BENEFITS OF A BLENDED APPROACH IN TEACHING UNDERGRADUATE MATHEMATICS

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Abstract

The purpose of this paper is to provide a discussion of the educational potential of a blended approach to teaching and learning in the context of the challenges related to mastering basic concepts in mathematics at higher education level. Based on the results of the application of blended learning and teaching for two consecutive semesters at a university of technology, their potential to support meaningful learning of undergraduate mathematics is discussed. The use of clickers, minute and muddiest point papers and board work as educational tools with incomplete sentences as evaluative tool, are discussed. The conclusion is that a blended approach to teaching and learning has many benefits when applied appropriately for a particular context. The lecturer's attitude remains vital for successful implementation of technology-enhanced strategies.

Keywords: Clickers, muddiest point papers, blended learning, tertiary mathematics and classroom research.

1. INTRODUCTION

Mathematics performance in higher education is identified as a global problem by many authors (Gerardi, 1990; Nongxa, 1996; Maree, 2009). Lecturers have to cope with an ever-expanding list of demands when students arrive at higher education institutions. In South Africa, as elsewhere in the world, students arrive with differences in schooling experiences, levels of prior knowledge, learning cultures, learning styles, meta-cognitive skills, backgrounds and motivational levels (Oliver, 2007:788). In this article it is argued that if a lecturer uses technology (clickers) appropriately, engages the students intellectually, selects their teaching approach purposefully, acts as a role model and creates emotional rapport with the students, student progress is inevitable.

Although Abrahamson (2006:13) emphasises that it is hard to model scientifically what it is that teachers do when teaching, he contends that an effective learning environment is learner-centred, knowledge-centred, assessment-centred and community-centred. Students have to construct new knowledge for themselves (Goff, Terpenny & Wildman, 2007:1), but this construction can be made easier by the lecturer if the correct intervention is done at the right time. It is essential that lecturers begin to explore the impact of blended approaches to achieve more meaningful experiences (Garrison & Kanuka, 2004:102).

There is an ever-increasing demand on lecturers to improve success rates, especially in students' first year of study (Maree, Pretorius & Eiselen, 2003:402). In an attempt to achieve better student performance in mathematics I wanted to address some of the factors that I perceived as contributing to poor performance. The stumbling blocks that stand in the way of success in mathematics are that our students do not have sufficient discipline and a proper learning culture (Rademeyer, 2009:394); do not manage their time optimally (Louw, 2009:371); attend classes irregularly (Louw, 2009) and struggle with misconceptions resulting from being taught at school by under-qualified teachers (Hattingh, 2009:353).

The aim of the article is to illustrate how specific strategies used over two semesters together with carefully selected different teaching approaches can achieve the required learning outcomes. In the study on which this article is based, blended learning was not seen as a hybrid between face-to face and on-line learning (Rovai & Jordan, 2004:32) but rather as a mixture of approaches in the classroom with a more holistic emphasis on student learning. Blended learning was seen as a combination of multiple delivery media that are designed to complement each other to promote learning (Singh, 2003:52). The aim was to allow students to demonstrate their knowledge while appealing to diverse learning styles and fostering independent and self-directed learning (Pape, 2010:17). The blended approach to learning was not just about finding the right mix between technology and lecturing, but rather to rethink and redesign the content delivery (Garrison & Kanuka, 2004:97).

Clickers were chosen as the technology based activity since the students in this study have limited access to computers and although on-line material was available, the majority could not access it easily. Clickers are little remote-control instruments that were used by the students to log in a response to a multiple-choice question. The lecturer's laptop was connected to a radio frequency receiver that received the responses and the results were immediately available in either a bar chart or pie chart. Possible misconceptions could be identified, discussed and clarified by supplying additional explanation and appropriate practice exercises before continuing to the next topic. TurningPoint software, which operates in the same way as PowerPoint, was used. Brueckner (2007:9) asserts that the use of clickers enhances student engagement and increases daily attendance. Clickers are important tools by which to record attendance, assess student understanding, encourage participation, learn from their mistakes and give feedback (Vajravelu, 2007:10). She agrees, however, that clickers should be used creatively along with other proven teaching methods. Kaufman (2009:5) found that the biggest advantage was that all students were placed on an equal playing field and Korosy (2007:4) indicated that students appreciated the ability to communicate their confusion without embarrassment.

Hara (2008:10) feels that whenever a subject requires sequential learning, clickers are indispensible in assessing whether concepts are mastered before one moves on. In my study the aim was to use clickers to monitor class attendance (Lowery, 2005:3); to give immediate feedback and thus to enable the students to see and discuss their results immediately (Wrzesniewski, 2008:1); to discover and remediate misconceptions as soon as possible (Wrzesniewski, 2008:1); to achieve active participation (Lowery, 2005:3); and to strive for student satisfaction (Lowery, 2005:3) for the Millennial[1] learners (Vernaza, 2007:1) in order to retain their attention.

2. THEORETICAL ISSUES

2.1 Blended teaching and learning

Blended learning is a hybrid of classroom and online learning that includes some of the conveniences of online courses without the complete loss of face-to-face contact (Rovai & Jordan, 2004:30). Voos (2003:2) suggests that it is unlikely that the 'blendedness' makes the difference in such courses, but rather the fundamental reconsideration of course design in light of new instructional and media choices and the learning strengths and limitations of each. In my study, students had the opportunity to access material on the university's learning management system (LMS), Blackboard, but everything they could access there was also available in class, during lectures. This study is regarded as a form of blended learning because of all the different strategies used in the teaching of this mathematics course.

2.2 Teaching strategies

The strategies used in this study for the teaching of Mathematics I (Mat171T) to Civil Engineering students at a university of technology were:

- Lecturing. Sometimes the lectures are based on PowerPoint slides, but I mostly work on the white board to explain concepts and solve mathematical problems.
- Clicker tests. The results from the clicker tests indicate existing misconceptions, and that informs my practice for the next day.
- Students working on the white board. These sessions follow on clicker tests and afford me an opportunity to select appropriate mathematical problems to practise while clearing up the identified misconceptions.
- Minute papers. Students are requested to reflect on a section of work and indicate one thing that they learnt that they had not known or understood earlier.
- Muddiest point papers. Students are required to reflect on a section of work and indicate one thing that is still unclear to them.

[1]Millennial learners are learners who are comfortable with technology and prefer it to form part of the teaching and learning process.

- Incomplete sentences. Incomplete sentences were used as an evaluative tool to collect student perceptions about the teaching strategies.

2.3. Classroom research

Angelo and Cross (1992) have championed classroom research. I agree with Kochis (2006:2) who defines classroom research as "the systematic investigation of the effects of our teaching on student learning for the purpose of improving instruction". It consists of two aspects: a repertoire of techniques for getting information from students about their learning and an effort to organise that information into a larger picture of practical learning theory. Classroom research is often criticised as being teacher-centred, but my study was student-centred because the students' learning was at the heart of the design.

2.4. Loud expert reasoning

Loud expert reasoning involves a think-aloud protocol where a problem is solved by an 'expert' and a verbal explanation is given alongside the written solution. Clement (1993:265) explains in a case study how different professors were asked to solve a particular problem in any way they liked, while thinking aloud. In this study students were not expected to be the experts, but as their confidence grew, many of them could verbalise their thinking. Typically, four students would solve four different homework problems on the board and then returned to their seats. The class would then be asked to assess the correctness of each one, followed by an in-depth discussion of possible notational errors, mathematical errors or calculation errors.

2.5. The EXCEED model

This model was designed in the Civil Engineering field and means Excellence in Civil Engineering Education (Estes, Mckune, Ressler & Welch, 2007). The model was developed by examining what attributes make a good teacher (Estes et al., 2007:58). The model consists of six aspects of good teaching, namely structured organisation, engaging presentation, enthusiasm, positive rapport with students, frequent assessment of student learning and appropriate use of technology. Estes et al. (2007) believe that students will progress better when their lecturer acts as a role model and they propagate the use of minute papers and muddiest point papers. How these methods are used is discussed in the methodology section of this article.

3. METHODOLOGY

This research project was a descriptive case study with elements of action research.

Mat 171T is a semester subject and every semester is considered to be a cycle consisting of many iterations of plan-act-observe-reflect. Observations and personal communication were documented in a reflective journal as part of data collection. Minute papers and muddiest point papers, incomplete sentences and assessment documents were used to collect data during 2010. The lesson design used during the two cycles as part of my professional practice in the mathematics class is explained below, followed by more detail about clickers, board work incorporating loud expert reasoning, minute papers, muddiest point papers and incomplete sentences.

3.1 Lesson design

During semester one of 2010 the lectures for a mathematical topic were developed according to a definite strategy. For the sake of this article the topic of differentiation is used as example. In lesson one the basics of differentiation was explained, including the theory and rules involved and sometimes the notes were posted on the Learning Management System (LMS) of the university. The lesson ended in sharing well chosen examples. Students went home with homework every day. This topic required the practising of techniques; therefore a clicker test would be introduced during the next period to assess students' competence. In Figure 1 a slide with the question and the graph of the responses is shown. Misconceptions were discussed and clarified and new work was introduced.

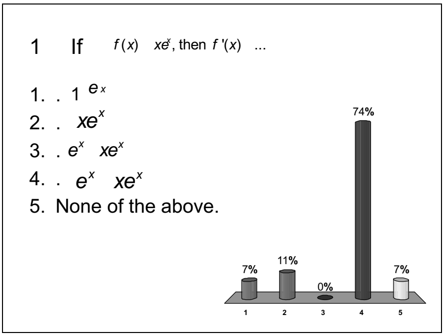


Figure 1: Bar chart of the responses to a clicker question

During the next lecture period students would practise carefully selected problems and volunteers would do the problems on the white board. There would be four questions on the board simultaneously and four students would complete them on the board and then return to their seats. A class discussion would follow and the opportunity to correct notational errors would be used. Students soon realised that mistakes are learning opportunities and nobody experienced the session as being stressful. As the semester continued students were allowed to improve on somebody else's answer by using a different colour ink. In that way we could still see the original attempt and could discuss the reasons for the incorrectness.

We used loud expert reasoning to model the correct approach. Midway students completed minute papers to reflect on their newly acquired knowledge and at the end of this session students completed muddiest point papers to indicate the misconceptions they might still have. The topic was concluded with a discussion of their muddiest points and ultimately a paper-based class test.

3.2 Clickers

In this study, clickers were not used every day, since clickers are seen as a tool and not a solution (Beatty, Leonard, Gerace & Dufresne, 2006:31). Clickers were only used when students' understanding of concepts was assessed. Four multiple-choice questions were typically constructed and displayed without the distracters (possible answers) on the screen. Students got the opportunity to solve the problems on paper for a predetermined time frame followed by an opportunity to look at the distracters and log in their answers on the TurningPoint system according to a strict time frame. At the end of all the clicking, we discussed the answers that were supplied and cleared up all possible confusion. Clickers guided me in the optimal choice of examples and exercises to eradicate students' misconceptions and increase their time on task (Owsten, 2007:609).

3.3 Board work incorporating loud expert reasoning

Mathematical notation is very important and in a tertiary setting it is difficult to monitor and assess. To overcome this limitation, the white board was frequently used and three to four students would work simultaneously on different problems. When they had finished, we discussed the solution in order to determine if it was correct, and if not, what had gone wrong. This opportunity was used to emphasise correct notation. Loud expert reasoning was effectively used in this context (Clement, 1993:1).

3.4 Minute papers and muddiest point papers

The technique of minute papers is used to guide students to reflect on their learning and students have to list one thing learnt that they did not know before. Muddiest point papers are even more useful since students are expected to select one aspect of the work that is still unclear to them (Estes et al., 2007:63). Initially students wrote vague or generic comments, but as the semester progressed and they realised that attention was being paid to those messages, their responses became very specific.

3.5 Incomplete sentences

The university has an existing form for lecturer evaluation by students, but it contains Likert-type questions and students seldom write specific comments.

The need to discover what they really think necessitates a different tool and subsequently they were given ten incomplete sentences and asked to complete them by writing the first thing that came to mind. Their responses, which were very insightful, are discussed in the results section.

4. RESULTS

The analysis of the data was done in different ways to suit each data collection method. The muddiest point papers were analysed quantitatively by listing the different aspects raised by students and determining the frequency of each one to identify the area where the biggest uncertainty was, but I used Tesch's method (De Vos, 1998:343-344) to analyse the papers qualitatively. My reflection journal and the incomplete sentences were all analysed using Tesch's method.

4.1 Academic results

The results given here are those for the subject Mathematics I (MAT171T) of students who were studying towards the Diploma of Civil Engineering during semesters one and two of 2010. The class group (semester one) consisted of 32 students of whom 24 had been admitted to the institution through the foundation programme. This programme is designed to allow access to students who do not completely comply with the necessary academic prerequisites for tertiary studies. They do the first semester over a year period in an attempt to prepare them to join the mainstream students. All of these 32 students had failed the subject previously and were repeating MAT171T. Traditionally, repeater students do not perform well, since they do not attend regularly and are of the opinion that they know the content. During the second semester there were 36 students in the new MAT171T group. None of them had entered through the foundation programme. Five of them had come from other tertiary institutions where they had failed their first year of studies in Civil Engineering. The Department of Civil Engineering has three first-year groups and the other two groups were taught mathematics by two colleagues. The academic results for both semesters can be seen in Table 1. My students are referred to as the 'target group'.

Table 1: Mathematics results for both semesters

	Cohort (all diplomas)	Success rate	Civil Eng (excluding the target group)	Success rate	Target group	Success rate
Semester 1	1057	51%	153	46%	32	81%
Semester 2	681	63%	71	61%	36	72%

When the students' baseline assessment (a multiple-choice test about basic mathematical skills such as fractions, exponents and logarithms) are compared with their final mark the graphs show an upward trend. In Figure 2 and 3 the graphs of semester one are shown separately for the mainstream group and the foundation group. The same trend was noticeable during semester two.

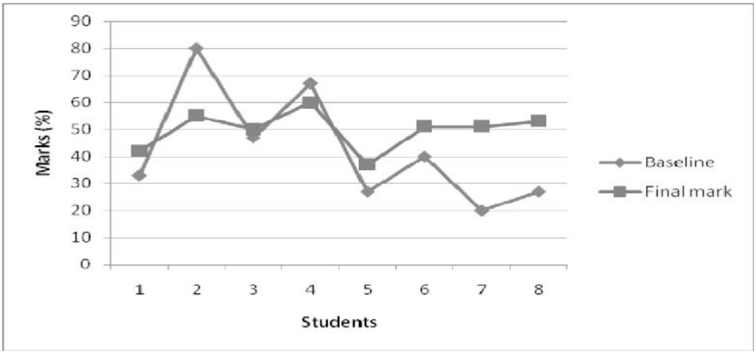


Figure 2: Baseline and final mark for main stream first-year students

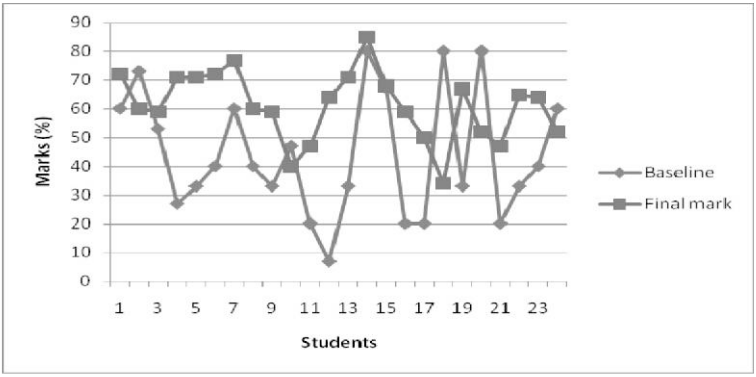


Figure 3: Baseline and final mark for foundation group

Most of the students performed better in their final mark, which indicates that they made progress despite a poor basic mathematical knowledge. One could deduce that the regular practice of concepts using clickers had an influence on their mathematics performance. The students who ultimately failed the course (less than 50% final mark) during the first semester were numbers 10, 11, 18, in the foundation group and 1 and 5 in the mainstream group.

When the average of clicker test results and predicates are compared, the resultant picture looks similar to the baseline results. The results of the clicker tests and final marks are shown in Figures 4 and 5.

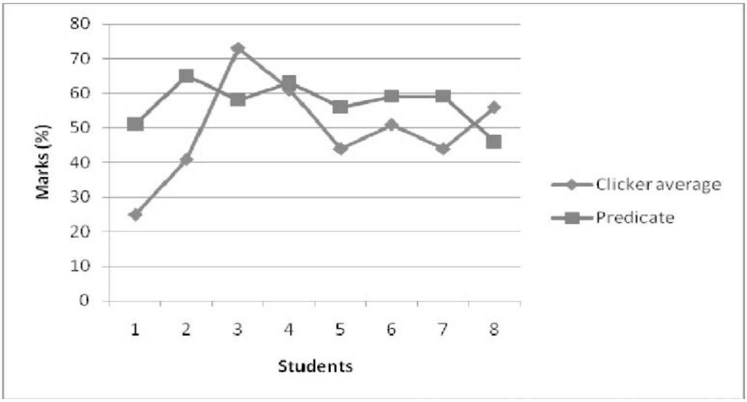


Figure 4: Clicker test average and final mark for main stream first-years

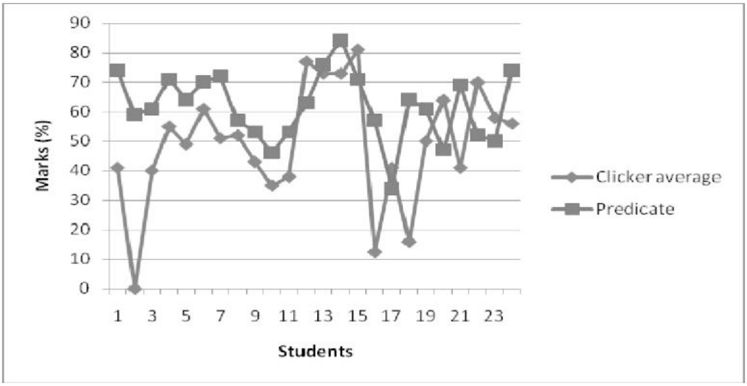


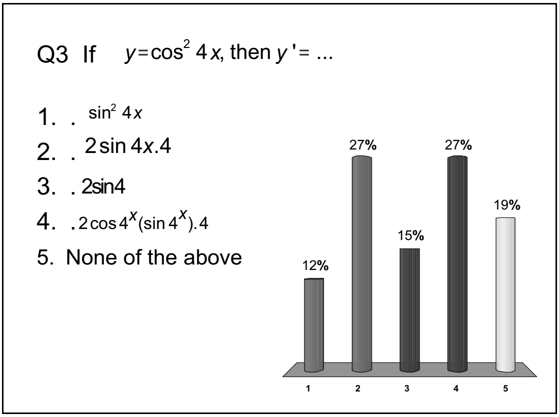
Figure 5: Clicker test average and final mark for foundation first-years

The extremely low clicker marks of students 2, 16 and 18 (Figure 5) are due to repeated absence and not to poor performance. The average clicker test mark is in most cases lower than the final mark, showing that their knowledge increased as they discovered their misconceptions and rectified it.

In the second semester the trends were identical, and the only significant change was that the cohort of students (all diploma student) performed slightly better than in semester one (Table 1).

4.2 Clicker tests

Guessing is always a factor when multiple choice questions are asked and I expected that students would guess some answers once the distracters were shared with them, but I did not realise the magnitude of their guessing. I discovered that students were guessing the answers when they did not have one of the distracters on their rough work paper, despite the option: "None of the above" that was a possible option in every question. By that time I already had good rapport with the students and they knew they could trust me. They also knew that the 'marks' for the clicker tests were not credit bearing. I therefore asked them to indicate if they had guessed the answers. A clicker 'test' would typically consist of four mathematics questions (questions 1, 3, 5 and 7) and four identical questions asking: "Did you guess the answer to the previous question?" (questions 2, 4, 6 and 8). These answers about the guessing were also logged into the system and the results were shown to students. I sometimes collected their rough work papers to assess their 'original' answers and could see exactly what they answered before they made their guess. This is, however, very time consuming. Figure 6 illustrates one example with the results.



Option four was the correct answer, yet one can see that an equal percentage chose option 2. In the follow-up question, 52% admitted that they had guessed the answer. This question assessed a differentiation technique that needs practising and the students' failure to even recognise the answer correctly indicated their lack of practice. Further analysis of the responses revealed that in this particular question, for instance in their paper responses, the results would have looked differently. If their responses were logged in truthfully the results would have been:

Response 1:	11%
Response 2:	0%
Response 3:	0%
Response 4:	31% (The correct response)
Response 5:	58% (None of the above)

The fact that the distracters had convinced students to change their initial answer – to another wrong answer – indicates that the work had not yet been mastered.

In such a case it gives the lecturer the opportunity to do more examples, but also to emphasise the importance of mastering the differentiation technique.

From personal communication it became clear that students perceived the clicking part of the process to be too fast, yet they admitted that when using clickers they were all forced to think and make a decision about the response to the question. They also emphasised that they preferred the style of getting all the questions at once and being able to solve the problems in any order they liked and then having to log in their answers afterwards. They were positive about the lecturer asking about their guessing, because that is also useful information in the remedial process.

4.3 Minute papers

Students initially struggled to verbalise their newly acquired knowledge in the minute papers. At some occasions I would pose a particular issue and request their reflection on that issue. Students were once asked to reflect on the two styles that were used in class to practise concepts, i.e. the clickers and working on the board. Students preferred to work on the board and they claimed that they had learnt more that way, had followed better and had generally left the class with a feeling of satisfaction that many of their 'problems' had been solved. It is possible that they had this feeling because the session on the board usually followed after a clicker session and the problems had been carefully selected to address their misconceptions.

One student (respondent 6) said: “I find that I understood better doing the work on the board” and another respondent said: “I like it when we do it on the board, because that's when we get to express ourselves. So I understand it when we work that way.”

4.4 Muddiest point papers

I used this technique during each topic in the syllabus, but the examples supplied here are on Vectors. The issue raised by most students (n=16) was that they just needed more practice. The magnitude and direction of vectors was highest, while the dot product and the cross product were second highest (n=3). Some remarks after the class were:

R35: I will be OK once I have practised.
R36: I have not been active this week, due to other tests. I will be fine. I'm not unfamiliar with vectors.
R27: I have a problem with sketching vectors.
R2: I am fine. Vectors are clear. The procedure of teaching was perfect! I did not find it difficult.
R24: I am still struggling with cross product.
R15: I struggle to see difference between cross and dot product, but practice will help.

Students shared their feelings freely during these occasions and even if they did not have a muddiest point, they did not hand a blank page back, but rather made a positive comment instead.

4.5 Incomplete sentences

The data from the incomplete sentences were used to support the findings that emanated from their academic results and their experience in the course. The sentences were analysed in context of the incomplete sentence using Tesch's method (De Vos, 1998:343-344). The themes that crystallised are discussed below.

4.5.1 Understanding

Students expressed their feelings of satisfaction during lectures because they felt that they always leave class having understood the work presented. This theme occurred most often in the incomplete sentence saying: “The lecturer teaches mathematics in a way that ...” and in: “The lecturer is always willing to ...” For example:

Respondent 3: “The lecturer teaches mathematics in a way that every student can understand what is going on in the subject.”

4.5.2 Helping

This theme occurs throughout all ten the questions, but most frequently in the context of the sentence: “The lecturer is always willing to ...” Respondent 7 wrote “…help whenever, anybody has a problem.

4.5.3 Attendance of lectures, doing of homework and asking of questions

The students commented on these issues in more than one of the sentences, but mostly in the sentence: “It is expected of me to ...”, Respondent 26 added “ … attend class every day and do my homework and pass my tests. That's all.”

4.5.4 Fun or enjoyment

Students mentioned that the lectures were often enjoyable and fun to attend. This response occurred mostly for the sentence: “Being in this class...” and respondent 15 completed it with: “... have helped me to enjoy math more than before and math have became one of my favourite subjects now”.

5. CONCLUSIONS

Classroom research can be very demanding and time consuming, but the purpose is to enhance students' learning instantly, not in the future. That means modifications need to be made immediately after and based on student feedback. The fact that students give feedback regularly and receive feedback from the teacher creates a sense of community that is important in tertiary education where students often feel isolated and alone.

The success rate of the students in these groups in comparison to the entire cohort could be linked to the teaching style and particularly the regular practising of concepts and techniques using clickers and board work.

Since guessing will probably never be eradicated when distracters are supplied, the use of clicker tests is more appropriate for remedial and formative purposes and not as credit-bearing tests. Due to the very structured approach that was followed, and the regular monitoring of class attendance, absenteeism was lower than usually experienced, but not eradicated altogether as could be seen in Figure 5 where it is shown that respondent 2 did not attend a single clicker test.

Clickers seemed to have played a role in the students' success rate, but the way clickers were blended into the teaching approach was central to the success. The combination of clickers, muddiest point papers and ordinary practising of problems on the white board, together with factors such as the size of the group, the emotional rapport that existed and their appreciation of the extra effort made also contributed to their success. The fact that their muddiest points and misconceptions identified in the clicker tests were treated in the lecture the next day made both strategies more useful and appropriate to their learning process. An effective follow-up strategy for the clicker tests in this blended approach was that students worked on the white board, since students had to show all their steps in the accepted mathematical notation and they could learn from each other again. The discussion of their attempts and the model answer proved to be conducive to their understanding.

If lecturers use a well designed blended approach to mathematics teaching, they will break down students' fear of this subject and will be more successful in maintaining students' attention while supplying immediate and appropriate feedback at their students' level of understanding. The lecturer's role and attitude is a strong predictor of success in the seeking and implementing of best practices in technology-enhanced environments.

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