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Bridging the divide: immersive virtual spaces for hybrid learning in remote teacher education

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Bridging the divide: immersive virtual spaces for hybrid learning in remote teacher education

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Abstract

Access to quality education in remote areas, particularly in the Arctic and small island regions, is often limited due to travel constraints. Hybrid learning offers a solution, but traditional video conferencing tools fail to fully engage online students. This study explores the potential of immersive virtual spaces in hybrid teacher education to create immersive and interactive learning experiences. As part of a larger design-based research on adapting higher education curricula to be taught in the metaverse, the study evaluates, through thematic analysis of multi-source data (planning meetings, emails, chat discussions, surveys), the affordances and limitations of higher education metaverse-based learning environments (HEMLE) in a teacher education course at the University of Hawaii, Mānoa. With 11 students, two teachers, two technology experts, and a researcher participating, findings indicate that this type of environment reduces spatial divides, enables seamless collaboration, and enhances student engagement. However, challenges such as technical difficulties, virtual reality sickness, and the need for specialized support highlight the necessity for strategic planning and technical assistance. The study underscores the transformative potential of immersive learning for hybrid teacher education, defines key design principles for adapting 2D learning activities to an immersive hybrid learning environment, and promotes social justice and sustainable educational access. While immersive hybrid learning environments offer significant advantages, their success depends on overcoming technological and accessibility barriers. In the Arctic and other remote contexts, integrating such tools can expand teacher education opportunities and improve educational equity. Future research should focus on refining HEMLE to enhance usability, scalability, and effectiveness in bridging geographical educational divides.

Keywords: TPACK-XD, hybrid learning environment, higher education metaverse-based learning environment, virtual reality, design-based research

Introduction

Providing equitable access to education in remote and underserved regions, such as Hawaiian small islands (Rao and Giuli, 2010) and the Arctic (Dyadik and Chapargina, 2021), remains a persistent challenge. Population ultradispersion, travel restrictions and infrastructural limitations reduce students' ability to attend in-person courses. Hybrid teaching and learning, which combines in-person and computer-mediated participation (O'Byrne and Pytash, 2015; Ellis and Goodyear, 2016; Obae et al., 2024) in a synchronous teaching situation, offers a promising approach but is heavily constrained by the limited potential of engagement offered by conventional 2D video conferencing tools like Zoom, Teams, Google Meet etc. (Overton, 2022; Maimaiti, Jia and Hew, 2023; Seitl, 2024).

The current study examines the role of immersive technologies in mitigating the challenges and limitations teachers encounter when creating virtual reality (VR), interactive, and equitable learning environments for teacher education. A learning environment "comprises the psychological, social, cultural, and physical setting in which learning occurs and in which experiences and expectations are co-created among its participants" (Rusticus et al., 2023). This study is an integral part of a larger design-based research (DBR) project, which aims to define the theoretical framework and principles for adapting curricula of higher education institutions (HEIs) to be taught in a metaverse-based learning environment.

The metaverse is "a vast extended reality set of worlds where physical and virtual reality intersect" (Slater et al., 2024). It combines immersive experiences and social interactions (Huang et al., 2023), incorporating interoperability, scalability, user-generated content (Maden and Yücenur, 2024; Song et al., 2023), and facilitating various human activities, like teaching and learning, to take place. A Higher Education Metaverse-based Learning Environment (HEMLE) represents a hybrid learning environment based on the concept of 'metaverse', bringing its educational, social, cultural, psychological, physical, and digital aspects within higher education. HEMLE fuses real-world and digital components with hybrid learning methods and metaverse immersive technologies (e.g. virtual reality, augmented reality, mixed reality). HEMLE is thus the overarching concept that will be used in the current research, referring to the particular use case of VR in hybrid teaching and learning.

As illustrated in Armstrong et al. (2022), DBR includes several iterative phases preceded by a deep understanding of the problem, the context, and the preceding research in the area. The DBR process was divided into three phases following Plomp and Nieveen (2013), spreading over four years. The current study is, in fact, representing the second DBR phase and thus is integrating the theoretical insights from the previous phase with a practical implementation. The TPACK-XD framework (Obae, in press), defined in the first phase of the DBR for HEMLE, was applied by the first author of this article and the two higher education teachers (co-authors of the article) in the specific context of the VR hybrid learning environment of a higher education teacher education course.

TPACK-XD is an update to the TPACK (Mishra, 2019) in the context of teaching in a HEMLE. It includes the different aspects of teacher knowledge for integrating metaverse technology in a higher education learning environment and supposes, besides the technological, pedagogical, content and contextual knowledge, specific learner characteristics and design knowledge.

In order to adapt different learning activities to a HEMLE, higher education teachers need to consider certain elements (Obae, in press):

- Use a design thinking approach
- Keep in mind the context, problem and learning goals
- Choose the appropriate learning environment
- Choose the most appropriate technology
- Select the most appropriate metaverse-access platform
- Plan for training time
- Choose the instructional design model to follow

These tentative design principles were put to the test in the context of a hybrid higher education course, and the current paper summarises the findings of VR-based HEMLE usage in teacher education, seeking to answer the following research questions:

- What are the affordances and limitations of using VR-based higher education hybrid learning environments?
- How can VR-based learning activities enrich traditional 2D ones in a hybrid teacher education context?
- Which design principles can we define for adapting hybrid 2D learning activities to be taught in an HEMLE?

The current study involved a design-thinking approach in itself. A problem identification step was followed by a needs analysis of the existing hybrid teacher education programs at the University of Hawaii, the development (design and construction of learning activities), the implementation and testing of immersive learning activities, the data gathering and finally the evaluation of learning experiences through participants' feedback and observation. This led to a reflection process that resulted in the current article, which will open the road to new problem(s) identification.

The problem identification was directly related to the geographical context. The study was conducted in the context of the Pacific Ocean, focusing on the 137 Hawaiian islands spanning over 2,400 kilometres. This region is characterised by unique geographical and environmental factors, including tsunamis, volcanoes, and earthquakes. Similar to the Arctic region, the spatial divide between people is large, as individuals can easily find themselves isolated from each other due to meteorological or geographical elements. Travel from one island to the other is done only by boat or plane, and, similar to what is happening in the Arctic region, travelling from one city to the other can become extremely expensive. Moreover, the option of moving to a bigger city is not always a solution, as people living in the countryside/small islands have fewer financial resources. These geographical, environmental and economic factors have an important impact on equal access to education. As illustrated in Figure 1 below, higher education institutions are focused on the main Hawaiian islands, so certain inhabitants of remote areas can find themselves in the impossibility of continuing their studies, similar to how people living in the Arctic region cannot always travel to study in the cities where Arctic universities are located.

Teachers training in areas with such sparse HEIs becomes difficult in face-to-face, thus putting in place an effective hybrid learning environment that gives equal access to learning activities to all students is essential. Nowadays, hybrid programs allowing participants to opt between face-to-face or online attendance through 2D apps (e.g. Zoom, Teams, etc.) have been put in place both in Hawaii and the Arctic region. But teacher education supposes learning how to interact and collaborate with others (Bergmark, 2023; Wijarwadi et al., 2025) and these mentioned 2D apps have serious limitations exactly

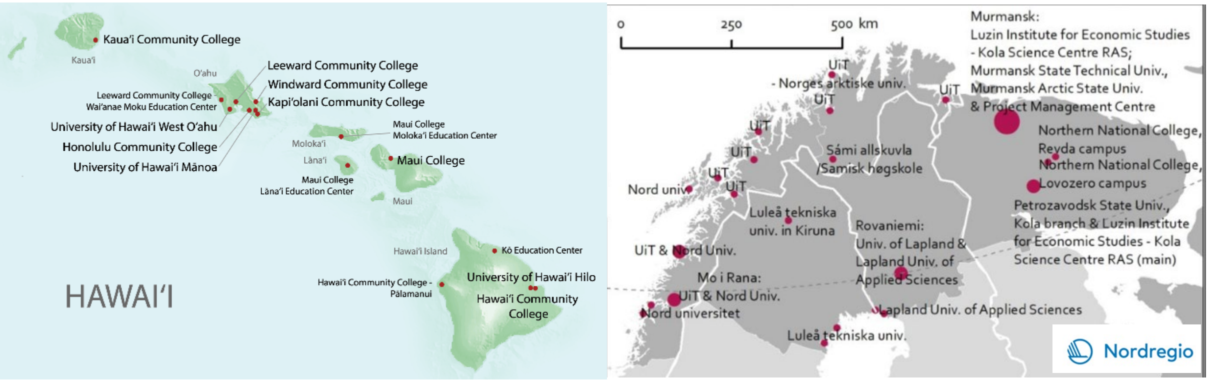

Figure 1: map of higher education institutions in Hawaii and the European Arctic area (University of Hawaii - Our Ten Campuses, 2025; Turunen, 2019)

in terms of collaboration and participants' interaction (Bailenson, 2021). The present paper explores the design principles for putting in place a HEMLE where VR combines with face-to-face attendance rather than the already in place 2D face-to-face combination.

Methodology

Process

The data collection for the current study was centred at the University of Hawaii at Mānoa, in Honolulu, specifically within the Learning Design and Technology Department in the College of Education, located on O'ahu island. Participants included 2 university teachers and their students aged 18+, coming from various islands, as well as international students, who, as noted by one participant in the experiment, "are legally required to attend classes in person—a regulation influenced by historical events such as 9/11".

The study was centred on the implementation of a Hybrid Here Or There (HOT) course model, which addresses the spatial divide in education by enabling synchronous teaching and learning for students and educators in different locations. This model combines synchronous and asynchronous tasks, using the HyFlex approach (Miller, Risser and Griffiths, 2013) to allow students the flexibility to attend sessions either in person or online. Asynchronous activities are managed through the Canvas LMS, while synchronous interactions occur via Zoom. As observed from the unstructured interview with the two university teachers that took place during the first of the three planning meetings, the 2D nature of these platforms limits collaborative potential. To enhance engagement, the study proposes transitioning from 2D to VR synchronous activities, aiming to create a unified space that ensures equal involvement, seamless collaboration, and immersive experiences for all participants, regardless of their physical location. Technologies used include VR headsets, FlowImmersive, RecRoom, and Zoom.

As the DBR involves “a collaborative partnership between researchers and practitioners” (Anderson and Shattuck, 2012) the current study was led by the first author alongside two higher education teachers one having delivered the course in the past years and one who was currently teaching the course during the research. Three online meetings were held for designing the learning activities and several email exchanges were used to settle the different implementation details.

The design of the VR-based learning activities was guided by the Carpe Diem Learning Design framework, “a collaborative, team-based, online learning design process, created through research and prototyping from the year 2000, and embedded in well-respected pedagogical research” (Salmon and Wright, 2014). This course design framework includes a six stage process emphasizing creating a blueprint, storyboarding, building a prototype, reality check, review and adjust, finalized with planning next steps. Carpe Diem is used by educators to create interactive and effective digital learning environments.

The selection of appropriate media was informed by Bates' principles (Bates, 2019), focusing on aligning instructional strategies with media characteristics to enhance interaction and learning outcomes. Key considerations included ease of use for students, networking opportunities, and addressing organisational issues. Factors such as cost, time, and the specific needs of students were also integral to the decision-making process, ensuring that the chosen tools supported effective and engaging immersive learning experiences.

The Carpe Diem process was initiated through the creation of a blueprint. The learning goals were defined by completing the Bates’ section template and choosing the one that the learning activities will focus on. As the second stage of the Carpe Diem process, a storyboard was created through the researcher-teachers consultation. A poker game in VR was envisioned, doubled by a data visualisation activity combined with discussions in a VR space. In order to make “effective decisions about the choice and use of media for teaching and learning” (Bates, 2019) and find the best appropriate immersive technology for the implementation of the learning activities, several VR platforms were analysed and compared through the sections model. Two platforms were chosen as they seemed to offer all the affordances necessary for the realisation of the learning activities: FlowImmersive and RecRoom.

Using the two VR apps chosen in the previous step, alongside Zoom, laptops, and two Oculus Quest VR headsets, the prototyping and reality check of the two learning activities was made by the researcher and the two teachers. Following this stage, review and adjustments regarding apps usage were made. Only one VR app (FlowImmersive) was retained for the implementation, as, due to certain updates, the RecRoom Poker game was discovered not to function properly anymore.

The implementation phase took place in a room specially equipped for hybrid learning with individual desks similar to the one illustrated in figure 1 below: “flat TV screen displays and a centre-of-room camera, microphone, and speaker which follows and zooms in on speakers’ faces for a face-to-face view (Meeting Owl 3). Each flat screen display is connected to a laptop and logged into the teacher’s Zoom meeting allowing different Zoom views to be projected to create a sense of immersion - students in the classroom being surrounded by their online classmates” (Obae et al., 2024). Three international students attended the hybrid course in person, while eleven others participated online. A range of technologies was utilised to facilitate the HEMLE, including the Canvas LMS for asynchronous tasks and Zoom for synchronous communication. Mobile tables and chairs were arranged to support flexible seating and laptops usage. VR headsets were provided to in-person students to facilitate immersive learning experiences. Additionally, the VR platform FlowImmersive was employed to create engaging and interactive virtual environments, ensuring seamless collaboration and inclusion of all students in the HEMLE, regardless of their physical location. Online students used their own devices to connect to Zoom and the VR space.

Figure 1: room organisation for hybrid teaching and learning at the University of Hawaii, Mānoa

Data collection

The data gathered for this study came from a variety of sources to ensure a comprehensive understanding of the HEMLE implementation and its outcomes. Informed consent from both teachers was gathered before the start of the experiment and institutional approval before involving students in testing the HEMLE learning activity. Once the data was gathered, this was stored on the main researcher's Google Drive so that the teachers involved in the research also have access to it. At the end of the study, anonymisation was performed by the main researcher and the data safely stored to his institutional OneDrive.

The first author kept a Word file with research notes that give an insight into the main steps of the design process. There were three online recorded meetings of 1h 32, 38 and 58 minutes. These took place via Teams and were held between the authors of this paper, providing insights into the planning and execution phases and highlighting the challenges and successes of the HEMLE. Adding to these live planning discussions, a series of 18 email exchanges between the authors, 10 emails sent between them and an immersive app tech representative, plus 18 Discord messages exchanged between the first author and another immersive app tech expert, offered a detailed view of the collaborative efforts and decision-making processes involved in designing the immersive learning activities. Planning documents (two Google Docs and one Google Sheet) served as a foundational reference for the structured approach taken. Additionally, post-implementation feedback from both students (3 respondents out of the 11 students participating in the research) and teachers (2 respondents out of the 2 teachers participating in the research) was collected through two Webropol surveys to evaluate the effectiveness of the HEMLE, capturing perspectives on engagement, usability, and overall satisfaction.

Data analysis

This multi-faceted data collection approach enabled the first author of this article to conduct a content and thematic analysis (Neuendorf, 2018; Humble and Mozelius, 2022) of the HEMLE design process using Atlas.ti. Given the exploratory scope of this DBR phase, coding was carried out only by the first author, who is also the primary researcher in the DBR process, with triangulation and audit trail done through the involvement of the two higher education teachers who participated in the experiment and thus became co-authors of the current article.

An initial inductive coding was initiated, and 10 categories were generated directly from the first reading of the primary documents. This approach enabled the identification of unanticipated insights regarding the practical challenges of immersive hybrid learning. In a second round of coding, TPACK-XD framework concepts were integrated to refine and extend the previously developed categories. Themes were developed iteratively, as the open coding in Atlas.ti was followed by axial coding to group related categories, and finally aligning them with the research questions. Triangulation across multiple data sources (e.g. meetings, emails, surveys, etc.) was used to corroborate findings and enhance the credibility of the analysis.

Findings

What are the affordances and limitations of using VR-based higher education hybrid learning environments?

Analysing the different code categories and themes through this research question lens, there is clear potential in implementing hybrid learning environments in both 2D and metaverse-based settings, but also certain challenges. Hybrid learning environments effectively reduce the spatial divide by enabling students from different locations to connect within the same learning space. However, setting up a HEMLE presents several technical challenges, including the limitations of immersive platforms and the need for specialised technical support. The study revealed that HEMLE can be accessed via VR headsets and computers, but thorough planning and prior testing of activities are essential to ensure smooth implementation. The selection of an appropriate immersive platform is crucial, as not all desired activities can be created by teachers without technical assistance. For example, using the already-made RecRoom poker game spaces was not possible as further coding skills would have been necessary to correct the errors the update brought in. Even if the researcher contacted an external specialist in building RecRoom environments, the issue would not be solved in time.

How can VR-based learning activities enrich traditional 2D ones in a hybrid teacher education context?

One significant finding after analysing the data is that immersive learning activities can replace the 2D ones in a hybrid learning environment, but that imposes certain considerations. First of all, there is the necessity of having a technical assistant during the setup of a HEMLE. This role is vital for addressing technical difficulties and ensuring that all elements of the learning environment are functional:

> We had issues with some of the headsets- only 3 of the 5 headsets worked. We were unable to conduct the statistics activity in RecRoom because the card game was broken… Half the class couldn’t get into RecRoom and had to do the fishbowl activity in Zoom… (Teacher 1)

In fact, in the learning activities design stage, the two higher education teachers had to meet with the FlowImmersive technical representative to learn how the app is functioning. On the other side, the creation of the poker game in RecRoom had to finally be abandoned due to an error in the app that was brought in by an update made more than one year before. Since then, the virtual cards could not be distributed any more, and, even though the researcher contacted a specialist in RecRoom spaces and games building, this one was not able to fix the issue quickly enough. The VR poker game was not used any more due to the technical issues, and a 2D version was used instead of the immersive one.

Additionally, prior training for students on how to use VR technology is essential to maximise engagement and minimise disruptions. One of the teachers remarked in the feedback that “the technology was still limited”, they weren’t able to get all students logged in at the same time, and “despite being reminded, some students didn't complete the orientation” (Teacher 2). This prior training in VR usage must be pre-planned and included in the curriculum in order to ensure a high quality of the immersive experience during the live class.

So, user design considerations are critical when creating VR spaces and learning activities in such immersive learning environments, as they directly impact the usability and effectiveness of the learning experience. One of the students, for example, marked in their feedback having experienced VR sickness (Chang, Kim and Yoo, 2020): “I got dizzy from the movement and flashing lights” (Student 3). Another one observed that reading information in a shared VR space was difficult when multiple users interacted simultaneously, as one person’s actions could alter the displayed information for everyone

(Student 2). Suggestions for improvement included displaying selected points statically on the screen to prevent disruptions. These insights emphasise the need for thoughtful design and user feedback to enhance the functionality and accessibility of HEMLE.

Which design principles can we define for adapting hybrid 2D learning activities to be taught in an HEMLE?

Building on the first stage of the DBR findings and the tentative design principles outlined in the introduction, the current experiment is confirming these findings. All TPACK-XD elements were present in the data, which shows the importance of this framework for teachers wanting to teach in an HEMLE. Nevertheless, the codes related to communication and technological knowledge had a clear overlap, bringing up the need of efficient communication with tech specialists. As the Discord conversation showed it, the technical jargon used naturally by the specialist often needs supplementary explanations when communicating with an educator, even though the latter has a certain level of technical background:

> Tech Specialist 2: [...] As far as making a Poker game, they would have to create it from scratch using Cv2 or just do it the old-fashion way with physical cards and player-enforced rules [...]
>
> Researcher: What does Cv2 mean? [...]
>
> Tech Specialist 2: Cv2 is the programming side of RecRoom, its own game engine.

Adding to this, the usage of certain VR app features might not be as intuitive as expected. For FlowImmersive, for example, the two higher education teachers went through over an hour's training prior to using the app, but even after that, some functionalities were confusing:

> [...] but I am not sure why there then look like when we tested the first time like every data point is individual data point. [...] Well, when I put it, uh, yesterday, when you click on a ball, it's still used their default data kind of thing. [...] Yeah, that's what I that's that's confused me. (Teacher 2)

Overall, while an HEMLE offers innovative opportunities for immersive and collaborative learning, their successful implementation requires careful planning, technical support, good communication skills and user-centred design combined with inclusion in the curriculum of prior VR usage training. Addressing these challenges can lead to more effective and engaging HEMLE, bridging the gap between in-person and online participants in teachers' education.

Discussion

HEMLE holds significant potential for revolutionising hybrid teacher education, particularly in remote regions. Enabling immersive collaboration, it bridges geographical divides and creates equitable learning opportunities. However, as the current research showed, successful implementation requires robust infrastructure, technical support, and careful instructional design. Participants in the study reported that the VR space offers a closer approximation to reality compared to traditional 2D environments, fostering a more natural interaction among students and enabling equal involvement of both face-to-face and online participants: "It was an eye-opening experience to see the immersive charts with VR" (Student 1). This experience, as noted by S01, allows learners to "feel, immerse, and sense the world," enhancing engagement and collaboration in ways that 2D platforms cannot replicate. The ability to bring all participants into the same learning space and allow them to interact almost naturally regardless of physical location, represents a significant advancement in reducing the spatial divide in education.

However, the study also revealed notable limitations of HEMLE. The current research studied only two learning activities' design and implementation processes, with a limited number of teachers and students involved. It becomes nevertheless clear that technical difficulties are a downside of this kind of learning environment. Hardware malfunction, the challenge of logging all students into the platform simultaneously, and the broken RecRoom poker game, make the need for technical support evident as teachers and students alike encountered obstacles that required specialised assistance. Additionally, VR sickness and participants' difficulties in manipulating the VR apps underscore the importance of preliminary VR training for users. These findings suggest that while HEMLE holds great promise, its successful implementation depends on addressing technical limitations, providing adequate training, and ensuring user comfort.

The design principles for moving from a 2D hybrid learning environment to an immersive one can be summarised as follows:

- Use a design-thinking approach
- Keep in mind the context, problem and learning goals
- Choose the appropriate learning environment
- Choose the most appropriate technology
- Select the most appropriate metaverse-access platform
- Plan for training time
- Choose the instructional design model to follow

Adding to this, the experiment on adapting 2D higher education learning activities to a HEMLE highlighted the need for the teacher to:

- Collaborate with the tech specialist

This collaboration between different stakeholders can happen only through the use of excellent communication skills. Teachers cannot learn about students' needs (e.g. VR sickness, VR usage knowledge level, etc.) if they do not initiate communication and if the latter do not communicate about it. Moreover, a positive user-experience can only be ensured through good communication and collaboration between the teacher and the tech specialist. This implies compulsory involvement both in the physical and virtual part of the learning environment of a third actor: the tech specialist. The teacher might have enough technical knowledge to supplement this role in the design phase but keeping in mind the great complexity of the HEMLE hybrid character, having an assistant to support with the technical part of the implementation will contribute to ensuring a positive and inclusive learning experience.

Implications for Arctic and remote education

The findings of this study have significant implications for Arctic and remote education, where accessibility and equity are critical challenges. The implementation of HEMLE offers a sustainable model for teacher education and professional development in these regions. By reducing the spatial divide, HEMLE enable remote learners to participate in immersive and interactive learning experiences that are comparable to those available in urban settings without having to travel. This approach supports social justice in education by ensuring that students and teachers in isolated communities have access to high-quality, engaging educational opportunities, regardless of their geographic location.

However, the successful adoption of such learning environments in the Arctic and remote contexts requires addressing specific challenges, such as technical limitations, the need for reliable internet connectivity, a tech assistant, and the provision of adequate training for both teachers and students. The study also highlights the importance of refining immersive tools to enhance usability and scalability, making them more accessible to users with varying levels of technical expertise. Additionally, future research should focus on developing strategies to ensure that immersive platforms are adaptable to the unique infrastructural and environmental conditions of remote areas and that tech specialists can be easily contacted to support in such contexts.

By overcoming these barriers, HEMLE can serve as a transformative tool for Arctic and remote areas education, fostering inclusivity and bridging the gap between face-to-face and online teachers' education learning experiences. This model not only enhances educational accessibility but also empowers remote communities by providing them with the tools and resources needed to thrive in an increasingly digital world. Continued innovation and collaboration among educators, technologists, and policymakers will be essential to realising the full potential of HEMLE in these contexts.

Conclusion

In conclusion, a HEMLE holds transformative potential for remote teacher education, offering immersive, interactive, and inclusive educational experiences that bridge the gap between urban and remote learners. By creating shared learning spaces that reduce spatial divides, such metaverse-based learning environments can provide equitable access to high-quality education, fostering social justice and empowering educators in isolated regions. However, the successful adoption of this innovative approach currently faces challenges, including technical limitations, VR-related discomfort, and the need for adequate technical support and user training. Additionally, aligning technology with pedagogical goals is essential to maximise the effectiveness of these learning environments in achieving the desired learning outcomes. Future research should refine immersive platforms, improve user accessibility, and explore ways to reduce VR sickness. It should also analyse the role of tech specialists and define the knowledge teachers need to communicate effectively with these key collaborators in the HEMLE design process.

Even with limitations related to the number of learning activities and participants, this research contributes to the growing discourse on the role of innovative educational technologies in advancing equity and accessibility in education, particularly for teacher education in remote and underserved communities. By bringing forward both the affordances and limitations of metaverse-based learning environments, the study underscores the need for continued refinement of these tools to enhance usability, scalability, and adaptability to diverse educational contexts. Future efforts should focus on developing user-centred designs, improving technical infrastructure, and providing comprehensive training to ensure that HEMLE can be seamlessly integrated into remote teachers' training education systems.

Ultimately, immersive hybrid learning represents a promising pathway toward creating more inclusive and engaging educational experiences for remote learners and educators. As technology continues to evolve, its thoughtful implementation, guided by pedagogical principles and a commitment to equity, can play a pivotal role in transforming education in the Arctic and other remote regions, ensuring that no learner is left behind in the digital age.

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References

ANDERSON, T., and SHATTUCK, J., (2012). Design-Based Research: A Decade of Progress in Education Research?. *Educational Researcher*, 41(1), pp.16–25. https://doi.org/10.3102/0013189X11428813

ARMSTRONG, M., DOPP, C., and WELSH, J., (2022). Design-Based Research: What is DBR, why might one do it, and how does one do it well?. In: R. KIMMONS, ed., *Education Research: Across Multiple Paradigms* . Education Research. pp.105–111. Available: https://open.byu.edu/education_research/design_based_research

BAILENSON, J.N., (2021). Nonverbal overload: A theoretical argument for the causes of Zoom fatigue. *Technology, Mind, and Behavior,* **2**(1). https://doi.org/10.1037/tmb0000030

BATES, A.W., (2019). *Teaching in a Digital Age - Second Edition*. Tony Bates Associates Ltd. Available: https://pressbooks.bccampus.ca/teachinginadigitalagev2/

BERGMARK, U., (2023). Teachers' professional learning when building a research-based education: Context-specific, collaborative and teacher-driven professional development. *Professional Development in Education*, **49**(2), pp.210–224. https://doi.org/10.1080/19415257.2020.1827011

CHANG, E., KIM, H-T., and YOO, B., (2020). Virtual Reality Sickness: A Review of Causes and Measurements. *International Journal of Human-Computer Interaction*, **36**, pp.1–25. https://doi.org/10.1080/10447318.2020.1778351

DYADIK, N.V., and CHAPARGINA, A.N., (2021). Digitalization in Education and Distance Barriers in the Russian Arctic: Problems and Prospects. *Arctic and North*, **43**, pp.144–160. https://doi.org/10.37482/issn2221-2698.2021.43.144

ELLIS, R.A., and GOODYEAR, P., (2016). Models of learning space: integrating research on space, place and learning in higher education. *Review of Education*, **4**(2), pp.149–191. https://doi.org/10.1002/rev3.3056

HUANG, Y., LI, Y.J., and CAI, Z., (2023). Security and Privacy in Metaverse: A Comprehensive Survey. *Big Data Mining and Analytics*, **6**(2), pp.234–247. https://doi.org/10.26599/BDMA.2022.9020047

HUMBLE, N., and MOZELIUS, P., (2022). Content analysis or thematic analysis: Similarities, differences and applications in qualitative research. *European Conference on Research Methodology for Business and Management Studies*, **21**(1), pp.76–81. https://doi.org/10.34190/ecrm.21.1.316

MADEN, A., and YÜCENUR, G.N., (2024). Evaluation of sustainable metaverse characteristics using scenario-based fuzzy cognitive map. *Computers in Human Behavior,* **152**, 108090. https://doi.org/10.1016/j.chb.2023.108090

MAIMAITI, G., JIA, C., and HEW, K.F., (2023). Student disengagement in web-based videoconferencing supported online learning: an activity theory perspective. *Interactive Learning Environments*, **31**(8), pp.4883–4902. https://doi.org/10.1080/10494820.2021.1984949

MILLER, J.B., RISSER, M.D., and GRIFFITHS, R.P., (2013). Student Choice, Instructor Flexibility: Moving Beyond the Blended Instructional Model. *Issues and Trends in Learning Technologies*, **1**(1). Available: https://journals.uair.arizona.edu/index.php/itet/article/view/16464

MISHRA, P., (2019). Considering Contextual Knowledge: The TPACK Diagram Gets an Upgrade. *Journal of Digital Learning in Teacher Education*, **35**(2), pp.76–78. https://doi.org/10.1080/21532974.2019.1588611

NEUENDORF, K.A., (2018). Content analysis and thematic analysis, *Advanced Research Methods for Applied Psychology*. 1st ed. Abingdon, Oxon: Routledge. pp.211–223. https://doi.org/10.4324/9781315517971-21

O'BYRNE, W.I., and PYTASH, K.E., (2015). Hybrid and Blended Learning: Modifying Pedagogy Across Path, Pace, Time, and Place, *Journal of Adolescent and Adult Literacy*, **59**(2), pp.137–140. https://doi.org/10.1002/jaal.463

OBAE, C., (in press). TPACK-XD: Elements to Consider When Creating Curriculum in a Metaverse-based Higher Education Learning Environment. *Seminar.Net*.

OBAE, C. et al. (2024). Insights Platform. Is the future of education 'hybrid'?. Available: https://eceuropaeu.sharepoint.com/:u:/r/teams/GRP-EACext-DigitalEducationHub/SitePages/Is-the-future-of-education-hybrid-.aspx?csf=1&web=1&e=CXoRac

OVERTON, S., (2022). Engagement challenges in a hybrid classroom: Reflections of a higher education tutor, *European Conference on e-Learning*, **21**(1), pp.331–337. https://doi.org/10.34190/ecel.21.1.788

PLOMP, T., and NIEVEEN, N., eds., (2013). Educational design research. Part A: an introduction. Enschede, Netherlands: SLO.

RUSTICUS, S.A., PASHOOTAN, T., and MAH, A., (2023). What are the key elements of a positive learning environment? Perspectives from students and faculty. *Learning Environments Research,* **26**(1), pp.161–175. https://doi.org/10.1007/s10984-022-09410-4

SALMON, G., and WRIGHT, P., (2014). Transforming Future Teaching through "Carpe Diem" Learning Design. *Education Sciences*, **4**(1), pp.52–63. https://doi.org/10.3390/educsci4010052

SEITL, C., (2024). There Is Another Room on the Other Side of the Screen: Learning via Zoom in a Hybrid Context. *International Journal on Studies in Education*, **6**(3), pp.463–485. https://doi.org/10.46328/ijonse.249

SLATER, M., BARNGROVER, M., FRIEDMAN, D., LOPEZ-TARRUELLA, A., NIAMUT, O., PAN, S.X., QUENT, M., and SANCHEZ-VIVES, M.V., (2024). *A Metaverse for the Good*. Zenodo. https://doi.org/10.5281/ZENODO.10993751

SONG, C., SHIN, S-Y., and SHIN, K-S., (2023). Exploring the Key Characteristics and Theoretical Framework for Research on the Metaverse. *Applied Sciences*, **13**(13), 7628. https://doi.org/10.3390/app13137628

TURUNEN, E., (2019). *Higher educational institutions in the Arctic*. Nordregio. Available: https://nordregio.org/maps/higher-educational-institutions-in-the-arctic/

UNIVERSITY OF HAWAII, (2025). *University of Hawaii - Our Ten Campuses*. Available: https://www.hawaii.edu/

WIJARWADI, W., NGUYEN, H.T.M., and ALONZO, D., (2025). Teacher collaboration: Conceptualisation and practice. *Professional Development in Education,* pp.1–19. https://doi.org/10.1080/19415257.2025.2504693