

## PHYSICAL SCIENCES PRE-SERVICE TEACHERS' VR-SUPPORTED 5E INSTRUCTIONAL PRACTICES DURING MICROTEACHING OF ELECTRON CONFIGURATION

**Samukelo Sibiyi, & Noluthando Mdlalose**

*Science and Technology Education, University of Johannesburg (South Africa)*

### Abstract

Teaching concepts that are abstract such as electron configuration remain challenging in Physical Sciences classrooms, particularly for pre-service teachers who are still developing their pedagogical and technological competencies. The integration of technology with inquiry-based teaching presents opportunities to support visualisation and strengthen instructional practice. This paper reports the findings of a qualitative case study exploring Physical Sciences pre-service teacher's implementation of a VR-enhanced 5E Instructional Model of Inquiry when teaching electron configuration during microteaching. The study focused on three Physical Sciences Post-Graduate Certificate (PGCE) pre-service teachers that were purposively selected from a South African university. The data was collected using lesson plans, non-participant classroom observations, semi-structured interviews, and stimulated-recall reflections. The findings from the lesson plans and semi-structured interviews indicated that pre-service teachers showed willingness to integrate VR and 5E Instructional Model during their teaching. VR was found to be effective as it promoted learner engagement, visualisation of abstract atomic structures, allowed the exploration and promoted the explanation during microteaching sessions and assisted in grasping the concept that is abstract. Challenges were identified during the implementation of the VR-enhanced 5E Instructional Model during micro-teaching such as limited instructional time allocated per pre-service teacher were not enough, technical difficulties due to lack of training, varying levels of confidence in the use of the VR tool from the pre-service teachers, and difficulties in coherently balancing the integration of all phases of the 5E Instructional Model while also implementing the VR tool. Despite these challenges being raised, the pre-service teachers also reported positive teaching experiences and recognised VR as a valuable tool for supporting inquiry-based teaching in science classrooms. The study recommends the purposeful inclusion of VR-supported inquiry approaches within teacher education programmes. Furthermore, opportunities for VR-based microteaching should be expanded to better prepare PGCE pre-service teachers for real classroom contexts and to strengthen their ability to implement inquiry-based instructional practices in Physical Sciences.

**Keywords:** *5E Instructional Model*, electron configuration, inquiry-based teaching, Physical Sciences, Virtual Reality.

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### 1. Introduction

Globally, the use of innovative technologies, particularly Virtual Reality (VR) is transforming the way science subject is taught by creating immersive learning environments that support conceptual understanding. Virtual Reality is implemented by a combination of technologies that are used to visualize and provide interaction with a virtual environment. These environments often depict three-dimensional space which may be realistic or imaginary, macroscopic or microscopic and based on realistic physical laws of dynamics, or on imaginary dynamics. In the education sector, commonly used VR technologies include immersive head-mounted displays (e.g., Oculus devices), desktop-based simulations, and mobile VR applications, which allow learners to interact with three-dimensional representations of scientific concepts in real time (Mojsoska, 2024). These technologies are increasingly adopted because they promote active learning, visualisation, and learner engagement, particularly in topics that are not easily observable in real-life contexts. However, challenges such as high implementation costs, limited access to resources, technical difficulties, and insufficient teacher training continue to hinder its widespread adoption in classroom practice. Electron configuration is a foundational concept in chemistry that explains how the atoms and molecules behave and as the results it is important for the learners to grasp this content. This topic is abstract because of its nature that stems from its focus on submicroscopic particles and symbolic

representations that cannot be directly observed, and they require the learners to mentally connect macroscopic, symbolic, and particulate levels of chemistry; this complexity has been shown to contribute to learning difficulties among learners (Salehzadeh, 2016). In the South African context, studies have further reported that learners struggle particularly with transitioning between these levels of representation, which negatively affects their conceptual understanding of atomic structure and related topics. One of the core difficulties lies in the fact that electron configuration requires the learners to simultaneously understand and integrate the content knowledge across three representational levels in Physical Sciences: the macroscopic (observable phenomena), the sub microscopic (particles and structures at atomic level), and the symbolic (chemical symbols and equations) (Keiner, 2020). According to Dorris (2022), learners struggle with chemistry as part of the Physical Sciences because it operates on three levels and it requires the macroscopic, sub microscopic, and symbolic and it requires the learners to be abstract thinkers. The VR visuals act as cognitive instruments that enable learners to express their conceptual comprehension with assistance from educators who provide support for their explanations. The integration between VR and the 5E model not only improves learners' understanding but also caters to various cognitive styles and learning speeds. Mojsoska (2024) states that the integration of VR with inquiry-based techniques enhances student engagement and understanding in STEM areas. Moreover, incorporating VR into 5E instructional model of inquiry equips pre-service educators with a cutting-edge teaching toolkit that readies them for tech-enriched classrooms. The 5E instructional model of inquiry offers a dependable structure, ensuring that VR is integrated with learning outcomes rather than being used independently. Hite (2022) contends that this alignment is essential to guarantee that digital tools effectively aid in mastering content instead of serving as distractions. The South African Curriculum and Assessment Policy Statement (CAPS), which is the national policy framework that guides the teaching and learning of Physical Sciences for Grade 10-12, explicitly promotes inquiry-based learning by emphasising the development of scientific investigation skills, critical thinking, and active learner engagement in the construction of knowledge (DBE, 2011), and that prepares the learners for the 21<sup>st</sup> century. These investigative skills are essential for understanding abstract scientific ideas like electron configuration, which numerous students struggle with because of its microscopic and theoretical aspects (Mavhunga, 2013). To address these challenges, Virtual Reality (VR) technologies are becoming increasingly popular in science education to connect abstract concepts with experiential learning.

## 2. Aims and objectives

Despite the growth in the global research about the effectiveness of Virtual Reality (VR) and 5E Instructional model of inquiry, most researchers have largely focused on learners' outcomes rather than on teachers' pedagogical practices and experiences. Furthermore, limited research within the South African context has explored how Physical Sciences pre-service teachers implement VR-enhanced inquiry-based approaches, particularly when teaching complex topics such as electron configuration during microteaching. As such, there remains a gap in understanding both the implementation processes and the experiences of pre-service teachers using a VR-enhanced 5E instructional model. As the results, this study aims to investigate Physical Sciences pre-service teachers' implementation of the VR-enhanced 5E instructional model of inquiry when teaching electron configuration during microteaching.

The following research questions were posed to guide the inquiry:

- What are Physical Sciences pre-service teachers' experiences when teaching electron configuration using the VR-enhanced 5E instructional model of inquiry during microteaching?
- How do Physical Sciences pre-service teachers implement the VR-enhanced 5E instructional model of inquiry when teaching electron configuration during microteaching?

In addressing these research questions, a qualitative case study approach was employed, in which four Physical Sciences pre-service teachers were purposively selected to participate in the study. These participants were selected based on their engagement in microteaching and their exposure to the VR-enhanced 5E instructional model.

The objectives of the study were to:

- Document Physical Sciences pre-service teachers' experiences when teaching electron configuration using the VR-enhanced 5E instructional model of inquiry during microteaching.
- Investigate Physical Sciences pre-service teachers' implementation of the VR-enhanced 5E instructional model of inquiry when teaching electron configuration during microteaching.

## 3. Research design & methodology

This study adopts a qualitative research methodology, which is appropriate for exploring in-depth insights, contextual understandings, and the meaning individuals or groups ascribe to a social or educational

phenomenon (Patton, 2022). The qualitative case study design has been specifically selected to guide the research, it enables an in-depth, contextualised understanding of how pre-service Physical Sciences teachers implement the VR-enhanced 5E instructional model during microteaching. Since this study investigates both the experiences and instructional strategies of a small group of participants within the structured setting of microteaching, a case study approach allows for the rich collection of descriptive data. Furthermore, the qualitative nature of the study aligns with the exploratory focus on participants' meanings, perceptions, and practices, which are best captured through open-ended, interpretative methods (Creswell, 2018). This design supports the study's aim of producing insights that are not generalisable in the statistical sense, but transferable to similar teacher education contexts.

#### **4. Data collection**

Participants of this study included pre-service teachers' pseudonyms as PGCET1, PGCET2, PGCET3 from one of the institutions in South Africa in Gauteng province. These pre-service teachers already had a minimum of 1 existing degree as the PGCE in Physical Sciences degree requires NQF level 7 in the science degree. To generate in-depth and context-rich data, this study used multiple data collection tools aligned with qualitative research and we used in four stages, namely: lesson plans (document analysis), stimulated recall reflections (video-based reflection sessions), semi-structured interviews, and non-participant lesson observations. The collected data provided insights into Physical Sciences pre-service teachers' 5E instructional model of inquiry practices during micro-teaching in a VR environment. The data was collected using 4 stages to ensure consistency with the data. During stage 1 the lesson plans were collected and analysed as they are authentic blueprints of how the pre-service teachers intend to teach electron configuration using VR-enhanced 5E instructional model of inquiry. In stage 2, the non-participant observation was selected so that the researcher can document detailed field notes during the pre-service teachers' microteaching lessons. In stage 3, Stimulated Recall Reflections (SRR) were conducted immediately after the microteaching sessions using video recordings to prompt participants to reflect on their instructional decisions, lesson delivery, and classroom interactions. In stage 4, the researcher conducted semi-structured interviews thereafter to explore participants' broader experiences of teaching with VR, including the usability of the application and their competence in implementing the 5E inquiry model.

#### **5. Data analysis**

The data collected was analysed using an inductive thematic approach involving repeated readings of observation notes, transcripts from stimulated recall reflections conducted after each micro-lesson, interview transcripts, and lesson plan artefacts submitted prior to microteaching. Initial codes were generated based on recurring patterns in participants' actions (e.g., "analogy to orbitals"), teacher intentions (e.g., "engage via scenario"), technical events (e.g., "controller error"). These codes were then clustered into broader themes that naturally aligned with the phases of the 5E Instructional Model of Inquiry. Additional cross-cutting themes such as technical competence, teacher role shifts, and assessment challenges also emerged during the analysis. To ensure trustworthiness, triangulation was applied across data sources.

#### **6. Results**

The data sources encompass by the structured lesson plans, non-participants observation notes taken by the researcher during the micro teaching, stimulated-recall reflections by the pre-service teacher immediately after their micro-teaching and the semi-structured interviews conducted via MS Teams with each pre-service teacher at their own convenient time. The findings from this study are reported phase-by-phase using the following phases: Engage, Explore, Explain, Elaborate and Evaluate.

##### **6.1. Engage**

Engagement strategies were intentionally chosen by the pre-service teachers in their introductions and aligned to different pedagogical aims based on what the pre-service teacher has planned for their micro-teaching: Teacher 1 emphasized analogical bridging by using our everyday experiences, which helps to grasp the learners attentions and related such daily experiences with the concept of electron configuration, and Teacher 2 used diagnostic questioning which assist a lot to check on the learners prior knowledge and assist in building the concept that is abstract with something that the learners they can easily relates with, and Teacher 3 aimed to build familiarity with the medium tool of instruction which is Virtual Reality (VR) itself. These approaches are consistent with 5E theory where Engage triggers curiosity and

reveals prior conceptions (Barufaldi, 2002). This phase is more centered as it stimulates motivation which creates the desire to learn more about the topic. The data show that, in practice, VR was not necessarily the primary engagement device at the beginning of the lesson, but the pre-service teachers preferred the short verbal hooks or analogies before full immersion with the device.

## 6.2. Explore

The Explore phase emerged as the stage with the strongest affordances of VR, as it required learners to actively engage in hands-on construction of atomic models. This kept the lesson progressing as the learners got immediate visual feedback when the atom gets to be made as well as the electron configuration for that atom and that promoted multimodal interaction. This phase is also learner-centered and incorporates active exploration within the VR tool. The table below will summaries the pre-services teacher's experiences of how they implemented the VR when teaching the electron configuration in the exploration phase of the 5E Instructional Model.

Table 1. Explore phase: summary across teachers (observations, reflections, interviews).

| Indicator                                                              | Teacher 1                                                                                                                    | Teacher 2                                                                       | Teacher 3                                                                                |
|------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| 1. Planned VR atom creation (lesson plan)                              | Yes                                                                                                                          | Yes                                                                             | Yes                                                                                      |
| 2. Learners given the opportunity for hands-on VR time.                | Yes, however they were monitored.                                                                                            | Yes, however they were monitored                                                | Yes, but their time was very less because of the technical issues that they encountered. |
| 3. Pre-service teacher well orientated about VR.                       | Competent                                                                                                                    | Still a novice but proficient                                                   | Struggling and resulted in frequent resets and restart                                   |
| 4. The reflection about the effectiveness of implementing the VR tool. | Positive about the Implementation and promoted a lot of visualisations                                                       | Positive and this motivated a lot of learners and kept them engaged and excited | Mixed as the tool was unfamiliar which led to the hindering of the flow                  |
| 5. The sample of their interview.                                      | "Using this tool is rewarding as in most of the times we are using our devices, and it get easy to use it..." says Teacher 1 | "Learners were captivated" says Teacher 2                                       | "I occasionally pressed wrong commands... had to reset" says Teacher 3                   |

## 6.3. Explain

The explanation phase is an essential, minds-on part of the 5E lesson. The explanation phase enabled the learners to describe their understanding and pose questions about the concepts they have been exploring. New questions were generated, and they promoted the discussion in the classroom and that kept the classroom engaged. This phase was a natural fit for the use of the VR tool because the visual, dynamic representations facilitated teacher-led conceptual clarification as the learners were able to inquire about how the orbitals got filled and why the atom were not created.

## 6.4. Elaborate

During this phase the teachers extended the learning by asking their learners to apply orbital rules to new atoms and asked them to reflect on the shape, and to explain if the electron configuration has any factor on it and PGCET3 explained how such atoms can help us in real-life. Elaboration occurred as the pre-service teacher designed tasks that required learners to apply concepts, for example producing electron configurations using unfamiliar elements. However, the data collected suggested that elaboration was sometimes superficial or constrained by practicalities due to the limited time using the googles and the availability of the VR device.

## 6.5. Evaluate

During the Evaluate phase, the pre-service teachers attempted to assess their lesson objectives per their lesson planning if they had been achieved. This was done by asking learners to construct atoms and present their electron configurations using the VR model without being assisted. The learners manipulated virtual atomic models, placing electrons into orbitals, and verbally explaining their configurations while the teacher was observing and asking follow-up questions based on their atomic structures. However, evaluation emerged as the weakest and the phase that challenged both teachers and learners, and all three pre-service teachers agreed on each other. Observations revealed that, although learners were able to complete the tasks, their responses were largely descriptive, and their focus was on what they visually observed in the VR simulation rather than demonstrating deeper conceptual understanding of the electron-configuration. This was further confirmed during post-lesson interviews, where pre-service teachers reflected on the difficulty of content grasping, conceptually grounded explanations from learners.

## 7. Discussion

The findings of this study show that pre-service teachers experienced VR as both an exciting and challenging instructional tool when implementing the 5E model to teach electron configuration. Participants expressed enthusiasm about the immersive nature of the tool, with one noting that “*the VR made it easier to visualise something I usually struggle to explain on the board*” (PGCET1). However, this excitement was accompanied by notable challenges, particularly as it was their first time interacting with VR in a teaching context. For instance, another participant reflected that “*I was not confident at first because I did not know how to fully integrate the VR with my teaching strategy*” (PGCET2). This lack of confidence can be attributed to their limited exposure to pedagogical strategies during their PGCE training, as highlighted by a participant who stated that “*we were not really trained on how to use such technologies in our teaching*” (PGCET3). Through reflections and interviews, participants consistently described VR as highly engaging, offering learners the ability to visualise abstract atomic structures in three dimensions which are difficult with traditional teaching and learning tools. PGCET3 noted that VR made them feel as though they had “stepped into a different world,” highlighting its immersive and transformative potential. This comment resonated with what was once said by the researcher Rammnarain’s (2021) argument that inquiry-based learning is strengthened when the learners they can manipulate concrete representations of abstract content to something that can be easily understood. Another critical finding relates to the Evaluate phase of the 5E Instructional Model, which all three pre-service teachers described as the most difficult stage to implement with VR. Their challenges can be explained by the limited assessment literacy since before they were enrolled for the different degree and they have not even yet finished a year in the education course. The participants were still learning how to move beyond descriptive questioning toward eliciting deeper conceptual understanding in the classroom.

## 8. Conclusion and recommendations

In conclusion, this study highlighted the transformative potential of the VR-enhanced 5E instructional model in supporting the pre-service Physical Sciences teachers to integrate the inquiry-based learning when teaching one of the abstract concepts of electron configuration. The PGCE pre-service teachers should be enrolled in the modules that will provide them with opportunities to practice lesson planning, microteaching, and reflection while receiving feedback on both pedagogical strategies and assessment practices as that will prepare them for the practical classroom. In addition, the novice teachers must pair with more experienced physical science teachers as that could help to build confidence in navigating the Evaluate phase of the 5E Instructional Model, which was identified as the phase that the participants struggled in. Addressing these gaps through professional development, curriculum guidance, and practical support can strengthen pre-service teachers’ confidence and pedagogical effectiveness so that as they become in-service teacher's they will be more than enough fit to shape the world.

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