Student Change Associated with Teachers' Professional Learning

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Teachers and students in nine rural Tasmanian schools have been associated with a research project providing professional learning for teachers in mathematics in a reform-based learning environment. Students completed surveys to measure attitudes and mathematics skills and understanding late in 2005 and late in 2006. Teachers completed profiles late in 2005 and participated in professional learning activities from then throughout 2006. The professional learning program is described and change in student attitudes and performance reported.

The MARBLE project began in mid-2005, the acronym standing for "Mathematics in Australian Reform-Based Learning Environments." The aim of the project is to provide negotiated professional learning opportunities for a group of rural middle school teachers that will enhance the outcomes of their students in relation both to the quantitative literacy needs of today's society and to the opportunity to study further mathematics and contribute to innovation in Australia. The project reported on initial data collected from teachers and students in relation to beliefs and attitudes (Beswick, Watson, & Brown, 2006) and to performance on a mathematical task (Watson, Beswick, & Brown, 2006). Brown, Watson, Beswick, and Fitzallen (2006) also provided details of the overall teacher profile outcomes. The purpose of this paper is to report on professional learning program and the resulting student change following the first year of the project.

Professional learning program. All professional learning programs for teachers are limited to some extent by available resources and although this project was funded by the Australian Research Council, the Department of Education Tasmania (DoET), and the Catholic Education Office Hobart (CEO), care had to be taken to use resources carefully. Research elsewhere had suggested that important features of programs were:

> (a) ongoing (measured in years) collaboration of teachers for purposes of planning with (b) the explicit goal of improving students' achievement of clear learning goals, (c) anchored by attention to students' thinking, the curriculum, and pedagogy, with (d) access to alternative ideas and methods and opportunities to observe these in action and to reflect on the reasons for their effectiveness. (Hiebert, 1999, p. 15)

These features are related to Shulman's (1987a, b) seven types of teacher knowledge required for successful teaching – content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners and their characteristics, knowledge of education contexts, and knowledge of education ends, purposes, and values – as well as to Hill, Rowan, and Ball's (2005) more recent focus on "Teachers' knowledge for teaching mathematics." Fitting all of these aspects into the time and resources was the challenge faced.

In particular in Tasmania, the Essential Learnings Framework (DoET, 2002; 2003) was the backdrop into which the professional learning was to fit in 2005. This curriculum framework, underpinned by a set of values and purposes, identified 18 Key elements within five Essential Learnings (Thinking, Communicating, Social Responsibility, World Futures and Personal Futures). Although the position of traditional Key Learning Areas (KLAs) was not specifically addressed in the framework, "Being Numerate" was identified as a key element in the Communicating Essential. This shift in emphasis recognised "Being Numerate" as a cross-curricular understanding and coincided with an increased focus on pedagogy and collaborative practice across the curriculum. Contemporaneously, a set of defined outcomes and standards (DoET, 2003) was produced for each key element. "Being Numerate" was one of the first against which teachers reported, in 2005.

Considerable professional learning to support teachers' adoption of the reforms was provided through the Department of Education. This included appointment of curriculum and assessment leaders in schools/clusters, printed and on-line material (planning proformas, exemplar units, and work samples to guide assessment). Much of the professional learning was generic, with only three curriculum officers working with a "Being Numerate" focus across the state. Face-to-face professional learning in this element was therefore limited and dependent on individual schools or clusters adopting a numeracy focus. To assist in addressing this issue, the "Being Numerate" team developed an extensive on-line resource for teachers (DoET, 2007a).

In 2006, amid controversy over the implementation of the Essential Learnings, the incoming Minister for Education announced that there would be a new curriculum in Tasmanian schools. The Tasmanian Curriculum would be a refinement to "make it easier to understand, and more manageable for teachers and principals" (DoET, 2007b, para 1). An initial draft was circulated to stakeholders and following a consultation period the refined framework consisting of eight areas was announced. Mathematics/Numeracy became a defined area against which both primary and secondary teachers are required to report. Information and Communications Technology (ICT) was embedded in all curriculum areas (DoET, 2007b).

The MARBLE project provided an opportunity for two clusters of Tasmanian schools to have an intensive focus on numeracy in addition to the other professional learning that was taking place. Although this project was firmly grounded in the context of curriculum reform, specific content and pedagogical content knowledge in the area of numeracy were identified foci. Professional learning literature then informed the planning process. For example, Schifter (1998) found that engaging teachers with the content of the mathematics curriculum that they taught, in ways that challenged and deepened their own mathematical understandings, was effective in assisting them to make changes to their classroom practice. Hawley and Valli (1999) asserted that teachers should be involved in the identification of what they need to learn and the process to be used and that collaborative problem solving should be included.

In December 2003, the Australian Councils of the Deans of Education and the Deans of Science issued a draft report on professional learning in science, mathematics, and technology in Australia. The report lamented the lack of systematic evaluation of student outcomes and of improvements in teacher confidence and knowledge as a result of professional learning experiences (p. 43). Burkhardt and Schoenfeld (2003) further made a direct call for more extensive, evidence-based measures of outcomes to be developed to satisfy stake-holders, including politicians. These evaluations became among the aims of the MARBLE project with a specific focus of the research to evaluate whether the professional learning made an impact on teachers and students with respect to teaching and learning of Mathematics. This paper reports on the results of student surveys that included items to measure both attitude and mathematics performance, in terms of skills and understanding.

Attitudes to mathematics. The term attitude is used to describe an evaluative response to a psychological object (Ajzen & Fishbein, 1980) and hence individuals' attitudes to mathematics refer to their evaluation of mathematics. Hannula (2002) separated such evaluations of mathematics into four categories, namely: emotions experienced during mathematical activity; emotions triggered by the concept of mathematics; evaluations of the consequences of doing mathematics; and the perceived value of mathematics in terms of an individual's overall goals. Of course, these are dependent upon such things as the nature of the mathematical activity engaged in at the time, the aspects of mathematics being considered or what is believed to comprise mathematics, and expectations for the future in terms of mathematics. This means that an individuals' response to written items aimed at assessing their attitude to mathematics is likely to reflect rather transient states. Other authors have also described the multidimensionality of attitude in terms of dichotomous evaluations. These include: confidence or anxiety (Ernest, 1988); like or dislike; engagement or avoidance; high or low self efficacy; and beliefs that mathematics is important or not important, useful or useless, easy or difficult (Ma & Kishor, 1997), and interesting or not interesting (McLeod, 1992). There are connections between these eight dimensions and Hannula's (2002) categories but they tend to emphasise emotional reactions less.

The Program for International Student Assessment (PISA) (2003) incorporated measures of affect and their influence on mathematical literacy (Thomson, Creswell, &, De Bortoli, 2004). Thomson et al. (2004) found that for Australian 15-year-olds, mathematics self-efficacy and self-concept had the greatest impact on mathematical performance of all of the variables considered, and that anxiety about mathematics was negatively related to performance in the subject. In addition, students' inclination to engage in mathematics is likely to influence their decisions about pursuing the subject beyond the school years in which it is compulsory and hence is a likely contributor to the declining enrolments in tertiary mathematics in many countries (Boaler & Greeno, 2000). A decline in attitude to mathematics with increasing grade level was also been noted by Boaler and Greeno, (2000) and some evidence suggesting that this might apply particularly to students' inclination to engage with the subject, to like it, and to find it interesting was presented by Beswick et al. (2006).

Mathematical performance of students. Analysis of curriculum documents and previous research highlighted the mathematical concepts associated with the middle school that are the foundation for the quantitative literacy skills needed by all students and for the formal mathematical content of algebra, geometry, probability, and statistics needed by innovators in mathematics science and technology. The five concepts identified as forming a foundation to these understanding were Number Sense, Proportional Reasoning, Measurement, Uncertainty, and Relationships. These dual purposes, everyday numeracy and formal mathematics that pose a challenge for teachers and curriculum designers, are recognised in the Essential Learnings framework:

> Being numerate involves having those concepts and skills of mathematics that are required to meet the demands of everyday life. It includes having the capacity to select and use them appropriately in real life settings. Being truly numerate requires the knowledge and disposition to think and act mathematically and the confidence and intuition to apply particular principles to everyday problems. … Access to higher levels of abstract symbolic operation opens new ways of thinking and future academic and vocational pathways. (DoET, 2002, p. 21)

This extract echoes the work of Steen (2001), who sees quantitative literacy as an integral component of all mathematics curricula. Appreciating the purposes and applications of the mathematical thinking they have developed within the formal mathematics curriculum is seen as a critical need for elite students as well as those who will not go on to study higher levels of mathematics.

Methodology

The research was conducted in two rural clusters in different parts of Tasmania, comprising eight DoET schools and one CEO school. The professional learning program involved middle years (grades 5-8) teachers.

Sample. The survey was directed at students in Grades 5 to 8. Due to students entering and leaving schools, and progressing to higher grades in 2006, not all students had survey results for both years. Table 1 contains the number of students in each year and the number of repeating students. Although all schools were asked to administer surveys to all students whose teachers took part in the MARBLE project, there are some missing data from some schools.

Table 1
Number of Students in Each Grade Each Year (repeating student numbers in parenthesis)

Year	Grade 5	Grade 6	Grade 7	Grade 8
2005	182	220	181	128
2006	138	168 (141)	154 (144)	102 (94)

Survey items. The student surveys included items to measure both mathematical performance and attitude towards mathematics. In terms of mathematical performance, the survey was written to reflect the five foundation concepts identified in the literature. Of the 35 distinct items forming 17 questions on the initial student survey, there was overlap in terms of items reflecting these concepts. Fifteen items had links to two concepts with the coverage being 15 items on Number Sense, 6 items on Proportional Reasoning, 7 items on Measurement, 10 items involving Uncertainty, and 12 involving Relationships. The items had various sources including Watson and Callingham (2003), Callingham and Griffin (2000) and Department of Education, Community and Cultural Development (1997). Student outcomes for one of the problems based on fractional parts of a nebulous whole were discussed in Watson et al. (2006). Items were scored using scoring rubrics adapted from the original sources.

The subsequent student survey administered 12 months later contained eight items in common with the initial survey and 18 other items, providing a total of 13 items on Number Sense, 6 on Proportional Reasoning, 2 on Measurement, 7 on Uncertainty, and 5 on Relationships. This included three items that linked to three concepts and one item that linked to two. The change in emphasis reflected student outcome levels from the initial surveys and teacher intervention (through the professional learning program) in 2006.

Consistent with the study of Beswick et al. (2006) 16 items to measure attitude were included comprising two statements from each of the eight identified dimensions, to which respondents indicated the extent of their agreement on 5-point Likert scales ranging from Strongly agree to Strongly disagree.

Procedure. The outcomes from the 2005 student survey were reported to the teachers in the project at the beginning of 2006 and specific interventions were initiated by the teachers working in school-based groupings. The disappointing survey outcomes related to number sense and basic proportional reasoning in 2005 led to adopting more work with these concepts at the beginning of the year and less work with the other foundation concepts. Also relevant to these outcomes are the professional learning activities offered to the teachers during the final term of 2005 and throughout 2006. These are summarized briefly in Table 2. Professional learning was delivered in two ways. Whole of cluster sessions were combined with case studies, where each school was assigned a researcher to be involved in a project of its own choice. All schools except one completed a case study, which were reported to the Management Committee of the project at the end of 2006. These varied greatly in the degree of intervention by researchers and the quality of the outcomes. Brown, Rothwell, and Taylor (in press) reported on one case where teachers negotiated with researchers to develop a framework for the teaching of numeracy, drawing on curriculum support materials and teachers' understanding of the school context.

Table 2
Summary of Professional Learning Activities for Teachers

Focus of Professional Learning	*Mathematical content knowledge*	*Pedagogical content knowledge*	*Knowledge of students as learners*	*Curriculum knowledge*
Whole of Cluster Professional Learning	Fractions Measurement Ratio Problem solving Tinkerplots (Data collection, handling, representation, interpretation, evaluation) Mental computation Place value Accuracy Space Decimals Percentages Proportional reasoning Quantitative literacy (in media)	Fractions Pi Chance and Data; (Designing surveys, collecting data, representing data, interpreting data) Problem solving Numerate language Mental computation strategies	Division Fractions Applying rubrics to students' responses Progression statements	Coordinating the mathematics curriculum Assessment: Formative and summative including use design and use of rubrics Making inter-disciplinary connections with science; SOSE Planning units of work – connecting understanding goals with teaching, learning and assessment
School Case Studies	Tinkerplots Constructing a school scope and sequence Student produced resource kits	Mental computation strategies Tinkerplots Developing conceptual understanding of fractions	Mental computation and problem solving strategies	Implementing an Inquiry Whole-school numeracy audit

Analysis of attitudes. The 16 items related to attitude to mathematics were common to the student surveys administered on both occasions. Paired sample t-tests were used to compare the responses of those students who completed the survey on both occasions. Effect sizes were also calculated as described by Burns (2000). The eight pairs of items relating to the each of the identified aspects of attitude in the literature were also combined and the totals similarly compared. In all cases scoring was reversed for negatively worded items so that a higher score represented a more positive response.

Analysis of mathematical thinking. The data from the mathematics tasks were analysed using the Rasch Partial Credit Model (Masters, 1982) with Quest computer software (Adams & Khoo, 1996). A set of 8 link items common to both administrations was identified, and these items provided an anchor set that established the difficulties of the items at each test administration relative to each other (Griffin & Callingham, 2006). Estimates of person ability were identified for each student in both 2005 and 2006, anchored to the same set of link item difficulties so that genuine comparisons could be made. The performance of students in each grade was summarised for each year of the project. These measures provided a comparison of performance by grade. Also, summaries from students who completed both tests provided a measure of growth across time.

Results

Attitudes to mathematics. Table 3 shows changes in the mean responses of students who responded to the 16 attitude items included in the survey in both 2005 and 2006. Five of the changes were statistically significant and in each case the change was negative and the effect size was very small.

Table 3

Changes in Responses to Attitude Items from 2005 to 2006 (Negative statements in italics)

Attitude item	Mean 2005 (n=378)	Mean 2006 (n=378)	Diff. 2006-2005	Std Dev.	Sig. (2-tailed)	Effect size
1. I find maths an interesting subject.	3.56	3.39	-0.17	1.16	0.004**	0.15
2. Other subjects are more important than maths.	3.12	3.11	-0.01	1.32	0.866	0.00
3. I plan to do as little maths as possible when I get the choice.	3.45	3.54	0.09	1.37	0.202	0.07
4. I really do <u>not</u> enjoy maths lessons.	3.49	3.46	-0.04	1.36	0.571	0.03
5. I find most problems in maths fairly easy.	3.27	3.10	-0.17	1.20	0.005**	0.14
6. Maths helps to develop my mind and teaches me to think.	3.94	3.92	-0.02	1.16	0.689	0.02
7. Maths we learn at school is important in everyday life.	4.20	4.26	0.06	1.09	0.256	0.06
8. Maths makes me feel nervous and uncomfortable.	3.62	3.58	-0.03	1.31	0.609	0.02
9. Maths is a dull and uninteresting subject.	3.54	3.51	-0.04	1.35	0.594	0.03
10. I enjoy attempting to solve maths problems.	3.60	3.48	0.12	1.19	0.048*	0.10
11. The problems in maths are nearly always too difficult.	3.60	3.55	-0.04	1.03	0.395	0.04
12. I usually keep trying with a difficult problem until I have solved it.	3.79	3.67	0.11	1.11	0.052	0.10
13. I don't do very well at maths.	3.43	3.19	-0.24	1.14	0.000**	0.21
14. Having good maths skills will <u>not</u> help me get a job when I leave school.	4.34	4.33	-0.01	1.35	0.849	0.01
15. Most of the time I find maths problems too easy and unchallenging.	2.65	2.37	-0.28	1.17	0.000**	0.24
16. I don't get upset when trying to work out maths problems.	3.71	3.75	-0.03	1.54	0.665	0.02

*$p<0.05$. ** $p<0.01$.

Table 4 shows the changes in aggregated means for each of the eight aspects of attitude that underpinned the design of the items, and for total attitude. As expected on the basis of the individual items in Table 3, what statistically significant changes there were, were negative and effect sizes were again small.

Table 4
Changes in Responses to Attitude Dimensions and Total Attitude from 2005 to 2006

Attitude dimension (Item numbers in Table 1)	Mean 2005 (n=378)	Mean 2006 (n=378)	Diff. 2006-2005	Std Dev.	Sig. (2-tailed)	Effect size
Mathematics is interesting (1& 9)	7.10	6.89	-0.20	2.08	0.051	0.10
Mathematics is important (2 & 7)	7.31	7.37	0.05	1.74	0.555	0.03
Inclination to engage with mathematics (3 & 12)	7.24	7.21	-0.21	1.91	0.830	0.11
Liking for mathematics (4 & 10)	7.09	6.93	-0.16	2.11	0.137	0.08
Self-efficacy in relation to mathematics (5 & 13)	6.69	6.29	-0.41	1.80	0.000**	0.23
Mathematics is useful (6 & 14)	8.28	8.24	-0.37	1.90	0.705	0.19
Confidence in relation to mathematics (8 & 16)	7.33	7.33	0.00	2.12	1.000	0.00
Mathematics is easy (11 & 15)	6.24	5.92	-0.32	1.68	0.000**	0.19
Total Attitude (all items)	57.29	56.18	-1.13	8.63	0.013*	0.13

*$p<0.05$. ** $p<0.01$.

Mathematical thinking. Figure 1 shows the change in performance between like grades in each year of the project. The pattern of achievement across the grades is mixed. Although there is a general increase in performance as students move through school, within grades only Grade 7 shows a significant improvement from 2005 to 2006 (t = 2.01; df = 312; p = 0.045). It does seem that MARBLE has been somewhat more effective in addressing the primary/high school transition than at the other grade levels.

Figure 2 shows the growth over time of students who entered MARBLE in Grades 5, 6 and 7. When this growth was considered by comparing achievement in the lower grade with the same students' achievement in the higher grade, all improvements were significant. This is not unexpected due to the general cognitive development as students move through school. In terms of the rate of growth, those students who began the project in Grade 5 had a higher growth rate than students who started in either Grade 6 or Grade 7, who showed a very similar trajectory.

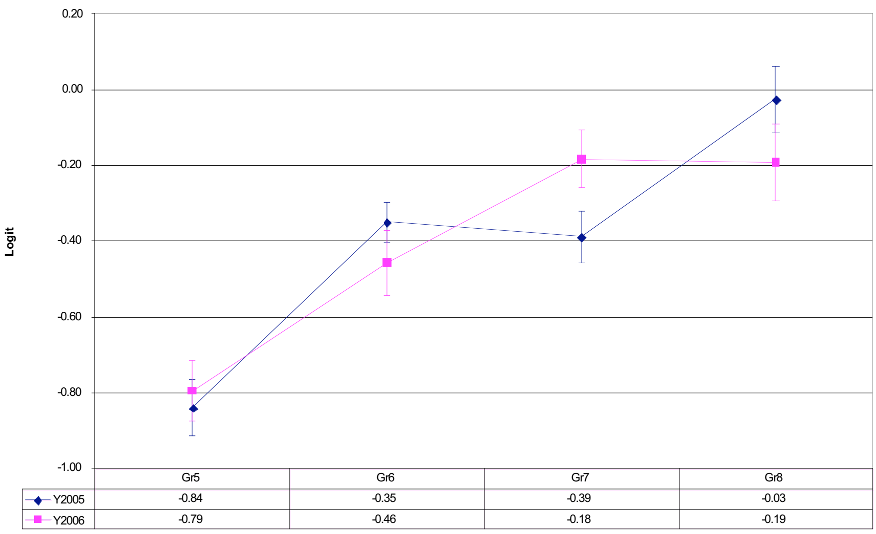

Figure 1. Change in performance by grade over time.

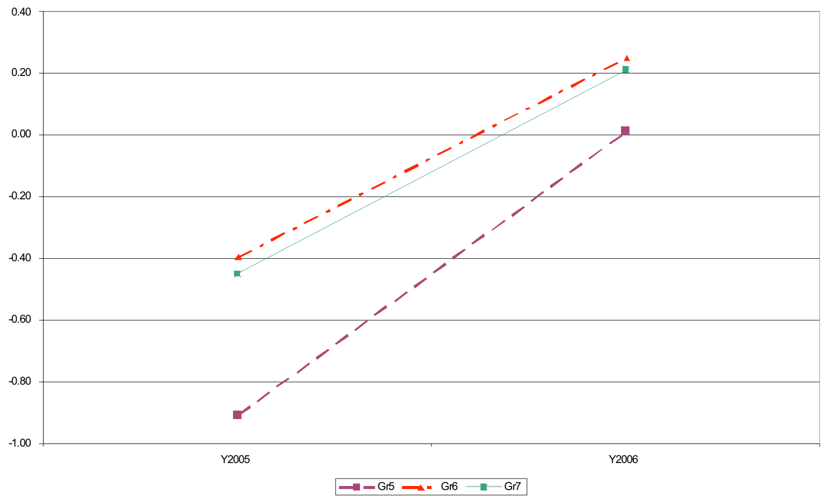

Figure 2. Growth over time by start grade in 2005.

Discussion

Although small, the direction of the changes in students' attitudes is disappointing. It seems likely that what we are observing is the previously noted deterioration of attitude to mathematics with year level (Beswick et al., 2006; Boaler & Greeno, 2000). Although linked (Thomson et al., 2004), the direction of causation between attitude towards, and achievement in mathematics is unclear with meta-analyses resulting in conflicting conclusions (compare Ma & Kishor, 1997 and Ma & Xu, 2004). In this study, the focus was very much upon improving teaching in the expectation that this would result in improved achievement and more positive attitudes to mathematics. A further possible explanation for these results lies in the transient and multifaceted nature of attitude to mathematics. In particular some aspects of attitude, particularly emotive responses (Hannula, 2002), are not readily accessible via written means.

The mathematical thinking outcomes were also disappointing across cohorts in the same grades, except for Grade 7. It is interesting, however, to note that to some extent the lack of improvement of performance at the high school transition, as noted for example by Callingham and McIntosh (2002) and Watson and Kelly (2004), was tempered, with improvement from Grade 6 to Grade 7. The stationary level of performance in 2006, of Grade 7 and Grade 8, was disappointing but it reflected a similar relationship of the Grade 6 and Grade 7 students in the previous year. This appears to reflect cohort differences in these grades.

Limitations. Several issues may have had an impact on the follow-up surveying of MARBLE project students after one year. The uncertainty associated with the curriculum and eventual change was distracting for many teachers and this was expressed at several of the professional learning sessions. Although the feedback from teachers following the professional learning sessions was positive, at times it was the impression of the authors that teachers were challenged by the topics covered (see Table 2) and may have been hesitant to implement them fully in their classrooms. There was also concern expressed by some teachers that the students were reluctant to try to the best of their ability in 2006 because the surveys did not count for their school assessment.

Implications. The outcomes from the 2006 student surveys were reported to teachers representing each of the nine schools at the beginning of 2007. At the meetings teachers were again, as in the previous year, asked to contribute to the planning in order to improve students' outcomes at the end of 2007. They were positive about the influence of the individual school case studies and wished to continue them as well as to work across schools within the clusters on topics of special interest at various grade levels. Taking into account the comments of Hiebert (1999) on the importance of sustained professional learning for teachers over time, it is hoped that another year will produce the desired outcomes.

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