences provided by virtual reality, augmented reality, and mixed reality. Examples: Desktop VR.

Standard Teaching Modes: Standard teaching modes refer to methods of instruction currently promoted as 'conventional'. Examples: lectures, workshops, or textbooks.

Indigenous Voices

From Northern Inuit lands to Southern Aotearoa New Zealand, Indigenous peoples of a variety of landscapes have actively used VR technology as a powerful tool for reclaiming visual sovereignty, revitalizing communities by prioritizing Indigenous-centered storytelling, and supporting Indigenous futurism (Wallis & Ross, 2021).

Task-Technology Fit

Howard et al. (2021) conducted a meta-analysis of VR training programs and found that no single VR technology (display hardware, input hardware, game attributes) were more effective than others. These findings are supported by other meta-analysis (Moro et al. 2021). Despite the seemingly consistent effectiveness, VR training programs that utilized technologies which maximized task-technology fit led to the most improved outcomes (Howard et al., 2021). Goodhue and Thompson (1995) describe this phenomenon as 'task-technology fit' or "the degree to which a technology assists an individual in performing his or her portfolio of tasks" (p. 216).

The concept of task-technology fit is supported by Makransky et al. (2019) where in comparing immersive VR, non-immersive desktop VR, and standard teaching methods, found that the immersive VR group more effectively transferred skills to solve problems in a physical setting and were also more intrinsically motivated.

Virtual Reality

Head-mounted displays (HMD)

Chen et al. (2019) found that in comparing immersive HMD to semi-immersive Cave Automatic Virtual Environment (CAVE) to non-immersive Personal Computer (PC) experience, learners more quickly learned physical movements if the VR quality was high. They also suggest that the following factors be considered in implementing VR in education programs:

- Fully immersive VR incorporate selective and adaptive reality (e.g. user body parts are visible)
- Cable-free HMDs or set up that is free of motion impediments
- High quality presentation including high resolution, vivid multi-modal, and free of visual distractions
- Comfortable learning environment

Liu et al. (2021) conducted an experimental study comparing a control group of 6th grade science students to an experimental group who were taught the same science material but through an immersive VR HMD experience. The study found that the experimental group had significantly **higher academic achievement and better engagement** (cognitive, behavioral, emotional and social) compared to the control group who were taught using standard teaching methods.

Wu at el. (2020) suggest that using theory driven learning design to complement and guide HMD-based teaching and learning is most effective. **HMDs have the potential to promote learning that is maintained over time and transferred to other real-world contexts** (Wu et al., 2020). HMDs have a greater impact on K-12 learners science education and specific abilities development when compared with lecture-based learning or even real-world practices.

Tablet or Handheld Devices in Education

Non-immersive technology-based learning like desktop VR or handheld devices are often more suitable for **inquiry-based learning**, where students can explore, play a game, or solve simple problems (Luo et al, 2021). Direct instruction is more appropriate in the hyper-realistic immersive VR experience in comparison to non-immersive VR (Luo et al, 2021).

Augmented Reality

Augmented reality (AR) using mobile devices has allowed educators to blend technology and standard teaching methods using print books. AR is facilitated using mobile apps that allow educators to place markers on the pages of regular books. These markers allow students to interact with additional multimedia content that goes along with the printed book.

Kucuk et al.'s (2016) study of using AR through mobile devices to teach anatomy found that when learning materials such as images, texts, and videos are presented in a well-organized and integrated manner, **students' engagement was high and cognitive load was lessened**. By avoiding unnecessary mental effort or distractions, this approach can enhance students' learning performance.

Sense of Presence, Cognitive Load, and Learning Outcomes:

Studies have shown that when a VR learning environment feels very realistic, it can make learners more motivated; however, when learners need to understand certain concepts to participate in that environment, the high realism of VR can make it harder for them to concentrate and remember things (Whitelock et al., 2000). Hyperrealism puts more strain on learners' memory and reduces learning performance (Hembrooke & Gay, 2003; Karpinski et al., 2013). Makransky et al. (2019) also found that in comparing the EEG results of students in immersive VR simulation to PC version of the simulation, immersive VR users appeared to be **overstimulated** later in the session and had lower levels of learning. For these reasons considering task-technology fit and instructional design is important.

Teaching & Learning

Indigenous Voices

here is a need for digital environments used by Indigenous learners to be built by Indigenous **creators**, having appropriate visual **effects** and cultural content (Dyson, 2004). In developing and delivering technology-based learning with Indigenous partners, centering the local practices and cultural protocols helps to maintain cultural integrity and community engagement (Loban, 2022). In First Nation communities in Australia, like those of the Torres Strait Islanders, and Canada, like the Cheam band of the Fraser Valley, sharing knowledge orally and through visualization has been important in maintaining knowledge and relationships (Loban, 2022; Lewis & Shepphard, 2006).

Multimedia Learning

Richard Mayer's Cognitive Theory of Multimedia Learning describes that using **graphics can enhance the power of words** to improve the understanding of academic content. Technology-based education can harness cognitive theory of multimedia learning to provide an opportunity where scientific concepts can be visualized in ways that the standard teaching does not support.

Further, using animations can enhance learning due to the opportunity for students to learn both how things are organized and how they change over time (I.e., structural and temporal knowledge) (Kucuk et al., 2016). Since animations can **visually demonstrate dynamic processes or concepts**, they can assist in forming mental models that capture these dynamic aspects (Kucuk et al., 2016).

Constructivism theory emphasizes that **learning occurs through experience**. Educational opportunities where students can interact with technology in a virtual setting provides the environment for this hands on learning to occur (Alrehaili & Al Osman, 2019).

Gamification

In a meta-analysis, Merchant et al. (2014) examined the impact of VR technology-based instruction in three categories: virtual worlds, games, and simulation environments. The findings of the analysis revealed that, within the realm of VR, games were more successful in enhancing knowledge acquisition compared to simulations and virtual worlds. Additionally, the study identified that students who engaged in game-based learning exhibited **high levels of knowledge retention**.

Games can be broken down to **scaffolded steps**, and designed to meet specific learning outcomes, which naturally supports users' learning (Alrehaili & Al Osman, 2019).

Instructional Design

According to Villena-Taranilla et al. (2022) as result of their meta-analysis of VR effects on learning outcomes in K-6 education, immersive experiences are best capped at **less than two hours**. In comparing VR degree of immersion, subject, and duration, shorter immersive sessions appear to be most effective in terms of students' academic achievement.

Wu et al. (2020) conducted a meta-analysis of 26 HMD learning research involving K-12, post-secondary, and mixed stage learners. VR learning duration varied from less than 30 minutes to over 1 hour. There was no significant difference in effect size with variation in learning duration. Findings did identify a need for users to receive **"adequate warm-up sessions"** to increase familiarity with the environment.

A case study conducted at George Brown University analyzed a pilot project utilizing Beyond Labz VR technology in STEM courses. The case study identified success in gradually increasing student participation in the virtual world. First, instructors demonstrated activities in the environment, then students could practice, and finally complete assessments independently (Chudaeva, 2021).

Scaffolding the virtual experience was indicated in the instructional design of 74 of 157 VR learning experiences analyzed by Luo, Li, Feng, Yang, and Zuo (2021), where the design of the virtual experience included step by step activities where a computer guided the learner through learning activities. This scaffolding included on-screen text guidance in the form of suggestions, error messages, and hints as well as pre-recorded narratives that explained processes, causes, and effects (Luo et al., 2021).

Assessments are a necessary part of technology-based instruction, whether these are conducted within the technology-based environment or are paper-based (Luo et al., 2021). Incorporating assessment in the virtual setting allows assessments to be offered in real-time which can be helpful to provide immediate and meaningful feedback to students (Luo et al., 2021).

Indigenous Voices

Torres Strait Virtual Reality (TSVR) is a VR game created to share the culture and knowledge of one of Australia's First Nations people, the Torres Strait Islanders (Loban, 2022). TSVR is an example of how cultural engagement, game development, and research can seamlessly intertwine and complement each other, resulting in a robust and culturally-centered VR game (Loban, 2022).

Recommendations resulting from the TSVR project include:

- Placing Indigenous voices as the centre of VR development with the reflection of local practices and cultural protocols. For example, utilizing a player-centred game design that reflect the democratic, iterative, and equitable community practices of the Torres Strait Islanders (Loban, 2022).
- The importance of iterative game testing with Elders and the Indigenous community to receive feedback from a cultural perspective and maintain cultural integrity of the game.

Early Years

In contrast to K-12 educational settings, higher education has witnessed a more widespread adoption of VR technologies, particularly in the domains of engineering, health, and medicine (Luo et al., 2021). However, implementation of technology-based learning has been implemented in elementary schools in areas such as safety education and social sciences (Luo et al., 2021; Smith & Ericson, 2009).

VR has been found to have a positive impact on the learning progress of students in grades K-6. When compared to other educational methods, VR has been seen to enhance the learning experience and contribute to better learning outcomes (Villena-Taranilla, et al., 2022). In contrast, Smith and Ericson (2009) compared knowledge acquisition of children ages 7 to 11 years who were taught using a CAVE experience with those who taught using standard teaching methods and found that there were no significant differences in the level of knowledge acquisition however those taught using CAVE had **higher motivation and engagement** in the learning activities (Smith & Ericson, 2009).

Huang et al. (2020) conducted an experimental study comparing motivation, problem solving, and learning outcomes of Grade 4 students who were taught science curriculum using a tablet-based digital escape room (DER) and a group of Grade 4 students taught with standard teaching methods. Although there were no significant differences in learning performance, the students in the experimental group gained additional learning experiences that went beyond what was covered in the standard assessment. The study confirmed that course design that includes games, learner-centered approach, and encourages problem-solving can **enhance motivation and improve problem-solving** skills in science classes.

Unique challenges may exist for implementing forms of VR in education for those in Early Years. When primary students engage in learning using VR, they tend to have less control over their own behavior, fewer strategies to help them learn, and be more easily distracted by the visual simulations (Yu & Xu, 2022). Early learners may be more strongly impacted by environments requiring **higher cognitive load** (Whitelock et al., 2000).

Senior Years

Chen, et al. (2020) found 10th grade students' learning performance and hands-on skills improved after using VR in STEM education, more so than a control group who did not use VR. An additional finding of this study was that learners using VR developed cyclical learning, where they applied their learning, identified problems, and actively worked to address their knowledge gaps within the activity, **effectively "learning by doing"** (Chen et al., 2020).

Alrehaili and Al Osman (2019) studied the effectiveness of an immersive VR role-playing game (IVR-RPG) called IVR-Honeybee, designed to offer students educational lessons on ethology, with a particular focus on the behavior of honeybees. The researchers compared knowledge acquisition and motivation of 13 to 16 year old learners with IVR-Honeybee, a non-immersive desktop game (DVR) as well as print-based book. The were no significant differences in knowledge acquisition across groups, however the IVR and DVR groups indicated **higher motivation and engagement in their learning.**

Considerations or Challenges for Use of Technology in Education

Kavanagh et al. (2017) identified 10 potential VR issues related to implementing VR in education.
The most significant issue reported is related to **software usability**, with 17 of 35 studies indicating this as a challenge in implementing VR in education. This issue encompassed situations where instructors and/or students had difficulty effectively using the software. This was a result of user error at times and as well as a result of **poor design** (Kavanagh et al., 2017). Kavanagh et al. (2017) postulated that lack of student engagement, identified by 11 studies as a major challenge, was due in part to existing challenges related to software usability and training.

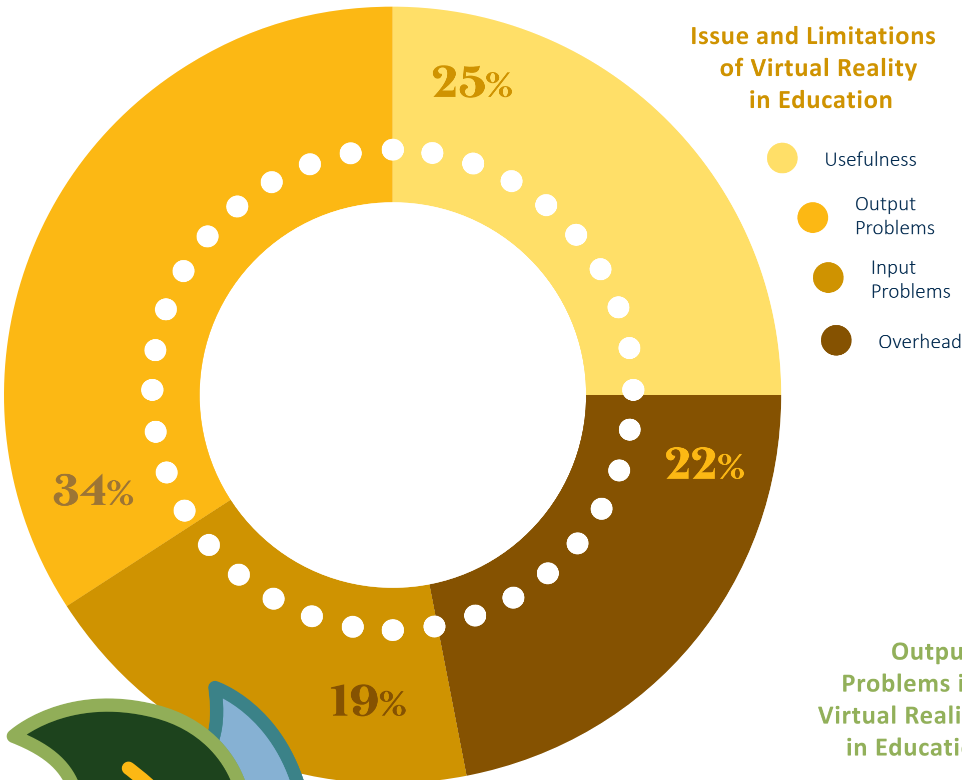
Six studies referenced challenges associated with **training costs** and time, in addition to the challenge of inconsistent training needs across instructors (Kavanagh et al. 2017). In the implementation of Beyond Labz, VR software, in George Brown University STEM courses, the need for faculty to have adequate training time was also indicated (Chudaeva, 2021). Faculty responses to the evaluation of the Beyond Labz project indicated that faculty found the technology to be **time consuming** to learn as well as to adapt their curriculum and learning activities to it (Chudaeva, 2021).

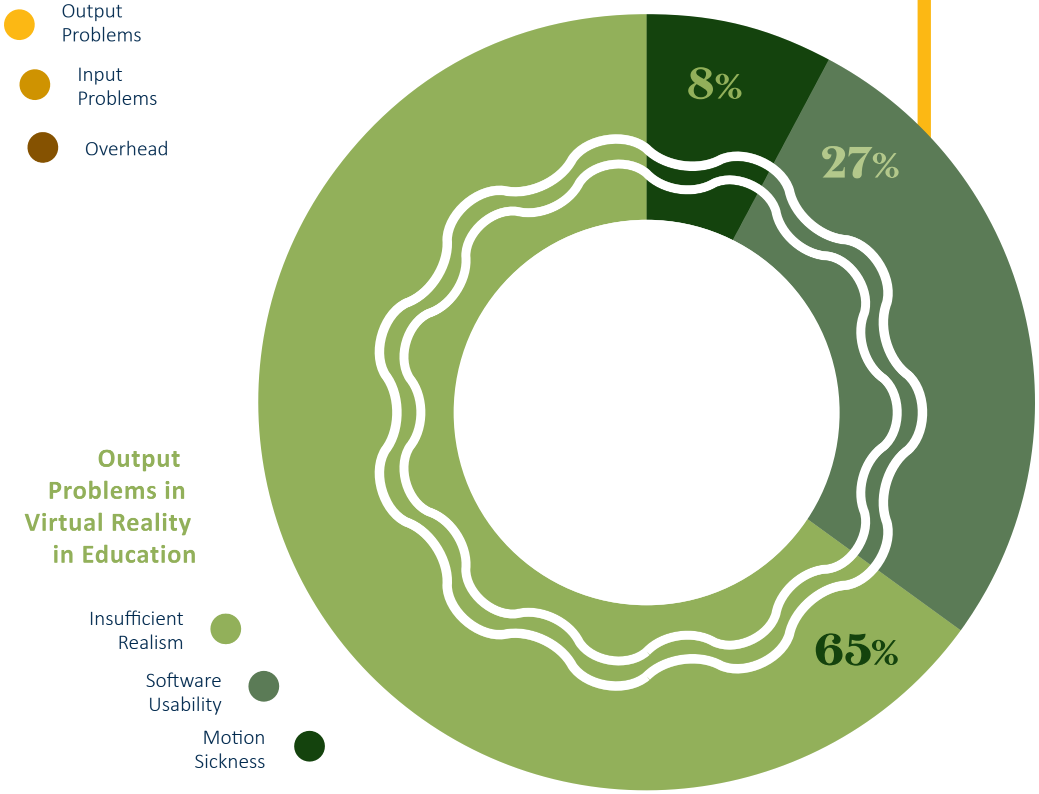
An added layer to the challenge of training is the **inconsistent digital literacy levels** of instructors as well as students, making it difficult to predict how much training may be required before implementing (Kavanagh et al, 2017).

In the George Brown Case Study, Chudaeva (2021) identified that 5% of students opted out of the virtual lab experience due to technical difficulties that were not further elaborated on. These technical barriers required faculty to create alternative activities for their students to participate in. Despite this challenge, it was also noted that the virtual lab activities in itself helped to further **develop students' digital literacy** (Chudaeva, 2021).

Chudaeva (2021) reported that in order to support students' participation in the virtual environment, faculty identified that sufficient time and support would need to be provided to **orientate students**.

Figure 1 and 2. Reported issues and limitations (obtained via thematic analysis) of 35 papers applying VR to education





Ethical Considerations

As outlined in this report, implementing forms of extended reality in education requires significant considerations related to educational level, technological design, and instructional design. Ethical considerations must also be considered, particularly when integrating traditional Indigenous teachings with digital technologies.

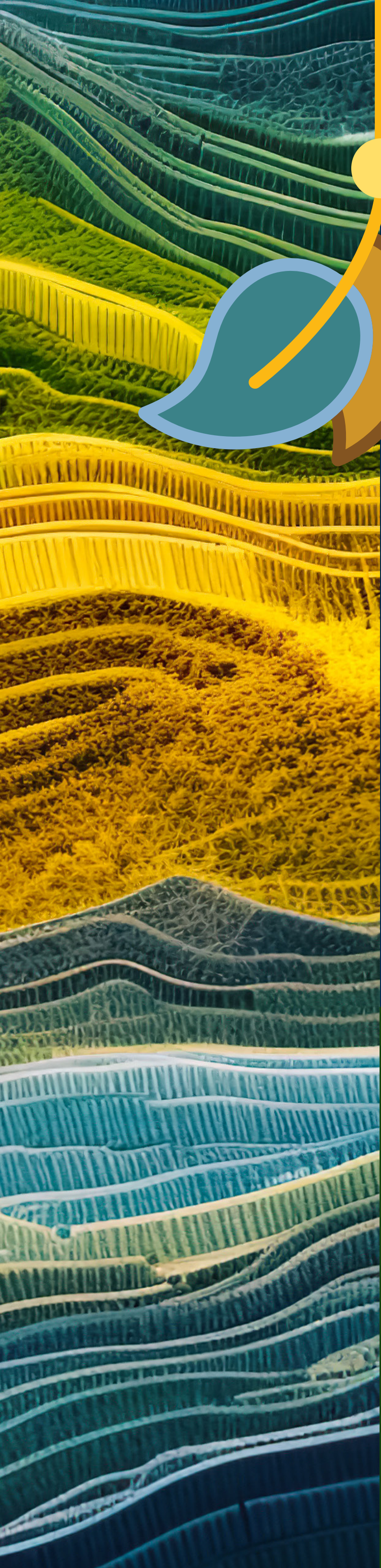
Ultimately, it is important to position local Indigenous partners and community not only as stakeholders but as leaders, where project outcomes can be **relevant and validated by the community** (Morton Ninomiya and Pollock, 2017).

Whether with extended reality or otherwise, the reconciliatory burden of Indigenizing education commonly rests on the shoulders of Indigenous educators; ethically, the necessary **resources, support, and control** must be allowed for these individuals to successfully carry out this work (Poitras Pratt and Gladue, 2022).

- the **Ownership, Control, Access, and Possession** (OCAP®) principles and training developed by the First Nation Information Governance Centre (FNIGC, 2023);
- and the **Tri-Council Policy Statement 2** as developed by the Canadian Institutes of Health Research (CIHR), the Natural Sciences and Engineering Research Council of Canada (NSERC), and the Social Sciences and Humanities Research Council of Canada (SSHRC) (Interagency Panel on Research Ethics, 2023).

Additionally, applying the unique cultural values, ethical principles, and practices of the specific local Indigenous community is important in order to uphold **social justice, equity, and Indigenous sovereignty** (Brannelly et al., 2013; Rowe et al., 2020; Willox et al., 2012).

While a strength of extended reality is the ability to transfer the user, in some degree, to another place and time, particular attention needs to be given to the potential negative psychological impacts of such activities (Howard et al., 2021). For example, the literature has shown that gamification in VR has the potential to increase student knowledge retention (Merchant et al., 2014); however, students can also experience overstimulation as a result of this immersive experience and when gamifying traumatic experiences, users may experience levels of distress (Makransky et al., 2019; Woolford et al., 2017). In the latter case, where Indigenous students may be impacted by intergenerational trauma, seeking counsel from the Survivor Governing Council and supporting Indigenous students with **fulsome cultural supports** has been advised (Woolford et al., 2017).



Key Recommendations

- There is potential for extended reality in education to empower Indigenous youth and to support the delivery of learning activities that honour cultural protocols.
- Consistently across the literature, findings show that technology-based learning increases students’ motivation and engagement in learning.
- Consideration must be given to instructional design and identifying the appropriate technology for the task and age of users.
- Several ethical considerations have been identified to support community, educators’, and students’ well-being in this context.
- Limited research has been done in the area of Indigenous teachings for food sovereignty and wellness with the use of technology-based education. There is an opportunity for the Myera project to contribute to the literature in this realm.

Moving Forward

In this project, we provided key background information that demonstrates the potential of technology to empower Indigenous youth and increase motivation and engagement in learning. In the following project, we will examine how this is being done through the Myera Virtual Circular Farm Model, learning experience, which provides youth with the opportunity to explore sustainable food management systems through Indigenous technology, set in the context of local communities.

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