TEACHING DATA ANALYSIS IN LARGE CLASSES USING CLICKER ASSESSMENT

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A search of the statistical education literature on "engagement", "active learning" and similar terms yields multiple papers. A common thread of these papers is getting students involved in the "process of statistics" by getting them to design observational studies, experiments and survey instruments, and to collect data in class, to bring to class or for use in small-group projects. The idea underlying these activities appears to be that if students are involved in the process of statistics they will better learn and understand the subject. Since 2011, I have been experimenting with clickers in large second and third year classes in data analysis. When clickers are used for in-class assessment, I have found that attendance, performance, enjoyment and student evaluations all show positive improvements. In this paper I look at some qualitative and quantitative results of various clicker models.

INTRODUCTION

Since the beginning of 2011, I have been experimenting with the use of student response systems (clickers) in large classes (100 students plus). Student response systems allow students to answer questions in class anonymously using small hand-held devices. Their answers can be recorded and stored electronically. The initial decision to try clickers was to address issues that had emerged in our 2nd year course in data analysis. The success with that initial trial led to the introduction of clickers into my 3rd year course in applied time series the following semester.

After a brief overview of some relevant literature on statistics education, I examine the issues that had emerged and the hope that clickers could address at least some of those issues. A brief discussion of the advantages of using clickers follows. The different styles of clicker questions, the different clicker assessment models that have been tried, their success or lack of it and some of the quantitative and qualitative results obtained are then presented. A discussion of why clicker assessment improves attendance, engagement in lectures, learning, performance and student evaluations follows.

I conclude that clicker assessment can create a *large class learning environment* that mirrors the style and success of the *Socratic Method* – question, answer, question, answer. This is achieved by using clicker technology to overcome modern peer pressure issues (Calverley, 2012) and get the students *engaged in thinking and learning* in every single lecture.

STATISTICS EDUCATION LITERATURE

If you search the literature using terms like engagement (Thompson, 2009), active learning (Larsen, 2006, Calverley, 2012) and similar themes (e.g. Smith, 1998), the papers that appear have a common thread: they promote the idea of getting our students *engaged* to help overcome statistics poor reputation as a subject and the resulting anxiety and/or fear of the subject this has created (Neumann, Hood & Neumann, 2009, Mvududu, 2003).

The types of *engagement* that are promoted include getting the students to design observational studies, experiments and survey instruments, to collect data in class or to bring to class for illustrative examples and exercises and to do small-group projects (Forster & MacGillivray, 2010). These activities engage the students in the *process of statistics*. Getting students involved in this way helps them understand the process, but how much does it help them to learn, or even better, to understand? There is some support that engaging students in the process does not necessarily improve student performance (Pfaff & Weinberg, 2009). Other threads in the literature encourage the use of real data and, where possible, the use of data that is relevant or interesting to the students themselves (Hall & Rowell, 2008). Group projects can bring these threads together and assist students to learn and understand (Forster & MacGillivray, 2010).

PROBLEMS AND CONCERNS

Early last decade our 2nd year course in data analysis underwent a substantial revision. The major aim was to incorporate fully worked case studies into the course. The second thread was developing students' communication skills in report writing using a set of Technical Notes and an Executive Summary (Forster, Smith & Wild, 2005). The assessment largely focused on the student's ability to write these reports (Forster & Smith, 2007).

My fear was that our students would regard the case studies as *templates to imitate* rather than focus on the *process* of data analysis with the data driving the analysis. With large classes, we had no viable way of assessing the students' abilities in the very important analysis phase securely. My final concern was poor lecture attendance, a concern shared by others (Greer & Heaney, 2004, Titman & Lancaster, 2011).

STUDENT RESPONSE SYSTEMS (CLICKERS)

Clickers allow lectures to become an interactive activity rather than a passive one (Calverley, 2012, Titman & Lancaster, 2011, Kaplan, 2011). With clicker assessment the students remain alert, listening to what is said so they can answer the next clicker question. Many even read ahead so they are aware of the clicker questions they are to be asked in the next lecture. Reading ahead is something we have been actively promoting for a number of years without success.

The major benefits for the students are twofold: instant feedback in every lecture on their level of understanding (Caldwell, 2007, Garfield, 1994) and actively participating as they know their individual responses are anonymous (Draper & Brown, 2004). They can also determine their relative position in the class; of interest to many of the better students.

For the lecturer the main benefits are also twofold: regular feedback on the students' overall level of understanding which facilitates identification of areas in the course and teaching that need revising or improving and, second, the most enjoyable lecturing experience I have ever had. To see the students *engaged in thinking and learning* in every class is incredibly rewarding.

CLICKER QUESTION STYLES

Some of the literature on clickers focuses on what is the right type or style of clicker question to use (Caldwell, 2007). My experience is that it is the use of clickers to make lectures interactive that is important. As long as the questions are relevant to the material being taught and the overall aims of the assessment, the detailed style and content of the questions seems to be of lesser importance.

There are two main question styles that I have used. The first involves questions around the content in the students' notes that either target concepts that should be revision (e.g. questions on 1st or 2nd year concepts in a 3rd year course) or questions that encourage the students to develop new ideas by asking a series of linked questions. These are *theory based questions*.

The second style, used in the 2nd year course, involves analyzing unseen data live on the computer. The scenario of the data is outlined first and then the entire analysis is driven by clicker questions: What do we do first? What type of plot should we do? What is the main feature of the plot? What do we do now? Which model should we fit? The idea here is to show the students that data analysis is a process you work through, not a case study that you imitate. In the 2nd year course, this activity makes up almost a third of the total lecture hours and more than doubles the number of data analyses they see during the semester. I call these *process based questions.*

To accommodate the unseen case studies, the detail from the students' notes was removed from the lecture slides. The time previously spent going through the complete case studies and reports in the notes was reduced. These are no longer analyzed live on the computer (Forster et al, 2005). This freed up sufficient time to do the unseen case study analyses live. This activity also allows us to assess the students' ability in going through the process of analyzing data on the computer, to some degree.

CLICKER MODELS, FINDINGS AND RESULTS

There is a multitude of ways that clickers can be used in data analysis classes. These include questions to motivate small group discussions (Bruff, 2010), to enable the use of contingent

teaching methods (Stewart & Stewart, 2013), for in-class tests or quizzes (Horowitz, 2006) and as part of the overall course assessment. I have used different models in large 2nd and 3rd year classes:

Model 1: Clicker Questions on Lecture Slides

My initial clicker trials in both the 2nd year data analysis course and my 3rd year applied time series course in 2011 involved having clicker questions on the lecture slides only. Many of the answers to these questions were already in the student's notes (see Model 2 below). There was no clicker assessment.

This model produced mixed results (see Table 1). The better students, who always seem to attend lectures, appeared to get the greatest benefit. Making comparisons to previous years is pointless for the 3rd year course as the content of the course was increased and heavily revised for 2010 and again for 2012 when the clicker questions were incorporated into the notes.

Table 1. Model 1 Results

Year	Course	Attendance (average %)	Pass Rate (%)	A-Rate (%)
2005 - 10	2nd Year	< 50	79	30
2011	2nd Year	70	85	41
2010	3rd Year	< 50	70	16
2011	3rd Year	< 50	70	27

Model 2: Clicker Questions on Lecture Slides and Included in the Course Notes

I immediately found that clickers were an incredibly useful teaching tool, so I revised the students' notes for both courses to include the clicker questions for 2012. The sections in the notes that answered the clicker questions (e.g. a description of the main features in a plot) were removed and replaced with the questions themselves in a consistent style with the question in a text box with room for the students to write answers and brief notes. The answer options for multiple-choice questions are not included in the notes. This enables students who read ahead to see what was to be asked but not necessarily be able to choose an answer beforehand. Some questions (e.g. Is there any evidence against the null hypothesis?) are common and the students would get to know what the standard options are. A Yes/No or True/False question would also be easy to pre-answer.

This model used in the 2nd year course increased lecture attendance slightly and the performance of the better students showed some improvement. The study by Calverley (2012) suggested those who did not use clickers would have needed credit to make them use them.

Model 3: Voluntary Assessment using Model 2 Set-up

In the 2nd semester of 2013, a colleague and I tried a voluntary clicker assessment option in the 2nd year course. The students who handed in the 4 written assignments on time could have their worst 2 assignment scores (5% each) replaced by their clicker score (10%), if it improved their overall grade. The first 2 weeks of classes were a trial period that did not count in the clicker assessment. The best 15 clicker scores from the remaining 30 lectures make up 5% with lecture attendance making up the other 5%. Attendance showed no real improvement after the third week of semester, but the performance of the better students improved.

Model 4: Compulsory Assessment using Model 2 Set-up

In the summer semester of 2013 (2nd year data analysis) and in the first semester of both 2012 and 2013 (3rd year applied time series) I had a compulsory clicker assessment component of 10% of the students' final grade. The 10% clicker assessment set-up was as described in Model 3 above.

In the data analysis course, apart from the clicker assessment component, everything else was as close as possible to business as usual. Our summer classes usually have slightly better students than the main semesters with pass rates and A-rates 6 - 7% higher over the years 2005 – 10. (See: Table 1) In 2010 I taught the summer class. In 2013, the course content and the order of the material was the same as in 2010 and I used the same assessment bank. The only real

identifiable difference between the two years was the 10% clicker assessment component. The pass rates and A-rates for the 2nd year course had been remarkably stable over time, even showing a seasonal pattern across the three semesters in which it is taught.

Table 2. Model 4 Results

Year	Course	Attendance (average %)	Pass Rate (%)	A-Rate (%)
2005 - 10	2nd Year	< 50	79	30
2010	2nd Year	< 50	80	35
2013	2nd Year	80	91	51
2011	3rd Year	< 50	70	27
2012	3rd Year	84	85	43
2013	3rd Year	81	92	63

The most surprising finding when using the compulsory assessment model was the incredible reduction in the number of student queries. Normally, on the day prior to the examination for applied time series there is a constant stream of students coming to my office, multiple emails and postings on the discussion forum. In 2013 there were 132 students enrolled but only 5 of the 131 students who sat the final examination visited my office, 3 emails arrived and there were no forum postings. While I have no hard data for previous years, this reduction implies the students not only know the material but are confident they understand it (Hubbard, 1997).

Some Student Views and Comments

Around 80% of the positive open comments made on the student evaluations of the lecturing and courses in which I have used compulsory clicker assessment concern clickers in some way. Clickers seldom appear in the negative open comments section of the questionnaire. Some student comments from evaluations and emails include:

- Making sure we came to class was great because i feel i understood time series so much better than my other stage 3 stats paper i am currently doing
- They are the best and most enjoyable lectures that I have had during my 3 years of undergraduate study, thank-you
- I find your teaching style very engaging and you make classes really interesting, which, in turn, is making the classes really enjoyable
- Using clickers meant that I not only showed up to every lecture, but was engaged the whole time and actually enjoyed myself
- I hope you and your clickers can help more students to get excited about Stats
- Thank you for an engaging and interesting semester.

In-class Questionnaire

A clicker questionnaire was administered to the 2nd year data analysis course in summer 2013. For the 6 point scale questions: 1 = low rating … 6 = high rating.

Table 3. Questionnaire Results

Question	Scale	Mean	Median
Clickers helped me to learn how to analyze data	6 point	5.25	6
Clickers helped me to enjoy learning how to analyze data	6 point	4.85	5
Clickers helped me to become engaged in class	6 point	5.56	6
Clickers helped me feel confident in my ability to analyze data	6 point	4.70	5
I found clickers: not useful ….. very useful	4 point	3.60	4
My exam performance will be: worse, same, better than usual	3 point	2.65	3

In response to a question on whether they felt clicker assessment was a good idea, 95% agreed that it was. When asked if they would have attended lectures if there had not been clicker assessment, 61% agreed that they probably *would not have attended*. This would have resulted in the level of lecture attendance I had unfortunately become accustomed to.

What did the students find good about using clickers (choose one option): instant feedback (44%), identify areas that were not understood (45%), easy marks (11%) and nothing good (0%).

What did they find bad about using clickers (choose one option): technology problems (49%), having to come to class (33%), nothing bad (18%) and clickers did not help (0%).

The distribution of the responses was very similar in the 3rd year classes.

CONCLUSIONS

First, the key to the success achieved with clickers is primarily, I believe, getting the students into class. Using 10% clicker assessment gets the students into class as very few students are prepared to forgo that percentage of their assessment.

Second, once you have the students in class, you have to get them *engaged* and you want them to be *engaged in thinking and learning*. When the class has clicker questions which count for assessment, this *engagement* is exactly what happens. The students are alert, listening to what is said so they can answer the next question. If a question is done badly, there is some chatter initially, but as soon as you begin to explain the correct/incorrect options for that question, the class goes quiet with heads down taking notes. The feedback they get after every question makes them aware of the areas they do not understand and directs their study efforts accordingly. At the end of a semester, the students are not studying the material afresh, they are just revising what they already know and largely understand.

The initial hope was that clicker assessment would lift the bottom end but it lifted the whole distribution. An added bonus is that they appear to enjoy statistics! After all, we enjoy what we are good at and we often become good at what we enjoy.

One aspect that initially puzzled me was the continuing improvement in the performance in the 3rd year course over all 3 years of clicker use. In 2011, although there was no formal assessment, I got far more insight than ever before into where the teaching was not getting through. As a result, the course structure was modified when the notes were revised to include the clicker questions for 2012. Some additional complementary material was added and a separate chapter called *Time Series Preliminaries* was inserted at the beginning of the course. The positive effect of these changes, suggested by the feedback from 2011, was evident in the improved performance. In 2012, the feedback suggested that some aspects of the way I was talking about things in class could have been creating confusion so my explanations were modified in 2013. Again, the students showed improvement in these areas. The clicker questions were done better and the performance in the final examination and their overall grades improved further. The content for 2013 remained unchanged from 2012.

Essentially, my students come to class and are given an *intellectual workout* for 50 minutes. Particularly with the unseen case studies in the 2nd year course, the teaching style mirrors the Socratic Method with the addition of modern technology so that it works in a large class setting without modern peer pressure issues (Titman & Lancaster, 2011). It is a teaching method that nurtured the intellect of Plato, and then Aristotle.

The major concern with clickers and assessment is technology problems. Clickers can be fickle. Lecture theatres with an inbuilt clicker system would overcome most of the technological issues.

The initial design or revision of a course to include clicker questions is considerable work. Developing sufficient unseen data analyses for the 2nd year course to be able to rotate them semester to semester will require considerable effort in the future.

The kind of *intellectual workout* my students experience is a significant workout for the lecturer as well. To keep the students engaged, the pace needs to be kept up. Surprisingly the comment "Slow down" that I used to get on evaluations has completely disappeared.

Using clickers for assessment, especially when running analyses live, requires a reasonable level of multi-tasking ability. Not everyone will feel comfortable doing the kind of lecturing discussed here.

Our students can enjoy statistics. Not only can they enjoy it, they can master it. If you offer the right carrot, you do not even need the stick. All you need to do is get the students into class and *engaged in thinking and learning*. Compulsory clicker assessment, at a suitable course percentage, is a vehicle that can achieve this.

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