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Are the benefits of clickers due to the enforcement of good pedagogy?

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Over the past 20 years Personal Response Systems (clickers) have rapidly gained favour in many universities across the world. This paper, explores the pedagogy behind the technology, in order to determine quantitatively if the change in lecturing style forced by the adoption of a clicker system is responsible for the improvements in student engagement and learning as has been documented elsewhere. We report the findings of a controlled study of a first year biology course in which half the class attended lectures where clickers were used to answer question, and the other half attended lectures with questions but no clickers. We found that overall grades obtained by the two different cohorts were the same (73%), as measured by end of course examination. This figure is much higher than the previous year's cohort (56%) whose lectures covered similar material but did not utilise embedded questions or clickers. Our study also found that student satisfaction of lecturers that used embedded questions was much higher than without this pedagogical change. However, classes that used clickers had 94.8% of students participating in answering questions with a correct response rate of 59.2%, while non-clicker classes had a participation rate of 42.1% with a correct response rate of 81.4%. From this, we conclude that while the pedagogy associated with lectures utilising embedded questions can explain many of the observed benefits experienced with the use of clickers, clickers are necessary to ensure a more honest response by students, thus providing lecturers with information to provide appropriate feedback. In addition, clickers are vital to ensuring that lecturers will adopt an 'embedded question' style pedagogy as without them we found a reluctance to do so, and a subsequent return to monologue-style lectures.

Keywords: student response units, pedagogy, clickers, lectures, large first year classes.

Introduction

Lecturing to large groups of students (300+) is currently the expected form of tuition at most undergraduate universities. The reasons for this have more to do with economics than pedagogy. Correspondingly, universities are now running the risk of losing students through lack of engagement in their university courses. One measure taken to reduce this problem is the

implementation of student response systems or 'clickers'. Clickers are relatively simple devices, designed to allow students to anonymously answer multiple-choice questions during lectures. Answers from the class can be displayed on a histogram, giving students instant feedback on the correctness of their own response in relation to the entire class. The lecturer, in turn is able to immediately correct for misunderstandings during lectures, thus promoting a change in lecture delivery and pedagogy. To this end, clickers are being widely used in approximately 600 universities worldwide, as reported by Associated Press (2005). Numerous published articles have catalogued the qualitative advantages students gain by attending lectures in which they are given the opportunity to directly and anonymously respond to questions with immediate feedback. These include; increased attendance, increased engagement, more fun in lecture and higher exam scores (Judson & Sawada 2002; Heward et al. 2004; Hall et al. 2005; Williams 2003). Observations from educators/researchers over the past 30 years have shown that the use of clickers can enhance student learning in a wide variety of subjects, especially in courses that require problem solving, such as physics, chemistry, medical education, mathematics, and computer science (Hake 1998; Burnstein & Lederman 2001; Wit 2003). As highlighted by Duncan (2005), survey results typically indicate that for a significant majority of students, the use of clickers in large classes increases engagement, motivation and ultimately the level of learning.

With such wide international acceptance of this evolving technology, combined with the vast amount of evidence that shows how the use of clickers can increase student engagement, attendance and understanding of course material (Hall et al. 2005), it is surprising to note that relatively few Australian Universities use the devices. This is of particular concern in fields of study such as the sciences where as suggested above, interactive questions embedded within lectures have a considerable effect on helping students understand difficult conceptual material and in problem solving (Crouch & Mazur 2001; Boyle and Nicol 2003; Kennedy & Cutts 2005; Bergtrom 2006). The contribution that clickers have made to science courses world-wide is confirmed by the number of universities that are now implementing them, especially within the large first year courses where their benefits are most obvious (Duncan & Mazur 2005). The cost of purchasing the device is likely to be a factor influencing their implementation across Australia, as was found in the United (Wattles & Williams 2006; Rosentahl et al. 2006). The average cost of clicker handsets varies depending on the system adopted, with one popular model retailing for AUS\$90 each, a cost that individual university departments are having to either cover themselves or pass on to the students enrolled in their courses.

Compounding the issue of cost is one of concern that the benefits obtained through the use of clickers may be attributed to the change in pedagogy required of lecturers who use the tool, rather than the technology. This begs the question "Is the cost of the clicker worthwhile or should lecturers simply be embedding questions within their lectures without the use of the clicker?" As postulated by Laurillard (2002), the learning process is best achieved when there is dialogue between teacher and student. In this way, the teacher can receive feedback on student learning which can then lead to modification of information delivered. Large university lecture courses generally lack this type of student/teacher interaction. However, it can be approximated through the use of clickers and questions embedded within lecture.

The effort required by lecturers using question embedded pedagogy is considerable compared to monologue-style delivery. This increase in active participation is due to the need to: prepare lectures with carefully placed embedded questions; active solicitation for answers to these questions; and subsequently addressing any conceptual or factual misunderstandings to

provide students with immediate feedback (Hall et al. 2005). Unfortunately, the need to invest extra effort into both making a lecture interactive and answering questions on the spot might seem too daunting to some lecturers. However, this required change in lecturer behaviour could potentially have a more significant effect on the notable change in student engagement than the documented changes derived from using the tool. The effect that the introduction of clickers has had on the change in pedagogy has been noted (Judson & Sawada 2002; Draper & Brown 2004), however, there is a lack of good quantitative data supporting the assertion that clickers are vital for successful pedagogy.

In this study, we propose to determine whether the positive results obtained by incorporating clickers and questions in lectures (Heward et al. 2004; Hall 2006; Williams 2003; Hake 1998; Burnstein & Lederman 2001; Wit 2003) could be obtained without using the clickers, by simply embedding questions within lectures and having students raise their hands to answer. If effective, this would reduce the financial burden of adopting this pedagogy to zero. To obtain these data we set up a study within a first year biology course that involved 2 groups of students, one group that used the clicker to answer questions in lectures and one group that received the identical, repeated lectures but raised their hands to answer questions. Our aim was to compare student attitudes, engagement, interest, attendance and grades between the two groups. We expected that: students would participate more and prefer using the clicker over raising their hands, because the anonymity of clickers would facilitate honestly attempting an answer; and student attendance would be higher in the group using clickers (Caldwell et al. 2006; Owens et al., 2004; Lopez-Herrejon & Schulman 2004); and if, as predicted, engagement and attendance was higher we expected increased exam scores in the clicker group.

Finally, we wanted to determine the effect of clicker use on lecturing style, particularly, whether they promote changes in pedagogy. For example, what proportion of lecturers that were given the opportunity to use the clickers would actually adopt this new teaching method? In addition, we wanted to discover if lecturers would embed questions in their lectures without access to clickers, even when strongly encouraged to do so. An interesting corollary of this study was how student perceptions of lecturers changed after the implementation of clickers and questions within their lectures.

Methods

Participants

The participants in the first part of this study were 450 students enrolled in a core first-year biology course at Flinders University in 2005 and 501 students enrolled in the same course in 2006. Students in the course were from 36 different degree programs, most of which specify the course as a core component to their program. A group of 5 lecturers were involved in teaching this course in 2006, 4 of which lectured in the same course in 2005. In 2005 the course ran as a traditional lecture series with no questions embedded. In 2006, lecturers were asked to embed 4-5 questions within each lecture. In the second part of this study, we compared the adoption of the pedagogy of embedding questions into lectures by lecturers in two first year biology courses running concurrently in 2006. A second elective course which had an enrolment of 125 students had 10 lecturers who were asked to embed questions within their lectures without the aid of a clicker. We emphasized the effectiveness of teaching with questions embedded and tried to convince the lecturers that teaching in this manner helps to engage students in the course and helps with their learning.

Study design

Since our largest lecture theatre holds only 300 students, each lecture is presented twice, once at 09:00 and a repeat lecture given at 13:00. This allowed for a controlled study where lecture content was identical (including embedded questions) but students in the 09:00 session were provided with clickers to answer the questions, whereas, students at the 13:00 session were required to hold up their hands to indicate their answer to multiple-choice style questions. We chose to give clickers to the 09:00 group since this session always has lower attendance and hence we were able to determine whether clickers significantly increased attendance. Attendance at each session was recorded and students typically attended lecture session only but there was some movement between both sessions.

Lecturers were asked to embed 4-5 multiple choice question within each lecture. Once a question was asked lecturers would give students appropriate time (1-2 minutes) to select their answer. Students were encouraged but not required to discuss their answer with classmates (peer instruction) prior to selecting their answer. Within the clicker group, student responses were recorded through the computerized software and stored on a laptop computer. In the hands-up class, the number of responses to each question was counted or recorded with a digital photograph if the number of students answering the question was too large to be counted quickly. Directly following the lecture the digital photographs were displayed on a computer screen and the number of students holding their hands up was counted and recorded. Within the clicker session, once all the responses were received a histogram displaying the responses was shown to the students. No histogram was available for the hands-up group but students could visually assess the proportion of students giving each answer. Lecturers would typically discuss the correct and incorrect answers with both classes. The investigation was run for the full 12 week semester. Due to technical difficulties and training of new lecturers, data from 16 complete lectures from both time slots was used.

To determine whether differences in student learning was based on pedagogy or technology being used, final exam grades were compared between the two groups in 2006 (with and without clickers – technology difference) and between the two years, (with and without questions embedded - pedagogy difference). Exam grades were used rather than final course grades because were most reflective of student understanding gained from lecture material.

A survey was developed to ascertain the student view of lectures with questions embedded, as well as on the use of clickers and hand-raising. Either a five-point Likert scale or yes/no questions were used throughout the survey. Students were asked the following questions:

- Q1. Did you enjoy using the clicker? (2006, clicker group only)
- Q2. Did you find stopping during lectures to answer questions disruptive? (2006, both groups)
- Q3. Do you think that asking question during lecture helped understand topic material? (2006, both groups)
- Q4. Would you be more inclined to answer the question if you knew the answer was anonymous? (2006, hands up group)
- Q5. Would you like to see clickers used in more of your topics? (2006, both groups)
- Q6. Overall do you think lecturers responded appropriately to the group's understanding of lecture material if many students answered the question incorrectly? (2006, both groups)
- Q7. Would you prefer to have a clicker to indicate your answer than to hold your hands up? (2006, hands up group)

- Q8. Has your experience in first year Biology made you decide to take more biology topics? (2006, both groups)
- Q9. Any other comments you would like to make about the topic. (2006, both groups 2005, all students)

The student response system used in this study was “Keepad” clickers with ‘TurningPoint’ software. The system included a receiver, software and handheld remote clickers. The Keepad response units are small devices (80 x 55 x 7 mm) that auto power on and off. They communicate via a radio frequency signal to a USB receiver interfaced to the TurningPoint software. The software is an extension of Microsoft PowerPoint which means a standard PowerPoint presentation can be quickly modified to include interactive questions. All student management data is held locally.

Results

Student grades

The 2006 cohort of students achieved proportionally higher grades when compared to the 2005 cohort of students (Figure 1). Interestingly, figure 1 also illustrates both a decrease in Withdraw/Fail grades, and a corresponding increase in all other higher grades obtained in 2006 compared to 2005

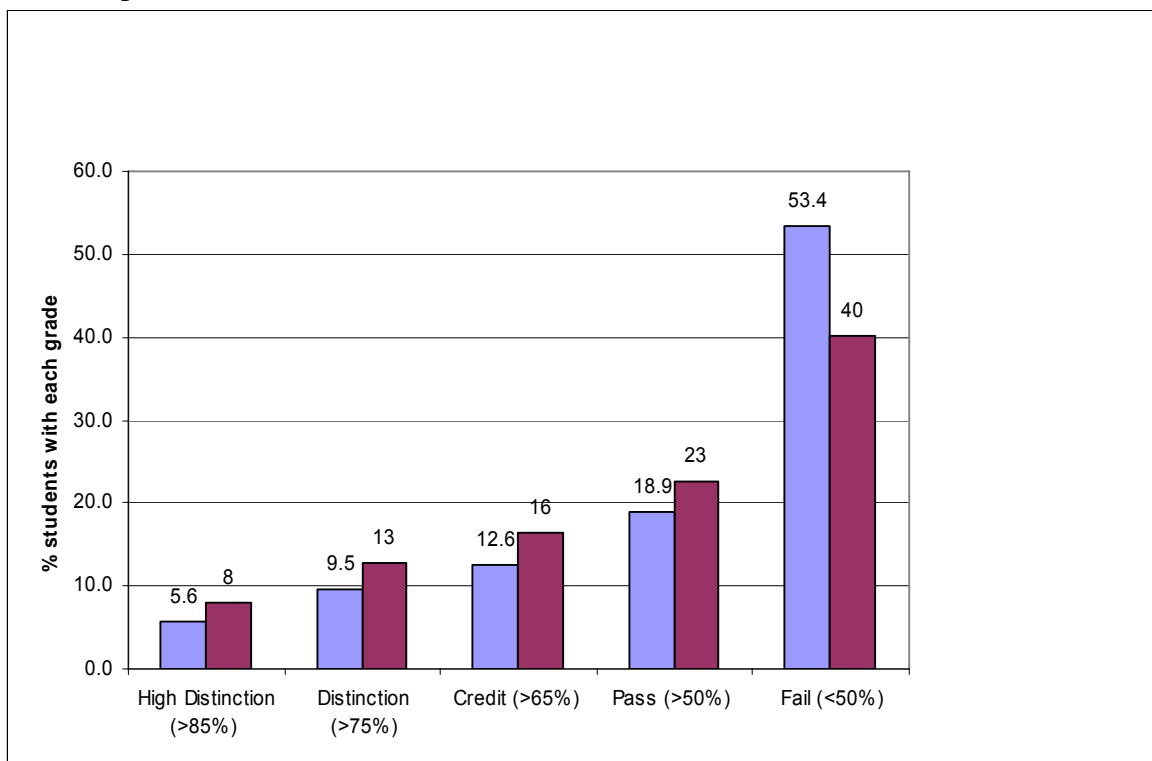


Figure 1: Comparison of 2005 and 2006 Exam Grades for BIOL1102
2005 data is shown in blue (n=461), 2006 data is shown in maroon (n=495)

A sub-sample of students who attended either only the 09:00 or the 13:00 sessions were compared to determine if there was any difference in exam grade. This sub-sample is considerably smaller than the total cohort because of the number of students that moved between the two groups and therefore were eliminated from the analysis. There was no difference in exam grades achieved by students in the clicker lecture (73% \pm 15.8% n= 38) were compared to the hands-up lectures (73% \pm 16.1, n=83) no difference was found. In

contrast, the average student exam grade in 2005 without questions embedded ($53\% \pm 20.7$) was significantly lower than in 2006 ($t=62.7$, $df=120$, $p<0.0001$).

Student response to questions

Student response to questions embedded within lectures differed depending on whether they used a clicker or show of hands to answer the questions. The average proportion of students answering questions using a clicker was 94.8% ($N=32$ questions), whereas the average proportion of students answering questions holding their hands up was 42.1% ($N=35$ questions). An unpaired t-test indicates a highly significant difference ($t=22.1$, $SD=9.76$, $df = 65$, $p<0.0001$) between the two groups.

We also found a significant difference between the number of students who answered questions correctly based on whether they used a clicker or not. The average number of students that answered questions correctly whilst using a clickers was 59.2%, whereas, the number of students answering questions correctly by holding their hands up was 81.4% , again highly significant ($t=-10.7$, $df=68$, $p<0.0001$).

We also compared student response rate with question difficulty. Question difficulty was determined by the number of students who answered questions incorrectly when using the clicker. As this group of students attempted 95% of the questions, it was assumed that their responses reflect question difficulty. There was no difference in the proportion of students answering easy or difficult questions when using the clicker, as evidenced by the 95% response rate. In contrast, students holding their hands up to answer questions would do so less frequently as the question became more difficult (Figure 2 $r = 0.384$, $p<0.01$).

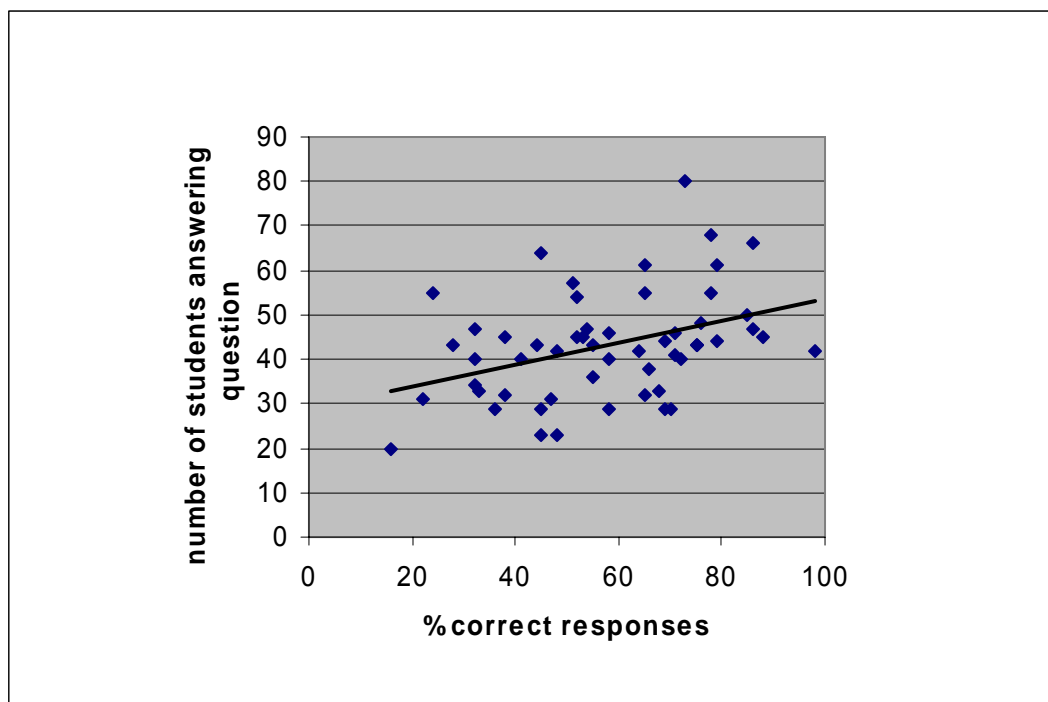


Figure 2: Correlation analysis of student rate of response to question difficulty

Student survey results from the core first year Biology course in 2005 were compared to those from 2006 to determine student's unsolicited opinion of lecturers who in 2005 gave traditional lectures without questions or clickers, with 4 out of 5 lecturers, using question and clickers in 2006. Interestingly, 20% of students in 2005 commented negatively about

lecturer's style and ability, whereas only 3% of students in 2006 gave negative comments about the lecturers.

In 2006 students were asked their opinions of clickers and their preferences for answering questions. The data on student opinions are as follows:

Q.1 Did you enjoy using the clicker?

Responses are shown in Figure 3.

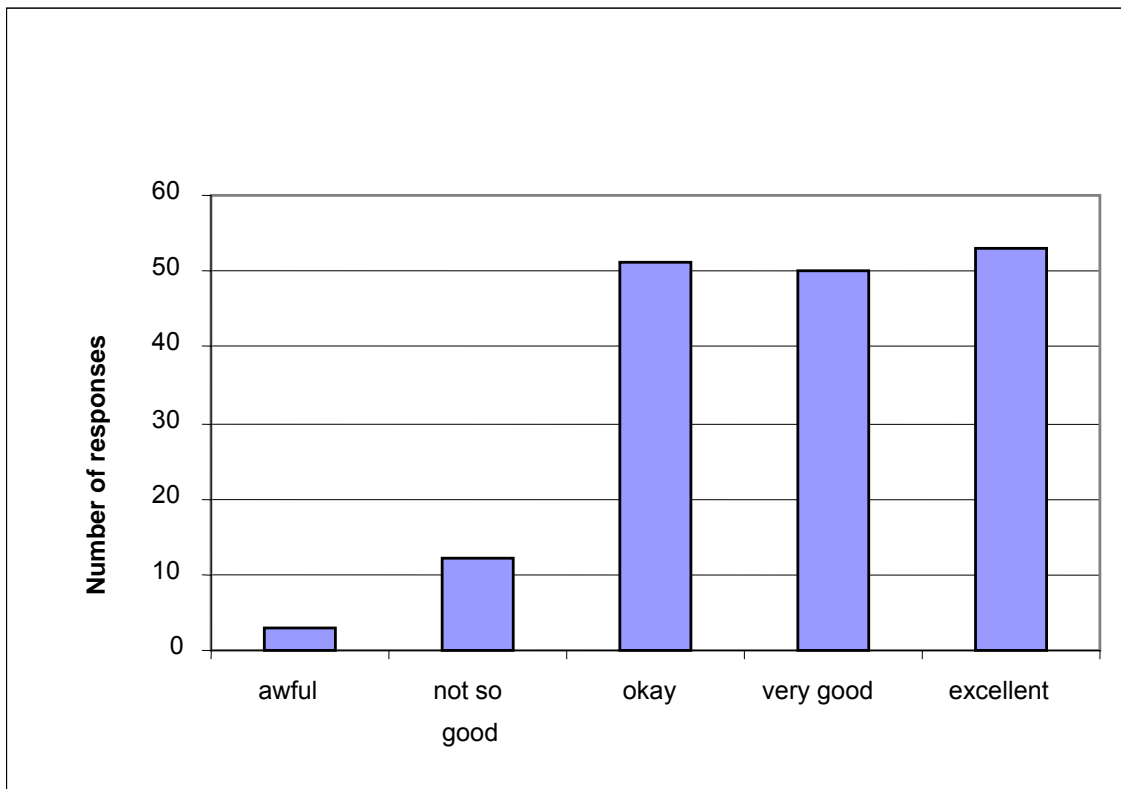


Figure 3: Students with clickers response to the question "Did you enjoy using clickers?"

Q. 2 Did you find stopping during lectures to answer questions disruptive?

Clicker group: 18.5% said stopping for questions was disruptive (n=173)

Hands-up group: 35.4% said that stopping for questions was disruptive (n=250)

Q3. Do you think that asking questions during lecture helped understand topic material?

Clicker group: 89.4% said yes (n=170)

Non-clicker group: 87% said yes (n=246)

Q4. Would you be more inclined to answer the question if you knew the answer was anonymous?

Clicker group: 80.5% said yes (n=169)

Non-clicker group: 53% said yes (n=250)

Q5. Would you like to see clickers used in more of your topics?

Clicker group: 83.4% said yes (n=169)

Q6. Overall do you think lecturers responded appropriately to the group's understanding of lecture material if many students answered the question incorrectly?

Responses are shown in Figure 4.

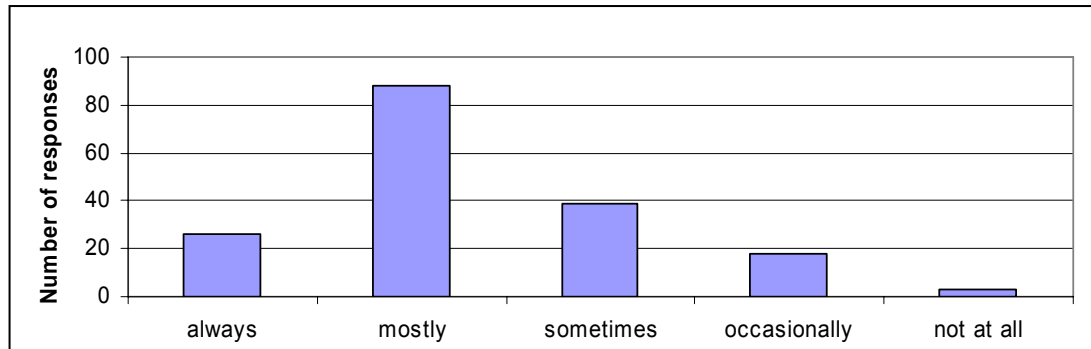


Figure 4 Students with clickers (n=175) response to the question “Overall, do you think that lecturers responded appropriately to the group's understanding of lecture material if many students answered the question incorrectly”

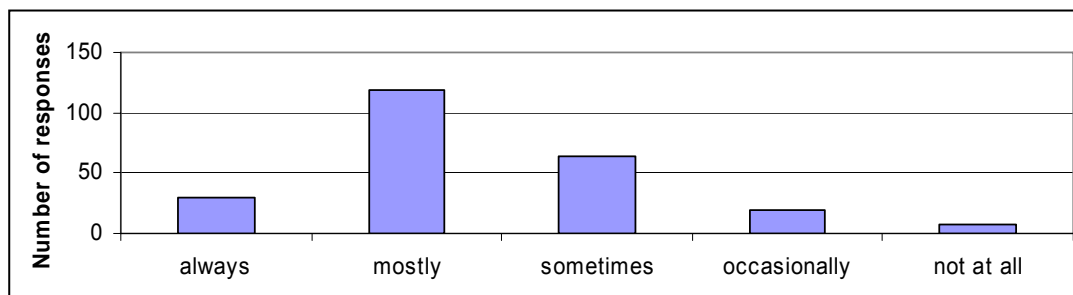


Figure 5 Students without clickers (n=239) response to the question “Overall, do you think that lecturers responded appropriately to the group's understanding of lecture material if many students answered the question incorrectly”

Q7. Would you prefer to have a clicker to indicate your answer than to hold your hands up?

Non-clicker group: 65% said yes (n=252)

N

Q8. Has your experience in first year Biology made you decide to take more biology topics?

15% of all Students responded no

85% of all Students responded yes (total n=420)

SET results

University approved Student Evaluation of Teaching (SET) questionnaires were also used to determine if there had been a shift in student attitude towards the course due to the change in delivery style. Table 1 shows the results of this SET evaluation for 2006, the year in which clickers and questions were used as compared to 2005 in which no clickers or questions were incorporated into lectures. A clear difference in mean student responses is shown from 2005 to 2006 and the standard deviations were consistently smaller, showing more conformity in the responses. The SET questionnaire utilises a 7-point Likert scale for students to indicate their attitudes with 7 being the most positive response.

Table 1: Comparison of Student Evaluation of Teaching for 2005 and 2006

SET Question	2005 mean student response \pm Standard deviation (n = 139)	2006 mean student response \pm S.D. (n =184)
Activities within the topic provided relevant learning experiences	5.1 (\pm 1.3)	6.3 (\pm 0.8)
I understood the concepts presented in this topic	4.9 (\pm 1.3)	5.8 (\pm 0.9)
The topic content was presented at an appropriate pace	4.8 (\pm 1.5)	5.8 (\pm 1.1)
The topic was presented at an appropriate level of difficulty	5.0 (\pm 1.4)	5.8 (\pm 1.0)
The teaching materials and resources were helpful in directing my learning	5.0 (\pm 1.5)	6.1 (\pm 0.9)
This topic helped me develop my thinking skills	4.7 (\pm 1.3)	5.9 (\pm 1.0)
I received useful feedback on my learning	4.4 (\pm 1.6)	5.6 (\pm 1.2)
Overall I was satisfied with the quality of this topic	4.9 (\pm 1.4)	6.3 (\pm 0.8)

Attendance

Clickers did not increase attendance rate at the 09:00 session as students continued to prefer the 13:00 session by a ratio of 2.25:1.

Qualitative Survey Analysis

Students' responses to an open-ended comment section of the survey were reduced to a series of quotes covering individual concepts. Four main themes arose from the comments, which are listed below:

1. The anonymity of clickers was important
2. No peer-pressure when using clickers compared to hand-raising
3. Students do not give honest answers when they can see what others are answering
4. Clickers are more fun to use

Lecturer response

The availability of clickers made a substantial difference on whether lecturers would choose to embed questions in their lectures. When clickers were strictly introduced and their usage by teaching staff actively promoted, 100% of lecturers utilised the technology and asked questions, with only one lecturer choosing to use clickers for only part (50%) of the time (Table 2). However, in the elective course where clickers were optional, but lecturers were expressly encouraged to introduce questions into their lectures, only 1 in 9 lecturers

embedded questions within lectures and only 2 questions were asked. All 8 other lecturers presented standard, monologue style lectures with no questions embedded.

Table 2: Use of embedded questions by lecturers teaching different courses

	Course 1: clickers	Course 2: without clickers
No. of lecturers	6	9
No. who used questions during lecture	6	1
No. who did not use questions during lectures	0	8

Discussion

The similarity in student exam grades between the clicker and hand-raising groups in 2006, combined with the better exam results in 2006 compared to 2005, shows that embedding questions in lectures on its own has a significant positive impact on student learning. Interestingly however, no difference was found between the exam grades of students who used a clicker and those who raised their hands to answer questions. This might not be reflective of what actually would occur under non-controlled conditions. Since lecturers were trying to keep lecture content the same, complete explanations of questions were made no matter how many students responded to the correct answer, thus producing little difference between the two groups. The results for students' response to questions in the lecture both highlights the importance of the 'anonymity' offered by the clicker system, and provides clear evidence for how clickers may enhance learning because a higher proportion of students responded to questions if they were able to remain anonymous in their answers. The lecturer thereby, gains a more accurate perception of the students' understanding of the course material and consequently, would clarify incorrect answers if required. This instantaneous 'snap shot' of class understanding may be misinterpreted in the 'hands-up' lecture, as indicated by the larger number of students who answer questions correctly with this method. Students commented that they would often follow the lead of other students who seemed to 'know' the answer to the question. Interestingly, this observed 'sheep effect', whereby students followed their brighter/braver classmates by raising their hands to the correct or even the majority answer, may in turn negatively effect the understanding of these students. Ultimately, the consequence of implementing questions without clickers could mislead lecturers into overestimating class understanding so they move through course material faster, thereby disadvantaging students other than the high achievers.

Lecturers were very disinclined to adopt this new teaching pedagogy unless the technology was available. Although one of the five lecturers was somewhat hesitant and did not use questions in all of her lectures, all lecturers made an attempt and most embedded the appropriate number of questions and used the technology as they had been instructed. Conversely, only one of nine lecturers who were asked in the same way to embed questions within non-clicker lectures did so, even though three of the lecturers were using clickers in the course which had them and were consequently aware of the benefits.

This is the first demonstration that quantitatively illustrates the effectiveness of the pedagogical change that comes about whilst using clickers, and also shows how difficult the change in pedagogy is to implement by lecturers unless a tool is incorporated. Mazur (in: Associated Press 2005) who is a strong proponent of using clickers in lectures, suggests that they are not essential, only helpful for the “shyer” student. Our data refutes this and indicates how important clickers are for accurately interpreting feedback from students as well as being essential for a pedagogical change resulting in a more productive learning environment. The greatest advantage of the clickers is their anonymity which encourages all students to attempt an answer thus allowing lecturers to receive honest, fast feedback on the level of student understanding giving them the opportunity to adjust content accordingly. The histograms and request for quick responses makes using clickers seem a competitive fun game with no chance of looking foolish, which is of course the best environment for adventurous learning.

Student satisfaction survey results of lectures that had embedded questions ranked consistently higher than lectures without questions, as shown by the SET results. In addition, students indicated that lecturers performed better when they used questions embedded in their lectures identifying the value students attach to communication or a perceived communication with the lecturer. It is clear from the comparison of student comments and the standard deviations of the data indicate a high level of agreement amongst the students in 2006, clearly providing strong evidence that they preferred the teaching in 2006 over that of 2005. The change in pedagogy combined with the advantages gained by using a clicker in large first year courses, not only increases student understanding of difficult concepts, but is also a highly valuable asset to help deal with transition to university.

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