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Grade 10 Learners' Science Conceptual Development Using Computer Simulations

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ABSTRACT
This study explored Grade 10 learners' science conceptual development when conducting practical work using Computer Simulations (CS) and compared achievements with those from Traditional-Chalk-and-Talk (TCT). A pre- and post-quasi-experimental research design was used. 53 learners were assigned to the Experimental Group (EG) and 52 to the Control Group (CG). The EG was taught using CS, while CG used TCT. Interviews were used to identify learners' experiences after interventions. The overall results show that learners in EG enjoyed science and developed conceptual understanding better than those in the CG (T-test, $p < 0.05$), (ANCOVA, $p < 0.01$). The achievements of girls (M=54.60, SD=10.93) and boys (M=54.39, SD=7.90) in EG after intervention were not significantly different $t(51) = -0.08$, ($p < 0.05$). Despite the high learner-to-computer ratio environment, these results compare well with those of low learner-to-computer ratio and this is good news to developing countries where there are limited resources.

Keywords: computer simulations, learner-computer ratio, practical work, performance

INTRODUCTION

Over the last decade, Information Communication Technology (ICT) has made rich and dynamic visual representations using personal computers (Annetta, et al., 2009). These visual representations give users of educational Computer Simulations (CS) the flexibility to make changes and to see the effects (Annetta, et al., 2009). CS provide learners with rich educational experiences and instantaneous feedbacks on the results of virtual experiments (Kaheru & Kriel, 2012; Podolesky, Perkins & Adams, 2010; Sentongo, Kyakulaga & Kibirige, 2013). Instead of teachers explaining what happens to one variable when altering another, learners will be able to observe on the computer screen. As a result, CS give immediate feedback to learners and help them to understand science concepts. CS experiments can alleviate the teachers' burden of buying expensive apparatus for use in a specific practical work. CS can engage learners in inquiry-based learning and enhance science conceptual development (Abdullah & Shariff, 2008; Folaranmi, 2002). Also, CS may provide learners with access to questions and methods of inquiry which are well aligned with the ways scientists use experiments for exploration and discovery (Podolesky, et al., 2010). While the use of technology can assist to improve learners' engagement in practical work in a science class, it has not been clarified on how technology can improve learners' science conceptual development (Taylor & Parsons, 2011). Consequently, many schools in South Africa do not use CS when conducting practical work in order to enhance science conceptual development. CS are envisaged to compensate for the resources required to perform practical work. In fact, CS saves the school from buying expensive equipment for the laboratory. Learners can do the practical work on virtual system. To the best of our knowledge there are very few studies in South Africa on learners' use of CS in practical work to develop science concepts. Therefore, this study explored Grade 10 learners' conceptual development of waves using CS during practical work. This study highlights the importance of learners using CS to enhance science conceptual development in high schools with limited laboratory resources. The findings from this study add to the existing literature of teaching high school science practical work using CS.

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Contribution of this paper to the literature

- This study is one of the few studies to investigate Grade 10 learners' science conceptual development and learners' interests in the science subject in the Southern Hemisphere. The study extends the use of simulations in class to the literature because most of the studies were carried out in the Northern Hemisphere with low learner to computers ratio whereas this study is in the Southern Hemisphere where the learner to computer ratio is high.
- Doing practical work using Computer Simulation enhances learners' interests in the science subject. The interest of learners, particularly of the below average, plays a significant role in enhancing science development.
- The study shows that the use of Computer Simulation can be a stepping stone for schools with limited laboratory facilities in developing countries to do practical work as well as problem-based learning.

LITERATURE REVIEW

The percentage of computer use in the developing South Africa is very low when compared with the developed countries. The discrepancy between developed and developing countries has been termed as 'digital divide' (Fuchs & Horak, 2008). Information Communication Technology (ICT) is not widely distributed in schools in Limpopo Province, South Africa. For instance, by 2012, only 13.5% of the schools in Limpopo had computer facilities installed and 4.9% of those schools used computers for teaching and learning. The percentage of computer use for teaching and learning is very low in Limpopo when compared with Gauteng Province which has 88.5% of the schools with computers installed and has 45.4% of the computers used for teaching and learning. Furthermore, Limpopo ranks the lowest in terms of the number of households with access to Personal Computers (Tlabela et al., 2007). Also, the learner-computer ratio in secondary schools in South Africa is as high as 17:1 (Sossa, Rivilla & González, 2015). This ratio is very high when compared with the developed countries in the Northern Hemisphere where the ratio is 1:1. Notwithstanding the discrepancies in computer access, use and ratio in the country, it is not clear how schools in Limpopo use the few computers to teach science and the effect of CS in practical work. It was hypothesized that the use of CS to teach practical work would enhance teaching and learning; and provide comparative advantage for learners to cope with the ever-demanding 21st century knowledge acquisition science process skills.

Computer Simulations for Science Teaching and Learning

Computer Simulations (CS) are instructional settings where the teacher can engage learners to acquire knowledge. CS motivate students' interaction with the real-life issues. During CS learners observe and experience the experiment on the computer screen. Since CS are closest to the reality, learners are most likely to experience concepts and their meanings. The use of CS can be incorporated into the learning environment. Furthermore, Hertel and Millis (2002) reported that learning through real-world scenarios and problems have been supported by *using* CS. Schools nowadays invest in CS to enhance conceptual understanding. Simultaneously, business leaders affirm that CS is a dynamic approach to teaching science to develop the 21st-century skills (Partnership for 21st Century Bosco, 2009; Skills, 2010).

In contrast, research continues to claim that most teachers do not incorporate CS in their teaching and any other technology remains at the periphery in Africa. In South Africa, only 16% of the teachers used computers for teaching purposes (Draper et al., 2006). The reasons for not using CS in teaching science are many and range from lack of infrastructure (DoE, 2007) to overcrowded classrooms (Onwu 1998). The lack of CS use in science in the Southern Hemisphere suggests that there is a challenge. This challenge needs to be resolved by providing computer infrastructure and training teachers on the use of CS to increase learners' science conceptual development in the 21st Century.

To teach is to engage learners in learning; thus, teaching consists of involving learners in the active construction of knowledge (Jenson, Lewis & Smith, 2002). A teacher is not only equipped with knowledge of subject matter but the knowledge of how learners learn and how to transform them into active learners (Jenson, Lewis & Smith, 2002). When a teacher goes into a classroom, s/he prepares a lesson by setting out the objectives that s/he wants to achieve at the end of the lesson. It then becomes the responsibility of the teacher to ensure that what is intended for learners to learn has been learned. The question will be whether the teacher transmits the information to the learners or provides an opportunity for the learners to construct their knowledge. Furthermore, Ivowi et al. (1992) found that the lack of funds to buy equipment for practical work in most schools was a contributing factor to poor achievement.

For a hundred years now, educators have tried repeatedly to reform science education (Fetters at al., 2002), educators help learners engage in scientific inquiry to improve learner achievement. In many instances, learners gain more through inquiry learning than in a passive class. The gain is in time with the aim of teaching which is to transform learners from passive recipients of other people's knowledge into active constructors of own knowledge (Palmer, 1998). Also, learners using CS may develop positive attitudes towards science (Shymansky, Kyle & Alport, 1983).

Computer Stimulating and Practical Work

Inquiry without practical work cannot assist the learners to easily attain scientific experiences (Hofstein & Lunetta, 2004). The reason is that inquiry-based learning includes laboratory work. Teachers use laboratory tasks to learn by doing, design experiments and investigate issues in a classroom (Ivgen, 1997). Laboratory tasks are envisaged to "provide model lessons and experiences, build relevant theory and content knowledge" (Lit & Lotan, 2013). Practical work has a central role in the science curriculum to generate interest (Hodson, 1993; Hofstein, 2004; Hofstein & Lunetta, 2004; Lazarowitz & Tamir, 1994; Lunetta, 1998; Lunetta et al., 2007; Tobin 1990). In many schools where learners are only taught using the traditional approach, learners have challenges to make sense of science. Many South African schools do not have access to laboratories (Makgato & Mji, 2006). Laboratory work provides learners with an opportunity to experience science. Meaningful learning of scientific theories and their application methods means that learning should be done using laboratory investigations (Kibirige & Tsamago, 2013). Moreover, engaging in practical work should encourage the development of critical thinking skills (Ottander & Grelsson, 2006). Tobin (1990 p. 405) states that "Laboratory activities appeal as a way of allowing learners to learn with understanding and, at the same time, engage in the process of constructing knowledge by doing science". Knowledge construction depends on the level of conceptual understanding of science. A learner exposed to practical work understands better how the world operates than a learner without exposure to practical work.

CS as an Alternative to Laboratory Work

Research shows that learners construct their understanding of scientific ideas within the framework of their existing knowledge (Bransford, Brown & Cocking, 2000). It means that learners must actively engage with the content and must be able to learn from the engagement (Osborne, Simon & Collins, 2003). When learners start to engage with the content, they start to fall in what the constructivists call "*Self-discovery learning.*" Scientific discovery learning is a highly self-directed and constructivist form of learning (De Jong & Van Joolingen, 1998) and this is possible especially in Problem Based Learning (PBL) (Barrel, 2010). Polman (1999) conducted a case study of a teacher who created a collaborative learning community and provided his high school learners with opportunities to "learn by doing" science. The teacher used constructivist pedagogy by giving special attention to collaborative visualization. Constructivist pedagogy can be supplemented in a number of ways, one being through CS.

Interactive CS can meet the needs of a learner where s/he can explore and build on his/her existing knowledge (Annetta et al., 2009). Thompson, Simonson and Hargrave (1996) defined simulation as a representation or model of an event, object, or some phenomenon and Geban, Askar, and Özcan (1992) confirmed that computers could be used in science education as teaching devices. Traditionally, computers are used in biology as tools for investigating various topics, collecting data, searching literature, planning experiments, and analysing data. These functions are very common in many science and biology laboratories. However, simulations are important for formulating and, improving the conceptual models that scientists and science teachers use in their practice and teaching (Geban, Askar & Özcan, 1992). In science education, a computer simulation according to Akpan and Andre (1999) is the use of the computer to simulate dynamic systems of objects in a real or imagined world.

Literature suggests that the success of CS in science education depends on its incorporation into the curriculum and how the teacher uses it (Sahin, 2006). If teachers do not use computers, it can be hard to use it for teaching. Furthermore, the non-availability of computers complicates the matter. For instance, in Zambia, there is learner to computer ratio of 143:1, and in such a case it is a challenge to use CS effectively (Shami, Mgaya & Nkwe, 2014; Wanjala, 2016; Chaamwe, 2017). Other challenges to computer users have been reported among teachers for instance, low computers competencies among teachers in Kenya (Wanjala 2016); and Botswana (Shami, Mgaya and Nkwe, 2014). CS is a tool for classroom instruction and laboratory work. Researchers studying the use of simulations in the classroom have reported overall positive findings. Literature indicates that simulations can be effective in developing content knowledge and process skills, as well as in promoting more complex goals such as inquiry and conceptual change (Bell & Smetana, 2008). Since in the 90s, new technologies have made rich and dynamic visual representations possible on common personal computers (Annetta et al., 2009). This visual representation gives users of educational simulations the control and flexibility to make changes and see the effects in real time (Annetta et al., 2009). With these advances, simulations can provide learners with rich educational experiences as well as instantaneous feedback on the results of a virtual "experiment," (Podolesky, Perkins & Adams, 2010). The fact that CS permits learners to understand abstract scientific concepts is an indication that their conceptual understanding of scientific concepts improves. Studies (Budoff, Thormann & Gras, 1984; Cherryholmes, 1966; Cruickshank & Tefler, 1980; Greenblat & Duke, 1975) have suggested that one way to enhance these kinds of cognitive skills is through educational simulations. Simulations are thought to increase learner participation (Boocock & Schild, 1968; Farran, 1968; Stembler, 1975) and allow low- achieving students much-needed practice in applying what they have learned to new situations to improve their achievement (Cohen & Bradley, 1978).

Another advantage of CS in science education is that it is cheaper than laboratory experiments regarding time and cost (Simmons & Lunetta 1993). During experiments, learners need to wait for the results of the experiment, and they seem to waste their time. Also, for the laboratory experiments, equipment is expensive, and that is a problem for poor schools (Jegede, Okebukola & Ajewole, 1991). For instance, generally a computer-simulated experiment can take 35 minutes, but hands-on experiment can take between 120 and 180 minutes. However, CS provides learners with a quicker way of understanding of concepts. While students do experiments with the computer, they can receive immediate feedback (Jegede, Okebukola & Ajewole, 1991). Also, learners using CS have opportunities for reinforced practice without having a teacher to spend extra time in preparing supportive materials. The use of simulation in a classroom aimed at changing the negative attitude the learners may have towards studying science. Most schools use textbooks to teach science, but hands-on science curricula have become increasingly popular over the last two decades in most countries (Harlen, 2004). Hands-on science typically engages students in the classroom. Engaging students in inquiry using CS can provide a powerful learning experience where learners not only learn about science content but also gain research skills.

METHODOLOGY

The study used both qualitative and quantitative approaches (Creswell, 2014). The quantitative approach was used to generate numerical data (Neuman, 2011; Sibanda 2009) and for its objectivity (Cohen, Manion & Morrison, 2007). The qualitative approach was used to provide tenets, such as learners' experiences after the intervention, which could not be captured through numerical data (Merriam, 2009) and for methodological triangulation (Denzin, 1978). It provides holistic understandings of rich and contextual non-numerical data (Mason, 2002) and it engages participants conversations in a natural setting (Creswell, 2009). Therefore, the inclusion of qualitative study complemented the quantitative data by providing appropriate learners' description regarding CS.

Design of the Study

A quasi-experimental design (Gersten, Fuchs, Compton, Coyne, Greenwood, & Innocenti, 2005; Campbell & Stanley, 2015) and phenomenological research design (Denzin, & Lincoln, 2005; Smith, Flowers, & Larkin, 2009) were used in this study. The quasi-experimental provided empirical data on the use of CS in the science classroom, and the phenomenology provided learners with the opportunity to describe their experiences regarding the use of CS in science lessons.

Sample

A purposive sample (Bernard, 2002) using criterion (Palys, 2008) was adopted, and the criterion involved searching for schools where learners were taught Science without laboratory work. 53 learners from school A (23 girls; 30 boys) and 52 learners from school B (28 girls; 24 boys) were randomly assigned to Experimental Group (EG) taught using CS and Control Group (CG) taught using TCT approach without CS, respectively. Considering normality and the context, in our case the whole class, Kraemer & Thiemann (1987) suggests 30 as the minimum number and in our case 52 and 53 are way above the minimum number of 30. Therefore these numbers were considered to be sufficient for data analysis.

Instruments

The achievement test was administered to both the EG and the CG before and after the intervention. During the intervention, the EG was taught the topic "Waves" using CS from Physics Education Technology (PhET). The PhET Interactive Simulations incorporate research-based practices to enhance the learning of Science and Mathematics concepts. For validity, a Content Validity Index (CVI) was calculated as 0.91. For internal consistency, "measure of the degree of the similarity between items" (Pieterson & Maree, 2007), the test with 25 items was piloted to 10 learners who were not part of the study. From the pilot study, a Cronbach Alpha coefficient (Cronbach, 1951) was computed, and questions with Alpha less than 0.7 were removed from the test. The final test consisted of 20 items with four possible answers and equivalent to 20 marks in total. The overall Cronbach Alpha coefficient of 0.89 was obtained and was deemed suitable for the study since it was ≥ 0.7 (de Vos, 2010). Also, interview questions were structured by the researcher to identify learners' experiences after teaching using CS and TCT. For Face Validity of the interview answers to the questions were assessed by two experts in education and their recommendations were effected before the interviews were conducted. Interview questions were piloted with six learners to determine their suitability. These learners were from similar environments and were not part of the study.

Data Collection

The CG and the EG were given a pre-test to determine their knowledge before the study. The EG was taught using CS, and the CG was taught using the TCT (Roth & Roychoudhury, 2003). Both groups were taught for four weeks during the second quarter of the 2015 academic year and worked on three sets of tasks by the second author to avoid personality effects. After that, a post-test was administered to both groups (**Appendix 1**). This post-test was the same as the pre-test they had completed previously. The only difference was that questions in the post-test were re-arranged to minimise recognition. For EG a central computer was connected to the overhead projector to enable all learners in class to see from a big screen in front. Also, three computers were available for use, and 17 learners accessed one computer at a time. The teacher started by demonstrating the concept of waves on the main computer and learners used computers assigned to their group to continue with the experiments. They used those computers to observe what happens to the transverse wave when the frequency of the wave is either increased or decreased. They also checked the relationship between the amplitude and the wavelength of the transverse wave. Learners in the EG observed the nature of different types of waves on the screen of a computer and tried to predict what would happen to the wavelength of the wave when the frequency of the wave was increased or decreased. They also predicted what would happen to the wavelength of the wave when the amplitude of the wave was increased or decreased. In each case, learners were asked to write their hypotheses. Here are three sample tasks from "Waves" that were used and characterised CS activities: 1) Learners were to establish the relationship between the frequency and wavelength of a wave. They hypothesised what would happen to the wavelength of a wave when the frequency was reduced or when the frequency was increased? 2) They were to establish how an increase or a decrease in the frequency of wave affects the amplitude of a transverse wave, and 3) They were to determine how constructive and destructive interferences occur. After that, they were required to demonstrate the movement of a transverse wave using the computer and observe what happened when a wave oscillated. For the CG, these concepts were explained to learners without CS. To reduce any harm done by omitting the CG from using CS, and to comply with ethical issues, the whole CG class was taught Waves using CS after the study was completed.

There were 15 lessons in total, 3 per week and the other 3 hours were for pre- and post-testing times. One lesson of one hour was used for learners to view the video on the concepts and make notes during week one. For acclimatisation, in a week each learner spent one hour watching the accessed website for simulation on waves and two hours were used to do practical work on the computer by manipulating the system. The other three weeks followed the same pattern for the following topics: motion of a single pulse travelling along a spring or a heavy rope; ripple tank to demonstrate constructive and destructive interference of two pulses; Identify the wavelength, amplitude, crests, troughs, points in phase and points out of phase on a drawing of a transverse wave. Finally, to extend their knowledge of waves on how to make sound using a "vuvuzela"- a native instrument that was popularised at the Soccer World Cup in 2010 played at every stadium; and how to make a string / or wire telephone as a way to include their indigenous knowledge systems.

The qualitative data was collected after the intervention of four weeks. Four learners from CG and four learners from EG were interviewed in order to determine their experiences. The percentages gained from the quantitative may not tell the feelings of learners. In fact, we used the qualitative approach to get it from the horse's mouth (Maoko & Kibirige, 2014). The interview schedule consisted of three questions: 1) What was your experience with Physical Sciences lessons?; 2) How did the teaching approach assist you in developing interest in Physical Sciences?; and 3) How much time do you spend studying Physical Science after the lesson?. Interviews were conducted with eight learners (labelled 1-8); one to four from the CG and five to eight from the EG (2 Females and 2 Males per group) in order to determine their experiences. Each learner was interviewed for a maximum of 20 minutes and the interviews were audio-recorded.

Data Analysis

Descriptive statistics (mean and standard deviations) and inferential statistics (T-test, Analysis of covariance-ANCOVA and a Mann Whitney U-test) were utilised from SPSS version 22. The differences between the EG and the CG for the pre- and post-tests were analysed using a T-test ($p < 0.05$). ANCOVA was used with a pre-test as a covariate to determine the impact of the CS after four weeks of teaching. Also, a t-test was used to determine if there were significant differences in achievements between boys and girls after four weeks of teaching in the EG. In addition, responses from semi-structured interviews from the two groups (EG, CG) were analysed thematically to identify learners' experiences in science. The audio recorded data were transcribed verbatim and transcripts were analysed using open, axial and selective coding (de Vos, 2010). During open coding transcripts were read sentence by sentence to determine key ideas followed by axial coding where key ideas were re-arranged to form subthemes. Lastly, during selective coding sub-themes were compared to the purpose of the study in order to generate main themes (de Vos, 2010).

Ethical Considerations

The participants were informed that they were under no obligation to participate in the study and that they were free to withdraw from the study any time with no negative consequences. Since participants in the study were Grade 10 learners (minors), they were provided with a Consent Form for their parents to allow them to participate in the study. Those learners from CG were later, after the study, taught similar wave concepts using CS to minimise the perception that they were discriminated against during the teaching.

RESULTS

The overall results reveal that learners in EG out-performed the learners in the CG. Learners in the EG (taught using CS) indicated that they enjoyed, developed interest and understood waves with ease, unlike learners from the CG (taught without CS).

Quantitative

The results of the pre-test for the EG achievements (mean 47.00 ± 14.00 SD) and the results for the CG (mean 35.60 ± 9.60 SD) did not differ significantly (T-test: -0.35, $p > 0.05$). After teaching for four weeks, the EG achievements (mean 56.00 ± 19.50 SD) was again compared to that of the CG (mean 39.60 ± 13.35 SD) and there were significant differences between the two groups (T-test: 0.52, $p < 0.05$) (**Table 1**). An effect size of 0.84 and a Cohen *d* of 0.41 were calculated for the EG.

Table 1. T-test results of the EG and the CG before and after (*Significant at p < 0.05)

		N	M	SD	T-test	P
EG	Pre – test	53	47.0	14.0	-0.35	0.00*
	Post – test	53	56.00	19.50		
CG	Pre – test	52	35.6	9.60	0.52	0.81
	Post – test	52	39.60	13.35		

An independent-samples t-test was performed to compare girls' and boys' achievement in the EG after intervention. The results show that the achievements for girls (M=54.60, SD=10.93) and boys (M=54.39, SD=7.90 in EG after intervention were not significantly different t (51) =-0.08, (p < 005) (**Table 2**). Therefore, the results show that CS did not discriminate between girls and boys in the EG.

Table 2. T-test results for girls' and boys' achievements after intervention. (*Significant at p < 0.05)

		Levene's Test for Equality of Variances		T-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig	T-test	df	Sig.(2-tailed)	Mean Difference	Std Error Difference	Lower	Upper
EG, (Boys & Girls)	Equivalent variance assumed	1.42	0.24	-0.08	51	0.94	0.21	2.60	5.43	5.02
	Equivalent variance not assumed			-0.08	43.25	0.94	-0.21	2.65	5.55	5.14

Using pooled data for boys and girls per group with pre-test as a covariate, ANCOVA test shows that there were significant differences between the achievement of the two groups ($p < 0.05$) (**Table 3**).

Table 3. ANCOVA summary results of EG and CG before and after (** Significant at p < 0.01)

Source	SS	Df	MS	F	*p*
Pre-test	24.58	24.57	4.23	0.06	0.01**
Post-test	36.41	36.41	6.27		
*Error	273.02	47	5.81		
Total	3845.00	49			

Qualitative

From semi-structured interviews **Appendix 2**, three themes were identified and these are: 1) Enjoyment; 2) Interest in Science; and 3) Ease to understand concepts. The themes from the CG are presented first, followed by those from EG.

Themes from the CG

Theme 1: Enjoyment

From question one, the researcher wanted to know learners' experiences during Physical Sciences lessons. In response to this question, all learners from the CG stated that they did not enjoy Science at all. Some even expressed that they think it was a big mistake for them to have chosen to study Physical Sciences as one of their subjects because they were unable to cope with the work. They indicated that, they thought they would perform practical work like other learners from their neighbouring schools, but they did not due to lack of resources. The teachers explained what the waves are and drew a few illustrations on the chalk board. On the extreme cases some of the teachers read directly from the textbook (Grade 11 Physical Sciences. Everything science by Siyavula) and often times learners did not understand what they wrote down. They tried to re-read after the lesson, but they still could not make sense of most of the concepts. Below are a few specific direct quotes from learners:

Learner 1: "I do not enjoy learning Physical Sciences because it is very hard to understand";

Learner 3: "I do not like Physical Sciences; I don't even know why I chose it because it is really difficult for me. No matter how much effort I put to the subject I still do not succeed in the test";

Learner 4:" I tend to fall asleep in a Physical Sciences lesson because there is very little that excites.

Learner 2: "I thought Physical Sciences was a practical subject, since we don't do any practical work. I do not enjoy studying Physical Sciences."

Theme 2: Interest in the subject

The second question sought to assess learners' interest in Physical Sciences as a subject, learners from the CG indicated that they found nothing interesting about Science. However, they agreed that everything in their lives revolved around Science but they still could not relate Science to their daily living. They felt Science was boring and did not provoke interest and this impacted on their achievements because they never passed the subject. Below are a few specific direct quotes from four learners:

Learner 1: "I was told that Science gives clarity to everything happening around us, but I have never seen anything to suggest it."

Learner 3: "I hate Physical Science, I have never passed the test and it does not seem like I will ever pass it."

Learner 4: "I have no desire to continue with Physical Sciences. I have had enough. I work hard and fail and because of that I hate the subject. Whenever I try to understand I become even more confused."

Learner 2: "I realised that Physical Sciences is not for people like me, maybe I am not gifted enough to study Science. I think I'm about to quit the subject."

Theme 3: Ease to understand concepts

On the last question that asked learners about how much time they spent studying Physical Science after the lesson, it appeared that they had different experiences. Some learners from the CG differed on the amount of time they spent on the subject. Some spent little time or they did not even bother to give time to the subject at all. Their reason was that they were struggling so it became pointless for them to spend time on something they did not understand. Some indicated that they spent a lot of time on the subject but that did not yield any results. They saw the study of Science as time consuming. Below are specific direct quotes from learners:

Learner 1: "Physical Sciences subject is time consuming. If I want to understand the content I have to spend a lot of time. I may not even pass it. I mean, it seems impossible to cover all the content in a given time."

Learner 3: "No matter how much time I spend on this subject, I just can't understand it."

Learner 4: "I gave myself enough time to understand Physical Science; I think I had lost a lot of it without gaining anything."

Learner 2: "I can't spend time on something I do not understand; I will waste time for other subject. I realised that Physical Science needs geniuses."

Themes from the EG

Theme 1: Enjoyment

All four learners from the EG had positive attitudes judging from the responses they provided to the questions. As the first question stipulated, the researcher wanted to know how learners enjoyed Physical Sciences lessons. In response to this question, all learners from the EG stated that they really enjoyed the Physical Sciences lessons. Below are some direct quotes from four learners:

Learner 5: "For the first time I have enjoyed the Physical Science class, I particularly loved the game-like environment. It was like a game. I never thought a computer could be used in this way to learn Science."

Learner 7: "If all subjects were taught the way we have been taught Science, then I would not have any reason to bunk the class."

Learner 8: "I can't' wait to get to my science class each day I go to school, I really enjoy doing science and observing experiments on the computer."

Learner 6: "I used to sleep in a science class but not anymore, I enjoy every moment."

Theme 2: Interest in the subject

On the second question that sought to assess the interest of learners on Waves as a topic, learners from the EG indicated that they found it highly interesting. They indicated that they could not comprehend the concept of waves, now they understood how waves occur and they were able to explain the types of waves. Below are some specific direct quotes from learners:

Learner 5: "I became more interested in Science more especially to the concept of Waves because of the CS. It made me realize what real science is all about and the observations helped me relate to what I read in the textbook."

Learner 7: "I find Waves to be more fascinating especially when we do experiments on the computer; I enjoy working with a computer too."

Learner 8: "I always want to know more about the world we live in and Science makes it easier for me to understand."

Learner 6: "I can't believe that Science can be so interesting as it was now even without practical work. This new way of learning Science does wonders."

Theme 3: Ease to understand concepts

On the last question that asked learners how much time they spent studying Physical Sciences after the lesson, some learners from the EG indicated that they spent much time because they loved the subject therefore they wanted to know more. Some indicated that they were no longer spending as much time as they did before they used CS because they now understood the Waves concept better than before they were exposed to CS. Below are specific direct quotes from four learners:

Learner 5: "I used to read many times without understanding, but after CS I could understand content after reading once. I now understand the concept of waves more clearly than ever before because of CS. I was happy to perform an experiment in my school despite lack of resources because of CS."

Learner 7: "I spend lesser time on my books these days because the observations that I got from CS help me relate to what I read in the text book about Waves."

Learner 8: "After the CS actually you do not need a lot of time to read the content because the content is right in your mind. That is to say, when I learn using CS I understand content much quicker and better than ever before."

Learner 6: "I spend more time because of the love I have for the subject, each time I study there is something that tells me to study more. I enjoy the time I spend studying Waves in Physical Sciences."

DISCUSSION

The study explored Grade 10 learners' conceptual development of Science concepts using Computer Simulations (CS). A pre-test was administered to both groups (EG and CG), and the results show that there was no significant difference in achievements of learners from both groups (T-test, $p > 0.05$), suggesting that learners both EG and CG had more or less similar understanding of waves concepts before instruction. However, in the post-test, learners in the EG performed better than learners in the CG and that the differences were significant (T-test, $p < 0.05$). An effect size of 0.84 was obtained, suggesting large positive effects for the EG and Cohen *d* of 0.41 obtained was greater than ($p > 0.35$), suggesting a large gain (Cohen 1988) for the EG. These results imply that CS improved learners' conceptual understanding of the science concepts studied.

CS improve understanding of Science concepts, and this ultimately improves the quality of Science Education. When learners who were taught using CS were interviewed, they claimed to spend less time to understand Science content. Also, in the case where the concept is not understood, at first, learners could replay the simulation to relearn, and this may improve autonomy in their studies. The autonomy observed in the EG in this study agrees with Jilani and Yasmin, (2016) and Tsai (2018). The increased understanding of the concepts in turn may increase interest in the subject. Thus, the interest formed during CS is vital to developing a positive attitude towards Science. These findings agree with Dalgety et al. (2003) and Covington (2000) regarding the importance of attitudes and motivation towards Science, respectively. Dwyer and Lopez (2001) also talked about learners being motivated when they experience realistic and authentic problems.

The EG learners' answers during the post-test imply that they had developed a clearer understanding of the Waves concept than their counterparts from the CG. The conceptual understanding exhibited by the EG agrees with Slotta (2002) and Tsai (2018) who indicated that learners might benefit from computer use which allows them to learn from each other and also to make them develop autonomous learning. The results are surprising because the high learner-computer ratio seems not to have affected learners' achievements. Also, the Cohen d of 0.41 suggests a large knowledge gain to reckon in favour of the EG. Hence, the use of CS can be a levelling ground for the 'have-nots' learners of the Southern Hemisphere with the 'haves' learners of the Northern Hemisphere (Halverson & Smitt, 2010; Stegmeir, 2015).

The development of positive attitudes has been reported in cognitive, behavioural and affective domains (Ajzen, 2005). In this study, semi-structured interviews were intended to uncover the affective domain by seeking learners' emotional feelings regarding Physical Science (Rajecki, 1990). Learners from EG developed and enjoyed learning science, but this was not the case with learners from the CG. The interview questions and probing questions sought to identify the learners' views and interests regarding the use of CS. Although it may seem like much time was spent on experiments in CS classes, learners reported that they enjoyed the teaching approach and it made them understand concepts much better than when the TCT approach was used. This is why some learners suggested that it took them a shorter time to read and understand the concepts. Learners from EG explained confidently the concepts of Waves and this suggests that CS enhanced their science conceptual development. While CS have been widely studied in the developed countries, this is not the case in Africa and in other developing countries. Our study is unique in that it combined both the quantitative and qualitative study regarding CS. Furthermore, the learners' views on the use of CS are very limited on the African continent. The learners' views in this study give credence to the fact that there are few studies on the learners' views on the use of CS in Africa south of the Sahara. The study results add to the scanty literature of the use of CS in the developing countries. The limitations of this study are that the participants in EG (53) and CG (52) were too few for generalisation and the content was limited to Waves only. Nevertheless, the findings of the study provide an insight on the potential for CS to arouse interest, as well as enhance conceptual development of Science concepts which are likely to improve the quality of education.

After four weeks of teaching, there was a significant difference in achievements of boys and girls in the EG ($p < 0.05$) when compared to those in the CG. These results are not surprising because CS as a strategy was applied to both boys and girls in EG. This suggests that CS was successful in narrowing the achievement gap between boys and girls because, as young girls, learners tend to be attracted to technology more than their older generation (Mavhunga, Kibirige, Chigonga & Ramaboka, 2016). This is in line with Baker's (2013) and Michael's (2013) findings regarding strategies focusing on learners' interests. In addition, learners benefit through engagement with concepts especially when they do practical work through "interactions, hands-on activities, and application in Science" (Hampden-Thompson & Bennett, 2013). During CS learners may interact with one another and share their conceptual understanding. Some of the concepts shared were constructive and destructive interference of two pulses; definitions and the meaning of wavelength, amplitude, crests, troughs, and sound waves in our everyday life. This is a remarkable outcome when one considers the high learner-computer ratio (Butcher 2003) which is 17:1 in high school and this ratio is better than 28:1 in the primary schools in the country (Sossa, Rivilla & González, 2015). In schools where there are limited or no laboratory resources, CS may improve conceptual understanding of practical work. This suggests that it is possible to use CS in place of a physical/manual laboratory experiments in the teaching of Science concepts (Choi & Gennaro, 1987). In the same vein, these results are good news to developing countries with limited resources to consider using computers to teach science regardless of the high learner to computer ratio. Also, our results are in agreement to Gerick, Eickelmann & Bos (2017) who contend that the higher the learner-computer ratio the lower the achievement. Currently, it is not clear as to what the results would be if the learner-computer ratio was lower than 17:1 used in this study and the effect of the delayed testing on learners' achievement and these need further studies.

Ideally, both simulations and hands-on practical work should be used to enhance conceptual understanding. CS may offer extra advantages in time so that when learners conduct manual laboratory work, they have a clear conceptual understanding and this may reduce the time learners spend on practical work experiments. This observation agrees with Kennepohl (2001) who contends that learners using CS have a slightly better conceptual knowledge of the practical work before manual practical work is done. Raimi's (2002) study in Pakistan found that laboratory work positively affected learners' achievements in Physical Sciences. Furthermore, Adesoji and Olatunbosun (2008) argued that learners tend to understand and recall what they see more than what they hear and this improves their achievements. The results indicate that EG achievements improved more than the CG. This improvement can be attributed to CS, which granted learners an opportunity to visualise the processes and conceptualise what they observed.

TCT used in the CG did not make learners enjoy Physical Sciences and their interest in the subject was low. This might have been due to the expository approach being too abstract in Science classes. It is no wonder learners spent a lot of time to understand Science content. Conversely, the EG spent less time to grasp Science concepts. This is because CS are potentially useful for stimulating learners' interest and providing a print on their minds better than TCT. Also, some laboratory experiments that may be expensive or dangerous to conduct may be observed on the screen (Slotta, 2002) especially if one considers the cost of apparatus for 17 learners as compared to a computer for the whole year! Thus, the use of CS contributes to conceptual understanding and may provide open-ended experiences for scientific inquiry and problem-solving skills. Such a teaching strategy is most likely to improve the quality of education (Livingston, 2017).

In conclusion, learners who were taught using CS were happy with the approach used. CS allowed the learners to gain conceptual development. The learners were "highly motivated", and it was not surprising that their achievements improved more than the CG and this suggests that CS enhanced learners' conceptual learning in Science.

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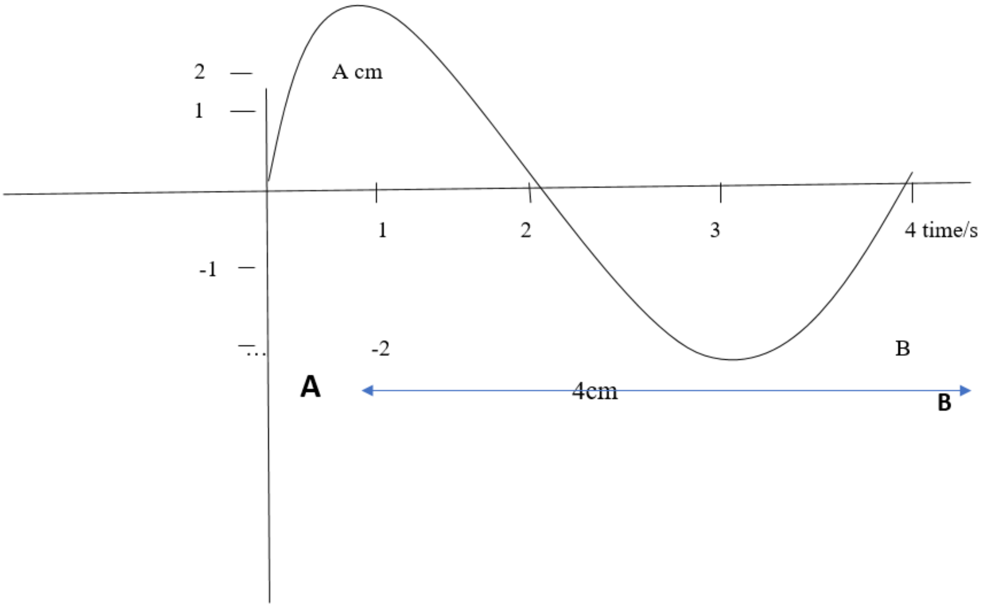
APPENDIX 1

Physical Science Grade 10 Achievements Test 1

MULTIPLE-CHOICE QUESTIONS

The diagram below is not drawn to scale; it illustrates the type of wave of a certain frequency. Refer to the wave to answer questions

Each question has only ONE correct answer. Write only the letter (A-D) next to the number.



1.1 What is the type of wave illustrated by the diagram above?

A. Microwave
B. Transverse wave
C. Longitudinal wave
D. Medium wave

1.2 What is the wavelength of this wave?

A. 3 cm
B. 2 cm
C. 4 cm
D. 12 cm

1.3 What is the amplitude of the wave?

A. 2 cm
B. 4 cm
C. 6 cm
D. 3 cm

1.4 How many wavelengths are illustrated in the diagram?

A. 4
B. 3
C. 2
D. 1

1.5 When the frequency of the wave increases, the amplitude…
   A. Increases
   B. Decreases
   C. Stay the same
   D. Decreases and then increases.

1.6 The increase in frequency will result in….
   A. Increase in the number of wavelengths
   B. A decrease in the number of wavelengths
   C. Doubling wavelength
   D. Tripling wavelength

1.7 Period of a wave refers to…
   A. The number of complete vibrations per second
   B. Time taken to form a wave
   C. Time taken for a complete wavelength to pass a point
   D. Frequency of a wave

1.8 When a crest of one wave coincides with a crest of another wave and it results in a bigger crest, it is called
   A. destructive interference
   B. cancellation
   C. constructive interference
   D. amplitude

1.9 T calculate the velocity one needs to take
   A. frequency
   B. wavelength
   C. wavelength and divide it by frequency
   D. wavelength times frequency

1.10 An increase in the frequency of wave means the pitch of sound…
   A. Decreases
   B. Remains the same
   C. Increases
   D. Fluctuates

1.11 The frequency of this wave is…
   A. 0.0009Hz
   B. 0.008Hz
   C. 0.12Hz
   D. frequency not given

1.12 What is the relationship between frequency and wavelength of a wave?
   A. Frequency is directly proportional to the wavelength
   B. Frequency and wavelength do not have a relationship.
   C. Frequency is inversely proportional to wavelength
   D. Frequency of a wave does not affect the wavelength

1.13 How long does it take for a complete wave to form?

A. 2s

B. 3s

C. 1.3s

D. no answer because no frequency given

1.14 The quality of sound is attributed to…

A. Amplitude of a wave

B. Speed of a wave

C. Waveform

D. Period

1.15 A dolphin emits an ultrasonic wave with frequency of 0.15 MHZ. The speed of the ultrasonic wave in water is 1500m.s^{-1}. What is the wavelength of this wave?

A. 0.1 mm

B. 10 cm

C. 100 m

D. 1 cm

1.16 Position **A** on the graph represents…

A. Trough

B. Wave

C. Point in phase

D. Crest

1.17 Position **B** on the graph represents…

A. Crest

B. Point in phase

C. Wave

D. Trough

1.18 The amplitude and the frequency of a sound wave are both increased. How are the loudness and the pitch of the sound affected?

	Loudness	Pitch
A.	Increased	raised
B.	Increased	unchanged
C.	Increased	lowered
D.	Decreased	raised

1.19 What points are considered points in phase?

A. Points that move perfectly in step with each other

B. Points those are close to one another

C. Points that are closely parked

D. Points on crest and trough

1.20 Low amplitude represents a…

A. loudness of sound
B. sound waves
C. No sound
D. Quality sound

2 x 20 = 40

______________________END____________END________________

APPENDIX 2

- Tell me anything you were told about Physical Science before you enrolled to study it.
- Do you enjoy learning PhysiRcal Science?
- What is your experience of studying Physical Science? Elaborate on the learning environment.
- How easy are Physical Science concepts for you to understand? Elaborated.
- What can you about the methods used to teach Physical Science?
- Is your study period for Physical Science the same as other subjects? Explain
- Do you have any other comment about Physical Science

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