Art. #1570, 14 pages, https://doi.org/10.15700/saje.v40n3a1570

Integration of MOODLE into the classroom for better conceptual understanding of functions in Mathematics

Nicholas Mlotshwa , Nyarai Tunjera and Agnes Chigona
Faculty of Education, Cape Peninsula University of Technology, Cape Town, South Africa
chigonaa@cput.ac.za

Many South African educational institutions are adopting learning management systems (LMS) into their daily teaching and learning practice. The Western Cape Education Department piloted Modular Object-Oriented Dynamic Learning Environment (Moodle), an LMS for improving teaching and learning. The objective of the research reported on here was to determine whether Moodle improved Grade 10 learners' conceptual understanding of the topic, functions, in mathematics. The research investigated two classes; one dependent upon a traditional chalk-and-talk teaching method (control), and another exposed to Moodle (experimental). It was found that learners constructed their own knowledge by drawing on resources embedded in Moodle and framed within a Social Constructivist theory. A hybrid e-learning framework was deployed; learners acquired knowledge by interacting with computers. Interaction was monitored and results were recorded using online surveys and tests. A quasi-experimental design was employed to compare the groups. The comparisons were statistically analysed. Results showed that the functionalities within the Moodle LMS were instrumental in improving conceptual understanding of mathematical functions.

Keywords: constructivism; digital technologies; functions; mathematics; Moodle

Introduction

Technology allows teachers and learners locally and internationally to accelerate and enhance tuition, this is why an increasing number of policy makers and implementers are adopting information and communications technologies ([ICTs], Howie & Blignaut, 2009). This growing trend of integrating LMSs into daily tuition and facilitating the understanding of mathematics is particularly beneficial in a developing economy such as that of South Africa. This is due to the high demand on mathematics, science and technology skills for developing its economy and competing in the Fourth Industrial Revolution (World Economic Forum, 2016). According to the National Council of Teachers of Mathematics ([NCTM], 2016) digital technologies can enhance the teaching and learning of mathematical procedures such as problem solving, reasoning and justifying.

The National Council of Teachers of Mathematics has taken the following position regarding teaching and learning using technology:

> It is essential that teachers and students have regular access to technologies that support and advance mathematical sense making, reasoning, problem solving and communication. Effective teachers optimise the potential of technology to develop students' understanding, stimulate their interest and increase their proficiency in mathematics. when teachers use technology strategically, they can provide greater access to mathematics for all students. (NCTM, 2016:para. 2)

South Africa's Department of Education (DoE) formulated a white paper on e-education (2004) setting out a four-phase strategy: immediate, short, medium and long term. The Western Cape Education Department's (WCED) 2018/2019 annual plan states as follows:

> The use of ICT – the 'Fourth Industrial Revolution' in education is an important medium for complementing the delivery of curriculum in most developing countries, including South Africa. We have seen the importance of ICT in education in the way it has simplified learning. The integration of e-innovation, e-governance and e-administration to enhance the use of ICT in teaching and learning will be the continued focus of our Operation Phakisa interventions, which are aimed at developing and modernising the skills of our teachers and learners to match the needs of the changing world. (WCED, 2018:2)

The WCED e-Learning Unit initiated the use of the Moodle LMS in 2009. It is freely accessible to any school in the Western Cape, however, to date the system remains partially utilised by schools. Moodle has numerous tools that can be used by both teachers and learners in the classroom. In 2013, the WCED saw the Moodle LMS implemented in selected schools in the Western Cape Province as a pilot project. Training and advocacy of the system was undertaken by these schools and some began using the platform in May 2014.

With this paper we extend understanding of previous studies related to ICTs for teaching and learning: we explore the integration of Moodle into mathematics tuition for better conceptual understanding of the topic, functions. According to Kotzer and Elran (2012), new e-learning environments contribute to teaching and learning if properly integrated within pedagogical frameworks. The research addressed the question: Does the introduction of Moodle in a constructivist way improve conceptual understanding of mathematical functions?

For the purpose of this article, the topic of mathematical functions will simply be referred to as functions.

Hypothesis

H_0: $\mu 1 = \mu 2$. A null hypothesis means that the adoption of Moodle has a significant relation to learners' conceptual understanding of functions and academic performance (a null hypothesis shows that the two means are equal).

H_1: $\mu 1 \neq \mu 2$. An alternate hypothesis means that the adoption of Moodle is not related to learners' conceptual understanding of functions and academic performance (the alternate hypothesis shows that the two means are not equal).

Literature Review

In their annual report, the Association for Mathematics Education of South Africa (AMESA) posits the need to identify useful ways of improving teaching of mathematics as a school subject (Govender & Junqueira, 2018). Studies have been conducted on how to stimulate and sustain learners' interest in mathematics (Yeh, Cheng, Chen, Liao & Chan, 2019). Most of these studies concentrated on using ICTs to improve learners' abilities in, and enjoyment of the subject. ICT resources nurture a positive attitude towards the subject as many digital natives (people born after 2000) are drawn to technology (Leendertz, Blignaut, Nieuwoudt, Els & Ellis, 2013). Notable research into the use of digital versatile discs (DVDs) in classrooms was conducted (Padayachee, Boshoff, Olivier & Harding, 2011). Remarkable results were obtained as learners used DVDs to blend learning. Technological advancements have improved the way in which teaching and learning is conducted in various learning institutions (Chigona, 2018). Frankl and Bitter (2012:80) note that "today's learners are more (inter-)active and engaged in the virtual world." Teachers need to take advantage of the available technologies to reach out to learners within their social spaces (Chigona, 2017).

E-learning theories

The 21st century is characterised by vast amounts of information which is mostly available in digital form. In the process of sharing information, virtual communities are more prominent (Anderson & Elloumi, 2004). This has created both opportunity and challenges in the education arena. The use of e-mails, chat rooms, blogs and a variety of social networking software has become a feature of youth culture (Frankl & Bitter, 2012). To achieve results in the integration of this learning process, education specialists have explored the pedagogical advantages and disadvantages of e-learning practices and devised various e-learning theories that support the phenomenon of technology in classrooms.

A constructivist approach outlined by Sultan, Woods and Koo (2011), asserts that learners construct their knowledge based on their interpretation of events and previous experiences. The foundations of this approach can be traced to Vygotsky and Piaget. Piaget developed a theory of cognitive constructivism: "Children are active thinkers constantly trying to construct more advanced understandings of the world" (Siegler & Ellis, 1996:211). Constant observations reveal that instructors in e-learning should strive to develop strategies and learning set-ups that create a constructivist environment for learners in the classroom – especially the concept of building on existing knowledge.

In the context of this study, this would imply that learners should be exposed to learning activities that incorporate technology resources they are familiar with before introducing new ones; moving from the known to the unknown (Mbagwu, Ozioko & Ogueri, 2017). Twenty first century learners are avid users of social media and instant digital communication applications. The use of such platforms for knowledge acquisition makes the learning process more efficient as the teacher does not have to explain or introduce the technology before engaging the content. Once the learner has domesticated the use of these technologies, they can explore others such as content specific websites, online tutorials or videos, which learners can resort to when they need assistance with a particular topic, reading, concept or any given task (Powell & Kalina, 2009). This approach allows learners to apply their minds before moving on to the next learning level.

In this study, a constructivist paradigm informed the design of the e-learning intervention used to encourage learners to construct knowledge. However, when the constructivist paradigm was introduced, it did not directly take into consideration the implications of digital technology in learning. Therefore, Hirumi's **S**tudent-**Cen**tred, **T**echnology-**R**ich **L**earning **E**nvironments (SCenTRLE) e-learning framework, presented in the next section, was employed. SCenTRLE is founded on constructivist principles and addresses the factor of technology among other factors.

The Hirumi's SCenTRLE e-learning framework

According to principles of constructivism (Vygotsky, 1978), learners learn best when they actively engage with the real world. The teacher's role is to create an enabling learning environment. In a traditional learning set-up, learners are receivers of knowledge while teachers are the only source of the knowledge. In a constructivist and technology-rich classroom, learning is learner-centred and the teacher facilitates the learning activities (Vinu, Sherimon & Krishnan, 2011). This understanding led to the formulation of a model for designing SCenTRLE by an American-based scholar, Hirumi (2002:497), who emphasised that "student-centred approaches to teaching and learning stress the importance of learners' past experiences, exploring individual needs and interests, promoting active participation, stimulate higher-order thinking, and developing life-long learning."

This study was informed by Hirumi's (2002) hybrid SCenTRLE e-learning framework. The study assimilated three levels because they were suitable for a school environment. The three levels are summarised in Table 1.

Table 1 Three levels of Hirumi's (2002) SCenTRLE e-learning framework

Level	Target	Notes
Lower level	Learner instruction	This level deals with instructions that the learner acquires from the instructor on what the section or aim of learning is about and what is expected of them.
Middle level	Learner↔Human interaction	The learner acquires knowledge from humans around them, for example, instructor and peers. Learners also gain information form non-human gadgets like computers and smartphones.
	Learner↔Non-human interaction	
Upper level	Learner self-interaction	The learner uses the instructions from the two levels above to self-educate, motivate and ascertain readiness to tackle complex tasks without any assistance from the environment around him.

The three levels of Hirumi's framework describe the learning process that learners go through in knowledge acquisition. The learners' first point of contact is the instructor (the teacher) who gives the learning objective. The learner makes sense of the instruction by interacting with other human sources, such as peers, discussing and comparing their varying understanding of the instruction as well as the information provided. The learners then engage with technological sources of information, i.e. the use of gadgets, for example, learner management systems and other prescribed online facilities. Once the learner has collected all the information from both sources, they begin to create their own knowledge based on what they have understood from both human and non-human interactions.

Teaching mathematics with technology

When ICT is integrated authentically into mathematics teaching, it becomes effective and helpful in delivering content (Joshi, 2017). The use of internet tools and audio-visual instruments embedded within ICT programs motivates learners towards learning; helping them to become independent. Researchers and programmers make it easier for learners to present their work through the development of graphing tools such as Geogebra, which assists learners to draw and interpret graphs within a short space of time (Joshi, 2017). Applications, like Geogebra, that are designed to work with other ICT tools, help learners to observe, represent and interact with mathematical concepts (Joshi, 2017). Chrysanthou (2008) opines that Geogebra in mathematics renders graphs and other shapes both pleasantly and practically. Hegedus, Laborde, Brady, Dalton, Siller, Tabach, Trgalova and Moreno-Armella (2017) describe Geogebra learners drawing Euclidean and Cartesian diagrams as some mathematical cyborgs who like to express themselves through tools.

Lessons in mathematics are 40 minutes on average, making it difficult for a teacher to attend to all learners in a particular lesson. The use of technology saves time by allowing the teacher more leeway. Pachler (2001) states that computers allow quick storing, displaying, analysing and synthesising so that learners have more time to think about what they have learnt.

Learning management systems (LMS) form one approach that characterises effective teaching with technology. The LMS concept developed directly from e-learning: web-based learning platforms offer classroom management for instructor-led training or a flipped classroom (Watson & Watson, 2012). The chief aim of LMS is to simplify instruction and teaching and maximising contact-time with learners as predicted by Coates, James and Baldwin (2005). This research project used Moodle, freely available Open Source software. Martin Dougaimas developed Moodle as a flexible LMS to conduct courses online or to support face-to-face teaching and learning. Moodle allows over 500 extended plug-ins for assignments, quizzes, grading, certification and collaborative learning. Coates et al. (2005) summarise the advantages of using LMS when teaching and learning. Moodle LMS facilitates flexible delivery of concepts where learners use learning resources uploaded by the teacher. LMS platforms support constructivist priorities through self-paced and active learning where learners work anytime, anywhere.

The LMSs vary according to their specifications but generally have the same setup with the following common features:

- Announcement area, e-mail, chat and instant messaging and discussion forums;
- Learning resources, learning object content and links to important internet sites like YouTube;
- Track activities, submission of assessments, multiple-choice testing, collaborative work and feedback
- Facilities for registering, enrolling learners and managing their activities. (Coates et al., 2005:23–24)

Methodology

This quantitative study incorporated an experimental design using a non-equivalent pre-test/post-test approach. The quantitative approach of this study guided the development of instruments used to collect data. We deployed pre-test and post-tests to explore and determine the effectiveness of the Moodle LMS for learners to master functions.

Sampling of Participants

Participants for this research were selected from a school (established in the late 1970s) located on the Cape Flats, Cape Town, South Africa, which formerly fell under the Department of Indian Affairs. Ninety-eight per cent of learners were Indian or Coloured, while 2% were black. For the research 221 Grade 10 learners were divided into six classes. The school was selected because it was one of the Dinaledi schools, which the WCED included as its Moodle focus pilot schools. The Dinaledi schools project is aimed at increasing access to mathematics and science at higher-level grades in underprivileged schools. The identified Dinaledi school receives a conditional grant to promote mathematics and physical science through improving teacher content knowledge as well as providing teaching and learning resources (Department of Basic Education, Republic of South Africa, 2015). Non-probability purposive sampling was conducted to select the participants: a statistical strategy is adopted when learners from a population under investigation do not have an equal chance of being selected (Jackson, 2015). The purposive sampling method was employed because participants were already part of a cluster and divided into classes. There was no need to separate the classes since that would have disturbed the entire Grade 10 setup. The six classes were considered uniform since these were created based on the subject-choice policy annually fixed by the school. This policy allows learners to be distributed to classes by subjects available in Grade 10.

Quasi Experimental Design

The quasi experimental design falls under quantitative research; employing a scientific approach by which a set of variables is kept constant, while the other set of variables is measured as the subject of the experiment (Bernard, 2000). Quasi-experimental design is referred to as causal-comparative, which seeks to establish a cause-effect relation between two or more variables (Creswell, 2003). We did not assign groups nor manipulate the independent variable. Control groups were identified and exposed to the variable. Results were compared with results from groups not exposed to the variable (Creswell, 2015). In this case, the design best suited the classroom set-up because we selected learners who populated the experimental and control groups as units; the groups were not split randomly. The protocol approximates an experimental design, which necessarily involves the application of an intervention in the experimental group and the following of events in the control group. An intervention involves any set of protocols or programmes closely observed for their effects. Two Grade 10 classes were selected randomly. The groups were considered non-equivalent since groups were randomised (Cohen, Manion & Morrison, 2007). Non-equivalent groups mean that the learning in class is not balanced equally among the control and experimental group and participants' experiences during the study differ. Some fit the experiment, while others did not. The two sampled classes had an equal chance of being selected for the traditional teaching model and the experimental e-learning teaching model. School authorities distributed the classes equally at the beginning of the year. Without privileging any characteristics, one class was chosen to be the experimental class and the other a control class. These two classes were then colour coded; one class of 36 learners named Blue (control) and the other of 39 learners named Green (experimental).

The differences in the extent of learning that would result in each of the study population groups depended on the effectiveness of the two teaching methods. The two groups were allocated identical assessments: marks were equally evaluated, deviations and differences were analysed and compared before the pre-test and after the intervention. The same process of analysis was repeated post-test. The mean differences were analysed using statistical analysis of the *t*-distribution and analysis of variance (ANOVA) in order to establish the impact of the intervention. The *t*-distribution was analysed with the software QuickCalcs (online) which was used to analyse the two classes that wrote the pre-test. The pre-test/post-test allows researchers to analyse the differences that can exist between the two groups. Additional data were extracted from the Moodle surveys, class participation and the login patterns in Moodle. All these data sources were used to reach conclusions in this research.

The Use of SCenTRLE Framework by the Experimental Group in Mathematics

We used the topic, functions, a grade 10 topic. The requirements and objectives of the topic according to the Curriculum and Assessment Policy Statement (CAPS) guidelines are:

- Work with relationships between variables in terms of numerical, graphical, verbal and symbolic representations of functions and convert flexibly between these representations (tables, graphs, words and formulae). Include linear and some quadratic polynomial functions, exponential functions, some rational functions and trigonometric functions.
- Generate as many graphs as necessary, initially by means of point-by-point plotting, supported by available technology, to make and test conjectures and hence generalise the effect of the parameter which results in a vertical shift and that which results in a vertical stretch and/or a reflection about the x axis.
- Problem solving and graph work involving the prescribed functions. (DoE, Republic of South Africa, 2003:12)

In the following section we discuss how functions was taught to the experimental group using the Moodle platform in relation to Hirumi's SCenTRLE framework. The control group was taught in the traditional way without the integration of technology.

Moodle Intervention Using SCenTRLE Framework

Learners were expected to draw and analyse functions such as a straight line, parabola, hyperbola, exponential, and trigonometrical functions. Previously, teachers presented these graphs on the blackboard while the learners looked on in curiosity. If they are required to practice drawing graphs, they draw inaccurate graphs, or take time to master the shapes of these functions. With the use of

MOODLE, the time it takes to plot and analyse graphs is reduced significantly.

Using the SCenTRLE framework, learning goals, objectives and outcomes were presented in the lower level of the intervention. We enrolled and created the login details of all learners from the experimental group into the MOODLE LMS for them to have sole access. This helped in preventing contamination of data from the control group as they were unable to access the LMS. Learners received instructions on how to use the Moodle LMS, access the Grade 10 topic, the work ethics involved and how to get help when needed. Teacher orientation to the Moodle system helps induct learners on how the system works and which functionality they are expected to use. Once learners had familiarised themselves with the Moodle application and understood what was expected, they were then exposed to next (middle) level.

In the middle level, we created content and learning activities for learners to go through by engaging with others and the Moodle learning resources. This exposed learners to human and non-human interaction. The teacher used discussion forums on Moodle to facilitate learner engagement.

In the final level, the teacher set up learning activities for the learners to individually explore and complete individual quiz assessments. At this level, each learner engages in self-study using Moodle resources and other online resources. The teacher created screen castings to create videos on functions. For example, the introductory screencast voiceover was for definitions of the term "functions" and other screencast videos on function tables, ordered pairs and graphing functions. The teacher also used YouTube videos to enhance concept comprehension. Each time a learner logged into Moodle, the program tracked the learner's activities and generated a report.

Data Collection Methods

A quantitative method was used to analyse the learners' written tests. The main data collection method was synthesized from quantitative methods: pre-tests, post-tests, and other data sets were extracted from within the LMS tools. Qualitative data collection was used: learners completed online surveys to express their opinions on the teaching and learning method and their experiences.

The tests were written in stages. At the initial stage (pre-test stage), learners were tested on prior knowledge to establish whether the two groups were similar. After the intervention had been administered in one class while the other class was taught in the traditional way, learners were again tested at the post-test stage. The results were compared using the test means to ascertain whether there was a significant difference between the result of the two groups. Communication with the facilitator was non-formal: learners were consulted when the teacher moved around in class, checking their progress. Learners also used instant messaging embedded within LMS interface.

Learners were evaluated on how they performed in

- Completion of tasks
- Interaction with peers

All the records were saved and were retrievable for analysis.

Data Analysis

Quantitative data were subjected to basic descriptive statistical analysis for identifying and comparing the pre-test and post-test means of class Blue and class Green. Moodle adoption in the sampled group resulted in improved learner academic performance. With Moodle, learners had access to individual and social interactions. The hypothesis for the study were as follows:

H_0: $\mu 1 = \mu 2$. A null hypothesis means that the adoption of Moodle has a significant relation to learners' conceptual understanding of functions and academic performance (a null hypothesis shows that the two means are equal).

H_1: $\mu 1 \neq \mu 2$. An alternate hypothesis means that the adoption of Moodle is not related to learners' conceptual understanding of functions and academic performance (the alternate hypothesis shows that the two means are not equal).

The distinction between H_0 and H_1 was based on examining the two mean values to determine whether the discrepancies were caused by the effect of the experiment or were because of sample variability (Peck, Olsen & Devore, 2012:836). The F-distribution statistic was used to analyse the variance of the two samples. Seventy-five learners were observed and tested for degrees of freedom; 73 were used to calculate the value that, if the F value was more than the critical value at 73 degrees of freedom, then it was to be statistically significant to reject the null hypothesis and conclude that the mean values were different. If the F value was less than the critical value, then there would be no significant difference between Moodle and traditional teaching (Wiersma & Jurs, 2005:387). Qualitative data were collected via LMS. The online survey was analysed using a Likert scale. The results were shown graphically and interpreted using a key that was available within the LMS. The results augmented quantitative data collected from class tests.

Ethical Considerations

Initial ethical clearance was sought from, and granted by, the Faculty Ethics Committee at the university where we are currently registered. Consent to conduct the study at the selected school was granted by the WCED. Permission to use school laboratories and other school equipment was granted by the principal of the school. The head of department (HOD) and the participating teachers signed consent forms. As the participants were all under the age of 18 years, we sought consent from the parents. Participants proffered all necessary information anonymously, since the results were to be used as feedback at the end of the research. The learners were informed how the research was to be conducted and how it would directly or indirectly affect them. The learners were notified that their marks and views were to be collected and used in research, without their real names being used. Timelines were submitted to the mathematics HOD and the research was integrated in the school term planning. Learners were protected in terms of data collection, consent, maintaining confidentiality and bias. To counter bias, we ensured that, even though different teaching methods were used, the content coverage was conducted equally with both classes. Although the researchers delivered the lessons in both classes, there was no wilful bias apportioned to one as opposed to the other. The only difference was the intervention with Moodle in the experimental group and traditional teaching with the control group.

Findings and Discussion

With this study was aimed at determining whether the application of Moodle in a constructivist pedagogical approach raised the conceptual understanding of functions in mathematics. Findings from the evaluation show that learners benefitted from adopting Moodle in learning functions in mathematics. The result demonstrates that Moodle could improve learners' conceptual understanding of functions in mathematics. Moodle functionality helped learners use videos, real-time chats, tasks and revision activities at the end of each section. Immediate feedback suggested that the learners actively constructed knowledge. The *t*-value result of 3.6744 was smaller to its critical value of 4.509. This revealed that the learners of the two sub-groups had similar prior knowledge of the domain of mathematical functions. After class Green had completed interactions with Moodle, they were given the post-test where they had a higher class mean than the control group, class Blue. We reject the H_0 of equal means to the post-tests.

Traditional Teaching Strategies

Normal face-to-face (F2F) lessons were conducted in both groups under study according to CAPS requirements of two lessons of 40 minutes each per week. Learners were apportioned tests to evaluate their understanding.

In the control group, class Blue, the teacher taught functions using traditional technologies – teacher-delivered lessons using the recommended *Classroom Mathematics Grade 10 Learner's Book* as the primary reference book, without applying digital technology. Interaction between peers within the group was noted during lesson delivery: learners assisted each other while they worked on complex function problems. The control class relied more on the presence of the teacher; making it difficult for "quiet or reserved" learners to ask for clarification. After class, there was limited access to peers or teachers due to a variety of learning activities. We observed that the learners faced challenges in completing their individual tasks due to increased transactional distance, unlike the experimental group, which used Moodle resources even after classes.

Moodle Mediated Teaching Strategies

In the experimental group, the SCenTRLE framework was employed. The lower level of the SCenTRLE framework refers to the initial setup of the ICT intervention. Data from the Moodle class were collected from Moodle LMS functionalities and applications embedded within the platform: Hot Potatoes, Screen-casting, Geogebra, Multiple Choice Quiz Maker and communication tools. Hot Potatoes allowed learners to do the exercise by completing blank spaces.

At the middle level of the SCenTRLE framework, learners where able to interact among themselves via Moodle forums as they sought for clarification. This interaction enabled the learners in the experimental group to interact as they explored. This process made it easier for them to use the LMS with minimum supervision. As a result, learners were independently using the system.

The Upper Level of the SCenTRLE framework is the highest level where learners engage in self-study using online resources (Hirumi, 2002). In this study the teacher produced and uploaded screencast on functions onto the Moodle platform. Screen-casting is a digital recording of a computer screen that enables the teacher to explain a process on the computer while recording it into a narrative video. The screencast video was then uploaded onto the Moodle platform for learners to access and study.

Figure 1 shows a screencast video introduction of functions, where the teacher linked the topic to learners' prior knowledge from their Grade 9 studies of the topic.

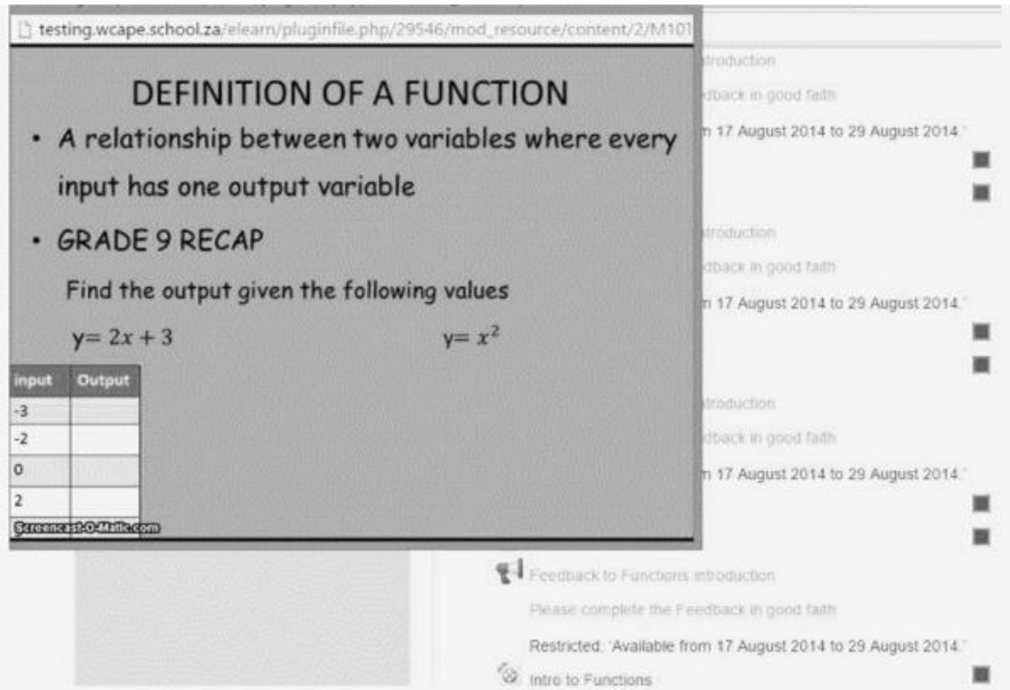

Figure 1 Example of a screencast uploaded onto Moodle

Learners in the experimental group used MOODLE to learn by watching, pausing and re-winding videos and were using collaboration forums to seek more clarification. The LMS had embedded quiz questions that automatically gave feedback so that learners were able to learn from their mistakes.

The screencasting tool enabled us to create content screencasts with voiceovers that afforded learners access to content at any time and place. We created graphs using function activity from the CAPS content, and we used Geogebra to demonstrate how to create a graph through a systematic screencasting. Using Screencast-O-Matic plugin, the class Green teacher added a three-minute video on how to plot graphs using functions. Learning occurred when learners processed information simultaneously through visual and auditory means. This intervention allowed repetitive actions and made screencasts particularly beneficial for concept mastery (Roblyer & Doering, 2014). The screencast provided a well-paced step-by-step demonstration of the procedure, backed by the teacher's friendly and familiar voice to enhance the learners' experience. The teacher also uploaded YouTube videos, i.e. Algebra Basics: What Are functions? - Math Antics (2016), that reinforced the comprehension of the function concept. This implies that the experimental group was exposed to a diverse variety of learning tools through Moodle.

At this level, the teacher also created individual assessments to test understanding of learnt concepts. The advantage of Hot Potatoes was that the results were immediately available to the learner. Learners who previously had to wait for their work to be manually marked by the teacher, could see the results immediately. Moodle-embedded functionalities enabled the teacher to move from text-driven chalk-and-talk demonstration to an activity-oriented teaching strategy that supported learner-centred learning principles. Learning also continued in the absence of the teacher, because learners were observed playing the videos after the lessons, emphasising self-directed learning (Lang, 2010).

Moodle has Geogebra embedded through interactive geometry software which allows the user to enter equations directly and draw accurate graphs and diagrams (Hohenwarter & Fuchs, 2005).

Figure 2 and Figure 3 show a Geogebra and free-hand drawn graphs respectively.

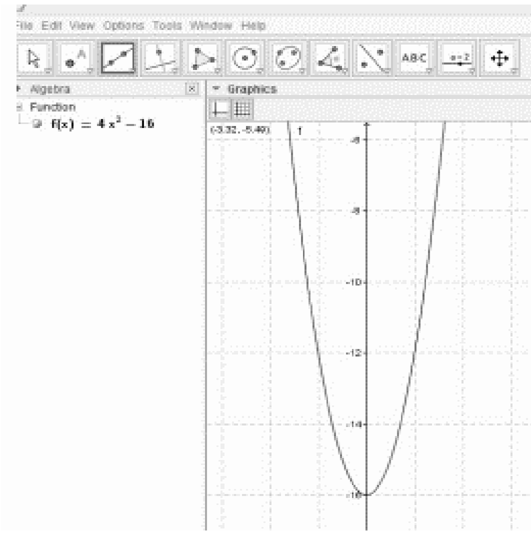

Figure 2 Geogebra graph

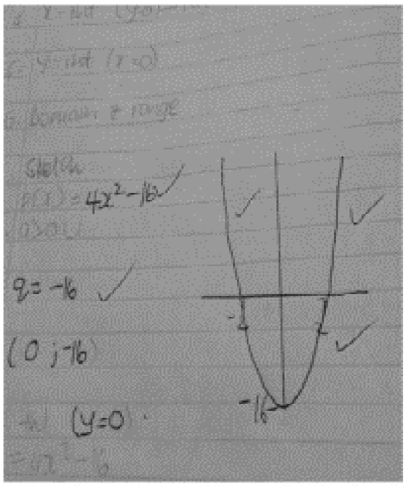

Figure 3 Free-hand drawn graph

We observed that learners (experimental group) who used the Geogebra application were able to comprehend functions graphs concepts in a shorter time than the learners who used free hand (control group). Although some researchers advocate for manual, hands-on processes in the learning of concepts, other researchers argue that the use of technology applications does not limit the learners' ability to master and comprehend concepts (Kotzer & Elran, 2012). The results of this study support that notion, since the experimental group performed better than the control group in their post-test. The time taken by learners to complete the task was markedly shorter compared to those doing free-hand drawn graph. More time was now channelled into application of the concepts of the topic than drawing.

Communication between peers and between learners and the instructor was important throughout the research. The SCenTRLE framework (Hirumi, 2002) outlines three levels of integration, which play a pivotal role in teaching and learning. Learners used Moodle, the instructor and peers to construct knowledge at an individual rate. The learners were able to communicate with the teacher when seeking clarification on concepts, and communicate with their peers, sharing information.

The Results of the Pre-Test

The same question paper was distributed to both groups for the pre-test where learners were expected to use prior knowledge about functions (in Grade 9 known separately as straight-line graphs and patterns). The pre-test was marked out of 30 and the pass mark was set at 50%. Fifteen of the 36 learners in class Blue passed the test, while 17 out of 39 learners in class Green passed the test. The results of the two groups were analysed using the *t*-distribution to compare group averages and to determine whether there was any significant difference between these two classes. The results are summarised in Table 2 below.

Table 2 Pre-test results

	Class Green (Experimental)	Class Blue (Control)
M	14.71795	13.94444
Pass	17	15
FAIL	22	21
Pass rate	43.58974	41.66667
Variance	27.89481	26.995855
SD	5.281553	5.195855

Table 2 shows the results from the QuickCalcs website which was used to analyse the results of the two classes that wrote the pre-test. For class Blue the mean was 13.944444, and for class Green the mean was 14.71795); the probability value (*p*-value) was greater than the significance level of 0.01 or 0.05. This difference led to a statement that the difference between the two means was not statistically significant to conclude that the means were different. Triola (2001:389) states that we therefore fail to reject the hypothesis. This is possibly because the two classes were drawn from a uniform population in Grade 9. Their content knowledge of functions at the beginning of this study was at the same level. This uniformity of these two classes made it possible for them to be used for this research.

Analysis of Pre-Test and Post-Test Assessments

Tests administered to learners in both classes were analysed using ANOVA. The first comparison compared the pre-test and the post-test to determine whether there was any difference in marks. The second comparison revealed the performance of the two classes against each other: the two pre-tests between the groups and the two post-tests between the two groups. The table below shows the results of ANOVA conducted for the tests.

Table 3 provides the analyses of the scores from the two tests; the pre-tests (before Moodle and before traditional) and the post-tests (after Moodle and after traditional). The conclusion reached from the analysis based on the *t*-statistic of the two tests after combining their variances, was that the means of the tests were indeed different. The result of the analysis of the two post-tests are presented in Table 4.

Table 3 Pre- and post-test analysis

ANOVA: Single factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Before traditional	36	502	13.94444	27.76825		
After traditional	36	600	15.38462	28.40081		
Before Moodle	39	574	14.71795	28.62888		
After Moodle	39	719	19.97222	30.02778		
ANOVA						
Source of variation	*SS*	*df*	*MS*	*t*	*p*-value	CI 5%
Between groups	1077.443	73	215.4885	3.6744	0.0004518	(4.509, 4.6662)
Within groups	6192.397	219	28.27579			
Total	7269.84	224				

Table 4 Post-test analysis

After Green	36	19.9722	5.4798
After Blue	39	15.3846	5.3292
t	*df*	*p*-value	CI, 5%
3.6744	73	0.0004518	[4.509, 4.6662]

The conclusion of the analysis of variance was based on the following (Triola, 2001:618):

If p-value ≤ 0,05 then reject the null hypothesis of equal means.

If p- value > 0,05 then fail to reject the null hypothesis of equal means.

Table 4 shows the post-test analysis between the two groups' assessment, which suggests that the *p*-value (0, 0004518) is less than 0,05 and *t*-statistic (3.6744) is lower than the confidence interval (3.9720). The analysis suggests that we reject the null hypothesis of equal means. We concluded that since the two means were different, the use of Moodle to teach functions showed its potential for improving learners' understanding of the function concept. The pre-test and post-test results revealed a marked difference. There was a difference compared to the group that used the traditional ways of teaching, which infers that the Moodle LMS tools could have played a major role in these results. The learners who frequently used Moodle displayed better results. The findings in the study singled out the affordances of Moodle's variety of learning strategies that were pivotal in the research and which made it possible for learners to achieve better scores than those taught through the traditional method.

Increased Interactions Using Messenger

Learners were able to interact independently with the LMS and the majority was able to use the tool easily. We observed learners communicating with peers and teachers. As learners understood the concept differently, it took some longer to understand than others. Learners were not pressured to move to the next concept; they had full control of how much they were willing and able to study at any one time. Figure 4 below indicates the frequency at which learners used Moodle messenger.

Figure 4 Learner messaging during the first two weeks

Figure 4 shows the first two weeks of the messenger intervention. Class Green used Moodle messenger to seek clarification for conceptual understanding of functions from the teacher and peers. The first week showed high messaging rates; possibly, because learners had initial challenges using Moodle LMS, or perhaps they had more questions to ask regarding the concept of functions. It was significant that the most interaction took place on a Sunday. Learners used the chat tool mostly on content related issues, although occasionally they used it for social communication. This tool was useful for learners with communication barriers in normal lessons. They presented their problems via the chats, ensuring that the learning process did not break down. The chat platform was important since there was no need to wait for the next lesson to understand a concept or to give other learners hints. Figure 5 below shows an extract of a chat section between a learner and the teacher. Studies of online messengers' synchronous interaction indicate that it empirically reduces transactional distance (Benson & Samarawickrema, 2009; Burgess, 2006; Moore, 1993). This reduction implies that the increased interaction can help learners learn concepts better, i.e. more thoroughly, quickly and in a sustained manner.

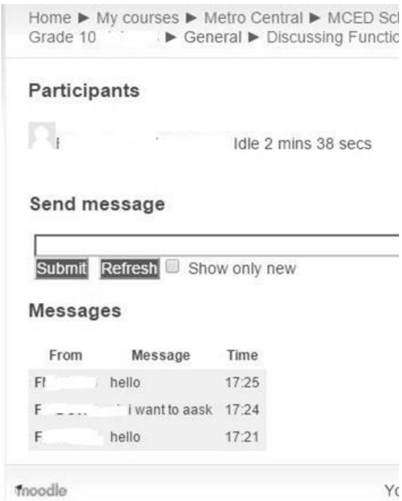

Figure 5 Chat session between a learner and educator

Virtual interactions have been researched and studies have shown that younger generations are increasingly using mobile-mediated social networks to share and communicate virtually and quickly with each other (Anderson & Elloumi, 2004; Prensky, 2005). In a social environment, learners share virtually anything that is of interest to them and their peers (Lambropoulos, Faulkner & Culwin, 2012; Rambe & Bere, 2013; Yang, Crook & O'Malley, 2014). The learner was able to win the teacher's attention within the space of three minutes, unlike a traditional setup in which a learner may have to wait for the next day to ask a question.

Anytime and Anywhere, Access to Learning Resources

Moodle affords anytime and anywhere access to learning resources and interaction with peers and teachers. Class Green had a normal F2F timetabled session with their teacher using Moodle learning resources, and using Moodle's virtual functionalities after class, which reinforced conceptual understanding of functions. Although class Blue had similar F2F class sessions with their teacher who employed traditional teacher-centred strategies, learners were required to complete written homework activities. Researchers have shown that improved access to online learning resources offers opportunities to create activities that enhance learning (Ally & Tsinakos, 2014; Ngaleka & Uys, 2013; Ng'ambi & Campbell, 2012). Ally and Tsinakos (2014) observed that the ubiquity of online learning is growing, increasing learning opportunities for learners in improvised situations in developing nations.

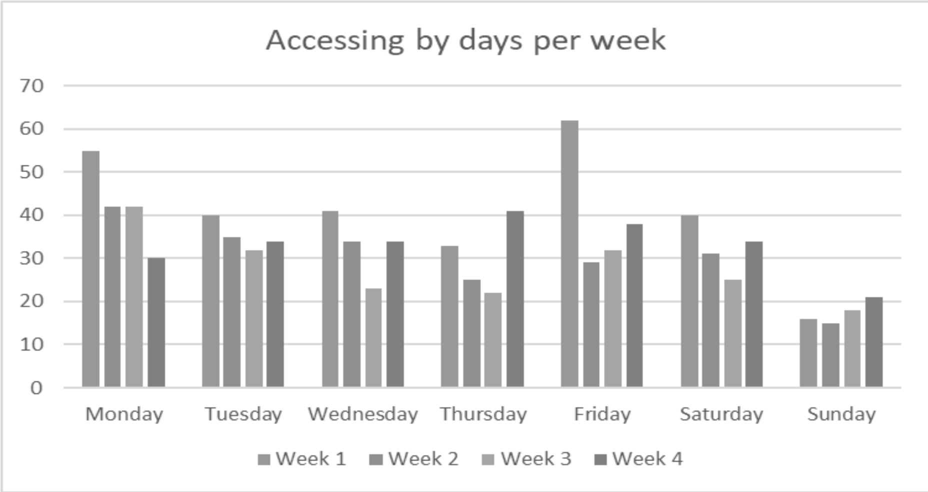

Figure 6 Learners accessing Moodle during the study

Figure 6 above shows learners' frequency of accessing the Moodle platform during the course of this study. The graph reveals that during the first week, learners actively logged onto Moodle; with Monday and Friday presenting the highest mean during the study. During the study an average access frequency of 33 engagements per day was recorded. Comparing this statistic with the control group, class Blue had limited F2F exposure as they had no further interaction outside of the classroom. Although the access frequency declined in week three, learner access increased during the final week. This could imply that learners were collaborating in preparation of the assessment, therefore were revising for the test.

Flexible Content and Constructivist Pedagogy Supporting Modules

Moodle offers teachers the opportunity to create flexible content and collaborative activities that learners can access anytime and anywhere. Moodle provides teachers with a variety of content modules: topics creation, assignments, dialogue module, chat, journals, resources, quizzes and workshops (Bates, 2015). Moodle LMS makes it easy to identify challenging areas of the different sections of activities. This information was used to prepare remedial work: emphasising unclear concepts.

Towards the end of the research, learners conducted an online survey and logged on during free time to answer questions. As soon as the participants finished the online survey, Moodle published the results of the participants' views. Overall results of the online survey displayed enthusiasm: learners were able to score the LMS above the "sometimes" to "often" levels. The online survey shows that there was active learning within the experimental group of learners. This stresses the importance of evaluating the significance and effectiveness of the process from lower to upper levels.

Benefits of Using Moodle

Moodle LMS measures learning in various ways. The facilitator traces how learners complete exercises and quizzes as well as challenging areas within these tasks. The rate at which learners completed tasks improved because learners had instant access to assistance and their results.

During lessons, learners used videos and other resources independently. They could use chat forums to consult their peers whom they felt comfortable with, then engaged with the facilitator whenever possible via the chat messages – even outside lesson time. Learners independently constructed knowledge; becoming the controllers of their own learning. Learners gained exposure to the content at different times and levels, and the facilitator was able to support those who were struggling.

Class Blue (control) used more costly handouts. Using the LMS became an advantage: the resources were online and available as Portable Document Format (PDF) files, eliminating the need for printing. The use of paperless teaching ensured that learners used these tools wherever they had access to the internet. Moodle allowed learners to be active authors within the environment, providing a platform to share ideas via individual and collaborative efforts (Ke & Hoadley, 2009, in Aranda, 2011:26).

Interaction with peers – the use of communication forums made it easier for learners to consult with each other without any barriers before engaging with the facilitator. Learners who understood concepts were seen sharing information during lesson time and discussion forums. They formed a community of practice (Chigona, 2013).

Testing of content – We noted that the quiz scores had improved as the lesson progressed. The results of the post-tests showed improvement in the conceptual understanding of functions compared to those of learners instructed in the traditional method. This distinction occurred because learners were using the LMS to re-teach themselves through videos and other tools freely available whenever they needed to learn.

Conclusion and Recommendation

In this paper we investigated whether the introduction of Moodle within a constructivist pedagogical approach improved conceptual understanding of mathematical functions. We used an experimental research strategy, which explored the effect of using Moodle-mediated learning of functions in mathematics in comparison to traditional means. This quantitative study included data collection by means of pre-testing and post-testing of the experimental and control groups.

The study illustrates that the use of the SCenTRLE framework afforded the successful implementation of the Moodle application (Jaradat, 2013). We posit that the integration of Moodle LMS into learning functions in mathematics supported learners to take responsibility for their own learning, therefore, improved their test scores after using Moodle-mediated learning activities.

We recommend that mathematics teachers integrate Moodle LMS into their CAPS curriculum delivery so that learners may benefit from the online resources.

We further suggest that WCED adopts the SCenTRLE framework in their in-service teacher training as it is easy and flexible in designing and sequencing e-learning integration into teaching and learning.

Future studies could explore using the SCenTRLE framework in other school subjects.

Acknowledgement

This article is an extraction from a master's thesis and a revised version of the paper submitted and presented at E-Learn: World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education in 2018. We thank the National Research Foundation for the financial support to produce this paper.

Notes

i. Published under a Creative Commons Attribution Licence.
ii. DATES: Received: 9 November 2017; Revised: 8 November 2019; Accepted: 11 December 2019; Published: 31 August 2020.

Authors' Contributions

Nicholas Mlotshwa conceptualised the research, collected data and participated in the data analysis and the writing of the article; Nyarai Tunjera participated in the literature review and the writing of the article and Agnes Chigona conceptualised the research, participated in the data analysis and the writing of the article. All authors reviewed the final version of the article.

References

Algebra basics: What are functions? - Math antics 2016. Video. 28 November. Available at https://www.youtube.com/watch?v=52tpYl2tTqk. Viewed 8 July 2020.

Ally M & Tsinakos A (eds.) 2014. *Increasing access through mobile learning*. Vancouver, Canada: Commonwealth of Learning. Available at http://dspace.col.org/bitstream/handle/11599/558/pub_Mobile%20Learning_web.pdf?sequence=4&isAllowed=y. Accessed 29 June 2020.

Anderson T & Elloumi F (eds.) 2004. *Theory and practice of online learning*. Athabasca, Canada: Athabasca University. Available at http://www.iadl.org.uk/res/forms/tpol_book.pdf. Accessed 29 June 2020.

Aranda AD 2011. Moodle for distance education. *Distance Learning*, 8(2):25–28.

Bates AW 2015. *Teaching in a digital age: Guidelines for designing teaching and learning for a digital age*. Vancouver, Canada: Tony Bates Associates Ltd.

Benson R & Samarawickrema G 2009. Addressing the context of e-learning: Using transactional distance theory to inform design. *Distance Education*, 30(1):5–21. https://doi.org/10.1080/01587910902845972

Bernard HR 2000. *Social research methods: Qualitative and quantitative approaches*. London, England: Sage.

Burgess JV 2006. Transactional distance theory and student satisfaction with web-based distance learning courses. PhD dissertation. Pensacola, FL: University of West Florida. Available at http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.537.1244&rep=rep1&type=pdf. Accessed 29 June 2020.

Chigona A 2013. Using multimedia technology to build a community of practice: Pre-service teachers' and digital storytelling in South Africa. *International Journal of Education and Development using ICT*, 9(3):17–27.

Chigona A 2017. Western Cape subject advisors' perception of their preparedness for connected classrooms. *Electronic Journal of e-Learning*, 15(5):444–454. Available at https://files.eric.ed.gov/fulltext/EJ1157980.pdf. Accessed 27 June 2020.

Chigona A 2018. Digital fluency: Necessary competence for teaching and learning in connected classrooms [Special issue]. *The African Journal of Information Systems*, 10(4):366–379. Available at https://digitalcommons.kennesaw.edu/cgi/viewcontent.cgi?article=1609&context=ajis. Accessed 27 June 2020.

Chrysanthou I 2008. The use of ICT in primary mathematics in Cyprus : The case of GeoGebra. MPhil thesis. Cambridge, England: University of Cambridge. Available at https://docplayer.net/4137488-The-use-of-ict-in-primary-mathematics-in-cyprus-the-case-of-geogebra.html. Accessed 30 June 2020.

Coates H, James R & Baldwin G 2005. A critical examination of the effects of learning management systems on university teaching and learning. *Tertiary Education and Management*, 11:19–36. https://doi.org/10.1007/s11233-004-3567-9.

Cohen L, Manion L & Morrison K 2007. *Research methods in education* (6th ed). New York, NY: Routledge.

Creswell JW 2003. *Research design: Qualitative, quantitative, and mixed methods approaches* (2nd ed). Thousand Oaks, CA: Sage.

Creswell JW 2015. *A concise introduction to mixed methods research*. Thousand Oaks, CA: Sage.

Department of Basic Education, Republic of South Africa 2015. *National Senior Certificate examination 2014: Diagnostic report*. Pretoria: Author. Available at http://www.education.gov.za/Portals/0/Documents/Reports/2014 NSC Diagnostic report.pdf?ver=2015-02-09-160830-153. Accessed 10 July 2020.

Department of Education, Republic of South Africa 2003. *National Curriculum Statements Grades 10-12 (General): Mathematics*. Pretoria: Author. Available at https://www.schoolnet.org.za/teach10/resources/eo/resources/curriculum/fet/Maths.pdf. Accessed 10 July 2020.

Department of Education, Republic of South Africa 2004. White Paper on e-Education: Correction notice. *Government Gazette*, 470(26734), August 26.

Frankl G & Bitter S 2012. Student perspectives on e-learning in a blended learning context. In M Gascó (ed). *Proceedings of the 12th European Conference on e-Government* (Vol. 2). Reading, England: Academic Publishing International Limited.

Govender R & Junqueira K (eds.) 2018. *Proceedings of the 24th Annual National Congress of the Association for Mathematics Education of South Africa* (Vol. 1). Johannesburg, South Africa: Association for Mathematics Education of South Africa (AMESA). Available at http://www.amesa.org.za/AMESA2018/Volume1.pdf. Accessed 21 April 2019.

Hegedus S, Laborde C, Brady C, Dalton S, Siller HS, Tabach M, Trgalova J & Moreno-Armella L 2017. *Uses of technology in upper secondary Mathematics education*. Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-319-42611-2

Hirumi A 2002. Student-centered, technology-rich learning environments (SCenTRLE): Operationalizing constructivist approaches to teaching and learning. *Journal of Technology and Teacher Education*, 10(4):497–537.

Hohenwarter M & Fuchs K 2005. Combination of dynamic geometry , algebra and calculus in the software system GeoGebra. In *Computer algebra systems and dynamic geometry systems in mathematics teaching*. Pecs, Hungary.

Howie SJ & Blignaut AS 2009. South Africa's readiness to integrate ICT into mathematics and science pedagogy in secondary schools. *Education and Information Technologies*, 14:345. https://doi.org/10.1007/s10639-009-9105-0

Jackson SL 2015. *Research methods: A modular approach* (3rd ed). Stamford, CT: Cengage Learning.

Jaradat M 2013. Students' motivation and instructors' technology use in higher education: A case study in the Gulf region. *Journal of Education and Practice*, 4(19):127–138. Available at https://www.iiste.org/Journals/index.php/JEP/article/view/7871/7928. Accessed 26 June 2020.

Joshi DR 2017. Influence of ICT in mathematics teaching. *International Journal for Innnovative Research in Multidisciplinary Field*, 3(1):7–11. Available at https://d1wqtxts1xzle7.cloudfront.net/53730643/201701003.pdf?1498991023=&response-content-disposition=inline%3B+filename%3DInfluence_of_ICT_in_Mathematics_Teaching.pdf&Expires=1593027103&Signature=SMGRkiiXX-RfBzewPTI4ygwRCE~zrqjPXc71Za5hkgvmPGdcs1iGGPFheIuNwc2i~fmUrhnzuIx4ihzDfn5RJxpmqdyJyetHFuahe2IXOjHTn2aNMdNd6P-WPCOdCc0q-2eBBn8cViVHsftjSd6L1SewnjfE7q4b9e4Z-dZLbtWYbGOFZmrbCg5n0eRzw5t31oH7lznmE96WwUZI3bQbY~Am6QRRJaBPFK-8DAX8597MBk3oG-jvQVDj2RDbBkpewWKrx7SsW4fR6Ar-0qAWr3iC-TefBjzW7jU2rBDCoxRexEfLvGtFHW2SqqNZ2smWWUgHrxAsZwDqusz0DtdvBA__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA. Accessed 24 June 2020.

Kotzer S & Elran Y 2012. Learning and teaching with Moodle-based E-learning environments, combining learning skills and content in the fields of Math and Science & Technology. In *1st Moodle Research Conference, 14-15 September, 2012*. Heraklion, Greece. Available at https://research.moodle.org/55/1/16%20-%20Kotzer%20-%20Learning%20and%20teaching%20with%20Moodle-based%20E-learning.pdf. Accessed 2 July 2020.

Lambropoulos N, Faulkner X & Culwin F 2012. Supporting social awareness in collaborative e-learning. *British Journal of Educational Technology*, 43(2):295–306. https://doi.org/10.1111/j.1467-8535.2011.01184.x

Lang QC 2010. Analysing high school students' participation and interaction in an asynchronous online project-based learning environment. *Australasian Journal of Educational Technology*, 26(3):327–340. https://doi.org/10.14742/ajet.1078

Leendertz V, Blignaut AS, Nieuwoudt HD, Els CJ & Ellis SM 2013. Technological pedagogical content knowledge in South African mathematics classrooms: A secondary analysis of SITES 2006 data. *Pythagoras*, 34(2):Art. #232, 9 pages. https://doi.org/10.4102/pythagoras.v34i2.232

Mbagwu FC, Ozioko RE & Ogueri E 2017. The extent of information and communication technology (ICT) infrastructure application in library and information science education in Nigeria. *International Journal of Library and Information Science*, 9(5):44–53. https://doi.org/10.5897/ijlis2017.0782

Moore MG 1993. Theory of transactional distance. In D Keegan (ed). *Theoretical principles of distance education*. London, England: Routledge.

National Council of Teachers of Mathematics 2016. *Computer science and mathematics education: A position of the National Council of Teachers of Mathematics*. Available at http://www.nctm.org/uploadedFiles/Standards_and_Positions/Position_Statements/Computer%20science%20and%20math%20ed%20022416.pdf. Accessed 21 June 2020.

Ngaleka A & Uys W 2013. M-learning with WhatsApp: A conversation analysis. In E Ivala (ed). *Proceedings of the 8th International Conference on e-Learning*. Reading, England: Academic Conferences and Publishing International Limited. Available at https://www.researchgate.net/profile/Charity_Ndeya-Ndereya/publication/288051189_Academic_staff's_challenges_in_adopting_blended_learning_Reality_at_a_developing_university/links/5d763cb6299bf1cb80935ec4/Academic-staffs-challenges-in-adopting-blended-learning-Reality-at-a-developing-university.pdf#page=302. Accessed 4 July 2020.

Ng'ambi D & Campbell A 2012. Influence of mobile learning discourse on human agency : A critical discourse analysis perspective. In P Lam (ed). *Proceedings of the 7th International Conference on e-Learning*. Reading, England: Academic Publishing International Limited.

Pachler N 2001. Connecting schools and pupils: To what end? Issues related to the use of ICT in school-based learning. In M Leask (ed). *Issues in teaching using ICT*. London, England: Routledge.

Padayachee P, Boshoff H, Olivier W & Harding A 2011. A blended learning Grade 12 intervention using DVD technology to enhance the teaching and learning of mathematics. *Pythagoras*, 32(1):1–8.

Peck R, Olsen C & Devore J 2012. *Introduction to statistics and data analysis* (4th ed). Boston, MA: Brooks/Cole, Cengage Learning.

Powell KC & Kalina CJ 2009. Cognitive and social constructivism: Developing tools for an effective classroom. *Education*, 130(2):241–251. Available at https://docdrop.org/static/drop-pdf/Powell-and-Kalina-U6g4p.pdf. Accessed 24 June 2020.

Prensky M 2005. What can you learn from a cell phone ? Almost anything ! *Innovate: Journal of Online Education*, 1(5).

Rambe P & Bere A 2013. Using mobile instant messaging to leverage learner participation and transform pedagogy at a South African University of Technology [Special issue]. *British Journal of Educational Technology*, 44(4):544–561. https://doi.org/10.1111/bjet.12057

Roblyer MD & Doering AH 2014. *Integrating educational technology into teaching* (6th ed). Harlow, England: Pearson.

Siegler RS & Ellis S 1996. Piaget on childhood. *Psychological Science*, 7(4):211–215. https://doi.org/10.1111/j.1467-9280.1996.tb00361.x

Sultan WH, Woods PC & Koo AC 2011. A constructivist approach for digital learning : Malaysian schools case study. *Educational Technology & Society*, 14(4):149–163. Available at https://www.jstor.org/stable/pdf/jeductechsoci.14.4.149.pdf?casa_token=hM8wj0nG8yQAAAAA:fkZFxgykRW4fbKg9d8OtqL_FXKJwx5WVEaMWjm1h1ceNKqj_3kD2qDcZQ6FTefIZhXUYEOHrBpMto3nsY_c8eCL9XRVjnnl9Wquse64pBd0kl9hE1j7Bdw. Accessed 16 June 2020.

Triola MF 2001. *Elementary statistics* (8th ed). New York, NY: Addison Wesley Longman.

Vinu PV, Sherimon PC & Krishnan R 2011. Towards pervasive mobile learning – the vision of 21st century. *Procedia - Social and Behavioral Sciences*, 15:3067–3073. https://doi.org/10.1016/j.sbspro.2011.04.247

Vygotsky L 1978. *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Watson WR & Watson SL 2012. An argument for clarity : What are learning management systems , what are they not, and what should they become ? *TechTrends*, 51(2):28–34. Available at http://cardinalscholar.bsu.edu/bitstream/handle/123456789/194513/Watson_Argument_Clarity_Techtrends_2007.pdf?sequence=1&isAllowed=y. Accessed 16 June 2020.

Western Cape Education Department 2018. *Annual perfomance plan (Version 1): 2018/2019 - 2020/2021*. Cape Town, South Africa: Author. Available at https://wcedonline.westerncape.gov.za/documents/annual-perfplan18/ld.html#APP2018-English.pdf*e_inf.html. Accessed 10 July 2020.

Wiersma W & Jurs SG 2005. *Research methods in education: An introduction* (8th ed). Boston, MA: Pearson.

World Economic Forum 2016. *The future of jobs: Employment, skills and workforce strategy for the fourth industrial revolution* (Global Challenge Insight Report). Geneva, Switzerland: Author. Available at http://www.hsrc.ac.za/uploads/pageContent/9352/WEF_Future_of_Jobs%20(002).pdf. Accessed 15 June 2020.

Yang Y, Crook C & O'Malley C 2014. Can a social networking site support afterschool group learning of Mandarin? *Learning, Media and Technology*, 39(3):267–282. https://doi.org/10.1080/17439884.2013.839564

Yeh CYC, Cheng HNH, Chen ZH, Liao CCY & Chan TW 2019. Enhancing achievement and interest in mathematics learning through Math-Island. *Research and Practice in Technology Enhanced Learning*, 14:5 https://doi.org/10.1186/s41039-019-0100-9