A LONGITUDINAL STUDY ON THE USE OF PEER INSTRUCTION WITH CLICKERS TO TEACH INFORMATION MANAGEMENT

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ABSTRACT

The objective of this research was to determine whether students would benefit from the incorporation of a teaching method known as peer instruction with clickers in first year information management classes at the University of Johannesburg, South Africa. Quantitative data was collected from selected classes over a period of two years. An attempt was made to confirm whether the benefits from using peer instruction with clickers recorded in previous studies were applicable to the subject of information management. Half of the selected classes used peer instruction as a teaching method, while the remaining half used a conventional face-to-face, one-to-many teaching method. Clickers were used to collect data from all classes, enabling a comparison of the two teaching methods. The different teaching methods applied revealed varying responses from the students, which also revealed different results in their class test scores. This quantitative data may potentially prove some benefits of using peer instruction with clickers to teach information management.

Keywords: clickers, information management, peer instruction

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1. INTRODUCTION

The use of technology in teaching has been around for many decades. Some of the early psychology scholars such as B. F. Skinner (1904–1990) investigated the use of technology to assist with learning, in an attempt to understand how humans respond to technology and how they learn under these conditions. These findings have made an impression on teaching and pedagogy. In a lecture delivered in 1964, Skinner (1965, 427) made these remarks: 'Teaching machines are largely misunderstood. It is often supposed that they are simple devices which mechanise functions once served by humans.' Skinner's remarks are true and remain a challenge for educators, as there is a need to better understand how technology can be used in education to improve and optimise the students' understanding.

Information communication technologies (ICTs) have made a substantial contribution to education. In the early part of the twenty-first century, there seemed to be a disconnect between the investment in ICTs in education and the returns, which created a need for refined evaluation of the performance of these technologies, as teachers were still coming to terms with the new possibilities they brought (Zheng and Xie 2016, 208). The impact of ICTs in education was previously investigated by researchers Pelgrum and Anderson (2001, 84), who noted the changes in policy action from many countries as they were evolving to initiate ICT supported pedagogical reforms in schools. The use of ICTs in education is not only driven by the need to improve learning but also to ensure students are equipped to one day work in a digital world where technology will be part of their daily tasks. ICTs in education have caused a shift in the focus of teaching, as conventional teaching emphasises the enhancement of content to improve education, while contemporary approaches focus on the way in which teaching is delivered and meaning is constructed (pedagogy) (Noor-Al-Amin 2013). ICTs in education have created new possibilities in the learning environment with virtual communities, effortless communication across a number of channels, multi-media content and augmented reality.

With regard to the possibilities ICTs bring to education, these technologies are changing the way instructors design classes and content for their students. Instructors have numerous options when considering which technology innovations to implement in the classroom, making it challenging to know how best to use the technology. An example of a popular innovation incorporated in many classes is a learning content management system such as Blackboard or Moodle. These learning content management systems gave instructors access to a large number of tools and applications to incorporate in the class, while the pedagogy may have been neglected, making little change in the way some instructors taught.

Electronic personal response systems, or clickers, are another example of a technological innovation that has found its way into the classroom. These clickers allow instructors to get instant feedback from their students. Previous studies have

investigated the merits of using clickers in the class and have recorded a numbers of benefits to the students (Hoffman and Goodwin 2006; Keogh and Wang 2009; Oigara and Keengwe 2011). However, little emphasis is placed on the pedagogy when incorporating clickers into the class. The objective of this research was to determine whether students would benefit from the incorporation of a teaching method known as peer instruction with clickers in first year information management classes at the University of Johannesburg (UJ), South Africa. This longitudinal research investigated the merits of using peer instruction as a pedagogy when incorporating clickers into the class. Data was collected over two years from first year information management students at UJ to see what effect using peer instruction with clickers had on students. Comparisons were made between either using a common teacher-centred approach with clickers, or using peer instruction with clickers.

The data analysed revealed some interesting results, potentially substantiating the merits of using peer instruction with clickers. This longitudinal approach helped to clarify trends and proved insightful. Instructors looking to be more innovative in the class by incorporating new technologies need to consider the pedagogy as a significant factor in optimising the potential benefits of the technology.

2. CLICKERS AS AN INNOVATION IN EDUCATION

The advent of more affordable computing devices has attributed to the integration of technology into education that is currently being experienced. The purpose of such technological integration is to use technology as an alternative instructional intervention to achieve educational goals and improve understanding amongst students (Smith 1997, 65). A number of technologies, such as learning content management systems and mobile computing devices, have proven to be useful in achieving these objectives.

An example of such a technological integration and innovation currently used in education is electronic personal response systems, or clickers. These are compact handheld devices usually working off infra-red or radio-frequencies that transmit and record students' responses to questions (DeBourgh 2008, 3). Clickers allow students and instructors to exchange ideas and information interactively in exercises often referred to as think-pair-share exercises. During these interactive exchanges, students complete concept tests, designed to explore the depth of their understanding (Steer et al. 2009, 30). Concept tests are built on questions that allow students to process and analyse information, encouraging them to think carefully about what they know and do not know. The questions used in concept tests are higher-order multiple-choice questions focusing on key concepts that the instructor is trying to teach, and can be compared to comprehension, application and analysis questions as defined by Bloom's Taxonomy (McConnell et al. 2006, 63).

Clickers can promote student engagement in a number of ways, such as:

- quizzes regarding assignments;
- testing students' conceptual understanding as part of a peer learning process;
- taking opinion polls;
- posting challenging questions to promote discussion. (Hodges 2010, 2009)

When students use clickers, they are asked to indicate the correct answer from a list of options (predetermined by the instructor). This practice in education is often associated with the stimulus-response pattern of behaviourist theory, where the revealing of a question is followed by feedback to re-enforce behaviour (Fies and Marshall 2006, 102). Clickers allow instructors to give rapid feedback to re-enforce behaviour, which according to Thorndike's law of effect is fundamental to learning (Keesee 2012).

Instructors using clickers have a number of choices on how to either publically or anonymously gather students' responses that are collected and displayed. Responses can be anonymous, or by clicker identification number, or programmed to reveal the students' names with their responses. This makes it flexible when incorporating this technology into the classroom, thereby allowing instructors a number of alternatives to best suit their pedagogical approach (Fies and Marshall 2006, 101).

Clickers can be successfully incorporated into the learning environment to ensure interaction, while providing students and instructors with real-time feedback. This real-time feedback allows the instructor to determine whether or not the students understand the work covered (Oigara and Keengwe 2011, 16). Clickers can raise the students' participation levels and improve the effectiveness of interaction, thereby promoting students to engage in active learning (DeBourgh 2008, 1; Hoffman and Goodwin 2006, 430). This shared communication helps instructors and students to clarify any misunderstandings (DeBourgh 2008, 1). The ability to anonymously display the students' answers in tests makes it easier and less daunting for the students to share their perspectives with peers (Bruff 2010).

The most common reported benefits of using clickers include: increased enjoyment in class; more effective group interaction; helping students with their own understanding; and helping instructors to be more aware of their students' difficulties (Oigara and Keengwe 2011; Roschelle, Penuel and Abrahamson 2004, 3). Clickers may be viewed as a low risk way to encourage student interaction, while making it entertaining. Clickers are useful for determining the students' level of understanding at any specific point, thus allowing instructors to be more proactive in their teaching (Hodge 2010). Clickers support innovation in instructional design, while engaging students in dynamic learning. This process can result in a high level of synthesis as students question their current understanding in an attempt to construct new knowledge (DeBourgh 2008, 2).

The use of clickers in education does pose some challenges, however. Instructors should also bear in mind that in instances where students do not own the clickers, the

handing out of clickers can be a time-consuming and troublesome process in larger classes (Keogh and Wang 2009, 17). According to Fies and Marshall (2006, 106), there are authors who are uncertain of the gains when using clickers in education and assign great emphasis to the pedagogical approach taken for effective utilisation of clickers in education. Clicker questions can enable deep learning with a pedagogical approach that supports interaction and debate (Bruff 2010). A popular pedagogical approach that can incorporate the use of clickers, and which supports interaction and debate amongst peers, is peer instruction.

3. PEER INSTRUCTION AS A SUPPORTING TEACHING METHOD FOR USING CLICKERS

Peer instruction is a teaching method formalised by Eric Mazur at Harvard University in the United States in the 1990s. This method of teaching steers away from traditional teacher-centred, face-to-face teaching and incorporates self-assessment and co-operative learning. Peer instruction attempts to inspire students' subjectivity and place importance on interactions during the learning process (Zhao, Cheng and Ding 2011).

Peer instruction requires students to work together in small groups where they discuss and defend their responses to the concept tests. These concept tests rely on timely feedback used by both the instructor and the students to improve performance (Steer et al. 2009, 30). Committing all students to answer a question and participate in a discussion around a particular question helps students to generate ideas on how to solve a particular problem. Together with clickers and supporting software, instructors are able to identify difficult questions and concepts with which students are battling (Bruff 2010). When the students answer these questions, it enables the instructors to determine whether or not the students understand the topics being taught and gauge their own response with their peers (Hodges 2010).

The important factors for peer instruction to address are how to stimulate the students' consciousness and guide them to explorative study (Zhao et al. 2011). Students perceive conventional teaching, where the instructor is physically far away from the seated students, and where communication is predominately one-way, as impersonal and intimidating (DeBourgh 2008, 3). Peer instruction differs from conventional teaching, offering an interactive alternative.

Peer instruction is not only limited to the use of clickers in the classroom, but it benefits greatly from this technology due to the easily interpretable output and facilitation of student feedback. Peer instruction is independent of the feedback method, thus it is not reliant on financial and technological resources (Fies and Marshall 2006, 103). Unlike more traditional methods of conducting peer instruction (e.g. show of hands or flash cards), clickers allow the instructor to get accurate feedback. Added to this, students are often captivated by the use of innovative

technology in the class (Hodge 2010). Hoffman and Goodwin (2006, 431) comment that in their own experience with using peer instruction with clickers, 'the benefits far outweigh the challenges'.

Peer instruction may be the most popular pedagogical approach used with clickers, but there are other approaches to effectively incorporate clickers into the class. An example of such an approach, which is largely based on similar concepts to peer instruction, is Class Aggregation Technology for Activating and Assessing Learning and Your Students' Thinking (CATAALYST). The core of this system allows the instructor to engage students by presenting probing questions, gathering responses and displaying the aggregate of the answer. This system is similar to peer instruction in its approach to ensure participation in the learning process (Roschelle et al. 2004, 2).

When conducting peer instruction classes some challenges have been identified by previous authors, for example, where some instructors found it difficult to construct questions to use for testing concepts that are challenging enough to engage the students (Hodges 2010; Keogh and Wang 2009, 12). Turpen, Dancy and Henderson (2010, 328) also identified this difficulty when constructing questions for concept tests as these questions need to encourage students to think and actively compare their answers in the quest for new knowledge. The construction of these questions can be time consuming, thereby adding to the preparation time for conducting peer instruction classes (Hoffman and Goodwin 2006, 431; Oigara and Keengwe 2011, 27).

While the development of concept test questions remains a challenge, some instructors who have experienced hesitance from students to talk in class, believe that this could be accredited to students attending conventional classes where they are not allowed to interact with their peers (Turpen et al. 2010, 327). Strategies that can be used to encourage students to participate in peer interaction can include starting the semester with easier questions to build the students' confidence; incorporating clickers into the classroom; and intervening in the organisation of groups early on.

Like any technological innovation, the power lies in how it is used. Peer instruction, along with similar approaches to teaching, can create a favourable environment for using clickers. There are many recorded benefits to using clickers, provided they are used constructively. The incorporation of technology into the classroom along with complimentary methods of teaching can improve the students' learning experience and have a positive effect on their academic performance.

4. RESEARCH DESIGN

This study used a positivist approach to understanding what impact the use of peer instruction with clickers has made on first year information management students at UJ. Quantitative data was collected from classes in 2012 and 2013, using clickers

to gather responses from questions asked, which was captured by TurningPoint software. This longitudinal study analysed and compared the data collected over the two years.

The data was collected from a total of eight classes from the two campuses where the classes are offered, namely, the Soweto Campus (SWC) and the Kingsway Campus (APK). Both these campuses are located in Johannesburg and are about 20 kilometres apart. The sampling method selected was a non-probability convenience sample, as only students who attended the classes were selected from the population. The number of students in these classes over the two years ranged between 87 and 242 students (based on the responses to the questions) (see Table 1). During each year a total of two classes on each campus were taught using clickers; on each campus one class was conducted using clickers without peer instruction and the other class was conducted using clickers with peer instruction, giving a total of four classes per year where clickers were used to collect data. The same lecturer presented all the classes.

Students in the 2013 classes were asked the same questions concerning their views on peer instruction classes using clickers as those in 2012; however, the concept test questions used during peer instruction classes differed between 2012 and 2013 as well as the class test questions. This was done because the data was collected at different times in the semester: in 2012 the data was collected in Class 6 and Class 7, while in 2013 the data was collected from Class 2 and Class 3. The reason for this change was an attempt to gauge whether the time in the semester would affect how students reacted to the use of peer instruction with clickers.

In summary all the students were asked five questions to gauge their views towards using clickers with and without peer instruction. A total of eight questions were used at the end of each class for a class test, while during peer instruction classes, ten concept test questions were used.

However, there were some limitations due to the design of the study, which were impossible to avoid. Due to the software used and the manner in which the data was collected, individual responses could not be tracked as there was not enough time to register every user to a clicker at the start of each class. This made it impossible to statistically prove any correlations or calculate any statistical significance. Aggregated data was used for the analysis. It should be noted that the clickers were supplied free of charge to the students which may have some influence on how the students reacted to the use of clickers. There are different models of payment for clickers which need to be assessed, including: partial payment from the institution; full cost to the student; and free, that is, funded by the institution.

5. FINDINGS

The collected data was exported from TurningPoint to MS Excel, where it was analysed and comparisons were made from between the two years. Table 1 looks at

the response rates for the eight classes where the research was conducted. For each year, two classes on each campus used the clickers, one of the classes was conducted using clickers alone, while the other class used clickers in conjunction with peer instruction. The maximum and minimum responses were used to determine the average responses. The average responses were also expressed as a percentage of the maximum responses to determine the average response rate. The combined average response rate for 2012 and 2013 was 93 per cent, while there was little difference between the maximum response rate of 96 per cent and the minimum response rate of 91 per cent over the two years. This indicates that only a very small number of students were not participating in all the questions asked during the classes (it is important to note that this participation rate is also affected by those students arriving late for classes and those leaving early). There was no noticeable difference between the response rate of the clicker classes with non-peer instruction (Class 6 and Class 2) and those classes that used clickers in conjunction with peer instruction (Class 7 and Class 3), suggesting peer instruction had no noticeable effect on the participation of answering questions.

Table 1: Participation rates for 2012 and 2013

Year	**2012**				**2013**			
Class	Class 6 (SWC)	Class 6 (APK)	Class 7 (SWC)	Class 7 (APK)	Class 2 (SWC)	Class 2 (APK)	Class 3 (SWC)	Class 3 (APK)
Most responses	157	137	143	112	115	242	166	267
Least responses	144	106	126	90	87	199	132	204
Average responses	150.73	123.69	133.44	102.75	108.93	229.93	153.37	250.08
Response rate as a percentage	96%	90%	93%	91%	95%	95%	92%	94%

Table 2 records the students' attitudes towards the use of clickers in both peer instruction and non-peer instruction classes. The students were asked to rate their experience on a scale from 1 to 4, with 4 being the most positive and 1 the least. Table 2 shows the results for 2012 and 2013 to see if there was any observed change in the students' attitudes towards the use of clickers in non-peer and peer instruction classes. Looking at the enjoyment of the classes, it is evident through the difference in means for 2012 and 2013 that the non-peer instruction classes seemed to be more enjoyable, while overall 2013 showed less of a difference in the enjoyment of the

classes between non-peer and peer instruction classes. With regard to the attention means recorded in both 2012 and 2013, there seemed to be an increase in attention when using peer instruction to conduct classes, while 2012 recorded a slightly higher difference in average means for attention between the non-peer and peer instruction classes. When observing the average means for understanding there seemed to be a different trend with regard to the differences: in 2012 an improvement in understanding was recorded during peer instruction classes, while in 2013 a slight decrease in understanding between the peer and non-peer instruction classes was recorded. The largest recorded difference in means was in 2012 for the increase in attention while using peer instruction. The second largest recorded difference in means was also in 2012, when the enjoyment decreased when using the peer instruction method. A factor that could have contributed to the decrease in the level of enjoyment recorded for both 2012 and 2013 classes could be a novelty effect of using technology in the class, since all non-peer instruction classes were classes where the use of clickers was first introduced. This novelty effect was observed in previous studies by Keogh and Wang (2009, 16) and Oigara and Keengwe (2011, 26) on the way students reacted to the clickers and peer instruction.

Table 2: Students' attitudes towards the use of clickers 2012 and 2013

	2012 Non-peer mean	2012 Peer mean	2012 Difference in means	2013 Non-peer mean	2013 Peer mean	2013 Difference in means
Enjoyment	3.25	3.01	–0.24	3.06	2.94	–0.12
Attention	2.97	3.28	0.31	2.99	3.09	0.10
Understanding	3.11	3.22	0.11	3.10	3.05	–0.05

The combined aggregated means for the students' attitudes towards the use of clickers for 2012 and 2013 showed an overall representation of the enjoyment, attention and understanding means (see Table 3). The combined average of enjoyment means showed a decrease between the peer instruction and non-peer instruction classes (-0.17), which, as previously mentioned, could be attributed to a novelty factor. The increase in the students' attention when using clickers with peer instruction was evident with the largest difference in the means (0.21). The difference in students' understanding when comparing non-peer and peer instruction classes was the least significant, showing a slight increase of 0.03.

Table 3: Combined attitude towards the use of clickers

	Non-peer mean	Peer mean	Difference in means
Enjoyment	3.15	2.98	–0.17
Attention	2.98	3.19	0.21
Understanding	3.11	3.14	0.03

Table 4 looks at the effect of interaction during a peer instruction class and the effect this had on the students' answers to the concept test questions. Table 4 records the percentage of correct answers for both pre interaction and post interaction questions in the class during the concept tests. As part of the peer instruction method, students were first asked questions by themselves and then they discussed their answers in small groups, this is where peer learning takes place. After these discussions, they were asked the same question again. In all the classes for both years there was a positive difference between the answers recorded after the interaction (post-interaction) and those recorded before the interaction (pre-interaction). The difference in pre- and post-interaction correct answers ranged from 5 to 12 per cent. The most significant difference of 12 per cent was recorded in Class 6 in 2012.

Table 4: Correct answers both pre-interaction and post-interaction for 2012 and 2013

	2012 Class 6	2012 Class 7	2013 Class 2	2013 Class 3
Correct answers pre-interaction	61%	58%	60%	64%
Correct answers post-interaction	73%	63%	69%	72%
Difference between pre- and post-interaction answers	12%	5%	9%	8%

The combined results for the correct answers for pre- and post-interaction during the concept tests (see Table 5) showed that there was a 9 per cent improvement in the correct answers. In 2013, a slightly higher increase was recorded in correct scores between pre- and post-interaction. Overall the noticeable improvement could suggest that the interaction taking place in the peer instructions classes has a positive effect on the students' understanding with an increase in correct answers.

Table 5: Pre- and post-interaction during concept test questions for 2012 and 2013

	Total 2012	Total 2013	Combined Total
Correct answers pre-interaction	60%	62%	61%
Correct answers post-interaction	68%	71%	69.5%
Difference between pre- and post-interaction answers	8%	9%	8.5%

In an attempt to see if the use of clickers with peer instruction does improve learning and understanding of the work covered, class tests were conducted at the end of each class (for both non-peer and peer instruction classes). The recorded results regarding the class tests seemed inconsistent (see Table 6); during classes in 2012 there was an overall 9 per cent improvement in the correct answers between non-peer and peer instruction classes; however, in 2013 only a 0.4 per cent improvement was recorded. This slight increase in correct answers for class tests in 2013 may have some link to the students' understanding scores recorded in 2013 (see Table 2). The understanding scores for 2013 were quite different to those recorded in 2012 – the understanding aggregated means recorded a decrease in 2013 as opposed to an increase in 2012. Reasons for this marginal increase in the class test correct answers in 2013 are not known and further longitudinal data collection may be able to determine whether or not this result is an outlier. The combined results showed an increase in correct answers of 4.7 per cent. A previous study conducted by Oigara and Keengwe (2011, 24) reported a 9 per cent improvement in the mean grades of students when using the peer instruction teaching method, which is similar to the results recorded during the study in 2012.

Table 6: Class test scores for 2012 and 2013

	2012 Classes average correct answers	2013 Classes average correct answers	Combined
Non-peer instruction	49%	60.4%	54.7%
Peer instruction	58%	60.8%	59.4%
Difference between non-peer and peer instruction	9%	0.4%	4.7%

Students were asked if they thought that all their classes for different subjects should be conducted using clickers without peer instruction or with peer instruction. Figure 1 shows that in 2012 the students had a more positive reaction towards using clickers in both the non-peer and peer instruction classes with the majority believing that

clickers in both non-peer and peer instruction should be used to teach their other subjects. Regarding the results for 2012, grouping the 'Yes' and 'Yes but not all' together gives an idea of how positive the students are towards using clickers in other subjects. With this grouping in 2012, the non-peer instruction classes recorded 89 per cent, while the peer instruction classes recorded 82 per cent, that is, a difference of 7 per cent. However, in 2013 the majority of students believed that the use of clickers in both non-peer and peer instruction classes should not be used to teach the other classes. Again, grouping the 'Yes' and 'Yes but not all' answers together for 2013, gives a very different result. Only 39 per cent of the students in non-peer instruction classes displayed positive views towards using this in other classes, while 44 per cent of students in peer instruction classes displayed positive views towards using this way of teaching other subjects, that is, a difference of 5 per cent. These statistics were considerably lower in 2013. There did seem to be a noticeable trend in 2013 when looking at the difference between the non-peer and peer instruction classes: peer instruction classes were better received and an increase in the 'Yes' answers was recorded.

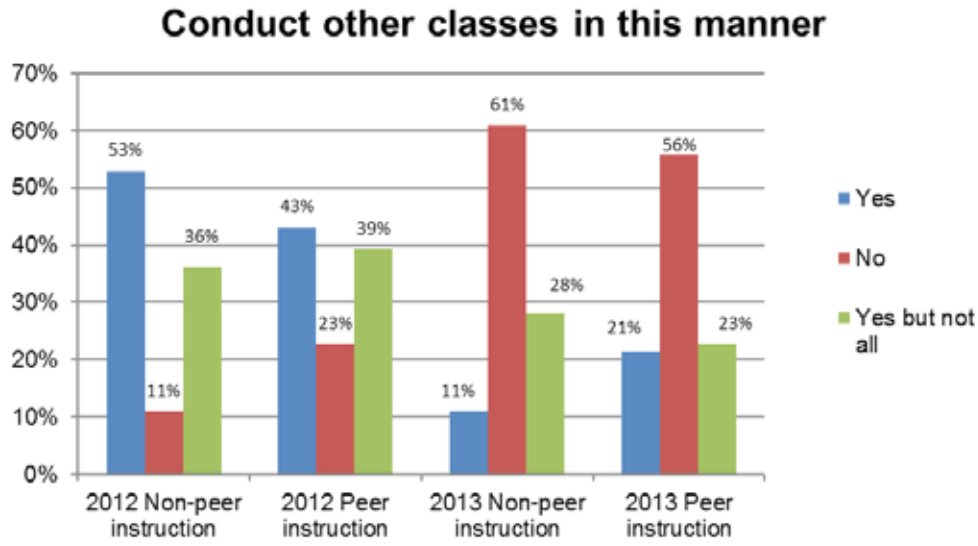

Figure 1: Conducting other classes using non-peer and peer instruction for 2012 and 2013

While summarising these findings some significant trends can help to determine what influence the use of clickers along with peer instruction made on first year information management students at UJ during 2012 and 2013.

- Based on these results there is uncertainty in determining what effect the time in the semester when data was collected had on the students' perceptions towards using clickers. Analysis of the data did not suggest that the difference in the results between 2012 and 2013 could be caused by the different times in the semester when the data was collected.
- Using peer instruction with clickers in classes has proven to be less enjoyable than using peer instruction without clickers. A possible novelty effect could have influenced the students' views, but in both years there seemed to be a decrease in the students' enjoyment when using peer instruction.
- Peer instruction had a positive influence on the students' attention. The statistics showed the largest difference in means, making it the most noticeable improvement when incorporating peer instruction into the class.
- Overall peer instruction helped to improve the students' understanding of the work covered. These improvements in understanding varied between 2012 and 2013; however, overall there was a slight improvement in understanding.
- The peer instruction class produced better class test scores with more students getting the correct answers. Again there was a variation in the data between 2012 and 2013, but overall there was an improvement of 4.7 per cent in correct answers obtained in the class tests.

6. CONCLUSION

The study has proved valuable by quantifying the benefits of using peer instruction with clickers in information management classes at UJ. Clickers, like any other tool, are only of beneficial use when used in a constructive manner. In the study, emphasis was placed on how the clickers are used by comparing two different pedagogical approaches. Peer instruction as one of these approaches has been refined over the years and proven to be effective in assisting students to learn; however, little previous research has compared peer instruction against other approaches.

The findings of the study revealed that there are some benefits when using peer instruction with clickers to teach information management as opposed to a more conventional teacher-centred approach. One of the most notable benefits recorded was an overall improvement in class test scores of 4.7 per cent. The students' attention increased during the peer instruction classes, and the students believed that there was a slight increase in their understanding of the work covered in peer instruction classes. It was interesting to note that there was also a recorded decrease in the enjoyment of the peer instruction classes. The peer instruction method involving a concept test did have a positive impact on the students with an average 8.5 per cent improvement in correct answers in post-interaction questions. On the whole peer instruction with clickers seemed to show positive gains when teaching information

management to first year students. These recorded benefits show potential for peer instruction with clickers to work in other management related subjects, where the learning of concepts differs from those in physics or mathematics where this approach was developed and refined.

This longitudinal approach to the study proved to be useful in confirming trends; however, some categories tested seemed to record differences over the two years between 2012 and 2013. This was most apparent for the improvement in correct answers for the class tests and the students' understanding, a further follow-up year of data collection may be able to help understand these differences. Further research in the use of peer instruction in other subject domains may be useful, as the majority of previous studies have been conducted in the scientific, engineering and mathematical domains.

Using clickers in education can be beneficial but strong emphasis should be placed on the pedagogy used. Refinement of a pedagogical approach may lead to a number of benefits. Technology is a catalyst in the equation for improved learning, relying on other ingredients to ensure success. As Byrom and Bingham (2001, 14) state, 'we have observed that this is the combined effect of pedagogically sound teaching practices and appropriate technologies that lead to improvements in learning'.

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