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EXPERIENCES OF TEACHERS IN THE ENACTMENT OF SIMULATIONS IN 5E INQUIRY-BASED SCIENCE TEACHING

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Abstract

Inquiry-based teaching and learning has been promoted in school curricula all over the world and it is described as an efficient method of teaching science in terms of understanding of the content and improving student attitudes towards the subject matter (NRC, 2012). Quintana et al (2004) defined inquiry as a process of raising questions and analyzing them with empirical data, either by manipulating variables directly through experiments or by creating comparisons using established data sets. Despite the widely reported benefits of inquiry-based learning such as developing critical thinking abilities, scientific reasoning, and a deeper understanding of science (Barrow, 2006), its implementation is still a challenge in many parts of the world. The research reported here is a part of a larger study that investigated South African teachers' use of simulating in enacting 5E (engage, explore, explain, elaborate and evaluate) inquiry. The 5E instructional model of inquiry is a model that can assist teachers in developing inquiry-based lessons (Ihejiamaizu et al., 2018) and it is a technique used by science teachers to produce students who are scientifically literate (Chitman-Booker & Kopp, 2013). Post-lesson interviews conducted with three teachers on their experiences of using simulations for 5E inquiry-based teaching. The interview data were transcribed and subjected to Saldaña (2009) coding to generate themes. The interviews focused mainly on the teacher's justifications of their pedagogical actions that they have employed when using simulations in enacting a 5E instructional model for inquiry. The results of this study showed that a simulated 5E inquiry lesson enables collaborative learning in the Explore phase of the 5E model where groups of students worked together to solve problems and complete tasks. The significance of this finding is that the use of simulations is an alternative to actual hands-on inquiry and can be effectively used to teach 5E inquiry. In particular, active and collaborative learning can be promoted through the use of simulations. The use of simulations could also address the challenge of resource inadequacy in South African schools. It is recommended that future research be conducted with a larger sample that includes a diversity of schools.

Keywords: *Computer simulations, inquiry-based learning, physical sciences teachers.*

1. Introduction

A number of studies have shown that IBL encourages learners to actively seek for answers, explore concepts rather than memorising (Herman & Knobloch, 2004; Slavin, 2006; Baker et al., 2008). Barrow (2006) argued that 'when students practice inquiry, it helps them develop their critical thinking abilities and scientific reasoning, while developing a deeper understanding of science' (p. 269). Despite the widely reported benefits of inquiry-based learning, its implementation is still a challenge in many parts of the world. Many authors have indicated that ICT offers different learning opportunities, and a need has been recognised to design a new 'integrated pedagogy' (Cornu, 1995). The aim of this study is to investigate the experiences of teachers in the enactment of simulations in 5E inquiry-based science teaching. In the case of the integration of ICT in the pedagogy of science education, it is necessary to understand how teaching and learning change as specific technologies are used (Koehler & Mishra, 2008). In education, ICT is significant as a means of supporting the teaching and learning process (Meyer & Gent, 2016). There is a consensus that ICT integration in teaching will improve teaching quality and the learning process (Voogt & Pelgrum, 2005).

2. Methodology

This research applied a case study approach in studying the experiences of teachers in the enactment of simulations in 5E inquiry-based science teaching. Post-lesson interviews were used to collect data and were based on the lessons presented by three teachers teaching in schools were ICT resources are being used. They focused mainly on the teacher's justifications of their pedagogical actions that they have employed when using simulations in enacting a 5E instructional model for inquiry. The data were then transcribed and coded according to Saldana (2009). Various statements on the transcripts were assigned codes. Following that, codes with similar characteristics were grouped together to form categories, from which themes emerged.

2.1. Sampling

This study was carried out using purposeful sampling. In a qualitative study, purposeful sampling is typically used to identify information-rich cases (Patton, 2002). The teachers in this study were chosen based on their support for an inquiry-based pedagogy and their recognition of the use of ICT in science teaching. Another criterion was that the teachers were teaching in schools with ICT resources, such as tablets. The sample comprised three Physical Sciences teachers from three high schools in Germiston, South Africa. These schools were also readily accessible to the research in terms of proximity to where the researcher was located.

2.2. Data collection and analysis

Teachers were asked to justify their pedagogical actions taken during each of the 5E stages. In order to stimulate teacher reflection, the researchers played segments of the video that were found to be important in terms of how teacher used an interactive simulation in their lesson. To analyse the post-lesson interview results, Saldaña (2009) coding was used. A verbatim transcription of the interviews was adopted, and various statements were given codes. Thereafter, codes were grouped together to develop categories that shared similar features, then different themes arose from the various categories and assertions were made.

3. Findings

The findings are presented according to the following themes that were generated from a qualitative analysis of the post lesson interviews.

Theme 1: Pedagogical affordances of using simulations when teaching 5E inquiry

Based on how Teacher 2 and 3 5E lessons unfolded, the teachers have said that simulations helped them in promoting collaborative learning (CL). This means that learners were given an opportunity to work in groups to enhance learning. The evidence of this was mostly seen in the Explore phase of the 5E when the learners engaged in hands-on activities using the PhET simulations in groups. CL is a teaching and learning educational approach that involves groups of students working together to solve a problem, complete a task, or produce a product (Laal & Laal, 2012).

See Teacher 2 and 3 excerpts below:

> PhET simulation also allows learners to work in groups. Through these 5E lessons I have learnt that students become more active when they work collaboratively than individually. And when technology is involved, they work more actively. They just love working with technology. (Teacher 2)
>
> The last point is that working with PhET simulation in a 5E lesson allows the learners to work together on something you know. I can say it promotes cooperation between learners. This gives the learners a chance to work in groups to make meaning. For example, learners were working together to construct circuits, after that they and to do group presentations. (Teacher 3)

Teacher 1 and Teacher 3 have said that simulations promote active learning. During the lessons, the students were actively involved in the learning process. The two teachers allowed the learners to participate more in the learning process. Studies have indicated that when students are actively engaged in the teaching process, they gain understanding (Biswas et al., 2005; Vreman-De Olde et al., 2013). See Teacher 1 and 3 excerpts below:

> The affordances of using simulations in a 5E lesson is to promote active learning. Learners are involved from the start of the lesson to the end. Simulations promote experiential learning. Learners were able to gather information from their devices and in my years of teaching.I felt like this is a good method of teaching. (Teacher 1)
>
> Another affordance of teaching using simulations is the discovery of new knowledge by learners. And I like this because if learners discover knowledge by themselves, in doing so they will

remember the knowledge for a long period, unlike when you directly teach in front of the classroom. (Teacher 3)

Theme 2: The pedagogical limitations of using simulations when teaching 5E inquiry.

Introducing a lesson during the Engage phase of the 5E lesson with a PhET simulation was challenging for teacher 2 and 3. The teachers said that PhET simulations may not support the Engage phase and the elaboration phase. Teacher 2 and 3 decided to use videos for introducing their lessons. See the teachers' excerpts below:

Firstly, as I have mentioned earlier, I feel like a simulation is not designed to introduce a lesson. Yes, some people can introduce a lesson using a simulation but as for me I was able to teach a portion of the 5E lessons using the simulations. As for the Engage phase and the Elaborate phase, using a PhET simulation was very challenging. (Teacher 1)

I have found it hard to introduce my lesson with a simulation. I don't know why. I could not think of any possible way to do it. But on the Explore phase I knew exactly what to do (Teacher 2)

Theme 3: The pedagogical actions of the teacher in each of the phases of the 5E inquiry model when employing simulations.

This section focused on the teacher's pedagogical actions and justifications of their pedagogical actions that they have employed when using simulations in enacting a 5E instructional model for inquiry.

Engage

Teachers 2 and 3 used audio-visual media which is a video as precursor to the PhET simulation. The teachers have said that they did this because videos centre the attention of students on the lesson. The teachers have also indicated that using a PhET simulation in the Engage phase posed a challenge to them as it was not clear how to use the simulation in that phase. This means that PhET simulations may not support all phases of the 5E instructional model. See Teacher 2 and 3 excerpts which support this statement below:

In this phase I have decided to use a video because a video provides interest to students. I chose a video in this phase because it centres the attention of the students on the lesson and it was challenging to use the simulation. But I then thought of a different way to introduce the lesson. (Teacher 2)

I believe the purpose of introduction is to grab the learner's attention and to make them ready for the lesson. I have used a video as a precursor to simulation to make the learners interested in the lesson or to have their attention, but as for starting the lesson with a simulation it was very challenging. (Teacher 3)

Explore

Teacher 1 and 2 promoted hands-on activities using the PhET simulation. The teachers listed a couple of reasons for allowing hands-on activities. According to them, hands-on activities on the PhET simulation help students to explain things from evidence and it also allow learners to work with little dependence on the teacher. motivation to learn. See Teachers 1 and 2 opinions below:

Doing hands-on activities helps students to explain things from evidence. This is important because students learn to work with little dependence on the teachers. The simulation was featured in this phase. Students had to construct their series and parallel circuits and identify the relationship between the circuits. They also had to record allowing students to do hands-on activities honestly improves the students' motivation to learn. These days learners prefer doing experiments in the palm of their hands. (Teacher 1)

The reason why I allowed the learners to do hands-on activities is because it allows the learners to be less dependent on the teacher. They can play around with the simulation and draws conclusion. I believe that doing science or to discover knowledge means that students will remember this in the future. (Teacher 2)

In the Explore phase, Teacher 3 used group work to facilitate inquiry learning during the 5E lesson. The learners were working in groups to collect data from the PhET simulation. He did this so that students could be productive and support each other because they were not used to the PhET simulation. See his explanation below:

I think learning becomes more effective when learners are working in groups because they assist each other, and it becomes more simple to solve problems when working as a group. Since they are not used to simulations, I thought it would be good for them to work together so they can share ideas and assist each other in learning. In this groups I have grouped my highflyers with the low flyers so that the high flyers can assist the learners that are at risk. (Teacher 3)

Explain

On the Explain phase, Teachers 1 and 3 allowed learners to do class presentations using the PhET simulations. The learners were presenting the data findings. From the learner's presentations the teacher would ask the learners questions and accept all reasonable answers from the learners when they supported their claims using a PhET simulation or their recorded data. See Teachers 1 and 3 descriptions below:

> Yes, students arrived to the answers based on their use of simulations. Their use of PhET simulations supported their explanations. Most of their explanations where correct. They would use the simulation in front of the class and support their statements. And I would accept what they say based on what they see from the simulation. Plus, most of the questions were based on what they did on the Explore phase. (Teacher 1)
>
> I have asked these questions after the learners have engaged with their simulation. But in some cases, learners had to support their answers using their recorded data from the simulation. (Teacher 3)

Elaborate

Teacher 3 allowed students to use PhET simulation to study the main concept in broader context. This means that students engaged in activities using the PhET simulation that related what they learnt to new events with increased levels of difficulty. This helped students to reinforce the new learning from the explain phase and adapt it to various circumstances. The example that Teacher 3 used was for learners to design a circuit where light bulbs would shine the brightest:

> So here I wanted to give students space to apply what they have learnt in a broader context. The activities that I have given to the learners aimed at reinforcing new skills. Learners had to connect circuit when light bulbs to shine the brightest, how are you arrange them? (Teacher 3)

Evaluate

During the Evaluate phase, learners were given a post-lab assessment to solve problems quantitatively and check their answers using the PhET simulation. The simulation was used to confirm the learners' theoretical values by checking the experimental values from the PhET simulation. A theoretical value refers to the value that the learners have calculated, and an experimental value is the reading from the simulation. The teachers said that they have used the post-lab assessment to assess the knowledge that the learners have learnt throughout the lesson. See teachers 1 and 3 excerpts below:

> I have given the learners a quantitative problem to solve as a post-lab assessment to assess the knowledge they have learnt uhm … during the lesson. I have instructed the learners to check their answers through the PhET simulation. (Teacher 1)
>
> I therefore decided to give learners post-lab assessments so that the learners can clearly communicate their findings from the use of the PhET simulations. (Teacher 3)

4. Discussion

The findings of this study shows that while other teachers were able to use the simulation in the engage phase, others used videos as a precursor to simulation. This study revealed that some simulations are good for introducing a lesson and some simulations are good for the lesson delivery. Therefore, using an audio-visual media as a precursor to simulation in the Engage phase is important if the simulation cannot support the Engage phase of the 5E inquiry lesson. A simulated 5E inquiry lesson enables collaborative learning in the Explore phase where groups of students actively work together to solve problems and complete tasks. Collaborative learning in a simulated 5E inquiry is the best when students communicate and share different opinions when given a problem to solve or a task to complete. Teachers allowed the learners to actively engage in meaningful interactions and higher-order thinking activities. This finding is similar to what Dillenbourg (1999), Smith and MacGregor (1992) mentioned in their studies that collaborative learning encourages active learning by involving students in meaningful interactions and higher-order thinking activities. Another finding in the Explore phase, is that the learners worked together in finding answers to open ended questions asked by their teachers as they gained understanding of scientific concepts, rather than receiving all instructions on what to do, how to do it, and when to do it from their teacher (Hussain, 2015). A simulated 5E inquiry lesson allows learners to do calculations and check their answers on the simulations in the evaluation phase. This is important because learners can trace their progress due to its high degree of interactivity in terms of user control and dynamic feedback (Podolefsky et al. 2010). Behaviorism theories says that immediate feedback correct errors and promote positive re-enforcement (Skinner,1953). When the simulation confirms the learner's correct responses it can motivate them to learn.

On the Explain phase, the teachers allowed learners to do class presentations using the PhET simulations. The learners were presenting the data findings. From the learner's presentations the teacher would ask the learners questions and accept all reasonable answers from the learners when they supported their claims using a PhET simulation or their recorded data. According to Chen et al. (2022) depending on the cognitive level of the students, this process develops their verbal skills while also improving their literacies and abilities such as logical reasoning and analogy. The National Curriculum and Assessment Policy Statement (CAPS) aims to ensure that learners acquire and apply knowledge and skills that are relevant to their own lives (Department of Basic Education, 2011) and presentation or verbal skill is a skill worth learning in the South African context.

5. Conclusion

The results of this study showed that a simulated 5E inquiry lesson enables collaborative learning in the Explore phase of the 5E model where groups of students worked together to solve problems and complete tasks. The significance of this finding is that the use of simulations is an alternative to actual hands-on inquiry and can be effectively used to teach 5E inquiry. In particular, active and collaborative learning can be promoted through the use of simulations. The use of simulations could also address the challenge of resource inadequacy in South African schools. It is recommended that future research be conducted with a larger sample that includes a diversity of schools.

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