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EXTENDING NATURAL SCIENCES LEARNING IN PRE-SERVICE TEACHER EDUCATION USING AUGMENTED REALITY-ENHANCED INQUIRY

Mafor Penn[1], & Umesh Ramnarain[2]
[1]*Department of Childhood Education, University of Johannesburg (South Africa)*
[2]*Department of Science and Technology Education, University of Johannesburg (South Africa)*

Abstract

As the world transitions to hybrid ways of working it is increasingly important that education is not left behind. The COVID-19 pandemic further exacerbated the need for teaching and learning to transition from face-to-face contact mode to remote, blended or hybrid modes of teaching and learning. In this study, a group of 32 pre-service Natural Sciences (NS) teachers engaged with *Jigspace*; a composite augmented reality (AR) application following an inquiry-based approach to learn identified NS concepts. The main aim of the research was to establish the usability of AR in PSTs' learning and the affordances of AR technology as part of a teaching and learning design that could improve achievement in content tests. In a quasi-experimental design, data was collected through pre- and post-intervention content tests followed by post- intervention focus group interviews with all participants. A paired sample t-test was employed to establish a significantly positive shift in content test achievement before and after AR-enhanced learning interventions. Findings from qualitative content analysis revealed that students were able to interact and learn more with AR learning models due to their semi-immersive attributes and the associated text mediation added to the application. Participants noted that just reading a textbook or written text was not usually enough for the formation of mental representations. Gesticular actions like *rotation, zoom in and out, animation, spinning, pulling and dragging* underpinned the main interactions with learning artefacts embedded in the AR applications. Some important 21st century skills, including collaboration, critical thinking and communication were enhanced as students spent time exploring concepts and addressing difficulties in chat groups and social media platforms. The research also contributes primarily to the role of mobile learning devices and AR in enhancing remote and blended learning of science concepts. Some implications of these findings for pre-service teacher education (PSTE) include: an urgency to transform NS teacher training to include technology-enhanced learning of science concepts: reforms in school policy to integrate mobile learning technologies like AR for the teaching and learning of science which will aid teachers to innovate when teaching science. Some recommendations for future research and practice are also covered herein.

Keywords: *Augmented reality, Jigspace, mobile learning, inquiry-based learning, pre-service teachers.*

1. Introduction

Innovations in technology and the rapid digitization of diverse spheres of life are becoming the *"new normal"* in the world today. As a result of these rapid changes in futuristic technology like artificial intelligence, robotics, augmented, virtual and mixed reality, educational environments from pre-school to universities are bound to adjust. This study as part of a broader study on the experiences of pre-service teachers (PSTs) on the use of Virtual and Augmented reality (VAR), examines the learning gains that are recordedpost an intervention with the augmented reality (AR) application *jigspace.*

Simply put, augmented reality (AR) is defined as the overlaying of 3-dimensional (3D) digital images on a real or physical environment or image (Akçayır et al., 2016; Azuma, 1997)). Usually, a mobile device which is AR compatible, for example a smart phone or tablet is needed to host AR applications. AR applications can be *markerless* or *marker based*. *Makerless* AR applications use the scanning of a flat plain by slowly rotating one's mobile device then finger placing the digital object when it appears on the screen of the mobile device. On the other hand, marker-based AR explores the scanning of printed markers either on paper or textile to locate and use 3D virtual images.

Some of the benefits of AR in NS education include improvement in spatial reasoning, learning, motivation and skills (Ibáñez & Delgado-Kloos, 2018). Other researchers report enhanced cognitive engagement and hence conceptual understandings (Dunleavy & Dede, 2014, Ke & Hsu, 2015) and subsequently improved achievement (Chu et al, 2019). Similarly reported challenges range from poor connectivity issues, application flaws (Singh et al., 2019) and the cost of good quality mobile devices especially in the African context. Despite the benefit associated with the integration of AR in learning, some pre- and in-service teachers still find it a daunting task to incorporate these technologies in their own learning and in their teaching practice. In the South African context not enough has been reported on the affordances of AR in NS learning especially in teacher education courses. It is for this reason that the researchers examined how NS learning in PST education could be extended by asking the following research question.

- To what extent is achievement in Natural Sciences enhanced or not when AR applications are integrated as learning tools in PST education?
- How would PSTs describe AR-enhanced NS inquiry learning experiences?

The main aim of this study was to examine ways in which PSTs' natural Sciences learning could be extended with the use of AR applications. Based on this aim the following objectives were set:

- To design and conduct an AR Based learning intervention with pre-service NS teachers.
- To evaluate PSTs' learning experiences of AR-enhanced NS inquiry.

The significance of the study reveals for AR integration as a sound learning and pedagogical tool in PST training in order to enhance technological and content knowledge (TCK) in the subject natural sciences.

2. Theoretical underpinnings

The use of AR in education has its groundings in educational theories including constructivism, cognitivism and some sub-theories of both theories including the cognitive theory of multimedia learning (CTML), embodied cognition, situated learning theories and collaborative learning theories (Sommerauer & Müller, 2018). For the purpose of this study, cognitive constructivism was considered to tap into two profound principles of AR which include interactivity and knowledge construction. The theory suggest that cognition is enhanced through active construction of knowledge, based on the existing cognitive structures of a learner (Piaget,1967). Cognitive constructivism was preferred as it resonated with AR applications selected and supported the inquiry-based instructional approach embedded in the design of learning interventions as well as the learning outcomes. Based on Piaget's (1967) cognitive constructivism and Vygotsky's (1978) social constructivism which together shape the nature of inquiry-based instruction. Constructivism is a paradigm that assumes that knowledge is subjective, contextual, and inherently partial and has become particularly prominent in science education through the focus on Inquiry (Minner, Levy & Century, 2010). According to Piaget (1971), constructivism is a paradigm shift from behaviorism and underpins how learners as individuals adapt and refine knowledge. This theory is aligned with appreciating what the learners bring into the classroom as prior knowledge, this means that teachers must be aware that learners do not come to the classroom as empty vessels, but they bring along their own prior notions of concepts. Within the framework of constructivism, learners construct knowledge, in relation to pre-existing schemas of knowledge that developed by previous experiences or interactions.

2.1. Inquiry-based instructional approaches and cognitive constructivism

An inquiry-based instructional approach was preferred for scaffolding the learning of selected NS concepts. Students had to interact with the content using the 5E instructional model of inquiry by Engaging, Explaining, Exploring, Elaborating and Evaluating their understandings of concepts.

Underpinned by social and cognitive constructivism, the 5E instructional model presents 5 phases through which learners can engage, explore, explain, elaborate and evaluate scientific concepts (ByBee, 2014).

When learners learn through an inquiry supported approach, it contributes to their social, intellectual, and psychological development. Using the 5E model, PSTs were provided with an opportunity to reflect on their prior knowledge of the NS concepts, gain new experiences using AR, communicate their learnings and show understandings of concepts by completing a content test. Figure 1 below shows dimensions of the 5E model followed for this study.

Figure 1. 5E instructional model for AR integration (informed by: Bybee, 2014).

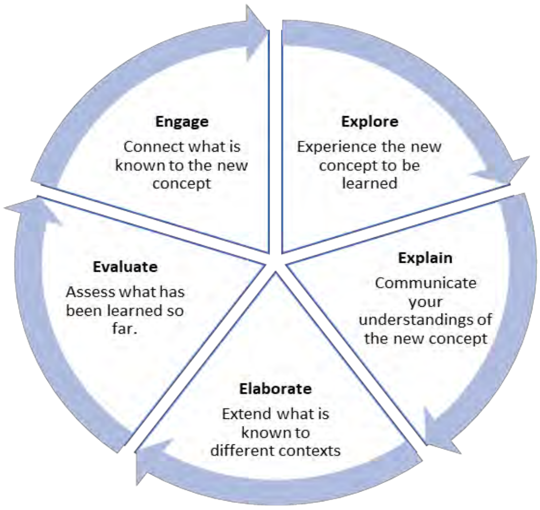

Figure 1 shows the five steps that make up the 5E cycle. This inquiry-based instructional approach is one easy to use approach for science teachers and provides the opportunity for students to co-construct knowledge in every learning scenario.

3. Method

A mixed methods case study design was considered for the research. Mixed methods case studies are particularly grounded in descriptive research of a case. This approach was preferred because the goal was to enact learning interventions with a specific group of PSTs in a particular educational setting.

Content tests and semi-structured interviews were used for the collection of data from 32 (n=32) pre-service NS teachers at a South African higher institution of learning. Participants included 21 males, 11 females and were third-year Batchelor of Education (Bed) students specializing in the Natural Sciences.

3.1. Learning interventions

Before commencing with learning interventions, PSTs were given a pre-content test on combustion reactions, specifically methane combustion and the movement of divergent plates based on the theory of plate tectonics. The aim of the pre-test was to establish their conceptual understandings and prior knowledge of the selected concepts as part of the engagement phase in the 5E cycle. In total, six steps were followed through the research process, from the identification of NS concepts to the administration of a post-test. The summary of two NS concepts reported in this paper is shown in Table 1 below.

Table 1. NS concepts covered in the course of learning interventions.

Application/device	NS strand	Topic	Learning Outcomes
Jigspace AR: Methane combustion (App Store on IOS devices) in the case of this study, *Ipads* were used	Matter and material	Methane combustion and Plate tectonics	-Describe combustion reactions. -Discuss the law of conservation of mass. -Critically analyse the effects of excessive methane combustion on the environment.
Jigspace AR: Movement of convergent and divergent plate (App store on IOS devices) in the case of this study *Ipads* were used	Planet Earth and Beyond	Plate tectonics	-Discuss tectonic plate movements. -Analyse the relationship between plate movements and earthquakes.

Table 1 summarises the AR application used during learning interventions, the NS topics, strands, and learning outcomes planned for participants to meet.

3.2. Data collection, analysis, and evaluation

Data was gathered by quantitative means (pre-and post-content test). Test were analysed by means of descriptive and inferential statistics using the statistical package for the social sciences (SPSS) version 27. After the analysis of pre- and post-content tests scores, semi-structured focus group interviews were conducted with participants, transcribed and analysed inductively using content analysis. These methods of data collection and analysis were preferred as they aided responses to the research questions posed.

All ethical dimensions were followed in collecting the research data. Collected data was triangulated and evaluated for accuracy using diverse techniques including, member checking and inter-coder reliability (100% agreement between 3 coders) for assigned codes on interview transcripts. Two NS subject experts content validated the administered content tests to ensure that they assessed what was intended in terms of the learning outcomes.

4. Results

This section presents the findings of the study in a manner that answers the research questions by firstly presenting the findings from pre- and post-content tests followed by the findings from semi-structured focus group interviews.

4.1. Extending achievement in Natural Sciences

Findings from quantitative data collected was aimed at showing variation in content test achievement pre and post-AR-enhanced learning. Table 2 below shows descriptive statistics and the results of the paired sample t-test in a comparative analysis of the pre-and post-test.

Table 2. Descriptive and inferential statistics.

Pairs	N	Mean	Std. Deviation	Std. Error Mean	t	p
Pre-test	32	61.44	9.72	1.72	-7.65	P< .01
Post-test	32	71.88	9.78	1.73		

As seen on the Table 2 above, the mean pre-test score was relatively lower at (M= 61.44%, S.D = 9.72) than the mean post-test score at (M = 71.88, S.D = 9.78). paired sample t-test t (32) = 7.65, p<.01 at 95% confidence interval indicated a statistically significant difference in achievement scores from pre- to post-content test. Due to the small sample size, it was critical to calculate the effect size of the difference and ensure that the reported shifts were strong and also based on AR-enhanced learning interventions. On SPSS 27, *Cohen's d (the effect size)* was estimated to be 1.33 which is considered very strong (Cohen, 1998).

4.2. AR-enhanced NS inquiry learning experiences

Findings from content analysis of transcribed follow-up focused group interviews revealed that PSTs found the 5E instructional approach useful for guided inquiry as they engaged with NS concepts. When asked of what would have improved their performance in the post-test, PST indicated that they were able to interact more within the AR application models due to their semi-immersive attributes and the associated text-mediation added to the *Jigspace (www.jigspace.com)* application. Participants noted that just reading a textbook or written text is not usually enough for the formation of mental representations. Five of the six focus groups indicated that hand gestures like pinching and rotation of AR models, zoom in and out, animation, spinning, pulling and dragging AR models were engaging, interactive and a fun way to learn, especially science concepts. Some important 21st-century skills, including collaboration, critical thinking and communication, were enhanced as students spent time exploring concepts and addressing difficulties in chat groups and social media platforms.

5. Discussion and conclusions

The findings of this study are indicative of the affordances of integrating AR in the teaching and learning of science concepts and correlate with the findings of other contemporary studies (Chu et al, 2019; Erbas & Demirer, 2019). One unique aspect from the findings is the positive effect of gesture in the cognitive process. Participants noted that hand interactions with *makerless* AR applications made all the difference when learning as they enhanced their enjoyment in the learning process. The 5E instructional approach and the level of interactivity in AR mainly accounted for content test achievement shifts, a finding also concurrent with literature (Akçayır et al., 2016; Erbas & Demirer, 2019). Skills like collaboration, critical thinking and communication were developed in AR-enhanced learning.

For practice, we recommend that the science education fraternity integrate mobile learning devices in combination with AR applications as a means of enhancing learning achievement in both remote and blended learning settings. For higher institutions of learning dealing with pre-service teacher education (PSTE), there is a need for transformation in the way NS teachers are trained. Technology-enhanced learning of science concepts is no longer an option but an imperative in dealing with learning post the onset of the COVID-19 pandemic. Reforms in school policies to integrate mobile learning technologies like AR for the teaching and learning of science are critical to aid teachers innovate when teaching science. We also recommend that science education researchers conduct larger scale studies on different aspects of AR-enhanced science learning including, theories that underpin AR integration, Pedagogical approaches best suited for AR integration as well as the effects of AR-enhanced learning on the affective domain.

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