
Impact of clicker technology in a mathematics course

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Abstract: This article reports on the implementation of clickers to improve the success rate of first-year mathematics students. There were 105 students registered in this course, in a university of technology in South Africa. In order to do this, an orientation test in the form of a paper-based assessment was first conducted to determine what students already knew. About 21.9% of the students did not take the test and 20% did not pass it. These results raised concern. Thereafter students were taught. After four weeks they were evaluated on their understanding of the concept taught in class. Results did not improve much, as 48.6% of the students did not pass the test. Therefore, a technology-engagement teaching strategy (TETS) using clicker technology was developed and implemented in order to improve the pass rate. Weekly continuous assessments or diagnostic tests were conducted in order to establish the changes in students' academic performance. A survey questionnaire was administered after the teaching and learning of incorporating clickers. This questionnaire also examined students' perspective on the usefulness of clickers in teaching and learning. The results showed that the effective implementation of clickers with the integration of a TETS improved students' success rate.

Keywords: Clickers; Technology-engagement teaching strategy; Academic performance

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1. Introduction

The use of clicker technology to promote interaction, engagement, involvement and changes among students' academic performance has been observed (Duncan, 2007; Simelane & Dimpe, 2011; Simelane, Mji, & Mwembakana, 2011). A clicker is a handheld, wireless or mobile device used to respond to questions (Educause Learning Initiative, 2005; Caldwell, 2005; Crossgrove & Curran, 2008; O'Donoghue & O'Steen, 2007). Bruff (2007) defines a clicker as an instructional technology that allows the lecturer to collect and analyse student responses to questions during class quickly. Clickers use radio frequency or infrared technology to record audience responses to questions. The abovementioned authors use different terminology to refer to clickers, such as a *wireless student response system*, a *personal response system*, an *audience response system* and a *classroom communication system*. In this article, the term clicker means educational technology, a wireless mobile device that allows the lecturers to rapidly gather and analyse student responses to questions during class. The clicker product used in this study is TurningPoint from Turning Technology (Simelane & Dimpe, 2011; Simelane, Mji, & Mwembakana, 2011).

Clickers have the potential to keep students motivated and engaged in classroom activities and increase a willingness to learn by discovering their own mistakes. Self-directed learning is encouraged by the use of clickers. The benefits of clickers are their ability to provide immediate feedback and to measure student understanding (Carnevale, 2005; Duncan, 2005). However, there are problems encountered in using clicker technology due to lack of student participation and interaction, lack of immediate student feedback on learning throughout the lesson, insufficient time for regular formative assessments and low pass rate. In order to really understand the potential of clickers, lecturers should rethink their whole teaching strategy and classroom activities (Beatty, 2004). This study was inspired by the study conducted by Simelane and Dimpe (2011) who wanted to see if the clicker technology would still work. It was conducted with mathematics students and it is a different group from the previous one.

The purpose of this study was to investigate whether technology-engagement teaching strategy with the incorporation of clicker technology could promote students' engagement, interaction and improved success rate in a mathematics course. Technology-engagement teaching strategy (TETS) is a rich and flexible teaching strategy that was developed with the integration of clicker technology in the teaching and learning process, to assist students to improve higher-order learning and active learning. TETS also assists lecturers to collect information about student understanding of the course concepts quickly and immediately. It is pointed out by Henke (2001) that when using technology in a classroom, the focus should be on teaching and learning rather than on technology. TETS was developed based on the analysis of the results from the orientation test and mathematics test 1. Clicker continuous assessments or diagnostics tests were conducted at the end of a lecture. Continuous assessment helps the lecturer to check learning in order to decide what to do next. Formative assessment was used during the lecture to measure the following: how well the students had understood the concepts, whether they were able to link the concept or idea to the previous one and whether they could apply these concepts (Simelane, Mji, & Mwembakana, 2011). In order to implement technology effectively, there should be a connection between technology and teaching strategies (McCoog, 2008). McCoog (2008) advises lecturers to select technology with effective ways of integration into teaching and learning.

This article reports on the implementation of clickers to promote engagement and interaction and to improve the success rate of first-year mathematics students. In order to do this, an orientation test in the form of a paper-based assessment was first conducted to determine what students already knew. An orientation test in a form of a paper-based assessment was first conducted to determine what students already knew. Moderate performing students did not make it, and the results roused concern. Thereafter students were taught by making use of the traditional method. In four weeks' time, students were re-evaluated on their understanding of the concepts taught in class. Results also did not prove that the teaching had been successful. Therefore, a TETS using clicker technology was developed and implemented in order to promote engagement and interaction and to improve the pass rate. Weekly continuous assessments or diagnostics tests were conducted in order to establish the changes in students' academic performance. This article will also report on the teaching and learning using the TETS with clicker technology. Students' perspectives on the usefulness of the clickers in teaching and learning will also be discussed.

2. Related work

2.1. Teaching model

Felder and Brent (2005) argue that there are several types of teaching strategies. Lecturers select a teaching strategy depending on the information or skill they are attempting to convey to students. Student success in the classroom is based on effective teaching strategies. Teaching students how to learn, what to learn, how to remember things and how to motivate themselves is what good teaching is all about (Henke, 2001; Saskatchewan Education, 1985; Weinstein & Mayer, 1983). Hence, in development and implementation of TETS in the instructional design, more attention was given to student success. We needed to motivate the students to use the tool in order to assist themselves where they were lacking with the subject matter. TETS, with the integration of clicker technology, made students aware of the mistakes they make when solving problems. They were therefore able to identify their mistakes and fix the problem immediately.

2.2. Technology-enhanced teaching model

Technological, Pedagogical and Content Knowledge (TPACK) is a technology-enhanced teaching model developed by Mishra and Koehler (2006). The TPACK was developed for lecturers, teachers and instructors to understand or acquire a certain type of knowledge in order to incorporate technology into their teaching of a specific content area (Koehler & Mishra, 2008; Koehler, Mishra, & Yayha, 2007; Mishra & Koehler, 2006). It is reported that this model clearly indicates that pedagogical applications of technology are intensely influenced by the content areas within which they are situated (Burgoyne, Graham, & Sudweeks, 2010). TETS was further developed making use of some principles of TPACK. The emphasis on TETS is on teaching and learning rather than on technology. The TPACK model describes the intricate interaction between a lecturer's knowledge of content (CK), pedagogy (PK) and technology (TK). This interaction results in four additional knowledges: pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical and content knowledge (TPACK) (Koehler & Mishra, 2008; Mishra & Koehler, 2006). Acquiring TPACK is not possible only by direct observation in the classroom. Observed instructional actions and interactions need to be

identified in decision-making processes so that the knowledge that supports such actions and interactions can be differentiated to determine the nature and extent of the TPACK teachers' planning, instructional actions, interactions with students, and reflections upon those actions and interactions, should *all* be examined (Harris, Grandgenett, & Hofer, 2010).

Crossgrove and Curran (2008) define just-in-time-teaching as a teaching strategy that incorporates the use of the internet to offer students a warm-up assignment or online teaching. Simkins, Novak, Clerici-Arias, and Goodman (n.d.) state that improving student learning through the use of short web-based questions or just-in-time teaching (JiTT) exercises delivered before a class meeting is the focus of JiTT (Mazur, 1997). The lecturer reviews students' responses to JiTT exercises a few hours before class and uses students' feedback to develop classroom activities focusing on learning gaps shown in the JiTT. Simkins et al. (n.d.) argue that JiTT enables lecturers to collect information about student understanding of the course concepts speedily and immediately before a class meeting, making it possible to modify activities to meet students' authentic learning needs. Furthermore, Simkins et al. (n.d.) state that JiTT enhances in-class teaching usefulness and effectiveness and improves student learning (Crossgrove & Curran, 2008).

2.3. Clicker-technology teaching model

Simelane and Dimpe (2011) point out that the integration of clickers into teaching and learning needs a teaching strategy. Lasry, Mazur, and Watkins (2008) state that teaching strategies are approaches used by lecturers to create a conducive learning environment and to specify the nature of the activity within which the lecturer and student will be engaged during the lesson. Two teaching strategies involving clickers were identified in this study. These strategies are the question cycle (Beatty, 2004; Beatty & Gerace, 2009) and the 'concept test' or 'peer instruction model' (Mazur, 1997).

To develop student interaction during lectures and to focus students' attention on main concepts are the basic aim of peer instruction (Mazur, 2009). Mazur explains peer instruction in the following manner: A lecture consists of a number of short presentations on key points, each followed by a Concept Test. A Concept Test consists of short conceptual questions on the subject being discussed (Mazur, 1997; Mazur, 2009). The students are first given time to formulate answers and then they are asked to discuss their answers with peers. According to Mazur (2009) this process forces students to think about the arguments being developed and it provides them (as well as the lecturer) with a way to assess their understanding. Each Concept Test has the following general format:

- (1) question posed = 1 minute;
- (2) students given time to think = 1 minute;
- (3) students record individual answers (optional);
- (4) students convince their neighbours = 1–2 minutes;
- (5) students record revised answers (optional);
- (6) feedback to teacher. Tally to answers;
- (7) explanation of correct answers = + 2 minutes (Mazur, 1997).

If students choose the correct answer, then the lecturer proceeds to the next topic. If the percentage is too low (less than 90%) he or she slows down and lectures in more

detail the same subject and reassesses it with another Concept Test. Caldwell (2005) argues that peer instruction is one of the teaching strategies that benefit clickers.

2.4. Clickers in teaching and learning

A study was conducted by Barragués, Morais, and Guisasola (2011) at the Polytechnic College of Sebastián University, Spain with 80–90 first-year engineering students using clicker technology. In this regard, clickers were incorporated with problem-based learning methodology. In this study, it was concluded that problem-based learning (PBL) methodology has been implemented regarding students working with created conceptual tests. The use of clickers in a PBL methodology played a vital role as it has been utilised to make students' ideas visible alongside their misconceptions. At the University of Wisconsin in Whitewater the results also showed that exam questions covering material taught with clickers as well as student performance was significantly high (Crossgrove & Curran, 2008). The increased retention of material taught with clickers for the non-majors course was observed but not with the genetics course (Crossgrove & Curran, 2008). Students indicated that discussing with other students is helpful. Caldwell (2005) argue that cooperation amongst student was observed when using clickers and it had a great impact in preparing students for cooperation in the work environment.

The results showed the score of the pre-test and post-test with the control group and experimental group producing a significant difference in favour of the post-test for the experimental group with 77% as compared to the control group, which obtained 42% (Barragués, Morais, & Guisasola, 2011). These tests scores imply that students in the clicker-technology class obtained high scores, which is evidence that there was an improvement in student learning.

However, the study conducted by (Simelane & Dimpe, 2011) at one of the universities of technology in South Africa with 95 Sanitation Safety and Hygiene first-year students explored the effective implementation of clickers to promote active learning and to increase participation during class. Findings in this study showed that in order to integrate clickers as a tool in teaching, a teaching strategy has to be in place. This is supported by Beatty and Gerace (2009) with their development of Technology-enhanced formative assessment (TEFA) as a teaching strategy used with the aid of clickers. Clickers were used in class for learning. Multiple-choice questions were incorporated into the presentation. Of the students, 84% revealed that the use of clickers assisted them to grasp the content and enabled them to apply it in a practical situation. The results also revealed that using clickers allowed students to be actively involved, to participate in class and to engage with learning. In this respect, (Simelane & Dimpe, 2011) point out the most beneficial use of clickers in the classroom is its ability to provide immediate feedback and to measure students' understanding. Classroom discussions among students were promoted to clarify the misconception. Beatty and Gerace (2009) point out that TEFA had two general purposes to help student expertise in science content and help students prepare for future learning.

3. Methodology

3.1. Participants

Participants comprised 105 first-year mathematics students at a university of technology in South Africa. All the students were registered for the Electrical Engineering Diploma where mathematics is a prerequisite. As a prerequisite the implication is that students cannot proceed without passing the subject. In first-year mathematics, the students take basic mathematics, which includes exponents, functions, wave theory, radiant measure, trigonometry and hyperbolic function. Certain topics, namely *matrices, vectors, complex numbers or mensuration, differentiation* and *integration* are also included in the syllabus. Of the participants, 14 (13.2%) were women and 29 (27.6%) men, while 62 (59.0%) did not indicate their gender. Their ages ranged between 17 and 31 years ($M = 19.81$, $SD = 2.385$) while 57 (54.3%) did not indicate their age. The results revealed that 39.0% (41) of the students indicated that they were registered for the course for the first time, and 4.8% (5) of the students revealed that they were repeating the course.

3.2. Instruments and procedure

Data was firstly collected using paper and pencil tests. Secondly, data was also collected using clicker continuous tests during the implementation of the TETS. Thirdly, a survey questionnaire about the use of clicker technology and students' perspective was collected, which included a section that requested the students to provide biographical data such as age gender, course, year of registration, etc. The results of the final exam were also used as an instrument to validate the success rate of the students.

3.3. Paper-based test

Paper-based tests were undertaken, using two methods: (a) orientation test and (b) mathematics class test. In the orientation test, questions were developed by the lecturer. This test consisted of ten questions. The aim of this particular test was to determine students' background knowledge of mathematics concepts. The concepts tested were *exponent, functions trigonometry and hyperbolic function*. The orientation test was conducted before any teaching of mathematics for the year had taken place. The class test had four questions, testing knowledge of *exponents, functions, wave theory* and *radian measure*. The total mark for the test was 20, and it took approximately 30 minutes to complete. The test was written about four weeks after the students had been introduced to basic math. In the class test, we wanted to determine whether there was any change after the teaching intervention.

3.4. Clicker test

Three weekly TETS tests, which we referred to as "clicker tests" were conducted. The aim of the clicker test was to make sure that students engage during the lecture and to ensure that they understood concepts better. Clicker test 1 consisted of three questions covering *differentiation*. Clicker test 2 consisted of four questions testing the knowledge of a *matrix*. Clicker test 3 consisted of four questions. Fig. 1 below gives an example of questions from each clicker test.

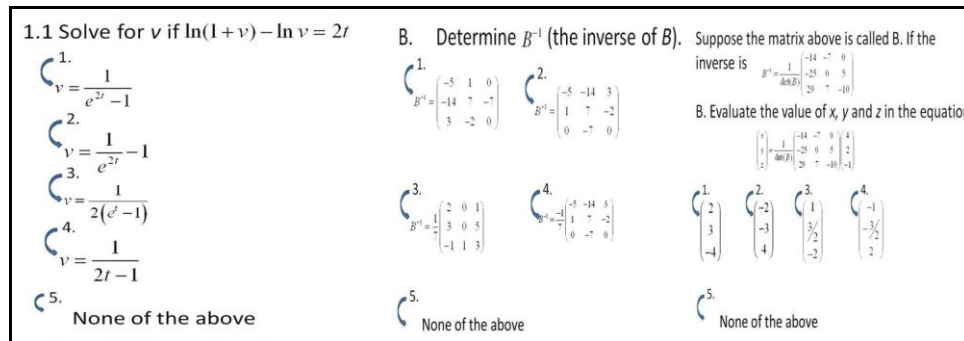


Fig. 1. Examples from Clicker test 1, 2 and 3

3.5. Survey questionnaire

A survey questionnaire on teaching and learning using clicker technology as well as student perspective was administered. We developed this questionnaire and it comprised of 16 questions. The first section was about teaching and learning using clickers. This section consisted of 11 questions. The second section consisted of four questions about student perspectives on the integration of clicker technology in teaching and learning. The last questions were about obtaining a clicker. In the first section, students were requested to provide data about teaching and learning using clickers where students registered their view on a 5-point Likert-type scale anchored by 1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree and 5 = strongly disagree. In this instance, the aim was to establish how clickers were used in the classroom. For example, students had to rate the items –

- (i) Using clickers helped me to pay more attention in class.
- (ii) Clicker questions helped me know how well I was learning.
- (iii) When responding to questions by using clickers, I analysed the question and worked out the problem using correct mathematical principles/formula/rules.

In the second section, students were requested to register their views on 5-point Likert-type scale entered by 1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree and 5 = strongly disagree. In this case, the aim was to gather students' views about the use of clicker technology in teaching and learning. For example students had to rate the items

- (i) I liked using clickers in class.
- (ii) Clickers were effective in promoting active learning and thinking during the learning process.

4. Results

4.1. Paper-based test

In the orientation test, 78.1% (82/105) of the participants wrote the test. The $M = 60.63$ and $SD = 17.850$. In all, 58.1% (61) passed the test and 20.0% (21) failed the test. The total number of participants who did not take the test was 21.9% (23).

In class test 1, 100 % (105) of the students wrote the test. The $M = 51.97$ and $SD = 15.875$. In total, the results showed that 51.4 % (54) of the students passed the test and

48.6% (51) failed the test. Table 1 shows the frequency distribution of the orientation test and class test 1.

Table 1
Frequency distribution of student academic performance

| Orientation test | | | | Test 1 | | | |
|------------------|------|---------|-------|--------|------|---------|-------|
| Pass | Fail | Missing | Total | Pass | Fail | Missing | Total |
| 61 | 21 | 23 | 105 | 54 | 51 | - | 105 |

4.2. Clicker continuous assessment

The TETS with the aid of clickers was developed based on an analysis of the results from the orientation test and mathematics test 1. Three clicker continuous assessments were conducted. In clicker test 1, 84.8% (89) of the students took the test while 15.2% (16) did not take the test. In total, 83.8% (88) of the students passed the test and only one student (1.0%) failed the test. The $M = 76.97$ and $SD = 26.173$. Out of 54 students who did not pass class test 1 and 21 students who did not pass the orientation test, the results showed that when TETS was implemented students did not pitch for contact sessions.

In clicker test 2, the $M = 57.15$ and $SD = 33.513$. In all, 80.0% (84) of the students took the clicker test 2. In total, 50.5% (53) of the students passed and 29.5% (31) failed the test. Of the students, 20.0% (21) did not take the test.

In clicker test 3, 90.5% (95) of the students took the test and 9.5% (10) did not take this test. The $M = 62.83$ and the $SD = 22.260$. In all, 77.1% (81) students passed the test and 13.3% (14) failed the test. Table 2 below shows the frequency distribution of the at-risk students and the correlation between the orientation test, class test 1, clicker test 1, 2 and 3.

Table 2
Frequency distribution of at-risk students and correlation between the orientation test, class test 1, clicker test 1, 2 and 3

| Test | Fail | Missing | Total |
|--------------------|------|---------|-------|
| Orientation test 1 | 21 | 23 | 44 |
| Class test 1 | 51 | - | 51 |
| CT1 | 1 | 16 | 17 |
| CT2 | 31 | 21 | 52 |
| CT3 | 14 | 10 | 24 |

4.3. Students' opinion on the integration of TETS with the use of clickers

In all, 48.6% of the students (51/54) completed the survey questionnaire. These students' score were $M = 32.47$ and $SD = 9.335$. When looking at the scores for the entire questionnaire with 15 items for internal consistency, the Cronbach's alpha (Cronbach,

1951) values are .818, suggesting that the items have relatively high internal consistency. Literature states that a reliability coefficient of .70 or higher is considered acceptable in most social science research situations, which implies that participants have provided reliable information. When analysing a covariance matrix, the initial eigen values are the same across the raw and rescaled solution. The Total Variance Explained shows that the eigen value for the first factor is slightly larger than the eigen value for the next factor (8.9 vs. 2.7). Additionally, the first factor accounts for 43% of the total variance. This suggests that the scale items are unidimensional. Table 3 below shows the factor-loading factor for the rotated factor and Cronbach’s alpha reliability scores for each item.

Table 3
Factor-loading factor for the rotated factor and Cronbach’s alpha reliability score

| Scale item | Factor | | |
|------------|------------------------------------|-------------------------|-----------------------|
| | Clickers for teaching and learning | Assessment for learning | Students’ perspective |
| CTL1 | 0.812 | | |
| CTL2 | 0.789 | | |
| CTL3 | 0.794 | | |
| CTL4 | 0.792 | | |
| CTL5 | 0.795 | | |
| CTL6 | 0.793 | | |
| AL7 | | 0.795 | |
| AL8 | | 0.839 | |
| AL9 | | 0.822 | |
| AL10 | | 0.798 | |
| AL11 | | 0.805 | |
| SP12 | | 0.794 | |
| SP13 | | | 0.876 |
| SP14 | | | 0.786 |
| SP15 | | | 0.781 |

The results showed that 48.6% (51) of the students responded to the questionnaire about their perception of the use of clickers with the integration of TETS for teaching and learning, while 51.4% (54) of the students did not return their questionnaires. In this study, results showed that 37.2% (39) of the students agreed and strongly agreed about their views on “I like using clickers in class”, 7.7% (8) of the student disagreed and strongly disagreed and 4.8 % (5) indicated that they were neutral. Students were also requested to respond to a question “I dislike using clickers in class”. The results revealed that 33.3% (35) of the students disagreed and strongly disagreed. Few of the students 12.4% (13) agreed and strongly agreed on this item. Students felt that using clickers with the integration of TETS proved to be effective in promoting active learning and thinking

during the learning process. Of the students, 34.2% (36) agreed and strongly agreed and 5.7% (6) disagreed and strongly disagreed. The results also showed that 35.3% (37) of the students thought that they should continue using clickers in class and agreed and strongly agreed on this item, while 9.5% (10) disagreed and strongly disagreed and 3.8 (4) were neutral on this issue.

5. Discussion

5.1. Paper-based test

The results from the orientation test showed that 20.0% (21) of the students failed the test. When looking closely at the results, it is observed that 21.9% (23) of the students did not take the orientation test. It may be argued that the test was written during the second week of class attendance. Therefore, it might have happened that students were still confused as to where to go for a contact session. But the results also raised some concern about class attendance. In class test 1, 100% (105) of the students wrote the test. The mathematics class test results also confirmed the results of the orientation test, namely that students' academic performance was indeed below average. Hence, the TETS was incorporated as an intervention to help those participants to incorporate higher-order learning in their studying and active participation in class. The class attendance was 100%, which reduced the concern identified in the orientation test. The students in this study belonged to the millennial generation or 21st-century students (Howe & Strauss, 2000; Kleinman, 2011). In order to assist them to improve their academic performance, (Katz, 1999, p. 7; McCoog, 2008) argue that these students require to be taught in a 21st-century teaching approach, which is technology innovation. For this reason, the TETS using clicker technology was developed as an intervention to assist such students to improve their academic performance and increase the success rate and class attendance.

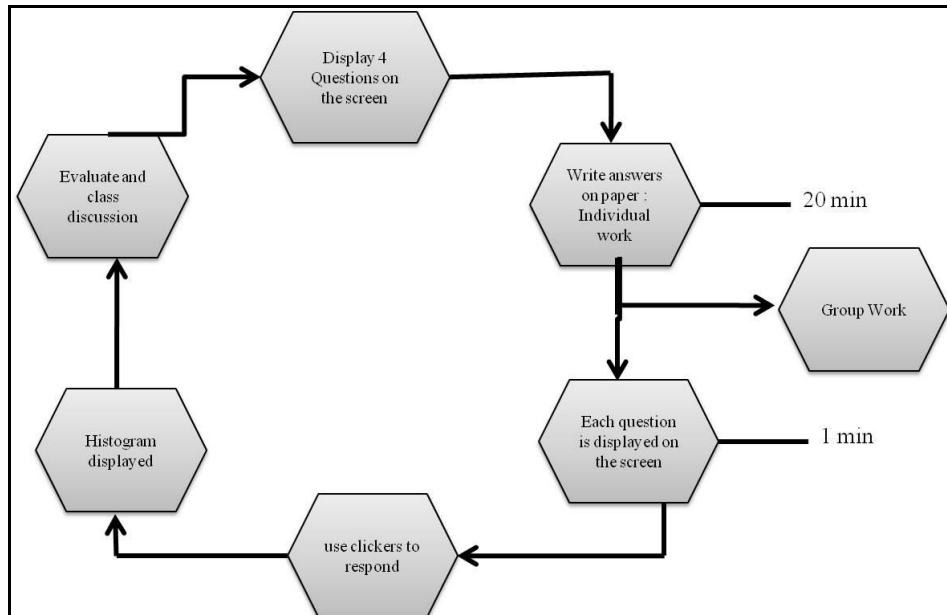


Fig. 2. Technology-engagement teaching strategy (TETS)

5.2. TETS in action

The TETS was developed following a number of activities carried out with first-year mathematics students. The activities involved two paper and pencil tests. Nolting (2009) indicates that lecturers should modify their teaching strategies or methods in order to have a better understanding of their students. Fig. 2 reflects the TETS. The results obtained from the orientation test and class test 1 formed the basis of the development of TETS. Three weekly tests were written using the personal response system commonly known as “clickers”. From the test results, we observed the increase in participants’ academic performance. Fig. 2 shows the proposed TETS.

According to Simelane, Mji, and Mwembakana (2011), TETS was effectively used to achieve the outcomes of the lesson. TETS was used to test the post-knowledge of the weekly lectures. Clicker tests were conducted to test whether students can synthesise the concepts and apply higher-order learning to solve mathematical problems (Simelane, Mji, & Mwembakana, 2011). The results showed improvement in students’ performance when compared to the paper and pencil test. This showed that participants performed better when concepts were being tested and were taught using clickers. Clicker tests were written on a weekly basis. The results showed that in all three tests, clicker test 1 = 16, clicker test 2 = 21 and clicker test 3 = 10 students were absent on these days.

It may be argued from the findings that some students did not attend some contact sessions. The results showed that 43.8% (46) of the students attended contact sessions all the time. Only one student indicated that he attended classes about half of the time. The literature states that one of the benefits of using clickers in class is to increase class attendance. In this case, most of the students were not coming to class even if they were told that they would do continuous assessments and that it would contribute to their predicate mark. The results showed one student failed this test. The aim of TETS with the incorporation of clickers was to assist those students who were not performing well to improve their academic marks and to achieve better marks. In this regard, TETS was implemented with its major focus on students who did not perform well in the orientation test and class test 1 as well as those who were not attending contact sessions. Therefore, the integration of TETS proved to be successful when 83.8% students’ academic performance increased as compared to a 58.1% pass for the orientation test and 51.4% for the class test.

5.3. Disadvantages of using TETS with the aid of clicker technology

Even though the study proved successful with an increase in students’ pass rate, there were some disadvantages with the use of TETS with the aid of clicker technology such as the clicker loan system, the lecturer’s workload, logistics and management of clickers and technical challenges. Neither the students nor the Department of Mathematics owned clickers. The lecturer had to book clickers from the Department of Teaching and Learning with Technology for the period of six months. The lecturer also needed an assistant who had to issue the clickers during the lesson while she was teaching. Students had to sign in and sign out after the lecture.

The use of clickers increased the workload on lecturer as compared to the traditional method of teaching. The lecturer had to carry the laptop, data projector and clickers to the classroom. This was due to the fact the classroom did not have the necessary equipment for the exercise. But the lecturer was motivated by the fact that the tool motivates students to learn, students become involved and engage in their learning and concentrate on the content rather than on the technology. The use of clickers did not

prolong the learning time. Technical problems were however encountered. Some of the clickers disconnected from the system while in use and the assistant had to reconnect the clicker to the system or exchange the clicker. Extra clickers were available because the lecturer registered extra clickers for all the sessions.

5.4. Students' academic performance

Table 2 show the at-risk students, where the major focus was on assisting them to improve their pass rate. It may be argued that the integration of TETS with weekly clicker tests proved positively. In this regard, we saw how the number of students who passed increase from clicker test 2 to clicker test 3. Students' semester results were added to their predicate score. In this instance, we observed an increase in the number of students qualifying for the exam, with only 7.6% (8) who did not qualify to write the exam. One can argue that these 8 students fell into a category of students who did not take the weekly test and only took the semester test.

5.5. Students' perspectives

The survey questionnaire was created based on TETS with the integration of clickers. From the findings, TETS and clickers was supported by the majority of students. Based on the results collected from 51 students, clicker technology optimally influenced use of clickers in teaching and learning. It is indicated that the use of clicker technology in teaching and learning will have positive impact on the implementation and integration of TETS as a technology-enhanced teaching strategy for innovative teaching. Meanwhile, the results for gender and students' perspective explained that these do not affect the millennial generation toward the use of clicker technology in teaching and learning. It may be claimed that the integration of TETS proved to be effective in promoting active learning and thinking during the learning process. It may also be argued that students perceive the use of TETS to be effective and useful and that this perception proved to be positive during learning in class. This supports the results from the clicker test where we observed an increase in students' academic performance as well as pass and success rates.

6. Conclusion and recommendations

In this study, we saw how the researcher and the lecturer accommodate 21st-century students and align the TETS and clickers to meet the requirements of these students. We also observed how the integration of TETS assisted the lecturer to ensure that students understood concepts in the classroom. This was observed by students' weekly clicker test where we saw improvement in students' academic performance as well as the overall pass rate. In this regard, technology was implemented effectively with its connection to content and pedagogy. When TETS, with the aid of clickers, was implemented, misinterpretations of concepts were clarified by the real-time feedback supplied by clickers; misunderstandings could be dealt with at the time they occurred when. Findings in this study revealed that TETS was implemented successfully. TETS, with the aid of clickers also improved students' academic performance as well as the pass rate. Above all, students in this study perceived clicker technology to be useful and effective and that it assisted them to improve their learning. Although the study produced positive results in terms of students' active involvement and participation in class when using clickers, challenges were encountered, like the loan system, logistics and management, time and technical problems.

Based on the findings reported here, it is recommended that lecturers should take into consideration the technology teaching strategies when incorporating technology in their teaching practises. Lecturers, instructors and teachers should understand or acquire a certain type of knowledge in order to incorporate technology into their teaching of a specific content area. Further research should be conducted using a similar study with a larger number of students within the mathematics group. The TETS should also be tested with another group of mathematics students.

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