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Profiling Teacher Change Resulting from a Professional Learning Program in Middle School Numeracy

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This paper reports on the use of a profiling instrument to evaluate an in-service professional development program for teachers of middle school numeracy. Two aspects of the use of the profile are reported. One relates to the aims of the profile to reflect Lee Shulman's seven types of teacher knowledge and to measure change in teachers with respect to them. The second relates to the success of the program and how this was judged from responses to the profile. Although the providers of the program were mainly interested in this second aspect, mathematics educators more generally should be more interested in the first due to recent trends to demand evidence-based evaluations of teacher professional development programs.

From the time of the seminal work of Shulman (1987a, 1987b), there has been considerable focus on the seven aspects of teacher knowledge that he argued were important: content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of students as learners, knowledge of education contexts, and knowledge of education ends, purposes and values. Various studies have focussed on one or more of these types of knowledge; for example Kanes and Nisbet (1996) focussed their research on content, pedagogical content, and curriculum knowledge, whereas White, Mitchelmore, Branca, and Maxon (2004) contrasted the pros and cons of professional learning programs focussed on either content knowledge or pedagogical content knowledge. Others, such as Ball and Bass (2000), have worked diligently on teachers' pedagogical content knowledge in classroom situations with detailed analyses of interactions with students.

In an attempt to provide a vehicle both to judge the professional needs of teachers and to evaluate mathematics teacher excellence, for example as suggested by the Australian Association of Mathematics Teachers, Inc. (AAMT) (2000), Watson (1998, 2001) created a teacher profiling instrument for teachers of chance and data. Although directed at this more recent part of the curriculum to judge needs and progress there, it was designed to be used more widely with suitable variations for other mathematical content. Watson's profile contained ten sections, each of which addressed either a single or in most cases multiple knowledge types as identified by Shulman (1987a, 1987b). In addition there was documentation of teachers' background and previous experiences of

professional development. The wording of the profile was intended to encourage reflective thinking on the part of teachers. A brief summary of the type of questions in each section of the profile is given in Table 1 (the complete profile is given as an appendix in Watson, 2001).

Table 1
Summary of Questions in Each Section of the Watson (2001) Profile

Section	Summary
1. Significant Factors	Brainstorm factors in teaching of Chance and Data, and in employing a teacher of them.
2. Unit Planning	Resources, contacts, preparation time and topics, arranged in order, for a unit on Chance and Data.
3. Lesson Planning	Similar outline plus methods and sequencing for a particular topic in Chance and Data.
4. Teaching Practices	Current teaching of topics, grades, enjoyment of self and students, student difficulty with topics, materials used.
5. Average and Sample	Familiarity with "sample" and "average" and how they would be taught.
6. Confidence	Likert scale of confidence in teaching topics in Chance and Data; e.g., chance language, median, odds.
7. Beliefs in Everyday Life	Likert scale on beliefs about statistics in everyday life.
8. Student Survey Items	For items taken directly from student surveys, what are likely student responses (both appropriate and inappropriate), and how the item would be used in the classroom.
9. Background	Years and grades of teaching, previous training in probability or statistics.
10. Professional Development	Use of prominent curriculum documents; previous and desired professional development.

Forty-three Australian teachers responded to Watson's original profile, completing it via an interview or in written form. Their responses were used to examine their teaching strengths and weaknesses in terms of chance and data, as

well as to suggest needs that might be addressed by future professional learning. Those teachers however were volunteers who were part of an AAMT project involving technology in teaching chance and data. The profile was administered once and hence there was no indication of whether the profile would be useful to document change in Shulman's (1987b) various types of knowledge over time.

The current study provided the opportunity to use a very similar profiling instrument in a context that would indicate whether it could measure change for teachers who took part in a professional development program. To some extent the success of the program in creating that change could also be documented and evaluated. Achieving these two aims would go some way to satisfying the call made by the Australian Councils of the Deans of Education and Deans of Science (2003) in their Draft Report on professional learning in science, mathematics, and technology: "the urgent need for more detailed evidence and research into the effectiveness of professional learning." The report lamented the absence of systematic evaluation of student outcomes and of improvements in teacher confidence and knowledge, particularly in the areas of discipline understanding and pedagogical content knowledge.

The specific research questions addressed by the current study are:

1. To what extent is the profiling instrument useful for measuring change in teachers' various types of knowledge?
2. How successful was the professional learning program in terms of facilitating change in teachers' knowledge?

Method

Context and Sample

The context for the study was a six-day professional development program for teachers of Grades 5 – 8. The program focussed on the numeracy topics found to be difficult for middle school students by their teachers and through numeracy benchmarking exercises. Fifty-two teachers were involved in the program with groups of three to five teachers attending from each of the chosen government schools. Teachers did not volunteer and their schools were provided with full teaching relief. Due to scheduling and funding demands, the program covered only 12 calendar weeks, with two-day sessions at the beginning and end and two single-day sessions roughly equally spaced between them. The content focus of the program included stategies for developing mental computation competence (e.g., Dole & McIntosh, 2005; McIntosh, 2005; McIntosh, De Nardi, & Swan, 1994), for using concrete materials to reinforce number facts, and for developing proportional reasoning as described in Tabart, Skalicky, and Watson (2005). The goal of the program was to increase teachers' knowledge in relation to Shulman's seven criteria in an environment designed to increase collaboration and planning among teachers within schools. A large number of published and concrete resources were supplied either to individual teachers or to schools and the program set aside time for teachers to meet and plan in their local groups. This included planning for interventions between sessions of the program and after it

finished. A detailed outline of the program is given in Watson, Beswick, Caney, and Skalicky (2005). There were some concerns on the part of the leaders of the program that this was a very short time to observe substantial change, given the other demands on teachers.

The Profiling Instrument

For this program the mathematical content specified in the sections of the profile was changed from Watson's original emphasis on chance and data to reflect the broader numeracy demands of the program. The structure of the profile remained similar, however, to cover Shulman's (1987a, 1987b) objectives and continue to encourage reflection. The only significant additions to the profile used by Watson (2001) were a Likert scale on Beliefs about Numeracy in the Classroom based on items in the survey used by Beswick (2005) and a final section, which asked teachers to identify their personal professional learning needs in relation to teaching for numeracy. The numeracy topics used in the Confidence scale were fractions, decimals, percent, ratio and proportion, numeracy across the curriculum, and critical numeracy in the media; mental computation topics included addition and subtraction of whole numbers, multiplication and division of whole numbers, and operations with fractions. The six areas listed for comment in the final section were Personal Understanding of Mathematics, Resources, Using Technology, Understanding Students as Learners, Assessment of Understanding, and Teaching for Understanding.

The profiling instruments used in the study are summarised in Table 2, including both the initial profile designed for the start of the program and a final revised version used at the end of the program. The final profile was somewhat shorter than the original. The authors identified some overlap between the planning sections on the initial profile and so Section 2 was removed in the final profile and Section 3 was reduced. It was also felt that similar information could be gained by giving teachers three student survey items, rather than six, in the final profile (see Section 7). It was not necessary to ask background questions a second time (Section 8). In addition, these revisions served to reduce the time taken to complete the profile.

Administration of the Profile

The initial profile was administered to teachers immediately before lunch on the first day of the program. It was carefully explained to the teachers at the outset that participating in the program was a requirement of the Department of Education as funding the program required evidence that it had taken place and some indication of any changes that had occurred. Many teachers, however, appeared resentful and/or threatened by being asked detailed opinions, explanations, and reasoning about their understanding and teaching of mathematical material. A number of teachers expressed concern at having to record their names on the profile and wanted to complete it anonymously. Some

teachers left some sections of the profile blank. For teachers who attempted most sections it took at least an hour and a half to complete the initial profile. Some teachers declined to answer some of the student survey items (see Table 2, Section 7), because they claimed that the questions were too difficult for their students and were thus not appropriate. At the conclusion of each session teachers were also asked to complete feedback forms. Unlike the profiles the feedback forms were completed anonymously. On the first feedback form completed at the end of Day 2 of the program, 36% of responses included complaints about having to fill in the teacher profile.

The final profile was administered to teachers before lunch on the last day of the program and was completed in less than an hour. On the feedback form filled in on the final day, no teacher mentioned the profile that they had just completed, suggesting that at this stage of the program, and in its shortened form, it was not an issue for the teachers.

Analysis

The analysis of the data from the teacher profiles was carried out in two ways. The descriptive written responses of the teachers were successively clustered into groupings by the authors as suggested by Miles and Huberman (1994). Each author was responsible for part of the profile and all authors agreed to the final clusters of responses. The data from the three Likert scales were analysed using *t*-tests when comparing primary and secondary teachers or paired *t*-tests when comparing pre-program and post-program responses. Effect sizes were judged using Cohen's (1969) criterion.

Results and Discussion

The results are presented in two parts. The first part reports on the findings from comparing the responses to the two profiles in terms of monitoring change. The second part reports on the implications drawn by the leaders of the professional development and how the profile helped in decision-making.

Changes in Responses over the Two Profiles

Perhaps the most obvious difference in the responses to the two profiles was the sheer number of words written. This was shown in all written parts of the profile. Although it may be that the use of fewer words in the initial profile was partially due to resentment at being required to complete the profile, the quality of the descriptions in the second profile suggested that change had occurred. In particular, in Section 9 of the first profile, covering teachers' assessments of their professional learning needs in relation to Numeracy, many of the first profiles just had comments like "Yes, I need it," whereas in the second profile there were full summaries of what the teachers felt had been gained throughout the sessions. The non-response rate for the six potential needs surveyed in Section 9 of the original profile ranged from 23% to 48%, whereas in indicating how well

these needs had been met by the program in the final profile, the maximum non-response rate for any topic was 5%. This may reflect to some extent teachers not being aware at the beginning of the program of what their needs were. Not all of the final responses indicated that all needs had been fully met, with a few, for example, indicating that there were still gaps in terms of assessment, although details were not given. Sections 3 to 7 of the profiling instruments (see Table 2) were the other ones used to evaluate teacher change over the program; each is considered below.

Unit Planning (Section 3). Teachers were asked to indicate the understanding goals of the chosen unit; how the topic would be introduced; the amount of class time that would be spent; teaching methods and groupings to be used; assessment methods and strategies; and lessons that would precede and might follow the topic. The teachers were also asked to indicate whether or not they had previously taught the unit and if so, whether they had enjoyed teaching it, and to indicate the response the unit generally elicited from students.

In the second profile compared to the first, the understanding goals suggested by teachers for the chosen unit were both more specific and more likely to relate to conceptual understanding rather than to skill acquisition. For example, one teacher's understanding goal offered on the initial profile was "All students to be able to confidently attempt any problem solving task set", whereas on the final profile the same teacher described the goal as: "Understanding that a fraction is part of a whole. A fraction is a quantity that can be ordered, compared and is useful in the real world. A fraction can be described as a decimal or a percentage." Greater specificity was also evident in terms of assessment strategies, assessment methods, and the activities mentioned in relation to teaching methods. The last of these was accompanied by decreased attention to the student groupings that would be used. Assessment in the final profile was less reliant on observations, collected students' work, and testing, and there was a greater emphasis on verbal interactions with students. Twenty percent of teachers in the second profile, compared with none in the first, made specific mention of the fact that, regardless of the assessment method they used, they would be interested in students' explanations of their thinking rather than just their answers.

A further major difference between responses on the two profiles was the prominence in the second profile of specific materials and activities that had featured in the program. These were particularly evident among suggested introductory activities and teaching methods. One teacher, who suggested the use of "lots of practical activities" on the first profile, indicated on the second that the following would feature among the teaching methods employed: "Experimentation – cut out 1/2, 1/4 – hands on. Use of clothes line and other such activities to provide dialogue and practical experiences." In the second profile the class time nominated tended to be longer and more realistic in terms of the stated aims. Teachers were also more likely to say that the time spent would depend upon the students' needs and that teaching of the topic would be ongoing and/or revisited throughout the year. On the first profile 35% of

Table 2 *Summary of Profile Sections and Types of Knowledge Covered*

Profile Section	Summary Description		Types of Teacher Knowledge								
	Initial Profile	Final Profile	Content	General Pedagogical	Curriculum	Pedagogical Content	Learners' Characteristics	Contexts Values	Ends/ Prof Dev.	Backgrd/	Reflection
1 Significant Factors	Brainstorm a) teaching of numeracy and b) in employing a teacher of numeracy	Brainstorm a) numeracy experiences for students and b) challenges/changes to teaching practice	✓	✓	✓	✓	✓	✓	✓	✓	✓
2 Planning a Numeracy Program	Identify resources, people, preparation time, topics and sequence	Not included	✓	✓	✓	✓		✓			✓
3 Unit Planning	Identify understanding goals, time, teaching & assessment methods, and lessons for a numeracy topic a) a topic of choice and b) either mental computation or percent	Identify understanding goals, time, teaching & assessment methods, and lessons for for fractions, decimals, percents proportional reasoning, or mental computation	✓	✓	✓	✓		✓			✓
4 Confidence	Likert scale of confidence in teaching topics in Middle School numeracy	As per initial profile	✓			✓					
5 Numeracy in Everyday Life	Likert scale on beliefs about numeracy in everyday life	As per initial profile	✓					✓	✓		
6 Numeracy in the Classroom	Likert scale on beliefs about numeracy in the classroom	As per initial profile	✓				✓	✓	✓		
7 Student Survey Items	6 middle school numeracy tasks a) include likely student responses and b) how item would be used in the classroom	3 middle school numeracy tasks a) include likely student responses and b) how item would be used in the classroom	✓		✓	✓	✓	✓	✓		✓
8 Background	Years/grades of teaching experience, mathematics courses studied✓	Not included								✓	
9 Professional Learning	Identify learning needs	Assessment of program in relation to meeting needs	✓		✓	✓		✓		✓	✓

suggested time allocations could be described as either appropriate (25%) or dependent upon the students (10%), whereas on the second profile 29% of the time allocations suggested were appropriate and a further 44% of the teachers did not specify a time because the topic would be revisited throughout the year and/or the time would depend upon the students' needs.

In the second profile more teachers provided details of preceding lessons for their units (71% compared with 63%). The difference was greater with respect to following lessons (81% compared with 40%). Descriptions of both preceding and following lessons were also characterised by greater specificity in the second profile than the first. There was a tendency, evident in both profiles, for teachers to conceptualise "number" in terms of whole numbers only and there were relatively few references to ratio and proportional reasoning in this and other sections of the unit plans. When these topics were mentioned it was often together without any distinction between them or any indication of an awareness of the links between proportional reasoning and any of fractions, decimals and percent. It seemed that teachers remained more comfortable with whole numbers than non-integral numbers, and least comfortable with the ideas of ratio and proportional reasoning.

Ninety percent of respondents on both profiles indicated that they had taught the unit described before and hence were speaking from experience. Given the high frequency in the final profile of mentions of activities featured in the program it seems that many teachers had trialled these activities within the life of the program. Most teachers (82% on the first profile and 92% on the second) who had taught the topic before indicated that they had enjoyed doing so, with almost all reporting positive responses from students. This may not be surprising as teachers are more likely to describe positive experiences than others.

Confidence (Section 4). In relation to Confidence in teaching various topics in the Numeracy curriculum, secondary teachers expressed more confidence than primary teachers on all topics. In the initial profile the mean differences ranged from very small (0.06) on mental computation with addition and subtraction of whole numbers to 1.25 (out of 5) points on the Likert scale for Ratio and Proportion. Differences were significant at the 0.01-level for Percent and Ratio and Proportion, and at the 0.05-level for Critical Numeracy in the Media, and Operations with Fractions. This outcome is likely to be related to the observation in the previous sub-section about lack of association of ratio and proportion generally with number work. Ratio and Proportion was the topic for which the least confidence was expressed by both groups. In the second profile confidence increased for both groups on all topics but the differences between primary and secondary teachers remained, with the largest mean difference being 1.03 points on Ratio and Proportion. In this instance there were significant differences at the 0.01-level for Ratio and Proportion and Critical Numeracy in the Media, and at the 0.05-level for Percent. For the overall differences in confidence in topics across time, changes were significant at the 0.01-level or less for Fractions, Decimals, Percent, and Operations with Fractions. All differences were positive reflecting increased confidence and the effect sizes were medium.

Numeracy in Everyday Life (Section 5). For the Likert questions involving beliefs about Numeracy in Everyday Life, there was strong disagreement on both the first and second profiles with the statement that "Nobody needs fractions any more." There was less but still relatively strong disagreement with a statement about not believing weather forecasts. Overall from the beginning to the end of the program there were differences on two of these items that had a medium effect size ($p < 0.01$). These were, "Understanding decimals and percents is becoming increasingly important in our society" and "I often perform mental calculations involving fractions or decimals." In both cases agreement was stronger in the second profile. For the second statement it is not known if the change was a result of learning during the program or just an increased awareness of operations the teachers often performed without thinking.

Numeracy in the Classroom (Section 6). For the Likert questions on beliefs about Numeracy in the Classroom, there were three statements where the effect size of the average change to greater agreement with the statement was medium ($p < 0.01$) at the end of the program. These had to do with teacher fascination with how children think, the importance of presenting mathematical content in the correct sequence, and the importance of justifying the mathematical statements one makes. The strongest levels of disagreement with items, consistent over both profiles (with means greater than 4 out of 5), were associated with being uncomfortable with an unexpected response by a student, belief in telling students answers as an efficient teaching strategy, and the opinion that teaching mathematics would be very difficult without a text book.

Student Survey Items (Section 7). This section, containing several numeracy items, asked teachers how the questions would be answered by their students, both appropriately and inappropriately, and also how the questions would be used by the teachers themselves in the classroom. This was an area where there were demonstrably more comments made in the second profile, as well as more comments involving strategies, both for the students and for the use in the classroom. The three questions asked on both profiles are considered here. Although the number of teachers responding to the item "90% of 40" was about the same (39 and 40) on the initial and final profiles, the total number of responses rose from 79 to 99 (25% increase) and the second time there was more variety in the suggested approaches to the problem. There were still four teachers who said that this problem was too difficult for their students or they would not use it in their classrooms. In the second profile, more incorrect answers for students were suggested, as well as more student answers including justifications. For the use of "90% of 40" as a basis for a classroom activity, only 27 out of 48 teachers in the initial profile indicated how they would work to build understanding of the problem. The degree of explanation or justification of the statements made varied but the most common general headings were "demonstrate correct process" and "work with percent." Only two teachers provided more than one suggestion. There was an increase to 38 teachers responding to this item on the second profile. The constructive explanations for use in the classroom in the final profile rose, with only one teacher giving a

"demonstrate the correct process" response. There were triple the number of suggested types of use of the problem in the classroom. Two teachers indicated they had not been teaching long enough to know more than one correct strategy for this problem. It is interesting that although quite a few teachers suggested students would work out 10% of 40 and multiply by 9, none in the initial profile said *they* would use this method. It was, however, suggested by five teachers in the final profile.

The second student item used on both profiles was "4 x 3/4". Thirty-seven teachers responded with suggestions for student responses to this question in the first profile. They provided, however, many more responses than for the previous item, a total of 88. Many of these were numbers only (e.g., 12/16, 3/16) with no descriptions of accompanying strategies. A few, however, suggested additive strategies (such as 3/4 + 3/4 + 3/4 + 3/4) or rearranged squares or circles split into quarters. On the final profile, 43 teachers responded with a total of 120 suggestions for student answers. More incorrect student responses appeared, as well as more responses accompanied by strategies. Although fewer responses were given in the initial profile for how the teachers would use "4 x 3/4" in the classroom than to what student responses might be, there were more suggestions based on modelling. This was balanced to some extent, however, by the number of responses related to "explaining" multiplication and "cancelling". Fewer teachers initially gave multiple responses to this part with 28 teachers providing at least one response. On the second profile more teachers, 40, responded, with a total of 52 ideas as to how they would use "4 x 3/4" in the classroom. There was more mention of using hands-on materials and specifically modelling 4 wholes divided into 3/4's with subsequent rearrangement into 3 wholes. As well there were more specific suggestions with a less rule-based focus than in the initial profile. Several teachers who made good suggestions introduced them with "I would ask students how they came about reaching their (incorrect) answers," or included reinforcing remarks like "4 times nearly 1 is a good estimation," then drew a representation.

The third item that asked for suggested student responses and potential classroom use on both profiles was an applied numeracy question based on pie charts from newspaper articles, hence focussing on percent. In the first profile the percentages in the pie chart added to 128.8%, whereas in the second profile they summed to 72.51%. Although the pie charts were different, the questions were the same. The recognition of the error in the pie chart was considered to be an important part of the responses to this item, either shown in suggested student responses or in how the item would be used in the classroom. In the first profile 23 of 40 responding teachers (58%) mentioned the error and of these 14 (61%) made reasonable suggestions for both student responses and uses in the classroom. In the second profile, 38 of 46 teachers (83%) noted the error and of these 30 (79%) made reasonable suggestions for both student answers and classroom use. Both of the percent figures are better for the second profile than the first, although media pie graphs were not a specific object of study during the program.

Implications for the Professional Development Program

The providers of the program were the "users" of the profile in terms of judging the improvement made by teachers as a result of the program. It should be noted that teachers had nothing to gain personally from filling out the profile as no individual data were provided to the employer. The only requirement was that a profile be completed. Two aspects of the responses of teachers were prominent in terms of demonstrating teacher change as a result of engagement with the program. These were the increased response rate noted in the final profile, and the reflective quality of responses in this instance. The percentage of responses overall was more than 95% for all sections of the final profile, with very few sections being left blank. In addition, the number of words per response also increased. Although there were a few teachers who made reflective comments in the initial profile, many more did in the final one. One explanation for this is that the program suited their needs, including the creation of a congenial collaborative environment for school groupings, and enabled them to become more reflective thinkers about the issues involved in middle school numeracy programs. This was illustrated in responses to Sections 1 and 9 of the final profile. Only four teachers indicated that the program had affirmed their current practice, whereas the majority indicated that they were re-examining and re-evaluating their practice and had been challenged by the program. The following comments are examples of some of the challenges and changes upon which teachers reflected.

> The program has really inspired me to want to play a leading role in maths at school and in working towards collaborative whole school planning. I have stopped being hung up on operations.
>
> This program has made me rethink many aspects of my practice, e.g. less emphasis on those things I perceived as necessary for students to 'know' before going to high school and increased emphasis on mental computation strategies.
>
> I've had to think about how I teach certain concepts, e.g. fractions, percentages and how I can manage this more successfully by various tasks and different contexts to achieve deeper understanding which can be transferred to other contexts.

In addition there were some interesting comments from teachers about their increased awareness of the importance and potential of developing this area: "[This has] given me a different perspective – more focus on relating what we do in the classroom to the mathematics happening around them." Many teachers expressed an increased awareness and interest in looking at the media as a resource: "I'm more aware of looking for 'numeracy' in the media." This was apparent in terms of exploiting the media "as a source of discussion" and particularly in making the mathematical concepts link to real life experiences. As well, teachers indicated "teaching for understanding" was an adequate part of the program but some went further, for example: "Some of the concrete activities have been most useful. The emphasis on concrete aids is one I now appreciate much more fully." Other teachers commented that in considering students as

learners the program was "a good reminder where kids with low confidence or those not willing to take risks are coming from and how they feel."

The positive change in eight of the Likert items, with significant difference and medium effect size, is suggestive that the program had some effect on the confidence, attitudes, and beliefs of the teachers who participated in the program. This is particularly encouraging given the acknowledged difficulty of effecting change in teachers' beliefs (Cooney, 2001) and the relative brevity of the program. That teachers became more confident in four areas of the numeracy curriculum is a strong point, although the mean value for Ratio and Proportion was in the end 2.35 (only just to the more positive side of neutral), indicating that there is likely to be more improvement needed in teacher confidence before the ideal is reached in terms of teaching this topic.

The teachers' improved ability to plan lessons and units of work was demonstrated in the comparison of responses to the two profiles. It seems that a major impact of the program was an expansion of the teachers' repertoires of activities and materials. Responses to these sections of the profile also indicate that the program was successful in shifting many teachers' emphases from skill acquisition to understanding, and from a focus on correct answers to an interest in students' thinking.

In terms of positive change in content knowledge and pedagogical content knowledge displayed in responses to the student items, this was observed both in proposed student responses and in potential classroom use of items. As the program had modelled ways to present mental computation strategies, pattern in work with tables, proportional reasoning, percents, fractions, and decimals, responses to the last survey items were particularly encouraging.

Among responses in terms of needs, and whether these had been met by the program, most striking was the response to the large resource of materials provided to individual teachers and their schools. Some teachers reported having no materials or professional resources related to numeracy at the beginning of the program. As noted in the Method section, the program was targeting particular schools and between three and five middle school teachers were selected from each school to participate. This, and the time for planning, may have been another factor that influenced the reflective attitude and positive gains of the participants and it was of interest to gauge the teachers' reactions. The teachers expressed positive reactions to this move, both in the final profile and other feedback.

Conclusion

Significant in the trialling of the profiling instrument in this study was the fact that it was used in an actual live setting involving professional learning where all participants completed the profile, not with teachers who volunteered to complete it as reported in other studies by Watson (1998, 2001). Not only did the use of the profile in this setting continue to reflect the knowledge indicated as important by Shulman (1987b), but also it provided strong evidence of teacher change resulting from a targeted professional learning program. Conclusions

relating to each of these aspects of the study are provided below in relation to the research questions.

To what extent is the profiling instrument useful for measuring change in teachers' various types of knowledge?

Although not considering some of Shulman's (1987a, 1987b) seven types of teacher knowledge in as much detail as other researchers (e.g., Ball & Bass, 2000; Kanes & Nisbet, 1996; White, et al., 2004), the breadth of coverage in this study was greater. Changes in six of Shulman's seven knowledge types were evident from teachers' responses to the two profiles. Positive changes in content knowledge were suggested in relation to fractions and percent by the more detailed responses to the student survey items in the final profile, and particularly by the increase in the number of teachers indicating their awareness of the error in the pie chart. The teachers' unit plans however suggested some lingering deficits in their knowledge of ratio and proportion. These inferences are consistent with the changes in teachers' ratings of their confidence to teach these topics.

The profile also provided abundant evidence of changes in teachers' general pedagogical knowledge, pedagogical content knowledge, and knowledge of learners. These were reflected in the unit plans, in the greater emphasis on exploring students' thinking, and in the increased reference to student related factors in determining the time spent teaching a topic. The two items from Section 6 for which significant change occurred also related to these knowledge types and the increases in the diversity and detail of teachers' suggestions concerning possible student responses to the student survey items provided substantial evidence of change in relation to these knowledge types.

Some of the evidence presented in relation to other knowledge types was also suggestive of change in the teachers' knowledge of the ends, purposes and values of education. In particular there appeared to have been a shift from seeing the purpose of numeracy teaching as the acquisition of skills, to viewing it as the development of conceptual understanding.

Responses to Section 9 of the profiles provided some evidence that teachers had increased their knowledge of education contexts in terms of their awareness of both material and human resources that were available to them. Change in curriculum knowledge was less evident because questions related to awareness and use of various resources, which may have revealed this, were omitted from the second profile. This was done because curriculum knowledge with respect to Numeracy was not a major feature of the program.

In summary, the profiling instrument applied in this context appeared well suited to measuring change in Shulman's (1987a, 1987b) knowledge types. It also went some way to addressing the plea of the Australian Councils of Deans of Education and Science (2003) to provide evidence on the effectiveness of professional learning. Although further steps may include collecting classroom observational evidence and outcomes for students, this is a beginning that offers a solution for those with limited resources.

How successful was the professional learning program in terms of facilitating change in teachers' knowledge?

The changes in teachers' knowledge evidenced by their responses to the profiling instrument were confirmed by their anonymous feedback provided at the end of four of the days of the program. It seems that the program did result in change in teachers' knowledge. Overall this change was in the desired direction. The apparent continuing difficulty with proportional reasoning was also highlighted and gave the providers important feedback for the next implementation of the professional learning program.

The evidence collected in association with this professional learning program supports the findings of Garet, Porter, Desimone, Birman, and Suk Yoon (2001) who considered a large sample of self-report data from teachers involved in a national professional development program for mathematics and science teachers in the United States. They found that the features of activities that had "significant, positive effects on teachers' self-reported increases in knowledge and skills and changes in classroom practice [were] (a) focus on content knowledge; (b) opportunities for active learning; and (c) coherence with other learning activities" (p. 916). The advance made in this study is that in several areas, particularly content knowledge, pedagogical content knowledge, and knowledge of students as learners, the data show actual evidence of change rather than just teacher reports of change.

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