Title:
STATISTICS CLICKS: USING CLICKERS IN INTRODUCTORY STATISTICS COURSES

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ABSTRACT

The use of handheld classroom response systems (often referred to as “clickers”) within two introductory Statistics courses at the University of British Columbia is discussed. Teaching introductory Statistics courses, particularly to non-specialist students in service courses, presents challenges to both the teacher and the students. Described here are ways in which the use of clickers can aid student learning and engagement, and as a helpful bi-product enlighten the instructor to sources of student difficulties. Some suggestions are made as to how to make effective use of clickers when teaching Statistics.

INTRODUCTION

Handheld devices by which students can respond in class to instructor promptings have various synonyms, including "classroom response systems (CRS)", "audience response systems (ARS)", "classroom communication systems", "personalized response systems (PRS)" and "electronic voting systems (EVS)", but we adopt the colloquial "clickers" here. The most common application of clickers in undergraduate teaching is when each student submits their answer to a question posed by the instructor, this being pseudo-anonymous in that although each answer is recorded by software on the instructor's computer, students' individual responses are hidden from their peers. Once responses have been polled the instructor can opt to display a bar chart indicating the distribution of responses. The use of such technology in university instruction is far from new, at least within certain branches of Science (see for instance, Mazur 1997, for a description of clicker use in Physics courses), but the implementation of clickers in Statistics courses - and more generally in the mathematical sciences - is less than widespread. Chance *et al*. (2007) review the use of technology in Statistics education, with clickers conspicuous by their absence.

There is now a substantial amount of literature on using clickers within the classroom for undergraduate teaching. Aside from articles discussing the practicalities of implementing response systems, there is a growing body of work on the effectiveness of clickers and suggestions for good practice. See, for example, Caldwell (2007) and Simpson and Oliver (2007) for recent surveys of the “clickers literature”. As with any technology, clickers are a tool that can be used poorly, so although not all the research points to conclusive evidence that clickers usage improves student learning, the perception at least within the "clickers community" is that if used effectively clickers can promote not only student engagement in class but also their appreciation and retention of concepts. There is scant literature on the use of clickers in Statistics courses (Wit 2003 appears to be the only readily available published study), this perhaps being driven by a notion - often held by learners if not instructors - that Statistics is a formula-based and technique-oriented discipline that does not lend itself readily to concept-based questioning well-suited to clickers use.

In what follows we discuss the use of clickers in two very different introductory Statistics courses at the University of British Columbia (UBC). The implementation of clickers in the Department of Statistics at UBC was in part prompted by the instigation of the Carl Wieman Science Education

Initiative at UBC (see www.cwsei.ubc.ca for more details), and commenced in Fall 2007 when the department used clickers in our course STAT 200: Elementary Statistics for Applications. The use of clickers in that course continues, and clickers were also adopted in 2009 in STAT 100: Statistical Thinking, a non-traditional first course in statistical science. We describe the impact and apparent effectiveness of clickers within these courses, highlighting perceived advantages of adopting clickers in statistical education.

THE IMPLEMENTATION OF CLICKERS IN STATISTICS TEACHING AT UBC

The course STAT 200 enrols about 800 students per year, nearly all from the Science Faculty at UBC, and the course is a somewhat generic introduction to the discipline. At present, six sections of the course are offered each year. Courses akin to UBC's STAT 200 are prevalent worldwide, often perceived as so-called "service" courses; such courses tend to differ materially only in the level of mathematical sophistication expected, and topics such as exploratory data analysis, correlation, elementary sampling theory, simple probability, regression, classical inference (including inference for the mean and proportions) and ANOVA are routinely covered in such courses. There is ample literature suggesting learners find many of the concepts included in introductory Statistics courses difficult to grasp. For instance, delMas *et al*. (2007) illustrate that student comprehension of confidence intervals and hypothesis tests are poor subsequent to taking a traditional introductory course in Statistics. In part motivated by some dissatisfaction with the teaching and learning experiences in STAT 200, the Department of Statistics at UBC opted to implement clickers in all sections of the course from Fall 2007. Students were informed in advance of the requirement to purchase a clicker, and that their clicker responses subsequent to the first few classes were to count toward their final grade. At the time of writing, six different instructors have used clickers in teaching STAT 200, with section sizes averaging about 125 students.

In 2008 the Department of Statistics at UBC offered STAT 100: Statistical Thinking, for the first time. This quite novel introductory course does not attempt to cover the concepts typically encountered in a traditional first course in the subject (like STAT 200), but aims to provide a stimulating and accessible introduction to the statistical sciences, promote statistical literacy and to show applications of Statistics in modern research and society in general. As such, the course has little in the way of core content, and in no sense attempts to replace a more formal, traditional introduction to the subject. The course is modular, incorporating six modules on each run, two being core (one on statistical literacy, the other on rudimentary probability), the remainder being determined by the interests of the available faculty. Modules have been offered on detecting abnormalities, Statistics in Health Sciences Research, genetics and genomics, statistical analysis with incomplete data and the design and analysis of clinical trials, for instance. The first offering of the course attracted about forty mostly Arts students, and the teaching team of five instructors - after the course, and being somewhat unhappy with the level of student engagement within the lectures - unanimously voted to trial the use of clickers in STAT 100 in the following year.

It should be noted that the experiences that are described here incorporate the use of two different clickers systems. Initially UBC opted to support Interwrite PRS, a relatively sophisticated system with numerous features though arguably a steep learning curve for an instructor using it for the first time. This perceived lack of user-friendliness prompted the university to move in 2008 to iClickers, a simpler and cheaper system. There are at least three other systems in use in North

America, so it would be unfair to critique the two used at UBC. It suffices to note that both systems have their "pros and cons": PRS permits students to enter data other than a single letter response (A to E) to multiple choice question. This has pedagogic value in teaching Statistics, and use was made of this feature in STAT 200 in 2007/08 with data collecting activities in-class (for example, students were requested to measure their hand and foot lengths, leading to interesting analyses of bivariate data). Some instructors found PRS difficult to use, however, whereas iClickers is easier to learn although offers limited features: student responses are restricted to one of the five letters A to E, for instance. Other than the cost, there was no obvious difference to the students between the two systems. See Burnstein and Lederman (2003) for a survey of systems available in 2003.

EXPERIENCES OF USING CLICKERS IN INTRODUCTORY STATISTICS COURSES

Certain features of using clickers in undergraduate instruction are reported repeatedly in the literature, in particular improvements in student attendance and engagement. Such aspects seem independent of how clickers are used. The mode of implementation in STAT 100/200 is closest to that described by Mazur (1997), mini-lectures followed short conceptual questions, and although his suggestion of peers convincing each other of the correctness of their answers was rarely adopted, it was usual to allow for peer discussion during and after the time students contemplated their recorded responses. Some educators advocate what they consider a more effective use of the technology, wherein each class is "question-driven" by a cycle of clickers questions, with mini-lectures interjected only occasionally (see Beatty *et al*., 2006). Beatty and Gerace (2009) advance a formal pedagogy for clickers usage.

We review here some of the perceived gains from the adoption of clickers in STAT 100/200 at UBC.

Improved attendance and engagement

There is irrefutable evidence that a small incentive (of as little as 2 or 3% of the final grade) was sufficient to increase student attendance appreciably. Instructors tended to report a 20-30% increase in lecture attendance after the first couple of weeks when using clickers compared to without, although the effect was not uniform and possibly depended on the time of the class and whether the lecturer tended to post lecture notes on-line which students could read without attending the lecture. In STAT 200, for instance, it had been common to observe as little as around 50% attendance at traditional lectures, but this was bolstered to around 75% when clickers were adopted. Similar increases were reported in STAT 100.

The level of student engagement is difficult to quantify, but all instructors reported a perceived increase when using clickers. Student interaction with the instructor clearly rose, particularly on occasions when most students had responded incorrectly to a question. Students at UBC are often quite reticent to admit that they do not understand something, perhaps fearing ridicule from their peers, but once enlightened by the knowledge that most of the class had misunderstood an idea the students would often be vocal and persistent in their desire to address their misconception. A notable example occurred with the following question:

Q: We take a sample of size 12 from a population, and compute the sample variance s^2. If you take a sample of size 120 you would expect the sample variance to be
(a) Smaller
(b) Larger
(c) Neither smaller nor larger.
This question was prompted by attempts on a midterm question hinting that students were under the misconception that the sample variance would be expected to shrink as the sample size increases. Sure enough, over 90% responded (a). The resulting discussion was lively and lengthy, and informative to both student and instructor. It transpired that many students were confusing the question with the behaviour of the standard deviation of the sample mean (which does decrease as the sample size n grows) and (the author as) the instructor had presumed that would be at the heart of the confusion. Unforeseen however was that some students responded (a) by reasoning that since the formula for s^2 has n-1 on the denominator, it must therefore decrease as n increases. In this instance most of the lecture was taken up with the discussion, a rather extreme (if welcome) contrast to the passive "learning" environment experienced pre-clickers.

A common occurrence was that students were most attentive following a clickers question where many had responded incorrectly. Good practice seems to be to discuss incorrect answers in an attempt to dispel confusions, perhaps asking for a volunteer to defend their faulty reasoning. Freed by the knowledge that others had made the same mistake, surprisingly many students were prepared to put forward to the class why they had reasoned as they had, even knowing their answer was wrong. As Wit (2003, p.16) remarks "... the psychological investment in that answer turns the student from a passive attendee to an active participant for whom the outcome has some emotional value."

Timely feedback
Too often in teaching Statistics courses do instructors become aware that students only seriously attempt to grasp the material close to midterm tests and the final examination. In some sense both parties - instructor and students - will buy in to the myth that students are appreciating the material being presented in the lectures, as without this premise a traditional lecture is patently worthless. The feedback that clickers questions can provide is two-way. On the one hand the students' understanding is challenged immediately, in real-time. Should they be repeatedly responding incorrectly to questions posed they are at least alerted to the fact, even if they are not motivated to being proactive in addressing the problem. Arguably more powerful is the impact on the lecturer: for example, having given what he believed to be a crystal-clear explanation of the concept of fitting a line by least squares, the author posed the following question:
Q: The least squares regression line is the line that makes the sum of the vertical distances from the line as small as possible. True or false?
Dismaying if illuminating was that the class split nearly evenly between the two responses, as if merely guessing. When confronted with evidence that contradicts the notion that most students have fully grasped a succinctly-explained concept, the instructor has little choice but to revisit the topic. The students are then particularly receptive to hearing the explanation that they had heard previously but not fully appreciated. This may imply that less material is covered in a lecture when clickers are used, but surely that is preferable to skimming over content during a class that few students attending are processing meaningfully.

Repeated revisits to difficult concepts

In recent years there has risen an awareness in the Statistics education community that many of the concepts traditionally taught in a first course in Statistics are very elusive to students. Ideas behind statistical inference seem particularly difficult for first-time learners with, for instance, the notion of sampling distributions being a pivotal, "gateway" concept without which the theory of interval estimation and hypothesis testing is meaningless. Chance *et al*. (2004), for example, review how resistant students are to grasping the concept of sampling distributions even when software tools are used to supplement the instruction. Recent research by the author and colleagues at UBC indicate that most students misunderstand the term "parameter" as it is used in a Statistics course, leading to unending confusion in the students' minds.

An obvious benefit of using clickers is that questions can be posed repeatedly on the same concept. Similar, "isomorphic" questions can be presented to the students in the hope that intermittently challenging a misconception can reduce the possibility of the misunderstanding being retained and so opening the door to understanding. Alerted to the fact that many students were confused over the use of the term "parameter" in STAT 200, numerous questions akin to the following were presented during a sequence of lectures:

Q. The label on Olliberry jam jars lists a mean content weight of 269 grams. A sample of 100 jars was selected from the main factory and weighed. The content weights averaged 264 grams. We will test to determine if the Olliberry jam jar label correctly identifies mean content weight. What is the parameter of interest?

(a) 269 grams

(b) 264 grams

(c) The mean weight of all Olliberry jam jars from the main factory.

(d) Whether or not Olliberry jam jars are underweight.

Two-thirds of one section responding to the above answered (c) correctly, with over a fifth entering (a). Improvement on this style of question can be monitored during a sequence of lectures, although the movement observed in STAT 200 is less positive than one might hope. An interesting facet of responses to such questions is that students appeared better able to identify a parameter when it was a proportion.

Continuous assessment

There is some evidence that frequent assessment within a Statistics course produces not only improved student learning but instils in the students a more positive attitude about the course (see Myers and Myers, 2007). In effect, use of clickers in-class provides a means of continuous assessment in a course. When responding to clickers questions students are, it is hoped, being "assessed" on their understanding of a concept, and the feedback from this assessment is instant.

A general consensus formed quickly within the teaching teams for both STAT 200 and STAT 100 that questions posed to the students in class should be concept-based, not focused on the use of formula or routine mathematical manipulation. Studies have uncovered that students can reproduce procedural aspects of applying statistical methodology despite having little appreciation of the fundamental concepts. Aware of this and its implications for the assessment of STAT 200, there was a move away from requesting students to carry out what are in effect routine calculations on the assessments for the course, and a move towards questions that probed their understanding of

concepts. Such questions had been given on tests before clickers were introduced in the course, but in part since the students had had little experience of answering such questions they often performed very poorly compared to their responses on more procedural tasks. By responding to concept-based questions during the lectures students become more attuned to the fact that their appreciation of the concepts is integral to the assessment on the course, and in addition become more experienced in answering such questions. Asking these questions verbally in-class, without collecting responses via clickers, evidently lacks the power that the *en masse* participation via clickers can produce.

At the time of writing about half of the faculty in the Department of Statistics at UBC has experienced teaching using clickers, and although the feedback from these individuals has been almost entirely positive it would be remiss not to address here some of the perceived problems and difficulties. These are described below, along where appropriate with actions that can be taken to minimize their negative impact.

- *The increase in attendance due to clickers usage is perceived by some to be a double-edged sword.* While all welcome more students to their lectures, there is a fear that students who consider they are attending somewhat under duress will be disruptive or otherwise adversely impact the classes. One way around this is to permit students to "opt out" of the clickers assessment should they wish, though this option has not been offered in STAT 100/200. Probably better is to attempt to impress on students the value of the clickers questions to their learning, and well-thought out questions can reduce the chance that students perceive they are wasting their time in going to the classes. Important is to ensure that clickers questions appear from the first lecture onwards, and that the questions are challenging - too many questions early on in a course where most (say > 80%) get the correct answer could reinforce in a student's mind that the technology is merely a way of enforcing attendance.
- *"Cheating" - students can bring along multiple clickers, say those of their absent friends, and score points for assessment in their absence*. This is a real issue with a large class, since the instructor is too busy teaching and handling the technology to monitor whether any students are holding multiple clickers. We dealt with this in the following way: it was made clear to the students that both loaning their clicker to a peer or bringing another person's clicker for use in a class were considered academic offences. Some policing is required, inevitably, but as long as this was visible and effective it could be quite minimal. A colleague would enter the rear of lecture room close to the end of a class and ideally during the time when a question was being posed. Any student holding more than one clicker would have them all instantly confiscated, with an instruction to make an appointment to see the instructor, bringing along their absent friend(s). At the subsequent meeting the students would be warned, told that their clickers marks up to that point would be deleted, and instructed that the Faculty office would be informed should they re-offend. This measure proved to be an effective deterrent in STAT 200. In STAT 100, with a class size of only about fifty and a small classroom, it was easy enough for the instructor to police alone.
- *There is additional work for the instructor incurred in using clickers*. This is beyond dispute, since preparing the questions is time-consuming, and collating marks at the end may be far from trivial. It should be kept in mind however that creating questions is largely a one-off exercise, and help is at hand both online (see for instance

www.ou.edu/statsclickers) and via textbooks (many textbooks include instructor supplements with questions that can be modified for use with clickers). Time-consuming squabbles with students about missed classes or forgotten clickers can be prevented by ensuring that some "free" absences are permitted (up to three is a suggestion) and also by having the weighting toward the final grade being low. Anecdotal evidence seems to suggest that if the weighting on clickers responses exceeds 5% students may feel motivated to quibble about ambiguous questions and missed classes, but with a weighting as low as 3% we did not experience such disputes. Collating the marks at the end of the course can be a chore, particularly in a multi-instructor course (like STAT 100, where it appeared that each instructor had to download their marks from WebCT separately and pass them on to the course convenor to collate). Having hands-on help for such tasks within the department is invaluable, but as with most things, performing the task once makes future repeats far easier.

- *Clickers are better suited for some topics than others*. As with any tool, clickers better serve some situations than others. Certain concepts almost necessarily call for rather wordy questions, or questions based on scenarios that take some time to describe, and then arguably using multiple-choice based questions can seem artificial. This was noticeable, for example, in the "Statistical Literacy" module in STAT 100, in which students were expected to critique statistical information in the media, probing student competence via multiple choice questions lacked the potency that concept-based questions held in STAT 200. For instance, the following question (which related to a quote from the media), probably suggests the correct answer in the wording:
  Q. To find information about a population of 280 million, a sample of size 1554 is
  (a) worthless because it is too small.
  (b) worthless because it is too small a proportion of the target population.
  (c) useful if the sample was taken sensibly.
  (d) useful only if the sample was taken without replacement.
  A further observation of colleagues in STAT 100 was that each module took perhaps its first class to "get going", and asking sensible clickers questions before some context was in place was difficult. Perhaps this could be addressed by asking questions that attempt to probe for the students' preconceptions about the topic at hand (say, clinical trials), but probably this would be more effectively done via small-group discussions.
  Sometimes, particularly in upper-level Statistics courses, the instructor may well wish for students to work through some activities in class that involve calculations or derivations. Again, small-group work with instructor support would seem preferable in such instances to using clickers questions, at least when class sizes are manageable.
- *What about if the technology fails*? Some reticence was admitted by certain instructors about being tethered to teaching using technology that could malfunction and leave them having to re-think their class in real time. Thankfully we have experienced only very rare equipment failures, and these usually related to hardware problems that were independent of the use of clickers, like laptops and projectors failing. In short, both systems used seem quite robust to in-class collapse, although at times when using PRS there were delays with the system registering student responses. The likely next step is to systems that use student cell phones for submitting responses, obviating the need for the purchase of dedicated hand-held devices.

- *Some students don't like clickers*. It would be unrealistic to expect every student to embrace the use of clickers. Based on student feedback collected at the end of the courses, however, the student responses to clickers were broadly positive. This concurs with the findings of Wit (2003), who reported that of students attending a clickers-based tutorial in a Statistics service course at Glasgow University, 87% of students saw more benefits than disadvantages in the use of clickers. Inevitably some UBC students complained about the expense – and in very rare instances refused to buy a clicker on the grounds of cost – but where negative comments emerged they tended to focus either on clickers being used a means to force attendance, or bemoaning that lecture time was taken up with what they perceived to be redundant activities. Not all students appreciate novel teaching methodology, and experiences of colleagues at UBC suggest a small subset of students will resist any alternative to the traditional didactic lecture.

On balance, and despite any perceived misgivings, the use of clickers in our introductory Statistics courses has been a largely positive experience.

LESSONS LEARNED AND SUGGESTIONS

It is the belief of the author that the use of clickers can promote active learning and appreciably enhance student understanding within an introductory Statistics course. Summarized below are some of the main findings and suggestions stemming from the experiences of Statistics faculty at UBC.

1. If using clickers in a course, use them in every class from the first onward.
2. Award a small percentage of the final course grade to clickers responses, less than 5% being a suggestion. Half of this can be weighted on participation. Students should be permitted to have a few absences without it affecting their clicker grades.
3. Inform students at the start of the course that cheating with clickers is an academic offence. Police for cheating with infrequent but visible interventions.
4. Anticipate a greater level of attendance, and student interaction, than with traditional lectures.
5. Use questions that probe for understanding of concepts rather than procedural skills. Evidence suggests that students can become adept at procedures in applying statistical techniques while harbouring a shallow understanding of the principles.
6. Ask questions that target concepts that are well-known to be difficult for students, such as notions of sampling distribution, parameter, p-values, confidence intervals, the philosophy of hypothesis tests and common misconceptions in probability. Repeatedly probe student understanding with a sequence of similar questions on the same concept, spaced over several classes.
7. Encourage student debate when more than 25% (as a rule of thumb) have answered incorrectly. Try to entice out of students their faulty reasonings, and where possible be armed with explanations and examples to dispel these misconceptions.
8. Expect to be surprised by the sources of students' misunderstandings, but deal with these respectfully and with tact. An instructor should ideally be genuinely interested in knowing how students become confused when learning their discipline.
9. Do not be overly concerned with clickers taking time away from covering content and examples in the lectures. Be aware that the time spent on clicker questions and the ensuing discussions will likely enhance student understanding of gateway concepts, thus freeing

them to read material productively in their own time.

10. Do not be afraid to try some "just in time" pedagogy. It was found that when being told they would be asked a sequence of clickers questions relating to a case study posted on the web two days before a lecture, most students had looked at the material in advance.
11. With multiple choice questions, sometimes insert "distracter" responses that to an expert in the field would appear ridiculous.
12. Review the responses to clickers questions and note common incorrect answers. These can be used as a basis for exam questions, for instance, and to modify lecture content and course design.

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Many good ideas take a generation or more to take hold, even in the absence of well-founded objections. There is little dispute that active learning is necessary for a learner to meaningfully grasp and retain concepts. There is also evidence to suggest that lectures with minimal student interaction provide too passive an environment to appreciably aid the learning for most students. Teaching an introductory Statistics course is a challenge to an instructor, particularly to a group of non-specialist students who may be poorly motivated to mastering the material. Clickers, while not a "silver bullet", can make the experience within an introductory Statistics course more satisfying for instructor and students alike.

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