Student perception of 'Clicker' technology in science and mathematics education

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We report on the results of integrating student response technology by Turning Point 2008©, simply referred to as clickers, into pre-service science and mathematics and education courses at the University of Southern Queensland (USQ), Australia. Many of the pre-service teachers have weak backgrounds in science and mathematics and lack confidence or interest in these subjects. This study investigated the use of clickers as a means of engaging students with science and mathematics classes and enhancing their learning outcomes. The effect of two different pedagogical uses of clickers on students' perceptions was also explored. In the science education classes, clickers were used as tool to identify prior knowledge and prompt discussion, whereas in the mathematics education classes, the clickers were used at the end of lectures to check that learning had occurred. Surveys were conducted in the science and mathematics classes using measures of students' perception of clickers and their contribution to overall learning. Although analyses of these data revealed positive student support for the use of clickers in enhancing student engagement and learning in both science and mathematics classes, students' responses in the science education classes were far more positive. Further, the impact of the approach used in science education on pre-service teachers' science teaching self-efficacy was evaluated. A pre-test and post-test in the science education class using the Science Teaching Efficacy Beliefs Instrument (STEBI) showed significant increases in science teaching self-efficacy, supporting the effectiveness of the pedagogical approach used in science.

Keywords: student response technology, science and mathematics education, student learning, pre-service primary teaching science self-efficacy beliefs

Introduction

There has been a serious decline in performance of Australian school students in international mathematics and science tests in the last twenty years (Masters, 2009; Stanley, 2009). A recent report (Masters, 2009) on Queensland primary schools has shown that the teaching of science forms a very small percentage of the enacted curriculum. When science is taught, the emphasis is on biological or environmental science and rarely on physical sciences. Negative attitudes by pre-service primary teachers to mathematics can manifest anxiety in their students (Vinson, 2001). Teachers with these views often demonstrate poor lesson planning and dilute mathematical content by focusing on non-mathematical related activities (Swetman, 1993).

This situation presents a challenge for Australian tertiary mathematics and science educators for a number of reasons. The majority of students enrolled in the pre-service primary education courses at the University of Southern Queensland (USQ) have not pursued science

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or advanced mathematics subjects (minimum requirement for STEM students at a first year tertiary level) in their final year of high school. Some of these pre-service primary teachers are disengaged or disinterested in mathematics and/or science, largely because of unsatisfactory experience of mathematics and science at primary school. The expectation of national and state curriculum authorities is that mathematics and science will be taught at all levels of compulsory education (K-10). In 2011, a new Australian National Curriculum will be implemented in all Australian states and this curriculum includes mathematics and science as one of four mandated subjects. To ensure that all new teachers are competent to deliver this imperative, the teacher registration authority on Queensland is introducing a competency test in mathematics and science content knowledge and pedagogical content knowledge (and also for literacy) that primary teaching graduates must pass before they can be registered to teach. These requirements mean that tertiary institutions delivering pre-service primary degrees are now under pressure to deliver graduates that are able demonstrate basic knowledge of science and mathematics content and pedagogy.

In response to the national and state expectations, the goal of USQ primary science and mathematics education courses is to engage students' with science and mathematics, improve their knowledge of basic content and build confidence in teaching these subjects. Building self-efficacy in mathematics and science teaching is an essential part of pre-service primary teacher education. Previous studies have shown that students learn more from teachers with higher self-efficacy that those with low self-efficacy (de Laat & Watters, 1995; Mulholland, Dorman, & Odgers, 2004). Foundation courses involving mathematics or science content alone do not appear to fully enhance pre-service teachers' teaching efficacy in these disciplines. However, mathematics and science education courses that integrate mathematics or science content and pedagogy (Moseley & Utley, 2006) and involve a range of learning experiences such as co-operative learning, experiential learning, lesson planning and practical experience in teaching, can be effective in increasing teachers' self-efficacy.

Using student response technology to engage students and enhance learning

Student response systems like clickers have the potential to be useful tools in supporting an interactive approach teacher education and thus contribute to student engagement, learning of content and teaching self efficacy (Duncan, 2006; Weerts, 2009). They provide students with the opportunity to test understanding, challenge thinking and provoke discussion. They allow all students to gain immediate feedback and compare their level of understanding in relation to the rest of the class with the added advantage of doing this anonymously and avoiding embarrassment.

Clickers are hand-held devices with an alpha-numeric keypad that are wirelessly connected to a USB radio receiver plugged into a central computer. As they require minimal technical knowledge and training, students find them easy to use. Turning Point software allows student responses to questions presented on power-point slides (multiple choice, true/false) to be recorded and immediately displayed as aggregate responses on charts (bar, histogram, pie). The lecturer can then choose to allow group discussion of the veracity of the aggregates responses before or after revealing the correct or best answer. Hoffman and Goodwin (Hoffmann, 2006) provide a review on the operation and uses of clickers.

Context for of the study- science education

The science education course chosen for this study was the second year course *Teaching Science for Understanding*, delivered in semester 1, 2010. A social constructivist approach was employed to deliver this course and clickers were used as a tool to promote cooperative learning in interactive workshop classes. The students were organised into groups. Prior to each session, students were required to undertake prior reading on science curriculum content and science pedagogy. At the beginning of each workshop, students were first asked to respond individually to a small number a multiple choice or true/false questions that tested their understanding of the pre-reading. The questions were devised to identify common science misconceptions that are held by primary school students and the wider community. An example is:

Plants absorb their food through their roots? True/False

Following the aggregate response of individual students to a question, the correct answer was not displayed. Students were then asked to negotiate a group response to the same question. They were encouraged to use evidence-based arguments with reference to the course readings to form a consensus answer. The agreed group response was then entered via the clickers, the aggregate responses shown and then the correct answers revealed.

If the group responses were mostly incorrect or split fairly evenly between correct/incorrect choices, the lecturer would then proceed to challenge and clarify student understanding through further explanation, class discussion or practical science activities. Alternatively, if most of groups provided the correct answer, the teacher moved on to the next question. Time was allowed at the close of the class for the small minority with incorrect response to seek individual assistance.

Expository approach – mathematics

The mathematics education course selected for this study was the fourth year mathematics course *Becoming Numerate*, taught in Semester 1, 2010. Students were expected to attend a traditional lecture theatre with no particular seating or grouping orientation. Prior to each session, students were advised to undertake prior reading on mathematics curriculum content and pedagogy but this was not mandatory. At the end of each lecture, students were asked to respond individually to a small number of multiple choice or true/false questions that tested their understanding of the lecture. An example of a typical question is:

Five divided by zero equals zero? True/False

Following the aggregate response of individual students to a question, the correct answer was then displayed. Students were then asked to discuss the overall outcome of the question and related reasoning. They were encouraged to use evidence-based arguments with reference to the lecture to form a logical argument. Once a consensus was reached by the entire class the next question was posed and the procedure repeated.

The research questions

The research questions underpinning this study were:

- Do students believe the use of clickers make a positive contribution to their engagement with learning?

- Does the type of teaching approach (constructivist or expository) influence students' response to clickers?
- Does a constructivist teaching approach, supported by the use of clickers, enhance pre-service primary teacher' science self-efficacy beliefs?

Methodology

The research questions were investigated using a quantitative approach. A survey was administered to thirty students in the *Teaching Science for Understanding* course and thirty students in the *Becoming Numerate* course at the conclusion both courses in semester 1, 2010. This survey consisted seven items developed by the authors to measure students' responses to the use of clickers. Each items was rated on a Likert-type five point scale, where 1 = strongly disagree and 5 = strongly agree.

A pre-test and post-test survey was conducted in the science education class in Semester 1, 2010 and comprised the Science Teaching Efficacy Belief Instrument (STEBI-B), first developed by Enochs (Enochs & Riggs, 1990) . The STEBI-B has been shown to be a valid and reliable measure of pre-service teachers 'science self-efficacy beliefs (Bleicher, 2004; Enochs & Riggs, 1990). It has been used in numerous studies to determine the effectiveness of pre-service science education courses in changing efficacy beliefs (Aydin & Boz, 2010; Moseley & Utley, 2006; Utley, Moseley, & Bryant, 2005). The STEBI-B instrument consists of two sub-scales – the 13 item Personal Science Teaching Efficacy Belief Scale (PSTEB) and the 10 item Science Teaching Outcome Efficacy Beliefs (STOEB) scale. Students were required to rate the items on all instruments on a Likert five point scale where 1=strongly disagree and 5= strongly agree. The STEBI-B instrument is found in the Appendix.

Data analysis

Descriptive statistical procedures and reliability analyses available through SPSS 17.00 were employed. Paired sample T-test were carried out on the STEBI scale, the sub-scales and individual items.

Results and discussion - clickers and teaching approaches

Table 1 shows the mathematics and science students responses to the use of clickers efficacy in their classes. The scale composed of all items (called clicker efficacy) was found to be reliable (Cronbach's α = .88 for science and α = .89 for mathematics).

Table 1: Comparison of means scores, standard deviation and reliability for clicker measures a fourth year mathematics education class and a second year science education class

Clicker scale item	Science		Mathematics	
	M	SD	M	SD
1. Using the clickers helped me identify areas of strength and weakness in content knowledge	4.13	0.51	3.55	0.99
2. Using the clickers showed me where I stood in relation to the rest of the class	4.07	0.69	3.81	1.01
3. Using the clickers made the classes interesting and engaging	4.30	0.88	3.65	1.14

4. Using the clickers prompted discussions	4.53	0.51	3.68	1.05
5. Using the clickers assisted my understanding of the concepts that were discussed	4.14	0.64	3.52	1.03
6. Using the clickers did not assist my learning†	4.30	0.60	3.48	1.23
7. Using the clickers was a waste of time†	4.47	0.63	3.58	1.18
Average	4.28	0.64	3.61	1.09
Scale Total	29.97	3.43	25.26	5.83
Cronbach's α	.88		.89	

†reverse coded

The difference in responses rates is consistent with the different teaching approaches taken by in the science education and mathematics education classes. Item 2 - *Using the clickers showed me where I stood in relation to the rest of the class* was the highest rated item in mathematics (M = 3.81) but the lowest rated in science (M = 4.07). As clickers were used as tool for testing understanding of mathematics content towards the end of a lecture, it seems reasonable that students would rank the comparative information they received from the feedback process as most important.

In science classes, the highest value (M = 4.53) was for Item 4 - *Using the clickers prompted discussions*, reflecting the fact that clickers were used to generate both small group and whole class discussions at the beginning of each workshop. It is possible that mathematics students also rated this item highly (second highest value of M = 3.68) because the information they received prompted discussion amongst them after classes or caused them to seek further assistance from the teacher following the lecture.

On average, the science students were more positive about the use of clickers than the mathematics students. The average response of mathematics students (M =3.61, SD = 1.09) was considerably lower than the average response of the science students (M = 4.28, SD = 0.64). This suggests that using clickers to facilitate an interactive style of teaching is appreciated far more than using clickers solely as a testing tool at the conclusion of an expository presentation. However, even in classes where the use of clickers is restricted to post-lecture testing for understanding, students still found using clickers made the classes interesting and engaging.

These results clearly indicate that the choice of teaching method used in conjunction with the implementation of clicker technology is paramount to achieving a heightened student perception of a course. Supporting this claim are preliminary results we have obtained in Semester 2, 2010, where a social constructivist approach was used in a first year mathematics education course.

The effect of constructivist pedagogy using clickers on science teaching efficacy beliefs

Means, standards deviations and reliability coefficients for the pre-test and post-test STEBI scale and subscales are reported in Table 2.

Table 2: Means, standards deviations and reliability coefficients for the Science Teaching Efficacy Scale and its two sub-scales for pre and post-test surveys

Scale		Number of items	α	M	Standard deviation
STEB	Pre-test	23	.74	79.08	7.20
STEB	Post-test	23	.73	84.80	5.26
PSTEB	Pre-test	13	.81	42.71	6.53
PSTEB	Post-test	13	.61	48.96	3.64
STOEB	Pre-test	10	.71	36.36	3.46
STOEB	Post-test	10	.84	35.96	2.96

Reliability coefficients are similar to those reported in previous studies, however the PSTEB post-test reliability is not ideal (α= 0.61), possibly because of the small sample under investigation (N=28). Paired Sample T-test (Table 3) revealed that science education course had no significant impact on students' STOEB. Statistically significant changes did occurred in PSTEB and STEB, but concerns about the reliability of the PSTEB post-test scale precludes confidence in the results of that scale. However, analysis of individual items on the PSTEB scale shows that prior to the commencement of the science education course the students had a neutral or negative view about their science knowledge base and their capacity to effectively teach science. At the end of the course, these beliefs had moved dramatically into positive territory with most differences being significant at the $p< 0.001$ level. The greatest difference was noted for Items 3, 7 and 11 concerning science conceptual knowledge and scientific processes. For those items the size of the effect ranges from very large to medium ($r = .62$, .40 and .33, respectively). This reflects the focus of the teaching approach employed by the lecturer. Similar changes were obtained in an independent study (Haeusler, 2010) that investigated collaborative team-based learning in another science education course taken by one of the authors.

Table 3: Paired T-Test of items of the Personal Science Teaching Efficacy Scale

	Pre M	Post M	Paired differences			t	df	Sig. (2-tailed)
			Diff (M)	SD	SE (M)			
1. I will continually find better ways to teach Science.	4.39	4.54	.14	.59	.11	1.28	27	.21
2. Even if I try very hard, I will not teach Science as well as I will most subjects†	3.54	3.46	-.07	1.05	.20	-.36	27	.72
3. I know the necessary steps to teach Science concepts effectively.	2.61	3.71	1.11	.88	.17	6.69	27	.00*
4. I will not be very effective in monitoring Science experiments†	3.75	4.00	.25	.97	.18	1.37	27	.18

5. I will generally teach Science ineffectively†	3.82	3.96	.14	1.08	.20	.70	27	.49
6. I understand Science concepts well enough to be effective in teaching Science.	2.93	3.43	.50	.92	.17	2.87	27	.01
7. I will find it difficult to explain to students how Science experiments work. †	2.79	3.71	.93	1.15	.22	4.26	27	.00*
8. I will typically be able to answer students' Science questions	3.04	3.57	.54	.79	.15	3.58	27	.00*
9. I wonder if I will have the necessary skills to teach Science†	2.50	3.11	.61	1.13	.21	2.83	27	.01
10. Given a choice, I will not invite the principal to evaluate my Science teaching†	2.75	3.46	.71	1.27	.24	2.97	27	.01
11. When a student has difficulty understanding a Science concept, I will usually be at a loss as to how to help the student †	2.96	3.75	.79	1.13	.21	3.67	27	.00*
12. When teaching Science, I will usually welcome student questions.	4.36	4.36	.00	.94	.18	.00	27	1.00
13. I do not know what to do to turn students on to Science†	3.29	3.89	.61	1.34	.25	2.39	27	.02
STEB	79.08	84.80	5.72	6.86	1.37	4.17	24	.00**
PSTEB	42.71	48.96	6.25	6.87	1.30	4.81	27	.00**
STOEB	36.36	35.96	-.40	4.08	.82	-.49	24	.63

**ρ<0.001, *ρ<0.05

Discussion and conclusion

Because of small sample sizes (N=28), and the absence of a control study, caution must be exercised in generalising the results of this research. The results however are broadly in harmony with previous studies (Aydin & Boz, 2010; Bleicher & Lindgren, 2005; Haeusler, 2010; Mulholland, et al., 2004). Our work has shown that a social constructivist teaching approach, using clickers as a tool to identify prior knowledge and to facilitate co-operative discussion, impacts positively on aspects of pre-service teachers Personal Science Teaching Efficacy Beliefs (PSTEB) but not their Science Teaching Outcome Expectancy Beliefs (STOEB). In our study the most significant changes in students' beliefs occurred for the items related to students' confidence in understanding and teaching science concepts and processes. This result is consistent with the objectives of the science education course.

Because the science education subject did not have a practical school experience component to it, it is not surprising that pre-service teachers' STOEB did not change. A recent study (Mulholland, et al., 2004) at another Australian university also confirmed that completion of that institution's science education courses by students had a positive effect on PSTEB but no impact on STOEB. We agree with their conclusion that pre-service students may not see the relevance of the teacher focussed questions of the STOEB scale because of the emphasis on a learner centred approach of the current school curricula. Other studies (Bleicher & Lindgren, 2005; Moseley & Utley, 2006) have shown that students undertaking science education courses that integrate science content and pedagogy and include a science teaching practicum achieved significant increases in both PSTEB and STOEB.

Our work shows that students find the use of clickers engaging, interesting and of assistance to their learning, even if they are used as a device to allow feedback on understanding at the conclusion of an expository lecture. A more powerful response is obtained if clickers are used as learning tools, situated within a social constructivist learning framework. Pre-service primary teachers' support for clickers as tools that assisted their learning of science concepts is in harmony with the observed increase in their efficacy in understanding and teaching of science concepts. However, further research on larger groups, including controls, is needed to clarify the nature of the relationship of clickers to teaching self-efficacy and learning.

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Appendix

Science Teaching Efficacy Belief Instrument (STEBI-B)

PSTEB Scale -Personal Science Teaching Efficacy Beliefs

1. I will continually find better ways to teach Science.
2. Even if I try very hard, I will not teach Science as well as I will most subjects.
3. I know the steps necessary to teach Science concepts effectively.
4. I will not be very effective in monitoring Science experiments.
5. I will generally teach Science ineffectively.
6. I understand Science concepts well enough to be effective in teaching Science.
7. I will find it difficult to explain to students how Science experiments work.
8. I will typically be able to answer students' Science questions.
9. I wonder if I will have necessary skills to teach Science.
10. Given a choice, I will not invite the principal to evaluate my Science teaching.
11. When a student has difficulty understanding a Science concept, I will usually be at a loss as to how to help the student understand it better.
12. When teaching Science, I will usually welcome student questions.
13. I do not know what to do to turn students on to Science.

STOEB Scale -Science Outcome Expectancy Beliefs

1. When a student does better than usual in Science, it is often because the teacher exerted a little extra effort.
2. When the Science grades of students improve, it is often due to their teacher having found a more effective teaching approach.
3. If students are underachieving in Science, it is most likely due to ineffective Science teaching.
4. The inadequacy of a student's Science background can be overcome by good teaching.
5. The low achievement of some students cannot generally be blamed on their teachers
6. When a low-achieving child progresses in Science, it is usually due to extra attention given by the teacher.
7. The low achievement of some students cannot generally be blamed on their teachers
8. The teacher is generally responsible for the achievement of students in Science.
9. Students' achievement in Science is directly related to their teacher's effectiveness in Science teaching.
10. If parents comment that their child is showing more interest in Science at school, it is probably due to the performance of the child's teacher.