Use of interactive computer simulations in the teaching of physical science

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Abstract
The use of interactive computer simulations in improving the teaching and learning of physical science is considered. The importance of interactive computer simulations is the ease of being recycled and hence its sustainability. It can be reworked, retried and used by the learners. The simulations are simple computer programmes that are able to move or represent difficult concepts, ideas or representations. The research in this case was to compare Interactive Computer Simulations with the traditional talk and chalk. The background to this research is the difficult faced by learners in doing experiments in school using traditional equipment. An alternative is looked at in this research – the use of interactive computer simulations. Use of these simulations could be easier for the educators and learners.
The experimental design is quasi-experimental, using intact non equivalent group design. The research design is a switching replications design whereby the treatment and control groups are used at certain times of the research. The study consisted of 104 learners from four schools in a rural setting in a predominantly rural province in South Africa.
The learners were from four different schools which were selected purposively in such a way that the school average final grade 12 results were above 50% for a period of four years.
The research design of switching replications design was used since it suited the different educator factors we had, with a teacher in each school confident with use of computers while others had to be strongly supported before using the computer simulations. These differences could be reduced through seeing them in both the control and treatment conditions hence the switching replications design. This also meant the intact classes would be the treatment group at one time and a treatment one in the other. Different groups would be seen how they reacted as a treatment group and also as a control group. In the case of the switching replications design with special reference to the treatment group in the first cycle, we would be able to determine if the treatment effect carries on to the second cycle when the roles are reversed and the group is a control group.
There are two hypotheses that are looked at in this paper, the first one is, Interactive computer simulations will lead to higher performance on an achievement test than the traditional talk and chalk The second one was Interactive computer simulations will lead to a higher speed of answering questions in a unit on geometrical optics than the traditional chalk and talk method.
The theoretical framework used for this research is based on the Sweller's Cognitive Load theory and Mayer's Multimedia Theory of Learning. The over-arching theoretical framework is the information processing wherein in order for information to go to the long term memory it must have been in the germane load. Sweller's Cognitive Load theory posits that the cognitive load is based on intrinsic, extraneous and germane loads (Mayer & Chandler, 2001 (Paas, Renkl, & Sweller, 2003)). The intrinsic load is based on the content or curriculum package, in our case, the geometrical optics, the way we teach and what we use to teach will determine the extraneous load and finally the free and what is left over is the germane load, the memory resources left for learning the actual stuff. On the other hand Mayer's

multimedia theory of learning (Holzinger, Kickmeir-Rust, Wassertheurer, & Hessinger, 2009; Mayer & Chandler, 2001; Plass, Hommer, & Hayward, 2009) indicates we learn through two channels. He further indicates the two channels as audio and visual, they are two but they are limited in uptake. In a given time they can only take up limited information. The visual and audio are also processed in different channels. The processing capacity of each channel is limited. The final aspect of this theory is that, learning is an active process, in order for learning to take place there must be participation and active interaction. It also indicates that if both channels are used the better would be the learning.

Data was collected in two ways. An instrument developed through use of achievement test items and skills questions. This particular instrument was tested for validity through use of experienced educators and pilot tested. Another way was through observing the learners as they wrote the tests. The time of handing in was noted.

SPSS was used for the analysis of the data collected for this particular research.

In this study, it is taken that when learning has taken place the learner will be able to respond faster to the aspect he has grasped. If true then we could see it in the way she has been able to answer the questions in the test taken. The test with regard to skills will also be assessed.

The importance of this research is in terms of use of technology. If it improves learning then we should be able to use it for the hundreds of thousands of learners in our school system who would benefit from use of technology. If it is not working, is there something in the setting that is not allowing the learners to perform that can be changed?

KEYWORDS:

Interactive Computer Simulations, Animations, Virtual learning, Physics Education, Science Education, Science Process skills.

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Introduction

The use of technology albeit computers is rampant with the way we do things being redefined. The way we communicate by use of cell-phones, face-book, twitter, skype and not to mention e-mails has changed a lot. The way people work as in banking through use of phones and withdrawing cash from banks by use of supermarkets is another of the many developments.

The use of computer use was investigated as a way of using technology in the teaching and learning environment. This research looks at four schools in Limpopo Province in South Africa.

Background

In an era where we have digital natives and digital immigrants (Prensky, 2001), it is important to use the tools of the natives to allow them to be their best. Prensky coined the word for children who grow up using the digital world. It is evident that South Africa, to say the least, has many of these. It might even be questioned whether it is automatic to be a digital native (Thinyane, 2010). An interactive computer simulation is an area which is being investigated to use for teaching and learning in the High school in the area of physical sciences. Physical sciences is important and it is important to note that it has three components to be acquired (Department of Education, 2008). It has the skills, knowledge and attitudes and values. The last is lumped together as attitudes and values. This research will look at the first two, namely, knowledge and skills. The skills that are being looked at are the science process skills (Kazeni, 2005; Rambuda, 2002). In the science process skills, one skill of identifying relationships between variables will be selected and used. Four schools in Limpopo Province will be selected and these will be looked at in detail.

Literature review

The use of interactive computer simulations will be looked at and literature from several disciplines will be looked at. This study is not the first one in the area. The reasons for the studies is due to physical science being a very difficult subject (Maree, Aldous, Hattingh, Swanepoel, & van der Linde, 2006; Gaigher, 2004) especially with regard to its constituent subjects of physics and chemistry there are efforts to improve the teaching and learning of it. Bayrak in a study to improve 1st year performance at the university (Bayrak, 2008) tried the use of interactive computer simulations with a specific computer software in Geometrical optics. Several others have tried in several other areas like the moon phases (Bell & Trundle, 2008); the electric currents (Farrokhnia & Esmailpour, 2010); working with graphs in kinematics (Brasell, 1987; Araujo, Veit, & Moreira, 2008) to determine if there was improvement when using interactive computer simulations. The studies quoted above are compared with the real experiments and not just interactive simulations on their own. Zacharia's work on a comparison of real and virtual experiments as he termed them showed that there was a great improvement in the learners when they used a combination of both interactive computer simulations and real laboratory experiments (Zacharia & Olympiou, 2011).

The use of the interactive computer simulations, come in several different ways, there is applets which are small computer applications which do small specific actions. Within this general categorisation of applets we also have physlets which are applications dealing with only physics concepts or phenomena (Carolus, 2009 & Moreno, 2007). The physlets or applets are animations of some nature. Animation is where pictures or text is made to move, it is being made to animate. It is the use of interactive computer simulations where this research is being made.

The importance of the simulations is tied to how it helps in what is being taught to end up in the long term memory. The theoretical framework for this research was based on Sweller's Cognitive Load Theory (Deschri, Jones, & Hekkinen, 1997; Plass, Hommer, & Hayward, 2009 & Zheng, Yang, Garcia, & McCadden, 2008) and Mayer's Cognitive theory of Multimedia Learning (Muller, Sharma, & Reimann, 2008; Plass, Hommer, & Hayward, 2009 & Liu, Andre, & Greenbowe, 2008). What ends up in the long term memory is first processed in the working memory. The working memory is limited in its operation and in its working. Whatever is put to the memory is not always processed for long term memory. Long term memory means, whatever is put there will be remembered for a long term or long time. The long term forms schemas, these are chunks of information which have been put together. If information is in the long term memory it can easily be retrieved and used in the short term memory with ease. The working memory has three components of load it

processes. It has the Intrinsic, extraneous and germane load. The intrinsic load is the load that is found in what is being taught. In the case of the research it is the geometrical optics. The extraneous load is the one due to how the unit or topic is being taught. The instructional strategies being used. The last component is the germane load, it is the load that is processes information which goes into the long term memory. The load ascribed to extraneous and germane are complementary. When the extraneous load increases it leaves little memory resources for germane processing. However if the extraneous load is reduced then it leaves a lot of resources for processing the information for long term retrieval.
The diagram below illustrates the model being used for the research:

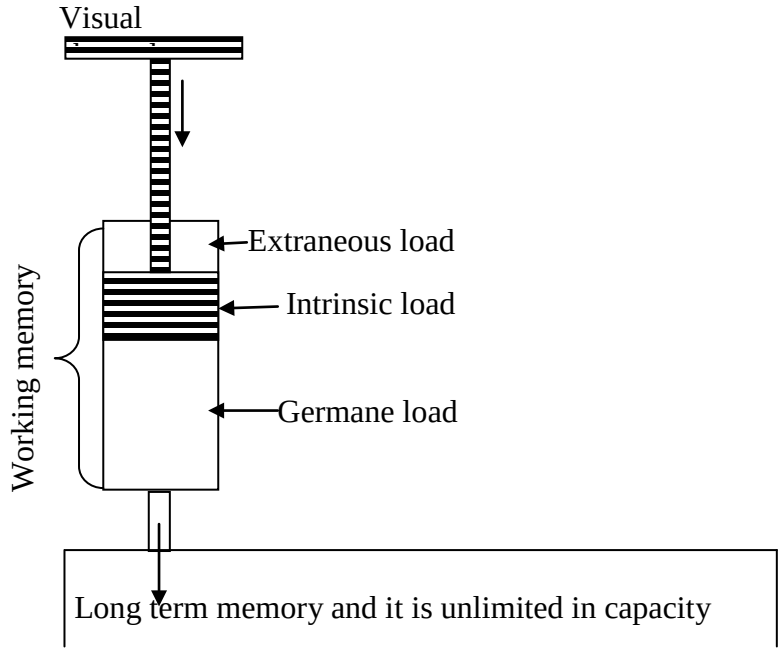

Figure 1 Theoretical Framework for use of the cognitive load in acquisition of science process skills. The pictorial analogy used is a hydraulic pump which can move up and down where if it moves down it means the extraneous load increases while the germane load decreases. Please note that for a given content or skills area or section the intrinsic load remains the same.

Research questions

The research had the following research question:
How will the use of interactive computer simulations affect acquisition of the skill of describing relationships between variables in geometrical optics for grade 11 learners?

And the following research sub questions:

1.1 To what extent will the use of interactive computer simulations affect learners' answers to items in an achievement test - describing relationships between variables in geometrical optics in physical sciences in grade 11?

1.2 How will the use of interactive computer simulations affect the speed of answering questions in a unit on geometrical optics compared to the traditional chalk and talk method?

Methodology

The Research design was the Switching replications design as indicated below:

N	O	X_1	O		O
N	O		O	X_2	O

The above design is a quasi-experimental design using an intact group. It is a Switching replications design wherein we have a pre post1 and post 2 treatments. The strength of this design lies in its having both the treatment and control. The treatments come at different times. The design for this case was used since the treatment groups had many different variables. It was four schools and in each of the schools the prevailing conditions were different. The educators teaching were quite different from the situation of work for example. The treatment, X_1, means Interactive computer simulations were used by the educator who normally teaches the class. In treatment, X_2, simulations of a different kind were used for the second group.

An instrument was designed based on Kazeni's instrument for science process skills (Kazeni, 2005); Test of Integrated Process skills TIPS (Burns, Okey, & Wise, 1985) and Test of Integrated Science Process Skills and the Limpopo Province common tests and examinations. The guiding content was as in the National Curriculum Statement content of Physical science (Department of Education, 2008). A 26 item test was developed and four specialists were asked to rank the various items with regard to validity and appropriate level for the group to use them. Two were Practising Physical science Educators one being a Chief Examiner and the other with over 20 years of teaching the subject and had been awarded the Best mathematics and Physical Science teacher of South Africa, the other two were Science Education Professors. To establish the validity, the Spearman Rank formula as modified by Ogunniyi was used and corrected for the tied ranking gave a validity of 0.873. The reliability of the instrument was used on a another school far removed from where the research was going to be, and a test-retest reliability taken and it was found to be 0.83.

There was a pre-test for all the participants to establish what their pre-knowledge was.

Two schools started with being taught using simulations and the latter part of the material was by using the educator uses normally. The other two schools started by using the teaching strategy the educator uses in a day to day environment and in the latter part of the unit they used simulations.

The simulations used for this research were from the PhET software (McKagan, et al., 2008) which is available freely on the internet. The particular simulatiosn were the geometrical optics ones.

The second instrument which was used was a Split-timer to determine the time taken for answering the test items. The Split-timer is available on the web and on the smart phones made recently. The one used can have split-times of up to 150 people. In the case of the research, the timer is switched on as soon as the test started; every time a learner finished the time was activated and each time was indicated and on the answer sheet the order of handing was indicated as 1, 2, 3 in sequence. After the test the times on the Split timer would be reconciled with the answer sheets.

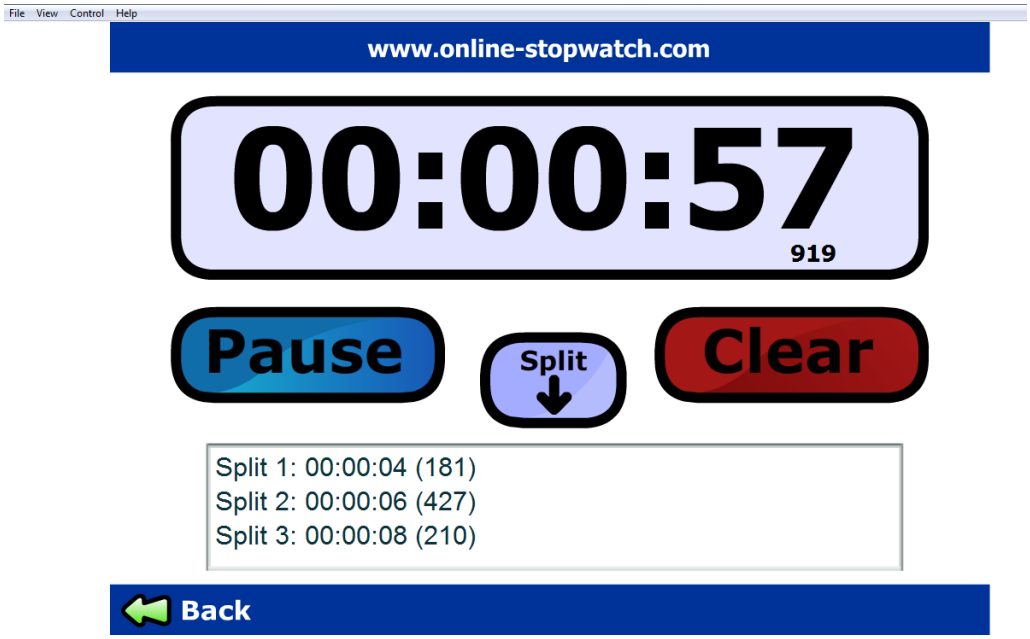

Figure 2 Split-timer

Data analysis

The following is the descriptive statistics from the data collected:

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