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THE USE OF VIRTUAL LEARNING ENVIRONMENTS AND ACHIEVEMENT IN PHYSICS CONTENT TESTS

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Abstract

In the advent of industry 4.0, the use of Virtual Learning Environments (VLEs) has become increasingly valuable for mediating the teaching and learning of science concepts. These VLEs embedded with simulations of real scientific systems, processes and accompanying learning activities, have been used to simplify concepts and enhance visualisation for science students and teachers alike. In South Africa, Physics Education Technology (PhET) and other free online simulations have been commended by several science teachers as useful tools for science learning in virtual environments. This baseline study examined the effects of using virtual learning environments (VLEs) on students' achievement in physics content test. Sixty eight (n=68) third year physical sciences education students from a South African teacher training programme participated in the study. A sequential mixed method explanatory research methodology was followed in investigating the effects of using VLEs on students' achievement in physics content test. The initial phase of the study constituted a quasi-experimental phase where a Physics content test was given pre and post virtual learning interventions using PhET simulation laboratories and the associated activities. This phase was proceeded by follow-up semi-structured focus group interviews with all the participants to establish their perceptions of virtual learning environments engaged with. Data from quasi-experiment was analysed using SPSS 25 and transcribed textual data from focus group interviews was analysed using thematic content analysis assisted with Atlas.ti 8. Findings from the study revealed that, mean achievement scores in physics content tests improved significantly post intervention in VLEs. From follow-up focus group interviews five themes stood out where students revealed that; (1) within the VLEs, they were able to visualise scientific micro worlds (2) Embedded activities and tasks enhanced self-directed learning and assessment (3) the virtual classroom space enhanced collaboration with peers on learning tasks (4) the VLEs provided a convenient way to learn sciences (5) The VLEs did not promote authentic science learning. The implications of these findings are that virtual learning environments are a relevant learning enhancer for science and physics learning in the 21st century. We therefore recommend based on these findings that, larger scale studies be engaged to further investigate the affordances of VLEs in science education, including all the factors that affect how students learn in VLEs.

Keywords: *Virtual learning environments (VLEs), content tests, visualisation, physics.*

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1. Introduction and background

In physics modules one of the prominent learning difficulties have been found to revolve around students' visualisation of concepts like forces, current, charges, magnetic fields, and other micro-scientific worlds (Aravind & Heard, 2010; Faour & Ayoubi, 2018). This study investigated the use of open access simulations and the associated learning activities in learning abstract physics concepts, within virtual learning environments (VLEs). Virtual learning has in recent times provided a platform for the extension of the traditional contact sessions in science teaching. Several researchers including De Jong (2017), Alhalabi (2016) and Pekrun (2016), postulate that, VLEs help students improve their visualisation of micro scientific phenomena and eventually conceptual understandings of abstract scientific concepts. Despite these accrued benefits of VLEs and the associated learning tasks embedded in them, not enough has been documented in the South African context on how they can be used effectively and the effects they have on students' achievements (Ramnarain & Moosa, 2017). Hence, this study set out to establish the possible effects that using VLEs could have on 3rd year physical sciences education students' achievement in physics content test at a South African university. We further interviewed the students using semi-structured interviews to establish their perceptions of the VLEs for learning physics concepts.

As the world increasingly transforms into a digital village, the use of available technological tools in science teaching and learning are inevitable for teachers and students alike. This is because the 21st century learners tend to rely on technology for the attainment of diverse goals (Merchant, Goetz, Cifuentes, Keeney-Kennicutt & Davis, 2014). For physics learning in particular learners find it difficult to relate to and visualise abstract concepts (Aravind & Heard, 2010; Merchant et al, 2014; Ramnarain & Moosa, 2017). This usually leads to the creation of several misconceptions in the minds of physics students which teachers must pay particular attention to, in order for new concepts to be grasped.

2. Aims and objectives

The main aim of the study was to investigate the effects of virtual learning environments on students' achievements in Physics content test. Based on this aim the following objectives were set

- To assess students' achievements in a semester Physics content test
- To provide virtual learning interventions on the assessed physics concepts
- To re-asses students' achievements by administering the same physics content test as a post-test.

3. Virtual learning environments

The use of virtual learning spaces have been widely endorsed in modern learning for enhancing students' interactions with content and making teaching and learning resources globally available (Merchant et al.,2014; Zacharia & Olympiou, 2011). This in essence implies that, students and teachers do not necessarily have to be at a physical location or classroom to have access to knowledge. For science learning, Virtual learning environments (VLEs) are learning spaces, usually online or off-line embedded with simulations, demonstrations and illustrations of scientific processes and system. What makes them unique is the addition of learning activities that implicitly scaffold a learner's use and interactions with the embedded content (Chamberlain, Lancaster, Parson & Perkins, 2014). In the South African context in particular, schools are provided with several Information Communication and Technology (ICT) tools, for teaching and learning, a strategy targeted by the Department of Basic Education to meet the 21st century imperatives for global education (Department of Education, 2004). In learning physics concepts this VLEs help learners to attain learning goals that may not even be feasible in a traditional physics laboratories. As indicated by some researchers, the simulations embedded in VLEs provide a platform where learners can "interact virtually with phenomena too dangerous to do in real time, and solve complex problems" (Krajcik & Mun, 2014, p. 356). With this notion in mind, science students should be able to use ICT effectively to enhance their learning while acquiring skills for the world of work beyond the classroom. The main problem that motivated this research is that even though the relevant ICT tools are available for learners and teachers in schools, not much been documented on their use and effectiveness in VLEs for South African students.

4. Theoretical underpinning

Although this study was underpinned by multiple learning theories, the main theoretical lens was Mayer's cognitive theory of multi-media learning. Mayer (2011), emphasises that, the use of multiple media (audio and visual) in representing concepts will have a positive impact on how students construct mental representations and eventually schemas. This points to the fact that hearing about a physics concept during traditional lectures is not sufficient for enabling long term retention and memory (Mayer, 2011; Mosotho & Mamontsi, 2014). The addition of visual 2-dimensional and 3-dimensional representations which mimic forces, charges, and electromagnetic fields help students to form a mental picture of abstract physics concepts. These mental pictures become engraved in their cognition and students are able to remember them even in the long term (Wang, Li, Yang, & Hao, 2013; Makransky, Terkildsena & Mayer, 2017). With this underpinning in mind, a virtual learning intervention for the study was designed using PhET interactive simulations, a project founded at the University of Colorado Boulder, which include many physics simulations and associated activities, available freely at http://phet.colorado.edu. *A google hangout* chat room was also introduced in the VLE, to ensure that difficulties could be shared with the instructor and peers.

5. The learning interventions

The students who participated in the study were 3rd year physical sciences education pre-service teachers. They were all enrolled for a physics module and conducted an anonymous online poll in which they selected the physics concepts that were most abstract and incomprehensible to them. We then obtained the results of the poll and established by simple counting that 82 of the students found Faraday's law of Electromagnetic Induction (EMI) to be quite abstract while another 72% of them indicated that Newton's third law on the conservation of momentum was incomprehensible and embedded with several misconceptions. At the beginning of the learning interventions student s further indicated that, Faraday's law of electromagnetic induction presented a complex relation between electricity and magnetism which was difficult to imagine merely looking at the drawings that are projected during lectures. They did not comprehend the time changes (dt) in a magnetic field and the several challenges associated to the flux rule. A learning intervention was then designed based on the presented challenges. Several PhET laboratories where introduced to all \students in the first week of the learning intervention by the researchers. These activities included Faraday's law lab, collision lab, momentum lab and velocity labs activities all obtainable from the following sites; https://phet.colorado.edu/en/simulation/collision-lab, https://phet.colorado.edu/en/simulation/faradays-law, https://phet.colorado.edu/en/simulation/momentum, https://phet.colorado.edu/en/simulation/velocity. All the embedded activities in the Virtual learning environment were exploited and the learning was mostly done in groups as collaborative tasks with the research facilitating processes in the VLE using an embedded google hangout chatroom. At the end of five weeks the students were then task to re-write the physics content test assessing these concepts.

6. Methodology and design

The study employed a sequential explanatory mixed methodology. In the first phase of the study all students were asked to write a Physics content test based on their understandings of Electromagnetism and collision/momentum taught during lectures. Thereafter, virtual learning interventions commenced and proceeded for 5 weeks during tutorial sessions. At the end of the learning interventions, the same content test was administered as a post test. The second phase, a qualitative inquiry employed 10 focus group semi-structured interviews with all the participants in 9 groups of 6 participants and 1 group of 7 participants aimed at obtaining insights into students' experiences (Creswell & Creswell, 2017), with virtual physics learning.

6.1. The Sample

The sample selected for the study was the same as the population (n=N) whereby, all 3rd year physical sciences (a combination of chemistry and physics) education students volunteered to participate in the virtual learning intervention. A single lecture and two tutorial sessions were held for the physics module each week. Students could not be separated into control and experimental groups because of the inherent learning implications, hence we adopted of a quasi-experimental pre- and post-test design for the study. Also for physics module this was the first time a virtual learning intervention was going to be used during tutorials to support the content acquired from lectures. Students were curious to explore different learning space, besides lectures and traditional laboratory sessions.

6.2. Data collection and analysis

A Physics content test was administered pre and post learning experiences in VLEs. The test constituted several test items related to the conceptual, procedural and application knowledge of learned physics concepts. The content validity of the test was established by one of the researchers and two other Physics education specialists. For this validated test, the focus was on the intra-item reliability based on the consideration that a question on EMI and all its sub-sections will not be the same as a question on momentum/velocity/collision. Intra-item Cronbach's alpha was obtained to be $\alpha= .80$. All pre and post test scores were captured and analysed using SPSS version 25. Data for the qualitative phase was collected by means of focus group interviews using the following pre planned questions and prompts;

- How did you find the the use of virtual learning simulation laboratories and the activities? Provide a brief explanation.
- Which aspects of the VLEs were useful in facilitating your learning of the identified Physics concepts?
- What was your impression of the chatroom aid embedded in the VLEs?
- Did you find the VLEs and the associated learning activities useful in improving your conceptual understandings of the Identified physics concepts?
- Please elaborate on what you see to be the possible advantages and disadvantages of using VLEs in Physics learning.

The transcribe textual data form these focus group interviews were analysed using thematic content analysis with the aid of Atlas.ti version 8.

7. Results

7.1. Descriptive and inferential statistics

At the end of the learning intervention phase all participants' scores for the pre and post-test were captures and analysed using SPSS version 25. Table 1 below shows the mean scores and standard deviations obtained from pre and post interventions physics content tests.

Table 1. Descriptive statistics

	N	Mean (%)	S.D	Std. Error Mean
Pre-test scores	68	59.68	9.25	1.12
Post-test scores	68	72.47	10.22	1.24

As seen on table 1 the mean Post-test score was higher at M = 72.47%, SD = 10.22 than the mean pre-test score at M= 59.68%, SD = 9.25.

After establishing that the data was normally distributed, we further conducted a paired sample t-test to establish if the observed increase in the post-test mean score was statistically significant at 95% confidence interval. The result of the paired sample t-test is captured on table 2 below.

Table 2. Paired Sample t-test.

Pair 1	df	Mean (%)	S.D	Std. Error Mean	t	p
Post-test scores	67	12.79	8,70	1.06	12.12	P < .01
Pre-test scores						

As seen on table 2 above, Post-intervention physics content test scores were significantly higher than the pre- intervention test scores with $t(67) = 12.12$, $p < .01$ at 95% confidence interval. These results suggested that there was a significant improvement in students' achievement in physics content test after the intervention with VLEs. Other factors might have affected the post test scores which were not covered in this inquiry due to the limitation of not having a control group.

7.2. Result of focus group interviews

From the analysis of transcribed textual data we generated codes and traced patterns that led to the generation of the themes discussed here below.

7.2.1. VLEs, facilitated the visualisation of micro worlds. 7 out of the 10 groups of students indicated that the VLEs enhanced their visualisation of micro-scientific phenomena. In the simulations they were able to see field lined motion and real-time graphs as they interacted in the VLEs. This feature of the VLE was believed to be the main reason why they tending to understand the physics concepts more.

7.2.2. Embedded activities and tasks enhanced self-directed learning and assessment. All 10 focus groups indicated that they were able to independently drive their learning within the VLEs such that they rarely felt the need to ask for help.

7.2.3. The virtual classroom space enhanced collaboration with peers on learning tasks. All focus groups also indicated that the interactive nature of the VLEs enhanced collaborative learning within and amongst their learning group. The chat room feature was said to have enhanced communication among group members, an affordance which helped them to complete tasks without necessarily seeing each other.

7.2.4. VLEs provided a convenient way to learn sciences. Again all the groups indicated that VLEs were great because they could be accessed from any location if a person had connectivity.

7.2.5. The VLEs did not promote authentic science learning. 8 of the 10 focus groups indicated that the VLEs was not quite useful in cases where authentic learning is required. They suggested that the use of VLEs can only be complementary of their traditional laboratory experiment.

8. Discussions and conclusions

Findings of this study based on the obtained results suggest that VLEs have the possibility of enhancing student's understandings of physics concepts. The findings also concur with other studies like

Zeichner and Zilka (2016) who found that once the initial of using VLEs have been dissipated students enjoy positive learning experiences within virtual learning spaces. (Zacharia & Olympiou, 2011) also found that for physics learning, conceptual understandings are enhanced when students combine traditional laboratory learning with interactive virtual learning. Just like the findings from the qualitative phase of this study, Hsu, Lin, and Yang (2017), found that students did not relate to the authenticity of virtual learning. We therefore recommend that VLEs considered as enhancers for physics learning in particular and science learning as a whole. From the qualitative phase of the study, it was noted there could be other factors that would possibly contribute to the improvement in the post test scores because of the limitation of not have a control group. We therefore recommend that, larger scale experimental research be conducted across universities whereby a control group could be identified and excluded from learning interventions with VLEs.

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