Using Clickers for Teaching Undergraduate Physics at the University of Queensland*

By Taras Plakhotnik, School of Physical Sciences, UQ

This deliberation is based on data collected when lecturing PHYS1002 course in the first Semester of 2007. Complementary information has been obtained in a survey conducted among the students taking the course. Some information has been obtained in private conversations with students taking PHYS2810 who had experienced the new technology during their studies at UQ.

Collected Data and the Model

Because a primary focus was on the use of the new technology (clickers) the results of the survey are grouped accordingly. Note that the students attending PHYS1002 in Semester 1 are mostly engineering students. It will be interesting to compare the results with the students attending the same course in Semester 2. These students will be mostly science students.

		Groups of students		
		Students possessing clickers	Students without clickers	Total
Possessing a text	New	20	18	38
	Second hand	5	5	10
	No	3	5	8
Percentage of students owing a text in each group and in total population		89%	82%	86%
Attending lectures	0-10%	1	4	5
	10-30%	1	5	6
	30-70%	7	8	15
	70-100%	20	11	31
Average attendance in each group and in total population		56%	38%	47%
Reading a text	Never (0.0)	2	9	11
	Seldom (0.1)	21	15	36
	Frequently (0.5)	4	4	8
	Always (0.7)	2	0	2
Average use of the text in each group and in total population		0.21	0.13	0.17
Hours spent studying physics (lectures and tutorial classes excluded)	Less than 1 hour	2	5	7
	1 to 2 hours	7	11	18
	2 to 4 hours	11	11	22
	4 to 7 hours	5	1	6
	More than 7 hours	4	0	4
Average hours in each group and in total population		2.8 h/week	1.3 h/week	2.1 h/week

* For an update on this project, go to http://www.physics.uq.edu.au/onp/ONP/Essays.html and click on the paper of interest

The survey covers 57 students out of total 74, which make 77% of the list number. The students are divided into two groups: students with clickers (total number is 29 or 51%) and without clickers (49%). If extrapolated to the whole class, the number of students with a clicker is about 39. This correlates well with the maximum number of responses to a single question ever obtained. The maximum number was 42 but the lecturer who asked that question believes that it was a technical glitch. The next biggest number was 32.

The Figure shows the average number of responses per question as the course progressed. No statistically significant changes are detected when the course changes its topic (from Electrodynamics to Optics and then to Relativity and Quantum Mechanics). The number of responses decays gradually.

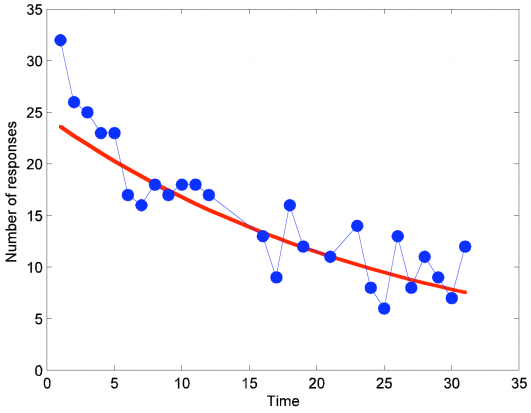

Figure. Decay of the number of responses per question with time. The data can be reasonably fitted with a function $N = 25 \cdot \exp(-t/9)$ if time t is measured in weeks. The number of responses is reduced by a factor of 2 approximately after every 6.2 weeks (half of the semester).

Table Analysis

1. There is no significant difference between the two groups of students regarding their ability/desire to buy a textbook. It seems that buying a copy of Tipler was not a difficult decision for most of the students. It is also plausible that $10 renting cost for a clicker was not an issue (the cost of the book is about 10 times larger than the rent).
2. On average (taking the lower bound for every interval) there should be 35 (47%) students present on every lecture (which looks like a reasonable estimate given the number of students actually present in the lecture theatre counted couple of times during the course).
   The average attendance for the students with clickers is 57%.
   The average attendance for the students without clickers is 37%.
3. There is a clearly higher attention to the textbook among the students possessing a clicker. If we assign 0 for never, 0.1 for seldom, 0.5 for frequently and 1 for always then the average text reading is 0.21 for the students with a clicker and 0.13 for students without a clicker.
4. On average, there were 15 responses per question. Given the average attendance of 57% for students with clickers and that 51% out of 74 students have a clicker; the expected average number of responses is 22. We conclude that about 70% of the students possessing a clicker and actually attending a lecture are keen to use the new technology.
5. The average maximum number of responses per lecture was 18. This means that on average 81% of the students possessing a clicker and attending a lecture have used the technology at least once during every lecture. This is a

good number (keep in mind that there could be students who left their clickers at home etc).

Model Considerations

It is interesting that the new technology had little if any effect on the number of students attending the lectures (although there was an unexplainable hope among the three lecturers teaching PHYS1002 that clickers will encourage the students to attend).

The origin of the exponential decay shown in Figure 1 can be explained in a model based on several assumptions. It seems to be reasonable to presuppose that if a student misses a lecture (either due to his/her physical absence or because he/she was not able to follow the lecture flow) then such a student does not return to the lecture theatre. Of course, there are always exceptions but apparently it will be increasingly more difficult to follow as the volume of misunderstood material mounts and a student quits when the volume reaches a critical value. We also assume that the number of students reaching the critical volume during every lecture is a constant percentage of the number of students present at the lecture. These two assumptions lead to the exponential decay observed experimentally. The experimental curve suggests that on average about 3% of the students attending a lecture reach their threshold level of coping with the course content and quit. The only way to stop the decay is to make the lectures compulsory (but this will not make the lectures useful for the students who have lost the thread). Given the diversity of the students it is probably not possible to find the learning curve suitable (but still interesting) for all of them. Another suggestion sounding most reasonable is to explain to the students that they should work harder at home and should use the textbook to study with the speed most suitable for them. In this case, the lectures will be heavily based on using clickers for identifying most difficult concepts, which can then be explained in the class. Given the current usage of the textbooks (see the table), the suggested approach seems to be unrealistic. But I believe that this could be changed if a substantial contribution to the final mark for the course will be derived from the performance of the students when answering the multiple-choice questions asked by the lecturer. Forcing the students to use the text this way will encourage their development as independent learners but provide rapid feedback on their progress.

An important issue when using this technology is the threshold of correct answers determining when understanding of a concept by an essential part of the class is achieved. It was suggested by some (the origin of this suggestion is probably Harvard University where active learning technology has been developed), that such a threshold should be set at the level of 70%-60% correct answers. In my opinion, even if all given responses are correct there is little hope that this was not achieved by a chance. Therefore a brief explanation given by the lecturer of why a particular answer is correct is absolutely necessary for every question.

Consider, for example, a multiple-choice conceptual question with a number of plausible answers. First of all, it is a very difficult if not possible to devise a large number of answers which all students without a clear understanding of the concept will consider equally probable. More likely, many students will identify two answers

to choose from and then press one of the two keys at random. And with 50% probability they will get it right. There will be some students having complete understanding and pressing the right key as well. There will be also students who decided not to participate in the quiz or who have forgotten to bring their clickers to the class. Taking 70% participation rate, which seems to be overoptimistic (see the discussion above), one can expect that 65% correct answers can be obtained even if only 30% of the participating students have made their choice consciously. An example below will clarify the reasoning.

Out of 100 students, 70 participated in the quiz, and 21 (30%) have understood the concept. 49 have made 50/50 guess and added 24 to the total of 45 correct answers. Under these assumptions, *TurningPoint* will report 65% correct hits.

Actually, a few students have reported negative past experiences with clickers because they have expected but have not received any explanation except for an indicated after the quiz correct answer. I think that this happened because the lecturer was groundlessly satisfied with 65% correct answers reported by the *TurningPoint*.

Because this technology has its origin in the United States, a comparison of the results achieved overseas to the UQ results is inevitable. However, one should be careful with any comparison especially when two countries are so different in size. The USA is roughly 15 times bigger than Australia (in terms of their populations). This means that we can have just one University on the average level of top 15 American Universities (this covers Harvard, MIT, Stanford, etc). The average level of our Group of Eight scales up to the average level of the top 120 American Universities. According to the raking of the top 500 world universities provided by the Institute of Higher Education, Shanghai Jiao Tong University, American number 120 is Kansas State University. UQ is ranked between 100 and 150 top world universities and could be certainly included in the list of top 100 American Universities but not in the top 50. All this is in a very good agreement with the simple statistical arguments listed above. In conclusion, one should be cautious when transferring technology developed in Harvard (an elite university of a big country) to other places. Training suitable and advisable for a professional football player may kill an unfit and overweight person.

Conclusions and Suggestions

The new technology will certainly not harm the ability of students to learn and as such can be safely used. However, it seems that significant improvement can be achieved only if the responsibility for learning will be more evenly distributed between students and lecturers. The home reading and self-studying should be made effectively compulsory (but not more compulsory than sitting the final exam or regular handing in tutorial problems). After all, ability for self-education and for absorbing new knowledge is probably the most important skill anyone expects from university graduates. The learning model may look as follows: Reading – Answering Test Questions Using Clickers – Explanation by the Lecturer – Answering Control Questions (clickers) and Participation in Tutorials. Just making attending lectures compulsory is not advisable in this context. The applicability of the active learning idea is worthy of further investigation. It is certainly true that any additional activity related to the subject will improve the learning outcome. However, one should not

underestimate the student's ability to learn by heart the correct answers to a limited number of multiple-choice questions. Concept questions are not easy to devise and it would be a lot of work to generate a completely new set every year. However, a sufficiently large bank of such questions can be collected over several years. One can also consider asking students to contribute to the concept questions databank (good new questions suggested by students can also generate premium contributions to their final marks). The quality of peer-to-peer instruction depends heavily on the average level of the students attending the class and therefore should be monitored.

You can lead a horse to water but you cannot force it to drink. This is probably all what I can tell (and suggest to remember) to the students who spend less than one hour per week studying physics outside classes.

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