TEACHER CHANGE IN A CHANGING EDUCATIONAL ENVIRONMENT

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This paper considers the change in teachers' confidence, beliefs, and knowledge with respect to mathematics teaching across a 3-year collaborative intervention, which although planned in a reform-based learning environment, took place as the reforms were rolled back and a new view of curriculum introduced. Of 86 middle school teachers involved at some time during the project only 19 completed both the pre- and post-profiles and of these only 11 had been in the project since its beginning. Teacher change appears more likely to have been related to the length of time in the program than to the state-wide curriculum changes.

Introduction

The Tasmanian project upon which this report is based was titled "Mathematics in an Australian Reform-Based Learning Environment" (MARBLE). The "reform-based learning environment" reflected moves of several Australian states to create values-based curricula "designed to meet current educational needs by making legitimate connections between disciplines" (Department of Education Tasmania (DoE), 2002, p. 11). The aims of the project within the context of the Tasmanian Essential Learnings curriculum (D*o*E, 2002) were to provide professional learning (PL) for teachers to assist them in enhancing middle school students' mathematical understanding necessary for the quantitative literacy needs of today's society (Steen, 2001) and for the further study of mathematics in order to contribute to innovation in Australia (Committee for the Review of Teaching and Teacher Education, 2003).

Research elsewhere had suggested that important features of PL programs included:

> (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)

Sowder (2007), in her extensive review, similarly advocated the need for ongoing PL. The challenge faced by the MARBLE PL program was fitting all of these aspects into the time and resources available.

Several papers previously reported on some of the outcomes of the MARBLE project. Pertinent to the current work, Watson, Beswick, and Brown (2006) reported on initial data collected on a fraction problem, indicating the strengths and weaknesses of teachers' pedagogical content knowledge (PCK) in relation to the task. Information such as this formed the basis of the interventions that took place during the project. Initial levels of teachers' confidence and beliefs were covered by Beswick, Watson, and Brown (2006). Change in students' attitudes (Beswick, Watson, Brown, Callingham, & Wright, 2011) and performance (Watson, Brown, Beswick, Callingham, & Wright, 2010) over the time of the project have also been reported. Initial analysis of teacher knowledge was provided by Beswick, Callingham, and Watson (2011). The current paper completes the data analysis by reporting on the changes that took place for teachers over the 3 years of the MARBLE project.

Background context for MARBLE

The background to the MARBLE PL program was the Essential Learnings Framework (DoE, 2002). This curriculum framework identified 18 Key Elements within five Essential Learnings (Thinking, Communicating, Social Responsibility, World Futures, and Personal Futures). "Being Numerate" was identified as a key element in the Communicating Essential and was one of the first Key Elements against which teachers reported in 2005. This emphasis recognised "Being Numerate" as an important cross-curricular understanding and coincided with an increased focus on pedagogy and collaborative practice across the curriculum.

Amid controversy over the implementation of the Essential Learnings Framework, in 2006 a new curriculum was announced by the incoming Minister for Education that would "make [the curriculum] easier to understand, and more manageable for teachers and principals" (D*o*E, 2007, para 1). Mathematics/Numeracy became one of eight defined areas of the curriculum against which both primary and secondary teachers are required to report.

Against this backdrop, the research question for this paper is: What changes occurred for various subgroups of teachers in the MARBLE project in relation to the knowledge and confidence for teaching mathematics?

The professional learning program

The initial experiences provided for teachers in the MARBLE project were summarised by Watson, Beswick, Brown, and Callingham (2007) in relation to mathematical content knowledge, PCK, knowledge of students as learners, and curriculum knowledge. PL topics in the earlier years of the project included quantitative literacy in the media, problem solving strategies, and assessment (formative and summative, and involving the use of rubrics). The final coverage of topics in the project is contained in Beswick et al. (2011). Topics included the use and benefits of concrete materials, planning a unit of work, and understanding common misconceptions with fractions.

The schools in the project were situated in rural areas of the south (five) and north (four, including one Catholic) of the state. Four of the DoE schools were district high (K–10), one was a high (7–10), and three were primary (K–6) schools; the Catholic school was K–10. Except for one planning session with representatives of all schools held at the beginning of the second year, all PL sessions were held within the two clusters of schools. There were 3 whole-of-cluster sessions in the first year, 11 in the second, and 10 in the third in each region. The sessions were largely the same in each cluster but on occasion the specific needs of teachers meant that modifications of content occurred or specific topics were included. Feedback, in addition to that reported here, was sought from teachers at the end of each session, and through meetings with school coordinators, face-to-face interviews with 19 teachers at the end of the project, and surveys of teachers who left the project (and school) during the project.

Methodology

Design and sample

The overall research design was a longitudinal study of teacher and student change with respect to the interventions as part of the project. As noted elsewhere (e.g., Watson et al., 2010) students' attitudes and performance were measured each year. Teachers completed a profile adapted from the work of Watson (2001) when they entered, and at the end of, the project.

It was envisaged that most teachers would be in the project for 3 years but as seen in Table 1, this was not the case. The table contains information on the teachers who took part in the MARBLE project. Some teachers did not participate for long enough to complete either the initial or the final teacher profile.

Table 1. Teacher participation in the MARBLE project.

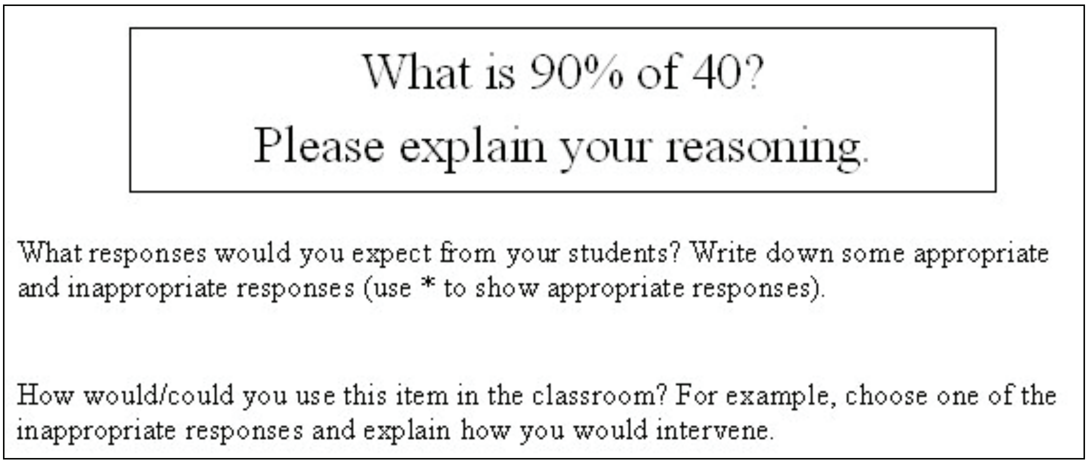
	Year 1	Year 2	Year 3	Total
Number of Teachers	42	47	54	
New Teachers	-	24	20	86
Completed Initial Profile	42	12	9	63
Completed Final Profile	11	3	11	25*

* Of the 25 teachers who completed the final profile, only 19 had completed the initial profile.

Instruments

The initial profile questions provided a data set comprising five sub-scales relating to teaching mathematics: Confidence, Everyday Life, Numeracy in the Classroom, General Pedagogical Knowledge, and Pedagogical Content Knowledge. Coded scores for items in the Confidence, Everyday Life, and Numeracy in the Classroom subscales ranged from 1 to 5, with higher scores representing more confidence to teach the concept (such as fractions) or a higher level of agreement with the given statement (e.g., "I need to be numerate to be an intelligent consumer").

General Pedagogy items were coded hierarchically, with higher scores representing higher levels of pedagogical knowledge. The highest level response (code 3) for the item, "How would you go about improving students' numeracy and mathematical understandings?", for example, indicated that teachers provided an integrated, high-level rationale for their written responses. The PCK items were also scored hierarchically and asked teachers to think about the range of responses their students would give to each of the numeracy items, and then consider how to use the items in the classroom. An example of a PCK item is presented in Figure 1.



What is 90% of 40?
Please explain your reasoning.

What responses would you expect from your students? Write down some appropriate and inappropriate responses (use * to show appropriate responses).

How would/could you use this item in the classroom? For example, choose one of the inappropriate responses and explain how you would intervene.

Figure 1. An example of a PCK item used in both profile administrations.

From the sub-scales a Combined Scale was constructed that was used by Beswick et al. (2011) to suggest a four-level hierarchy for teacher knowledge for teaching mathematics. These levels were labelled Personal Numeracy, Pedagogical Awareness, PCK Emergence, and PCK Consolidation, based on the outcomes of Rasch (1960) analysis, to reflect increasing ability of teachers to express confidence in their capacity to teach topics, to cope with numeracy in everyday life, to agree with student-centred statements about numeracy in the classroom, and to display sophisticated general pedagogical knowledge and PCK for mathematics.

Analysis

The original data set used by Beswick et al. (2011) was augmented by one teacher; the software Winsteps (Linacre, 2006) and the Rasch Partial Credit Model (Masters, 1982) were used for the analysis reported here. Of the 59 individual profile items, 49 were common to both initial and final profiles and were used to link the two profiles for analysis. The 49 link items provided an anchor set that established the difficulties of the items at each test administration relevant to each other and estimates of person ability were identified for each teacher in the original and follow-up profile, anchored to the same set of link item difficulties so that genuine comparisons could be made. These ability measures were used as a basis for subsequent analysis. *T*-tests were used to compare the mean ability levels of all teachers who completed either the initial or final profiles and paired *t*-tests were used to compare those of teachers who completed the profile on both occasions. Effect sizes were calculated as described by Burns (2000), looking at the profile items as a whole and separated into the five sub-scales.

Results

The results for the overall profile and the five sub-scales are presented in four stages, comparing the initial and final profiles completed by the following groups of teachers: all at the start (n = 63) with all at the end (n = 25); those who completed both initial and final profiles (n = 19); those who began in Year 1 and completed both profiles (n = 11); and those who began in Years 2 or 3 and completed both profiles (n = 8).

Table 2 shows that in comparing all teachers who completed the initial profile (n = 63) and/or the final profile (n = 25) there was little change in the overall Combined

Scale, Confidence, Numeracy in the Classroom, or PCK. The change in teachers' reaction to numeracy in Everyday Life was significant and negative. The mean ability score for this subscale for teacher ID17, for example, fell from 4.6 to 1.4, a difference of 3.2 (raw score range of 1 to 5). The only significant positive change for this group occurred in relation to general classroom pedagogical knowledge, which, from the effect size, should have been observable in the classroom.

Table 2. Change for all teachers completing initial and/or final profiles.

	Original (*n* = *63*)		Follow-Up (*n* = *25*)		*t*	*p*-value	Effect size
	mean	SD	mean	SD			
Combined scales	0.57	0.45	0.61	0.41	0.391	0.697	0.09
General Pedagogy	-0.24	0.82	0.45	0.87	3.530	0.001**	**0.83**
Confidence	0.84	1.21	0.87	0.94	0.120	0.904	0.03
Everyday Life	1.70	1.30	1.03	0.75	2.397	0.019*	**-0.56**
Numeracy in the Classroom	0.52	0.41	0.54	0.41	0.231	0.818	0.06
PCK	-0.03	1.36	0.16	1.34	0.596	0.553	0.14

* Significance <.05. ** Significance <.01.

Table 3 contains parallel results for the 19 teachers who completed both profiles, regardless of when they began with the MARBLE project. The results were in the same direction and were similar to those in Table 2.

Table 3. Change for teachers who completed both initial and final profiles (paired t-tests).

	Original (*n* = *19*)		Follow-Up (*n* = *19*)		*t*	*p*-value	Effect size
	mean	SD	mean	SD			
Combined scales	0.61	0.45	0.64	0.47	0.165	0.870	0.05
General Pedagogy	-0.08	1.00	0.53	0.98	1.889	0.067	**0.6**
Confidence	0.91	1.39	0.93	1.04	0.050	0.957	0.02
Everyday Life	2.02	1.49	1.17	0.78	2.180	0.036*	**-0.69**
Numeracy in the Classroom	0.55	0.33	0.56	0.38	0.023	0.982	0.01
PCK	-0.30	1.64	0.06	1.48	0.704	0.486	0.23

* Significance <.05.

Table 4 summarises the results for the 11 teachers who were involved in the MARBLE project for all 3 years and completed both profiles. The *t*-values are not significant, except for Everyday Life, due to the small sample size, but the effect sizes are larger than for the other groups of teachers. For the 11 teachers, only Numeracy in the Classroom showed no change, whereas PCK showed a meaningful increase reflected in the effect size. Results for General Pedagogy and Everyday Life were similar to those for the large data sets of which they were a part. Using Burns' (2000) classification of ± 0.4 as a significant effect size for this type of data, the combined scale of all items for these teachers shows an almost significant effect size at 0.38. This differs considerably to the effect size seen in Table 2, showing almost no difference. Using the four-level hierarchy described by Beswick et al. (2011), three of the 11 teachers achieved a higher level in the follow-up profile administration; one moving from Level 3 (PCK Emergence) to Level 4 (PCK Consolidation), and the other two from Level 2 (Pedagogical Awareness) to Level 3. Two teachers shifted in a negative direction, moving from Level 3 to Level 2, however the degree of movement was very small. Other teachers remained within the same level. Overall, the mean ability score from the first profile administration to the second went up for 7 teachers and down for 4 teachers.

Table 4. Change for teachers who participated for 3 years and completed both initial and final profiles (paired t-tests).

	Original (n = *11*)		Follow-Up (n = *11*)		t	p-value	Effect size
	mean	SD	mean	SD			
Combined scales	0.65	0.37	0.79	0.35	0.926	0.366	0.38
General Pedagogy	-0.20	1.19	0.48	0.97	1.486	0.153	**0.61**
Confidence	1.20	1.18	1.37	0.79	0.627	0.538	0.26
Everyday Life	2.36	1.45	1.30	0.70	2.177	0.042*	**-0.89**
Numeracy in the Classroom	0.55	0.36	0.56	0.39	0.074	0.942	0.03
PCK	-0.85	1.87	0.26	1.38	1.590	0.127	**0.65**

* Significance <.05.

Table 5 summarises the results for the 8 teachers who were involved in the project for 1 or 2 years only and completed both profiles. The results are similar to those of the other participants in relation to an improved general pedagogy, a decrease in relation to use of numeracy in Everyday Life, and no change in relation to Numeracy in the Classroom. The big changes, however, were with respect to Confidence and PCK, which were negative and brought about a negative change in the Combined Scale. These teachers appeared to have experienced an “implementation dip” in terms of the PCK aims of the project.

Table 5. Change for teachers who participated for 1 or 2 years of the project only and completed both initial and final surveys (paired t-tests).

	Original (n = *8*)		Follow-Up (n = *8*)		t	p-value	Effect size
	mean	SD	mean	SD			
Combined scales	0.57	0.57	0.43	0.55	0.492	0.630	-0.23
General Pedagogy	0.10	0.71	0.59	1.06	1.103	0.289	**0.52**
Confidence	0.65	1.68	0.33	1.09	0.449	0.661	-0.21
Everyday Life	1.54	1.50	1.00	0.90	0.884	0.392	**-0.42**
Numeracy in the Classroom	0.57	0.30	0.56	0.39	0.057	0.955	-0.03
PCK	0.47	0.88	-0.22	1.65	1.039	0.317	**-0.49**

Discussion and conclusions

In answering the research question about change in teacher knowledge and confidence over the 3 years of the MARBLE project, two aspects of the results are considered. The first is the overall disappointing outcome for teachers generally. The second is the better performance of the 11 teachers in the project for 3 years.

The numbers in Table 1 support Hiebert's (1999) view that, regardless of the focus on explicit goals, students' thinking, and alternative ideas, little impact can be expected if the time of exposure is not measured in years (plural). The reasons for the turnover of teachers were not related to the content of the PL as only one teacher of the 86 expressed disagreement with the aims of the project and actively withdrew. The other teachers left the project because of changed roles or schools. Many of the exiting teachers, surveyed informally, expressed thanks for what they had achieved from the program, and some indicated that they regretted leaving.

Although the numbers are small, the more positive outcomes for the teachers who were in the project for the 3 years are encouraging, particularly with respect to PCK. As reported by Watson et al. (2006), the teachers initially struggled with PCK tasks. The improvement suggests that at least some of the requirements set out by Hiebert (1999) and Sowder (2007) were met during the program. Perhaps it is possible to speculate that difference in the PCK outcomes for the 11 teachers in the program for 3 years and the 8 in it for 2 years or less reflect the difficulty in taking up new ideas associated with teaching numeracy and having the confidence to trial them purposefully in the classroom. It may be that the teachers who were in the project for 3 years had similar experiences but persevered and hence came out with more proficiency in their PCK and Confidence. It would appear that at least 3 years are needed to overcome the "implementation dip" that the somewhat radical change in numeracy practice brought about. That the eleven teachers also displayed the same negative change in relation to numeracy in Everyday Life as did the other teachers, suggests that generally all of the teachers became more realistic in their assessment of their ability to handle numeracy in everyday settings.

The authors would suggest, somewhat facetiously, that others should choose for their interventions, schools with little staff movement and systems that do not change their curriculum during a 3-year period. Unfortunately this is not the real world. The Linkage Partner in this project purposely chose two rural clusters of schools where it felt help with numeracy was needed; however, little was done outside of MARBLE to alleviate the problem of teacher retention and issues of rurality. As to system change, although unfortunate and creating an observable underlying tension for teachers, it was not felt by the authors to be a major factor in the outcomes of the research.

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