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Pre-Service Science Teachers' Reflections on Using Virtual Reality Open Educational Resources in Life Science Education

Wiets Botes[1]*

[1] *Sol Plaatje University*, SOUTH AFRICA

***Corresponding Author:** wiets.botes@spu.ac.za

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ABSTRACT

The use of VR-based OERs in STEM education has the potential to enhance teaching and learning by making it more immersive and interactive. Despite their increased availability in higher education, there is limited understanding of how these resources support pre-service life science teachers' subject knowledge and pedagogical skills. This study examined the reflections of 13 pre-service life science teachers on VR learning experiences using Human Anatomy VR software, guided by Kolb's Experiential Learning Theory (ELT). Through focus group discussions, VR interaction screenshots and eye-tracking data, the study provided qualitative insights into how VR enhanced their understanding of life science topics and reshaped their teaching perspectives. Four key themes emerged: i) immersive engagement with subject knowledge; ii) development of digital pedagogical competencies; iii) evolving perceptions towards VR integration; and iv) challenges such as motion sickness. The study underscores the benefits of VR in improving content mastery and digital teaching skills, offering valuable insights for curriculum developers and policymakers in STEM teacher education. Future research is suggested to explore VR applications in mathematics, physical science, and rural education.

Keywords: Open-educational virtual reality resources, Experiential Learning Theory, pre-service life science teachers, Human Anatomy VR.

INTRODUCTION, LITERATURE, AND RATIONALE FOR THE STUDY

The rapidly advancing field of digital technology has significantly transformed higher education by introducing a range of innovative teaching tools and methodologies designed to enhance the student learning experience (Wang & Li, 2024). In initial teacher education, one notable innovation is the use of virtual reality (VR) open educational resources (OERs). These VR-based OERs combine the benefits of open educational resources with the interactivity and immersive qualities of virtual reality, providing personalized learning opportunities for pre-service teachers (Adelana et al., 2023). This integration creates a dynamic platform for teacher training, enabling pre-service teachers to engage in realistic simulations and practical exercises that transcend the limitations of traditional classroom instruction (Analyti & Mitropoulou, 2024; Penn, 2022; Rasmitadila et al., 2020; Kalimullina et al. 2020). For instance, virtual reality environments enable pre-service teachers to explore detailed representations of human anatomy or take a virtual journey through space to deepen their understanding of the solar system. These immersive experiences are further enhanced by interactive assessments, including live polls, quizzes, and rating scales, which effectively measure their comprehension of the material presented. This approach provides a deep and engaging learning experience, leading to improved understanding and retention of the subject matter that prospective

teachers must master (Borowska-Beszta & Smieszek, 2018; Nyaaba et al., 2024; Ural & Oztas, 2021). A specific software programme capable of offering immersive learning experiences in virtual reality format is Human Anatomy VR.

In light of recent educational advancements, this research project will explore how the teacher development program in the Faculty of Education at a selected university in South Africa can benefit from integrating VR-based OERs into its course offerings. Currently, the Faculty of Education has not fully utilised the potential of VR-based OERs in its curriculum design and delivery. This study, therefore, aims to evaluate the effectiveness of incorporating these resources into teacher training by capturing the rich experiences of pre-service life science teachers' use of VR-based OERs. The significance of this research lies in its ability to offer valuable insights into the application of VR-based OERs in the pre-service teacher development process, specifically in the context of life science education. These insights are expected to lead to practical recommendations for integrating VR-based OERs into teacher development programmes. The findings of this study will benefit curriculum developers involved in teacher development programs and may also have important implications for policymakers focused on modernising teacher education in STEM fields. Ultimately, this study seeks not only to enhance traditional teaching methods but also to transform initial teacher education into a more dynamic, effective, and contemporary practice.

BACKGROUND TO THE STUDY

The implementation of VR-based OERs in STEM pre-service teacher education shows promise in shaping the qualities and skill sets of future teachers (Makransky & Petersen, 2021). For example, studies have shown the potential of immersive technologies in stimulating experiential learning and science process skills (Nyaaba, Akanzire & Nabang, 2024), which are key pre-service teacher attributes in science and mathematics education (Rodríguez et al., 2023). Van der Want and Visscher (2024) explain that virtual reality education not only promotes the development of content knowledge among pre-service teachers but also encourages pedagogical innovation in complex subjects such as anatomy, chemistry, physics and molecular biology.

The Department of Mathematics, Science, and Technology Education at a selected South African university has prioritized the acquisition of Meta Quest 3 VR headsets. This initiative provides pre-service teachers with the opportunity to engage with immersive technologies, particularly virtual reality. This approach is in line with the University's Institutional Strategic Plan, which emphasizes the importance of becoming a digitally advanced institution that prepares graduates to integrate current digital technologies, such as virtual reality, into their teaching practices. From an academic perspective, this initiative aligns with emerging evidence indicating that incorporating new digital technologies, like VR-based OERs, is essential for enhancing the technological pedagogical content knowledge (TPACK) and building the confidence and competence of pre-service teachers in using educational technologies (Karadayi & Gencel, 2024; Sridana et al., 2025).

As both a researcher and a lecturer responsible for the professional development of pre-service life science teachers, I was particularly interested in exploring how VR-based OERs could enhance their understanding and mastery of life science topics. Additionally, I aimed to investigate how these resources might inspire a renewed teaching philosophy among a carefully selected sample of 13 pre-service life science teachers. Conducting this research is essential because virtual reality has the transformative potential to enhance situated learning experiences. These experiences allow pre-service teachers to explore complex topics, such as human heart anatomy, in ways that traditional teaching methods cannot (Merchant et al., 2014). A study by Ferdig (2020) suggests that immersive simulations can help bridge the gap between mastering content and effective teaching methods. In simpler terms, Bower et al. (2020) and Santarossa et al. (2023) explain that engaging with virtual reality learning environments enables pre-service teachers to experiment with technology-driven, immersive teaching strategies that are grounded in student-centred, inquiry-based, and constructivist approaches.

PROBLEM STATEMENT

The use of VR-based OERs in STEM education holds significant potential to transform teaching and learning in a more immersive, interactive, and engaging way (Bower et al., 2020; Ferdig, 2020). However, despite the increase in the availability and accessibility of VR-based OERs in higher education, little is known about how VR-based OERs can enhance the subject-specific knowledge and pedagogical skills of pre-service life science teachers. Some contend that the use of VR-based OERs in the context of STEM teacher development remains underutilised and poorly understood (Kavanagh et al., 2021). This underutilisation largely stems from pre-service teachers' lack of exposure and limited pedagogical guidance on how VR-based OERs can promote their professional development. Against this backdrop, research is required to explore the experiences of pre-service teachers in using VR-based OERs as part of their teacher development. Conducting this study is important as it provides valuable insights and strategies for the effective integration of VR-based OERs in teacher education, specifically in the area of STEM

pre-service teacher development, thereby contributing to the scholarship on adopting immersive virtual reality technologies in the diverse context of teacher education.

THEORETICAL FRAMEWORK: EXPERIENTIAL LEARNING IN STEM TEACHER EDUCATION

Given the aim of the study, which was to report on the reflections of pre-service teachers regarding their use of VR-based OERs, the application of Experiential Learning Theory (ELT) was considered an appropriate fit (Hunegnaw et al., 2025). Initially coined by David Kolb (1984), ELT serves as an educational framework for understanding how knowledge is acquired and utilised through concrete and immersive learning experiences. ELT occurs through a continuous cycle of hands-on learning, reflective observation, abstract conceptualisation of the learning process, and active experimentation. In this context, the pre-service life science teachers' use of Meta Quest 3 VR headsets during classroom interactions facilitated experiential learning by immersing them in virtual STEM environments, enabling them to engage with complex anatomical topics related to the functioning of the heart. This approach aligns with Kolb's assertion that meaningful learning occurs when pre-service teachers engage with, reflect on, and apply their learned experiences in an authentic context. In other words, through the use of VR-based applications such as Human Anatomy VR, pre-service teachers were not merely viewed as passive recipients of information but rather as active participants in the learning process. According to Van der Want and Visscher (2024), this approach promotes deep learning and stimulates critical thinking among pre-service teachers.

Aligning the ETL with this study reveals that the 'concrete learning experience' is central to the VR learning environment. Specifically, the use of software such as Human Anatomy VR provides immersive and realistic experiences for pre-service teachers, enabling them to engage with complex topics related to the heart's functioning in ways that traditional teaching cannot. For instance, the software application enables pre-service teachers to "enter" the bloodstream, navigate through it, and explore the different chambers of the heart, providing them with a situated learning experience. This approach makes the learning process tangible and relatable, thereby enhancing their content knowledge. This aligns with the work of Makransky and Petersen (2021), who suggest that experiential VR learning promotes retention and conceptual clarity since pre-service teachers can develop mental models that support their long-term knowledge acquisition.

The next phase of the immersive experience involves reflective observation (Karadayi & Gencel, 2024). During this process, pre-service teachers are encouraged to reflect on their VR experiences and share their insights with peers regarding whether VR can serve as a valuable pedagogical tool for teaching anatomy-related topics. The reflection process allows pre-service teachers, as future educators, to consider how their learners might perceive and engage with concepts within a VR learning environment (Karadayi & Gencel, 2024), thereby bridging the gap between theory and practice. The use of VR in STEM education is well-known for its student-centred and inquiry-based teaching approaches. Kavanagh et al. (2021) further note that such forms of reflection can occur through debriefing sessions, such as Focus Group Discussions.

RESEARCH METHODOLOGY

The use of a qualitative research approach was well-suited for generating rich qualitative data that deals with the life science pre-service teachers' reflections on their use of virtual reality open educational resources, such as the Human Anatomy VR software package, as part of their life science teacher training. The selection of a qualitative research approach enabled the collection of in-depth insights into how pre-service teachers experienced the use of Human Anatomy VR software, which aimed to enhance their life science subject knowledge and pedagogical skillsets related to life science teaching. This approach enables naturalistic inquiry by capturing the nuanced interactions, reflections, and meaning-making of participants' engagement with the Human Anatomy VR software, using Meta Quest 3 virtual reality headsets.

In addition to adopting a qualitative research approach, the study employed an intrinsic case study research design (Merriam & Tisdell, 2016). It is suggested that an intrinsic case study research design enables an in-depth inquiry into a specific case of interest (Merriam & Tisdell, 2016). In the context of this study, the case involved 13 life science pre-service teachers and their engagement with the software package titled Human Anatomy VR, which utilised Meta Quest virtual reality headsets. This specific inquiry allowed for a deep exploration of how the Human Anatomy VR experience served as a mechanism to inform knowledge comprehension and stimulate in immersive digital pedagogies, specifically in the context of life science education.

RESEARCH SETTING AND PARTICIPANTS

The study included a purposive sample of 13 pre-service teachers who were specializing in life science education. This purposive sample is drawn from a larger cohort of pre-service teachers enrolled in their final year of the Bachelor of Education Degree. Purposeful sampling ensures that participants are selected based on their relevance to the research questions (Bouncken et al., 2025). Given this understanding, a purposive sample of 13 pre-service teachers was selected due to their i) specialisation in life science teaching and ii) their familiarity with virtual reality technology. Given the relatively small sample size of 13, I believe that the pre-service teachers were an appropriate fit for an in-depth qualitative inquiry into their reflections on using virtual reality open educational resources, such as Human Anatomy VR software, as part of their life science teacher development. However, several limitations to the study should be noted. One limitation of the study is the small sample size of only 13 pre-service teachers, which may restrict the generalizability of the findings to a broader population. Additionally, the focus on participants with a specific specialization in life science education and familiarity with virtual reality technology may introduce selection bias, as their experiences might not represent those of pre-service teachers in other disciplines or with varying levels of technology exposure. Lastly, the reliance on qualitative data may limit the comprehensiveness of the insights gathered, as personal reflections could be influenced by individual biases or varying interpretations of the virtual reality tools used.

DATA COLLECTION AND PROCEDURES

Given the qualitative focus of the study, a multi-layered approach was employed to capture qualitative data. In particular, the selection of a semi-structured focus group discussion, the use of digital screenshots, and the utilisation of eye-tracking capabilities offered by Sight Lab VR were deemed appropriate for reporting on the rich reflections of life science pre-service teachers on their use of the Human Anatomy VR software. The semi-structured focus group discussion was audio-recorded, transcribed verbatim, and interpreted through a thematic analysis process. The findings from the semi-structured focus group discussion were also made available to the pre-service teachers to ensure an accurate depiction and reflection of the discussion that transpired (Morse, 2023). The semi-structured focus group discussion was particularly helpful in gathering verbal data on the pre-service teachers' personal experiences with engaging with the Human Anatomy VR software. To capture these personal experiences, a set of predetermined questions was posed to the pre-service teachers during the semi-structured focus group discussion aimed at targeting particular responses associated with their i) life science knowledge retention and ii) their potential interest in the use of immersive digital pedagogies such as virtual reality. These questions are captured in **Table 1** below:

Table 1. Semi-structured interview schedule for focus group discussion

Question posed	Focus area
How did the Human Anatomy VR experience enhance your understanding of anatomical concepts related to the heart, the circulatory system and cells in the human body?	Life science subject knowledge retention
Which aspects of the virtual reality experience were helpful in promoting knowledge related to anatomical concepts of the heart, the circulatory system and cells in the human body?	Life science subject knowledge retention
In which ways do you think virtual reality can be used to support the learning process of learners with complex topics in life science?	Life science subject knowledge retention
How confident do you feel about integrating virtual reality into your life science teaching practice?	Stimulating immersive digital pedagogies
How has your experience with virtual reality technologies influenced your understanding and application of teaching methodologies applicable to life science?	Stimulating immersive digital pedagogies
Which challenges or limitations do you foresee in making use of virtual reality in your teaching practice?	Stimulating immersive digital pedagogies

Apart from the structured focus group discussion that took place, I also relied on digital screenshots provided by the pre-service teachers as photographic evidence of their engagement with the Human Anatomy VR software. This approach enabled the visual capture of key events that depict the pre-service teachers' engagement with the Human Anatomy VR experience. This participatory approach not only amplifies and foregrounds the pre-service teacher voice (Morse, 2023) but also allows for deeper insights into the educational value, accessibility and applicability of open-educational virtual reality use in the life science classroom.

Finally, I could also rely on the eye-tracking capabilities offered by a trial version of Sight Lab VR to generate and capture data, thereby gaining a better understanding of how pre-service teachers interacted with the Human Anatomy VR application. The use of eye-tracking capabilities, in this instance, provided a unique perspective on the pre-service teachers' learning behaviour and reveals the intricacies of their learning experiences (Gabel et al., 2023). To be specific, the tracking of pre-service teachers' eye-gaze patterns between animated scenes (measured in seconds) along with fixation counts (measured in frequency) regarding specific animated scenes provided valuable insights into what captured their attention and what they found engaging during the virtual reality experience (Jarodzka et al., 2017). In this study, eye-tracking focused on animated scenes related to the anatomy of the human heart, the human circulatory system, the physiology of the human brain, and cells in the human body.

Following a multi-layered approach to collecting data resulted in a level of methodological triangulation. For example, the verbal responses gathered through the focus group discussion were compared to the eye-tracking data offered. Additionally, the provision of digital screenshots that depict key events during the pre-service teachers' engagement with the Human Anatomy VR experience was instrumental in verifying the accuracy of the data. Finally, all findings were reviewed by the team of pre-service teachers to ensure that accurate and reliable data were captured. Lastly, by making the empirical data publicly available, this study will enable future researchers to evaluate the relevance of the findings in similar contexts.

It is also worth noting that a thematic analysis approach was employed to make sense of the rich empirical data generated from the three data collection techniques mentioned previously. To ensure an accurate representation of the data, the empirical data were transcribed, coded, and then categorised into emerging themes, thereby ensuring a level of academic rigour (Maher et al., 2018). The generated themes centred around pre-service teacher experiences associated with knowledge comprehension of topics related to the subject life science, as well as their potential interest in the use of immersive digital pedagogies such as virtual reality.

ETHICAL CONSIDERATIONS

For the purpose of this study, stringent ethical considerations were implemented to safeguard the rights and well-being of the 13 pre-service teachers participating in the research. Initially, all pre-service teachers provide informed consent, fully understanding the nature of the study and the role they will play. Privacy and confidentiality were rigorously maintained throughout the research process. All empirical data collected were anonymised to prevent any possibility of identifying the participants. Furthermore, pre-service teachers had the option to withdraw from the study at any time without consequence. Additionally, I carefully managed power dynamics with the pre-service teachers to ensure that there was no coercion or feelings of intimidation, maintaining a professional and respectful relationship with them. Finally, the ethical approval was received from the University's Senate Research Ethics Committee to ensure all ethical standards were met, thereby protecting the interests and integrity of all involved.

FINDINGS AND DISCUSSION

The study reported on the pre-service teachers' reflections on using virtual reality open educational resources, such as the Human Anatomy VR software package, as part of their life science teacher development. Given this aim, the use of a semi-structured focus group discussion and the capturing of digital screenshots regarding the pre-service teachers' engagement with the software package were instrumental in data generation. In addition, the study further utilised the Sight Lab VR eye-tracking capabilities to provide a deeper understanding of how pre-service teachers interacted with the features of the Human Anatomy VR software package. By analysing the eye-gaze patterns of pre-service teachers, including fixation counts and the duration spent focusing on specific images while using the software, I gained valuable insights into what captured their attention and what they found engaging during the virtual reality experience. The eye-tracking data was used to support the pre-service teachers' verbal responses derived from the focus group discussion that took place. Following a thematic approach, it was determined that pre-service teachers' experiences regarding the virtual reality experience rendered four prominent themes. These themes were titled as 'Immersive engagement with and understanding of life science subject knowledge', 'Digital pedagogical skillsets developed related to life science education', 'Perceptions and attitudes towards virtual reality use in life science education', and 'Motion sickness related to virtual reality use'. What follows next is a deeper analysis and interpretation of the themes against the backdrop of the main theoretical tenets of Kolb's Experiential Learning Theory.

Theme 1: Immersive engagement with and understanding of life science subject knowledge

The first prominent theme generated through the focus group discussion, as well as captured screenshots of the pre-service teachers' use of the Human Anatomy VR software, dealt with their immersive engagement with and understanding of life science subject knowledge. Developing robust subject knowledge is a core expectation of any teacher development programme (König & Kramer, 2021). In the context of life science teacher development, pre-service teachers' development of a solid foundation of subject knowledge will assist them in conveying complex concepts with clarity and confidence. The latter is essential to facilitating a deeper understanding and engagement among learners in class. It is widely acknowledged that this in-depth knowledge enables a pre-service teacher to effectively integrate scientific concepts with teaching strategies (Hilfert-Rüppell et al., 2021).

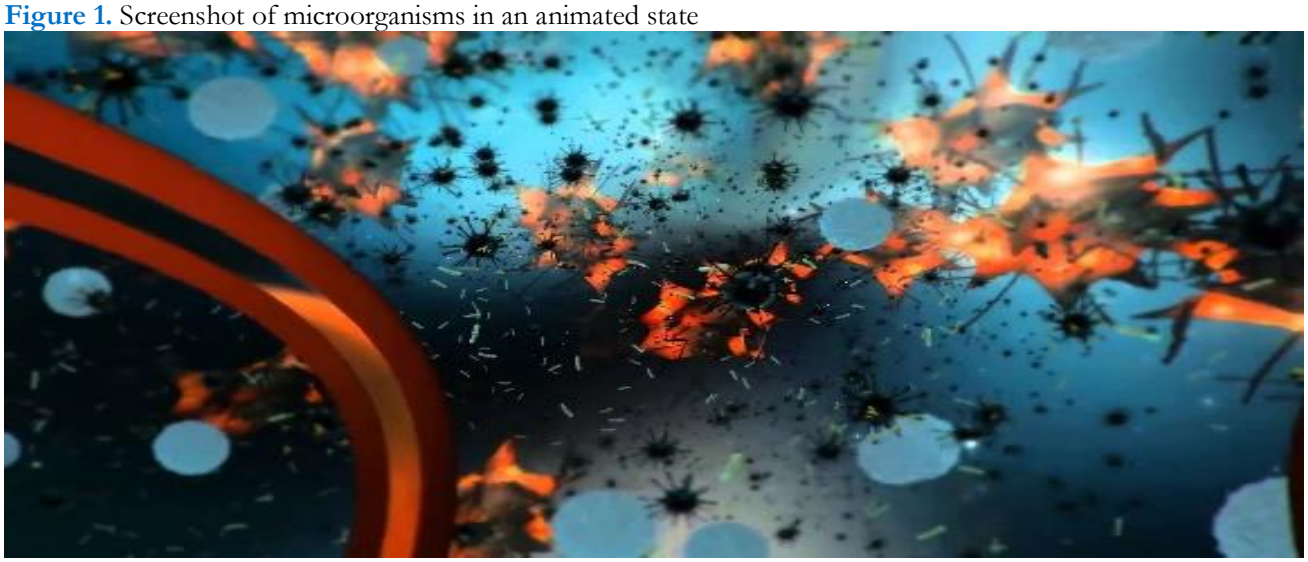
Given the importance of pre-service teachers possessing thorough subject knowledge, their engagement with the Human Anatomy VR application sparked feelings of knowledge development and retention. One of the participants had the following to say:

> *"It's been made so clear how oxygen flows through the body… I was actually the oxygen molecule… [learner laughing]. I used to confuse oxygenated blood with deoxygenated blood, specifically in terms of which kind of blood enters the heart. I mean, the textbook provides a static photo, and this breaks the visualisation of the process. But wow, being the molecule and moving into the heart, through the chambers into the pulmonary veins, is just something else"* *Participant 7*

This particular response vividly describes how the Human Anatomy VR software not only provided an immersive experience but also resulted in an enhanced conceptual understanding of *"the flow of oxygen through the circulatory system"* and *"the distinction between deoxygenated and oxygenated blood"*. The phrase "*I was actually the oxygen molecule"* speaks volumes about a sense of embodied learning, depicting how the virtual reality learning experience allowed pre-service teachers to take on the role of a moving molecule in the human body. The phrase *"the textbook provides a static photo, and this breaks the visualisation of the process"* suggests that the pre-service teachers were enabled to serve as active participants within an immersive and dynamic learning process, a departure from the traditional passive and rote learning encounter (Pellas, 2025). From the quote, one also finds that a common misconception has been addressed. In particular, the pre-service teacher expressed confusion about whether *"oxygenated or deoxygenated blood enters the heart."* However, given the use of virtual reality, this misconception was addressed through the immersive and spatial journey that virtual reality allowed for. The latter emphasises the potential of virtual reality in clarifying complex and abstract processes that are otherwise considered as flat and static images in textbooks (Analyti & Mitropoulou, 2024).

Another example of immersive engagement with life science topics occurred when a pre-service teacher took a journey through the human body by exploring it from a microscopic perspective. During this encounter, the pre-service teacher *"entered"* the human body to identify the various microorganisms present in the bloodstream. This time around, visual depictions of one pre-service teacher's *"journey through the human body"* can be observed in a captured screenshot from their virtual reality encounter, as shown in **Figure 1** below.

Figure 1. Screenshot of microorganisms in an animated state



From this particular screenshot, one can identify a blend of vibrant, floating, colourful components, such as cells, viruses and bacteria, with distinctive shapes. This immersive learning engagement presents a visual exploration of cell-like structures interactively to the pre-service teachers. Makransky and Petersen (2021) remind us that engaging in such immersive and interactive learning allows for abstract and deep learning, therefore fostering deeper connections with disciplinary knowledge.

Participant 3 shared more substantial verbal evidence of immersive engagement with life science topics through virtual reality when she mentioned that:

"To be honest with you Sir, this was so much fun, but one learns at the same time, actually awesome." *Participant 3*

This brief response highlights the pedagogical value of their experience with the virtual reality application, yielding a fun and educational experience. The phrase *"actually awesome"* suggests that the virtual reality experience did not distract the pre-service teachers from the learning experience but instead fostered enhanced engagement and retention. This supports the notion that a virtual reality educational experience serves as a powerful tool for initiating deep learning and fostering intrinsic motivation in science education (Makransky, Terkildsen, & Mayer, 2019). Makransky, Terkildsen & Mayer (2021) remind us that virtual reality can transform abstract scientific concepts into visual and tangible experiences, making them more comprehensible and engaging for students. This enhanced engagement is likely to improve students' understanding and retention of complex scientific concepts.

Theme 2: Improved digital pedagogical skillsets

The second theme, generated through a combination of focus group discussions, captured photographs of the pre-service teachers' use of the Human Anatomy VR application, and eye-tracking capabilities, addressed their exposure to innovative digital pedagogies. A fundamental expectation of the teacher development programme in the Faculty of Education at a selected University is for pre-service teachers to develop the ability to act as agents of change in their understanding and implementation of quality teaching. One approach to achieving this is by rethinking quality teaching through innovative and inclusive methods that utilise recent digital technologies, such as virtual reality.

This strategy aligns with the selected University's Institutional Strategic Plan, which emphasises the importance of becoming a digitally advanced institution that equips graduates with the skills to integrate current digital technologies, such as virtual reality, into their teaching practices. In this context, the engagement of pre-service teachers with the Human Anatomy VR application seems to inspire thoughts about transformative teaching in the future. For example, one participant made a remark that seems to point to VR-inspired ideas for inquiry-based, visual and learner-led teaching:

"Playing with the VR really made me think about my role as the teacher… I really don't want to be that type of teacher that just teach in a normal way, I also want to create special experiences for my learners like this where learners can [feel] science. Just imagine how well grade 10 kids will do with difficult concepts such as the heart… It really comes down to transforming and reimagining how one teach with technology and allow learners to really connect with knowledge in an authentic way."

Participant 7

Participant 7's response highlights a significant shift in their identity and approach as a future life science educator. This suggests that the pre-service teacher is moving from traditional content delivery to becoming an experiential and transformational practitioner. Phrases like *"feel science"* indicate a pedagogical change toward affective engagement, characterised by immersive and emotionally resonant learning (Makransky & Petersen, 2021). It also implies a growing awareness of learners' diverse learning needs, necessitating an interactive and multi-sensory teaching approach.

Another participant had the following to say:

"This was so cool. It was just something else… this immersive experience using the app made it easier for me to understand the concepts. I made me feel the subject matter in a way that traditional methods couldn't… It was more connected. It changed how I view my teaching, I mean, creating learning scenarios that are creative is so important" *Participant 1*

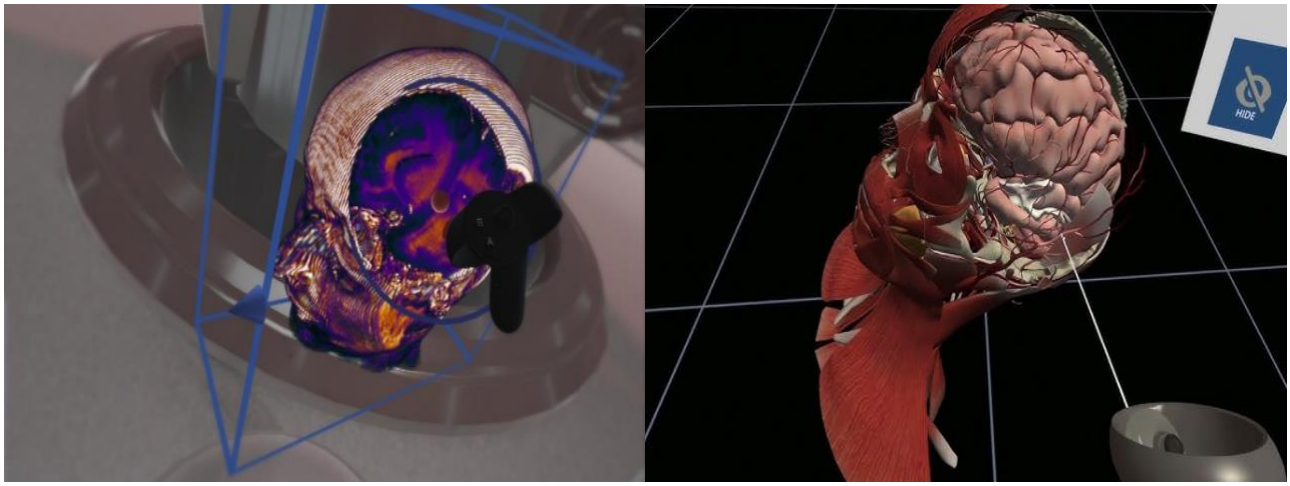
A closer look at the pre-service teacher's response suggests that their engagement with the Human Anatomy VR application had a profound impact on their teaching philosophy. From the response, a deeper connection with

the subject matter is described, which is not often the case through traditional teaching methodologies. The statement *"create learning scenarios that are creative"* highlights the aspect of transformative pedagogy, as the pre-service teacher was able to reflect on their personal beliefs and practices as a future life science educator. The assumption is that the pre-service teacher adopts the notion of an active, learner-centred teaching approach using virtual reality technologies. This form of teaching aligns well with Vygotsky's (1978) social constructivist theory, which emphasises the importance of engaged and collaborative learning experiences as a means to promote deep learning.

On the other hand, the phrase *"it made me feel the subject matter in a way that traditional methods couldn't"* highlights the emotional and sensory engagement with the content that promotes both understanding and retention of knowledge. This approach aligns with the view of Makransky and Petersen (2021), who emphasise the importance of individuals being emotionally engaged in the learning process. In addition, the phrase *"feel more connected"* is consistent with the view of Parong and Mayer (2021), who suggest that immersive learning experiences have the potential to provide rich, multisensory experiences.

In support of this statement, captured footage of the pre-service teachers' engagement with the Human Anatomy VR application visually depicts a level of virtual reality immersion, as well as a shift to a more sensory-driven approach to learning. This particular screenshot illustrates how a pre-service teacher was able to explore anatomical regions, including the brain, skull, head, and neck.

Figure 2. Screenshot that depicts the cross-section of the brain in an animated state



With this description in mind, the use of the Sight Lab VR eye-tracking capabilities proved helpful in tracking the participant's eye movements during her engagement with brain physiology. This time, the data were captured in a table format that indicated the participant's fixation duration for the different areas of the brain and the fixation count, which showed how many times participant 5 focused on a particular region of the brain.

Table 2. Eye-tracking data of participant 2

Organelle	Fixation Duration in seconds	Fixation count
Cerebrum	27,1	22
Cerebellum	11,4	11
Brainstem	6,8	8
Frontal Lobe	21,2	15
Other (e.g., background)	4,9	5

A closer look at **Table 2** reveals a comparison between the 'Fixation Duration,' measured in seconds, and the 'Fixation Count' across the different Areas of Interest, as explored in the Human Anatomy VR application. The highest fixation duration and count recorded were for the Cerebrum (27,1 seconds) and Frontal Lobe (21.2 seconds). This suggests that the pre-service teachers focused intensely on these two brain regions. This frequent and extended focus was actively engaged with, which indicates that active learning took place. Interestingly, the high fixation duration on the Cerebrum (22 times) could suggest that a more intense reflection occurred with this brain region. This level of fixation on the region of the brain aligns with what Dewey, decades ago, coined as

'experiential learning', which is characterised by learners reflecting on their learning experience to gain better insights into the physiological and functional aspects of knowledge (Dewey, 1979).

Finally, there was a relatively lower fixation (4,9 seconds) on "other areas," such as the scene animations and graphics. This supports the notion that the pre-service teachers remained focused on the relevant brain regions rather than being distracted by the immersive animations. The assumption, therefore, is that the virtual reality environment captured the attention of the pre-service teachers by directing their focus to regions of the brain that are of interest. Overall, the data suggested that two specific areas, namely the Cerebrum (22 times) and the Frontal Lobe (15 times), were more focused on time and frequency.

Theme 3: Perceptions and attitudes towards virtual reality use in life science education

The third theme, generated through a combination of focus group discussions, captured screenshots of the pre-service teachers' use of the Human Anatomy VR application, and eye-tracking capabilities, explored their perceptions and attitudes towards virtual reality use in life science education. In teacher development, a reformed perception and attitude towards emerging technologies, such as virtual reality, can serve as a mechanism for enhanced learner engagement with complex topics in the life science school syllabus through immersive, hands-on learning experiences. As Kolb's (1984) experiential learning theory suggests, integrating technology into life science teaching will enable active, learner-centred learning, which is beneficial for deep learning.

With this understanding of a reformed perception and attitude towards emerging technologies in mind, one participant had the following to say during the focus group discussion:

> *"Being inside the cell was so cool. I could actually see everything [referring to cell organelles] in motion and made me realise that the inside of the cell is actually all connected to the brain of the cell [referring to the nucleus]. I went of exploring the other parts [organelles] but could see how it links up with the function of the nucleus which was amazing.."* *Participant 8*

Given this verbatim response, one can take it a step further by drawing on the eye-tracking data of participant 8 during his engagement with the topic *"A Journey into a Cell."* The data captured in **Table 3** below include the different organelles of a cell that were focused on during the virtual reality experience, along with the fixation duration (the time the pre-service teacher stared at the organelle) and the fixation count (the number of times the pre-service teacher focused on the organelle).

Table 3. Eye-tracking data of participant 5

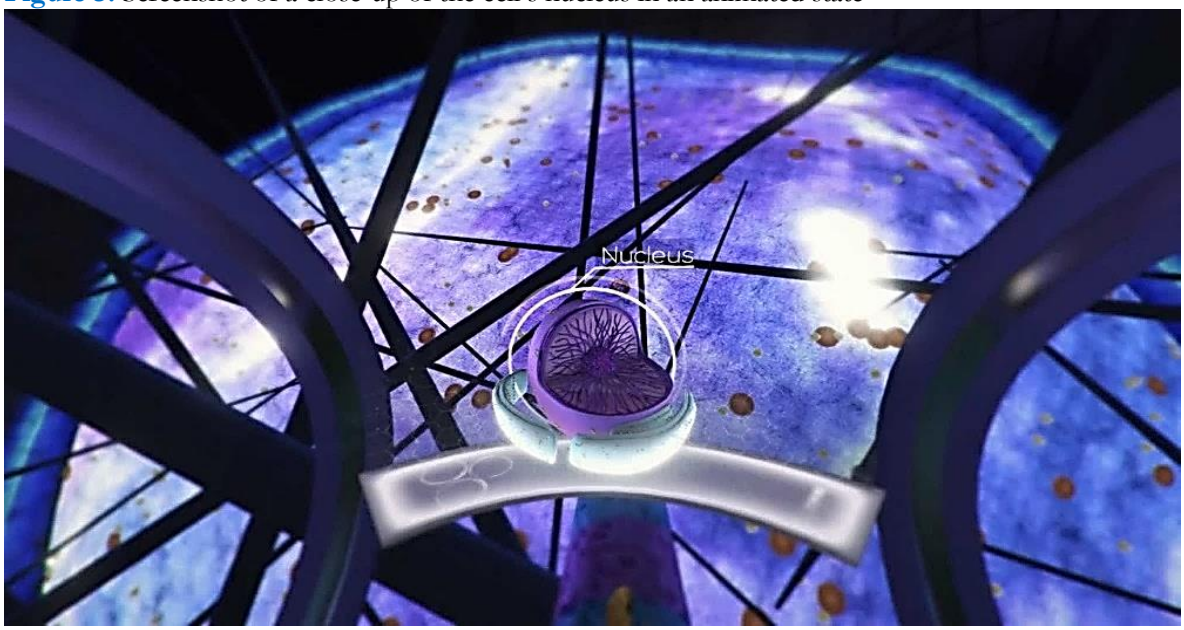
Organelle	Fixation Duration in seconds	Fixation count
Nucleus	34,2	22
Mitochondria	17,2	14
Endoplasmic Reticulum	15,9	8
Ribosomes	11,3	6
Golgi Apparatus	7,8	5
Lysosomes	5,4	4
Plasma Membrane	27,8	18
Cytoplasm	15,6	9
Vacuoles	4,3	3

A closer look at **Table 3** suggested that the Nucleus received the highest attention, both in terms of duration (34,2 seconds) and frequency (22 times), reflecting its central role in cell function. This aligns with his verbal response, which suggested that his attention was predominantly focused on the 'nucleus of the cell'. Both the verbal response and the eye-tracking datasets indicated the immersive nature, underpinned by emotional and cognitive engagement, of the virtual reality learning experience, which was characterised by active engagement with disciplinary knowledge regarding the cell's components.

Apart from the verbal responses and eye-tracking data provided, a screenshot from one of the pre-service teachers' engagements with Human Anatomy VR appears to depict a close-up image of the nucleus of a cell, along with other intricate details such as the cell membrane, cell filaments, and other cell organelles.

From the image, one can see the colourful purple and blue hues, which refer to the cytoplasm of the cell, with supporting golden dots representing the ribosomes of the cell. This provides the virtual reality user with a first-person perspective and an enhanced sense of scale and detail in the microscopic world. Although the image appears static, there is still a level of immersion at play, as it places the user at the centre of the cell, titled the nucleus, which is one of the most critical components of a cell.

Figure 3. Screenshot of a close-up of the cell's nucleus in an animated state



From the image, one can see the colourful purple and blue hues, which refer to the cytoplasm of the cell, with supporting golden dots representing the ribosomes of the cell. This provides the virtual reality user with a first-person perspective and an enhanced sense of scale and detail in the microscopic world. Although the image appears static, there is still a level of immersion at play, as it places the user at the centre of the cell, titled the nucleus, which is one of the most critical components of a cell.

Theme 4: Motion sickness related to VR use

Unfortunately, the pre-service teachers' engagement with the Human Anatomy VR App also posed some challenges related to motion sickness. Dennison et al. (2021) explain that motion sickness arises from a sensory mismatch between the pre-service teachers' visual stimuli and physical movement. Although the general feeling was that the VR experience provided an immersive and engaging learning experience, it is essential to note that not all pre-service teachers would find the experience meaningful.

For example, a participant had the following to say.

"It was nice in the beginning, but I'm not used to it. I felt so weird and had to stop after a while. It's almost like feeling disorientated, a little bit dizzy. This did not make it nice at all and I missed some of the content". *Participant 1*

Another participant echoed a similar response by stating:

"Jeez, I felt a bit weird while I was using it and that takes away from the learning experience. I also felt a little bit anxious using it". *Participant 6*

Both responses indicated that the participants experienced discomfort due to motion sickness while using virtual reality technology. It is widely reported that motion sickness is perceived as a barrier to the effective use of virtual reality technology in the classroom. Rizzo et al. (2011) remind us that this is quite common for users who are not accustomed to virtual reality. Studies suggest that motion sickness is a primary reason educators do not utilise virtual reality in their teaching, potentially underutilising its potential in teaching and learning practices (Rizzo et al., 2011). Some suggest that pre-service teachers are gradually exposed to virtual reality in shorter intervals to counter these issues. Some argue that the user should also progressively increase the duration of virtual reality engagement over time (Crudu & MoldStud Research Team, 2025). The assumption is that this approach will help pre-service teachers become familiar with virtual reality technology.

DISCUSSION

The study reported on the reflections of pre-service teachers regarding their use of virtual reality open educational resources, specifically the Human Anatomy VR software application, as part of their professional development as up-and-coming life science teachers. Given the qualitative focus of the study, a multi-layered

approach was employed to capture empirical data. In particular, the selection of a semi-structured focus group discussion, the use of digital screenshots taken by the pre-service teachers, and the utilisation of eye-tracking capabilities offered by Sightlab software were essential in formulating four prominent themes that informed their reflections. These themes were 'Immersive engagement with and understanding of life science subject knowledge', 'Digital pedagogical skillsets developed related to life science education', 'Perceptions and attitudes towards virtual reality use in life science education', and 'Motion sickness related to virtual reality use'.

Initially, it was revealed that the use of Human Anatomy VR software enabled pre-service teachers to explore and engage with complex life science topics in a manner that traditional teaching and learning methods do not offer. This aligns with Dede's (2009) perspective on the significance of virtual reality to foster deep engagement and understanding of learning content. Pre-service teachers' mastery of subject knowledge is a core expectation of the teacher development programme in the Faculty of Education. Evidence of subject knowledge retention was expressed through phrases such as *"better understanding of the flow of oxygen through the circulatory system"*, *"the distinction between deoxygenated and oxygenated blood is much clearer"* and *"the textbook provides a static photo, and this breaks the visualisation of the process"*. Photographic screenshot evidence of their engagement with the virtual reality software further solidified the level of immersive learning that took place (see **Figures 1** and **2**).

In the second instance, it was revealed that the use of the Human Anatomy VR software enabled pre-service teachers to adopt digital pedagogies in their life science teaching and reconsider their attitudes toward the use of virtual reality in this context. The use of virtual reality software prompted reflection on transformative virtual reality-inspired teaching ideas that are inquiry-based, visual and learner-led. For example, phrases such as *"Playing with the VR made me question my role as the teacher"* and *"I really don't want to be that type of teacher that just teach in a normal way, I also want to create special experiences for my learners like this where learners can [feel] science"* are indicative of a transformed teaching philosophy, specifically in the context of life science education. These comments are consistent with the University's Institutional Strategic Plan for 2025–2029. The plan emphasises the importance of becoming a digitally advanced institution that prepares graduates to integrate current digital technologies, such as virtual reality, into their teaching practices.

The potential of virtual reality in teacher education is significant (Makransky & Petersen, 2021; Parong & Mayer, 2021). However, challenges such as motion sickness and initial discomfort with immersive technologies are still prevalent. Theme four specifically focused on the issue of motion sickness related to VR usage, as illustrated by comments such as *"I felt a bit weird while using it"* and *"I also felt a little anxious using it."* This highlights why Park et al. (2025) emphasise the importance of gradual exposure to VR learning, which helps pre-service teachers acclimate to the technology.

Reflecting on the study, it is clear that virtual reality offers an innovative and engaging approach to education, particularly in the life sciences, as demonstrated in **Figures 1, 2** and **3**. Additionally, **Tables 2** and **3** present eye-tracking data indicating that pre-service teachers were both cognitively and emotionally engaged in a meaningful VR learning experience. This immersive approach aligns with various contemporary pedagogical frameworks. The insights shared by pre-service teachers strongly correlate with Kolb's Experiential Learning Theory (1984), which suggests that learning in the life sciences is most effective when it involves active participation, reflection and application of knowledge. The study revealed that pre-service teachers actively engaged with life science topics through virtual reality learning, developed digital pedagogical skills, and reflected on their attitudes toward incorporating virtual reality into their teaching to enhance their effectiveness.

CONCLUSION

The study focused on pre-service teachers' reflections regarding the use of virtual reality (VR) open educational resources, specifically the Human Anatomy VR software application, as part of their development as life science teachers. It enabled an in-depth exploration of how the Human Anatomy VR experience informed their understanding and stimulated interest in immersive digital teaching methods, particularly in the context of life science education. To achieve this goal, the researcher utilized a combination of focus group discussions, digital screenshots documenting the pre-service teachers' interactions with the Human Anatomy VR software. This approach generated qualitative data that aligned with the pre-service teachers' reflections on their use of virtual reality. Through these various data collection techniques, the research revealed four prominent themes in the pre-service teachers' reflections:

i. Immersive engagement with and understanding of life science subject knowledge
ii. Development of digital pedagogical skill sets related to life science education
iii. Perceptions and attitudes toward the use of virtual reality in life science education
iv. Motion sickness related to the use of virtual reality

This research provides valuable insights into the teaching and learning scholarship regarding the use of virtual reality in developing life science pre-service teachers. It emphasizes the importance of subject knowledge retention,

the development of digital pedagogy skills, and teaching effectiveness. The findings of this study will benefit curriculum developers involved in teacher development programs and may also have important implications for policymakers focused on modernising teacher education in STEM fields. The research encourages further exploration of how VR open educational resources can:

i. enhance pre-service teachers' subject knowledge,
ii. transform their teaching philosophy with virtual reality in mind, and
iii. improve the digital pedagogical skill sets of STEM pre-service teachers within the context of virtual reality education.

Focusing on virtual reality in STEM education offers a promising avenue for creating more dynamic, engaging, and immersive teaching experiences in the field.

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