Changing the Professional Knowledge of Teachers

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Concept mapping exercises were used to determine whether changes to teacher knowledge had occurred as a result of their involvement in an early numeracy professional development program. Findings indicate that the most significant change to teacher knowledge occurred in relation to how children learn mathematics. While some change was evident in teachers' pedagogical knowledge, there was little change to teachers' knowledge of mathematics content.

A common assumption is that the more mathematical content knowledge a teacher knows, the more effective they will be in teaching it (Alexander, Rose, & Woodhead, 1992). While this assumption seems logical and is no doubt desirable, there is little research evidence to support this in practice (Rhine, 1998).

Recently, a study by Askew, Brown, Rhodes, Johnson and William (1997) sought to explore the knowledge, beliefs and practices of experienced primary school teachers. They found that what distinguished highly effective teachers of mathematics from other teachers was a particular set of understandings which underpinned a particular array of teaching practices. Askew et al. (1997, p. 3) concluded that "highly effective teachers of numeracy themselves had knowledge and awareness of conceptual connections between the areas which they taught in the primary mathematics curriculum", but that this was *not* associated with having high levels of formal education in mathematics. They also found that highly effective teachers were more likely than other teachers to have undertaken mathematics-specific professional development over an extended period of time. The researchers concluded that while having an extended knowledge base of mathematics is helpful, it is not necessarily enough to ensure effective teaching of mathematics. Furthermore, they concluded that what seemed to matter more was the nature of that knowledge—the more effective teachers had a better understanding of the interconnectedness of mathematics concepts and possessed a good understanding of children's mathematical thinking.

The study reported here is concerned with primary teachers' professional knowledge of mathematics. It is part of a larger study conducted on behalf of the NSW Department of Education and Training (DET) to evaluate its early numeracy program—Count Me In Too (Bobis, 2000). Investigations designed to investigate the impact of this program on teachers and children have been reported at previous MERGA conferences. Since many of these reports contain detailed descriptions of various aspects of the program (e.g., Bobis & Gould, 1998; Wright, 1998) they will not be repeated here. Instead, a brief introduction to the program is provided along with a rationale for the current study based on the program's main aim and specific findings of previous investigations.

Professional Development of Primary Teachers in Mathematics

Count Me In Too (CMIT) has been operating in NSW government schools since 1996. It is a classroom-based professional development program that has as its main aim: "for teachers to better understand children's mathematical strategies and their development from less sophisticated to more sophisticated strategies" (Stewart, Wright, & Gould, 1998, p. 557). Hence, there is a major focus on the development of children's mathematical thinking.

In 1996 an evaluation of the program focused on the impact it had on the professional development of teachers (Bobis & Gould, 1998). Open-ended questionnaires and structured interviews revealed that, generally, teachers considered that they had gained knowledge relating to mathematical content, teaching strategies and of children's mathematical thinking.

The investigation reported here intended to extend these findings by exploring the impact of Count Me In Too on the professional knowledge of teachers more explicitly. Rather than relying on teachers' self-reports of change, this study documented what, if any, knowledge changed and how it changed. More specifically, it was designed to address the following research questions:

1. Does Count Me In Too have an impact on the professional knowledge of teachers?
2. If so, how does the professional knowledge of teachers change as a result of their involvement in Count Me In Too?

The Study

To determine whether changes to teacher knowledge had occurred as a result of their involvement in CMIT, data from two research tools were combined and compared—concept mapping and semi-structured interviews. While the two data gathering strategies were complimentary, restrictions on length necessitate that this paper only deal with findings from the concept mapping exercise.

Concept Mapping

Concept mapping has been used to examine how individuals change and organise their knowledge (Jones & Vesilind, 1996). It has been shown to be a powerful and sound method for assessing conceptual change and allows researchers to see how knowledge is restructured over time (Markham, Mintzes, & Jones, 1994).

Researchers using concept mapping usually adopt a scoring scheme to assign a numerical value to each map (e.g., Chinnappan, Lawson, & Nason, 1999). Such scoring systems often rely on information being categorised as *examples, hierarchies, crosslinks*, *links*, *nodes* and *key nodes*. For an explanation of each category and an associated scoring scheme, the reader is directed to Jones and Vesilind (1996).

Such quantitative methods have not always been considered appropriate and some researchers have used only qualitative methods to analyse concept maps (e.g., Williams, 1998). For the purposes of this study, an analysis that relied solely on a quantitative or a qualitative analysis of the maps was considered inappropriate. Attempts to apply a scoring system similar to that outlined by Jones and Vesilind (1996) ignored the *type* of knowledge possessed by teachers. Since an aim of this study was to investigate the impact of CMIT on the professional knowledge of teachers it was more revealing to simply note the frequency with which each type of knowledge occurred. Hence, the basic units used in the quantitative analysis were *key nodes*, *links* and *crosslinks* associated with a *type* or *source* of knowledge.

Participants

Participants were drawn from the Sydney Metropolitan area. Twelve teachers from 4 primary schools participated in the investigation. While the final selection of teachers for inclusion in the study rested on their willingness to participate, a number of criteria were considered. Namely, the desire to include teachers of both genders, drawn from a variety of school districts and with a range of teaching experiences. Of the 12 teachers included in the study, three had been teaching for less than 8 years, six had been teaching between 12 and 20 years and the remainder had each taught for more than 20 years.

Procedure

Teachers were relieved from teaching for approximately 2-3 hours on each of two occasions—once at the start of the study just prior to their involvement in the CMIT project, and again approximately 4 months later. On the first occasion, teachers received standardised instructions on how to draw concept maps and were given an opportunity to draw a practice map about sample topics, such as sports. They were then asked to draw a concept map about the *knowledge they have to allow them to teach mathematics*. After a short break, each teacher was interviewed. The purpose of the interview was threefold:

1. It provided an opportunity for teachers to explain their concept maps to the interviewer;
2. It allowed the concept map to be used as a prompt to solicit teachers' knowledge about teaching mathematics to young children; and
3. It was used to gather information relating to the experiences and factors teachers perceive as being responsible for their existing knowledge of mathematics, the teaching of mathematics and how children learn mathematics.

During the initial interview, teachers were allowed to modify their map using a different coloured pen if they desired. Questions adapted from Jones & Vesilind (1996) were used to prompt discussion of each teacher's concept map. For a full list of questions and a discussion of the interview findings see Bobis (2000).

On the second occasion, teachers were asked to study their previous map and to decide if they would like to either draw a new map, modify and redraw the old map, or leave the old map as it was. After drawing their second map, teachers were interviewed for the second time. The major purpose of this interview was to allow teachers to explain the changes they had made to their original concept map and why.

Results and Discussion

This section presents and discusses the findings of the quantitative data derived from an analysis of the concept maps constructed by all 12 teachers. However, discussion will focus on one teacher—Theresa, a Year 3 teacher with 7 years teaching experience. Theresa's concept maps have been included to assist with an explanation of the results. These have been redrawn with a computer graphics program to allow them to be more easily read (see Figures 1 and 2).

Analysis of Concept Maps

Key nodes categorised as a type of knowledge were sub-divided to include the categories of content knowledge, pedagogical knowledge and knowledge of children's cognition. Examples of key nodes that were categorised as content knowledge from Figure 1 are "Topics", "Language", "Symbols" and "Problem Solving". The lines linking each of these key nodes to an example of content, such as "prime" and "subtraction", were categorised as node links. Hence, in Figure 1 (the concept map constructed by Theresa during the first round of interviews) there are 4 instances of key nodes pertaining to the teacher's content knowledge, 37 instances of links to more specific examples of content knowledge and 1 instance of a crosslink stemming from the key node "Problem Solving".

Of the 12 teachers participating in the study, 10 elected to modify their original concept map during the second concept mapping exercise and 2 teachers (including Theresa) decided to draw new maps. Table 1 summarises the mean number and standard deviation of key nodes, links and crosslinks for each category of knowledge for the whole teacher sample on the two occasions in which concept maps were constructed. Individual results for Theresa are presented in Table 2.

Table 1 highlights a number of features typical of the maps constructed during the first concept mapping session. These include:

1. The relatively high number of key nodes and node links associated with pedagogical knowledge;
2. The relatively low frequency of features associated with mathematics content knowledge, children's cognition and source of knowledge; and
3. The minimal level of integration between the different types of knowledge as evidenced by the low frequency of crosslinking.

A comparison of the means for the two mapping exercises reveals several trends in the concept map changes. For example, it is evident that there was:

1. A decrease in the frequency of key nodes and node links categorised as content knowledge;
2. An increase in the frequency of node links categorised as pedagogical knowledge and knowledge of children's cognition; and
3. A slight increase in the level of integration between the different types of knowledge as evidenced by the increase in the frequency of crosslinks.

It is evident from Table 1 that concept maps constructed prior to the commencement of CMIT contained more key nodes associated with teachers' pedagogical knowledge than any other type of knowledge. This category encompassed a wide range of knowledge regarding how teachers teach mathematics. For example, it included key nodes relating to teachers' knowledge of grouping children for instruction, their knowledge and use of resources and of various assessment strategies. Such key nodes were linked to numerous examples illustrating teachers' familiarity with the variations existing within each of these sub-categories. The large number of pedagogical knowledge node links can be explained in this way. For instance, the first concept map constructed by Theresa (see Figure 1) links 4 examples to the key node "equipment" and 5 examples to the key node "evaluating". Further characteristics of Theresa's concept maps are summarised in Table 2.

Table 1
Analysis of Concept Maps for Round 1 (R1) and Round 2 (R2). Standard deviations are in brackets (n=12)

Information	Mean Number of Key Nodes		Mean Number Of Node Links		Mean Number of Crosslinks	
Types of Knowledge	R1	R2	R1	R2	R1	R2
Content	1.7 (1.3)	0.9 (0.8)	6.8 (10.6)	4.5 (5.1)	0.2 (0.4)	0.5 (0.7)
Pedagogical	4.2 (2.4)	4.5 (2.4)	31.8 (18.3)	37.9 (20.7)	1.5 (2.0)	1.8 (2.6)
Children's Cognition	0.8 (0.6)	3.3 (5.8)	4.6 (4.1)	11.8 (5.0)	0.4 (0.7)	1.3 (2.0)
Source of Knowledge	1.3 (2.0)	1.5 (2.2)	7.3 (11.0)	8.3 (12.3)	0.7 (1.8)	0.7 (1.8)

Key nodes relating to teachers' content knowledge were less frequently represented on the concept maps than those relating to pedagogical knowledge. This was mainly due to the fact that teachers grouped their content knowledge under one key node. For example, one teacher used a single key node, titled "Topics", to encapsulate all mathematical content knowledge. Major content areas relating to the strands in the NSW Syllabus, *Mathematics K-6* (1989), were then linked to this single key node. On the other hand, the same teacher used 6 key nodes to map all the pedagogical knowledge she possessed.

Table 2.
Frequency of key nodes, node links and crosslinks on Theresa's maps for Round 1 and Round 2

Information	Number of Key Nodes		Number Of Node Links		Number of Crosslinks	
Types of Knowledge	R1	R2	R1	R2	R1	R2
Content	4	1	37	10	1	1
Pedagogical	3	2	25	20	2	2
Children's Cognition	0	3	1	19	1	6
Source of Knowledge	0	0	0	0	0	0

The initial concept map constructed by Theresa (Figure 1) is typical of those containing a large number of key nodes and node links categorised as content knowledge. It will be noticed from her concept map that she recorded numerous examples of content, thus making her tally of node links quite large compared to other teachers who gave few or no specific examples of content.

The overall low mean score for key nodes relating to the way children learn mathematics is explained by the fact that such knowledge was not represented in 4 of the 12 teachers' initial concept maps (see Table 1). This does not mean that these teachers knew nothing about children's cognition before undertaking CMIT. Instead, it may indicate that such knowledge was not of sufficient importance to these teachers to be given recognition as a key node at this point in time.

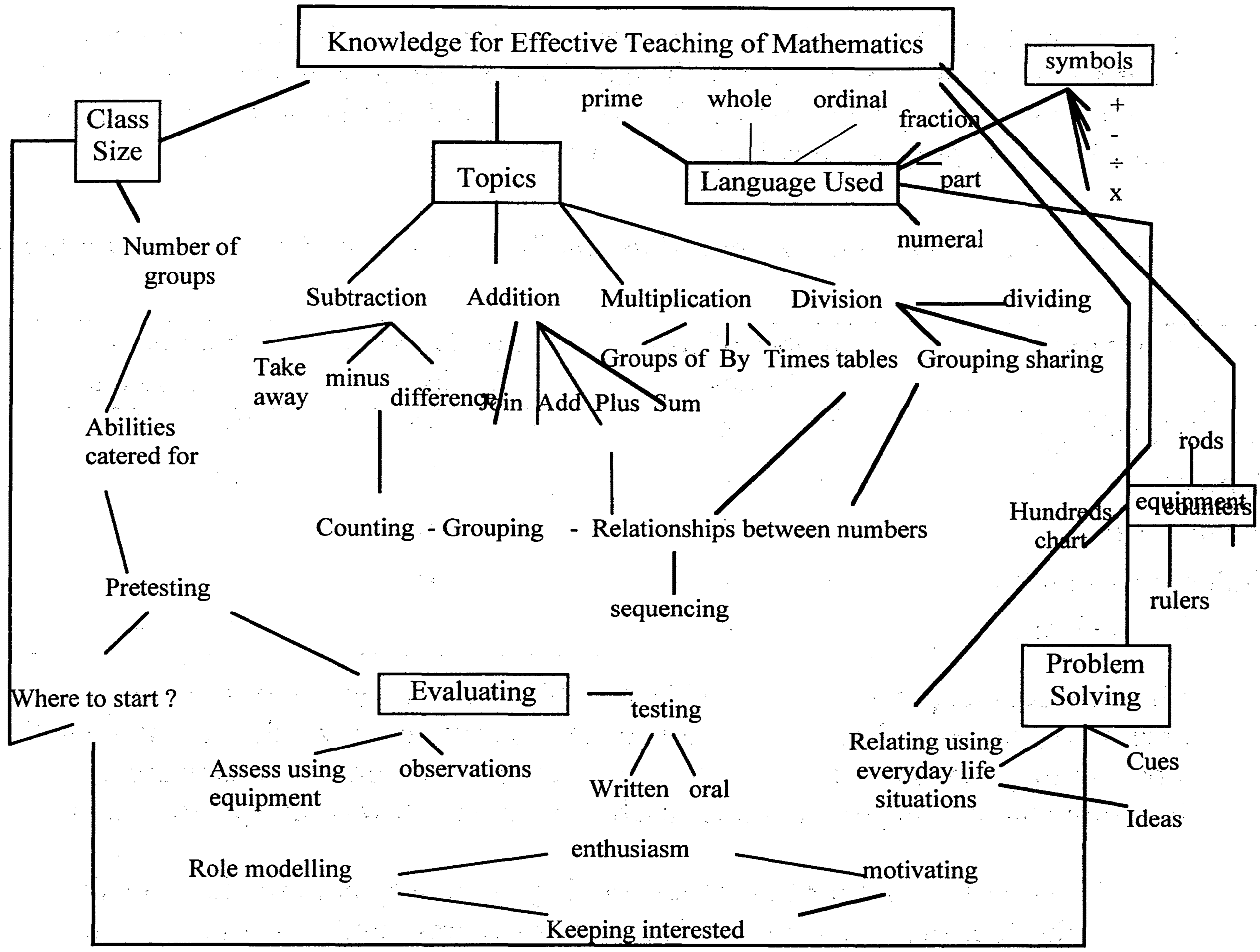

Figure 1. Concept map constructed by Theresa during the first concept mapping session.

Another feature relating to initial concept maps that is highlighted in Table 1 is the minimal level of crosslinking. Crosslinking between the different types and sources of knowledge occurred in 7 teachers' initial concept maps (see for example, the crosslink between "problem solving" and "where to start?" in Figure 1). While more crosslinks were evident from features associated with pedagogical knowledge than any other type or source of knowledge, these were still proportionally low given the high frequency of key nodes associated with this type of knowledge. This small number of crosslinks indicates that there may be a lack of integration between the different types of teacher knowledge.

It will be noted from Table 1 that the mean number of key nodes and node links categorised as content knowledge actually decreased in the second concept mapping exercise. This is because the frequency with which this type of knowledge was represented on the concept maps remained relatively stable from one mapping session to the next for *most* teachers. However, there was one exception to this which accounts for the decrease in the overall frequency of features related to mathematical content knowledge being represented on the second round of concept maps. The initial concept map constructed by Theresa contained a large number of key nodes and node links in the category of content knowledge (see Figure 1 and Table 2), but during the second concept mapping session Theresa constructed an entirely new map that contained few features of the first (see Figure 2). Hence, while examples of content knowledge dominated the first map, the second map contained few examples of content knowledge. Instead, Theresa's second map indicates that she is now much more focused on her knowledge of how children learn mathematics—the stages of mathematical development and the strategies children use to help them solve mathematical problems at each stage.

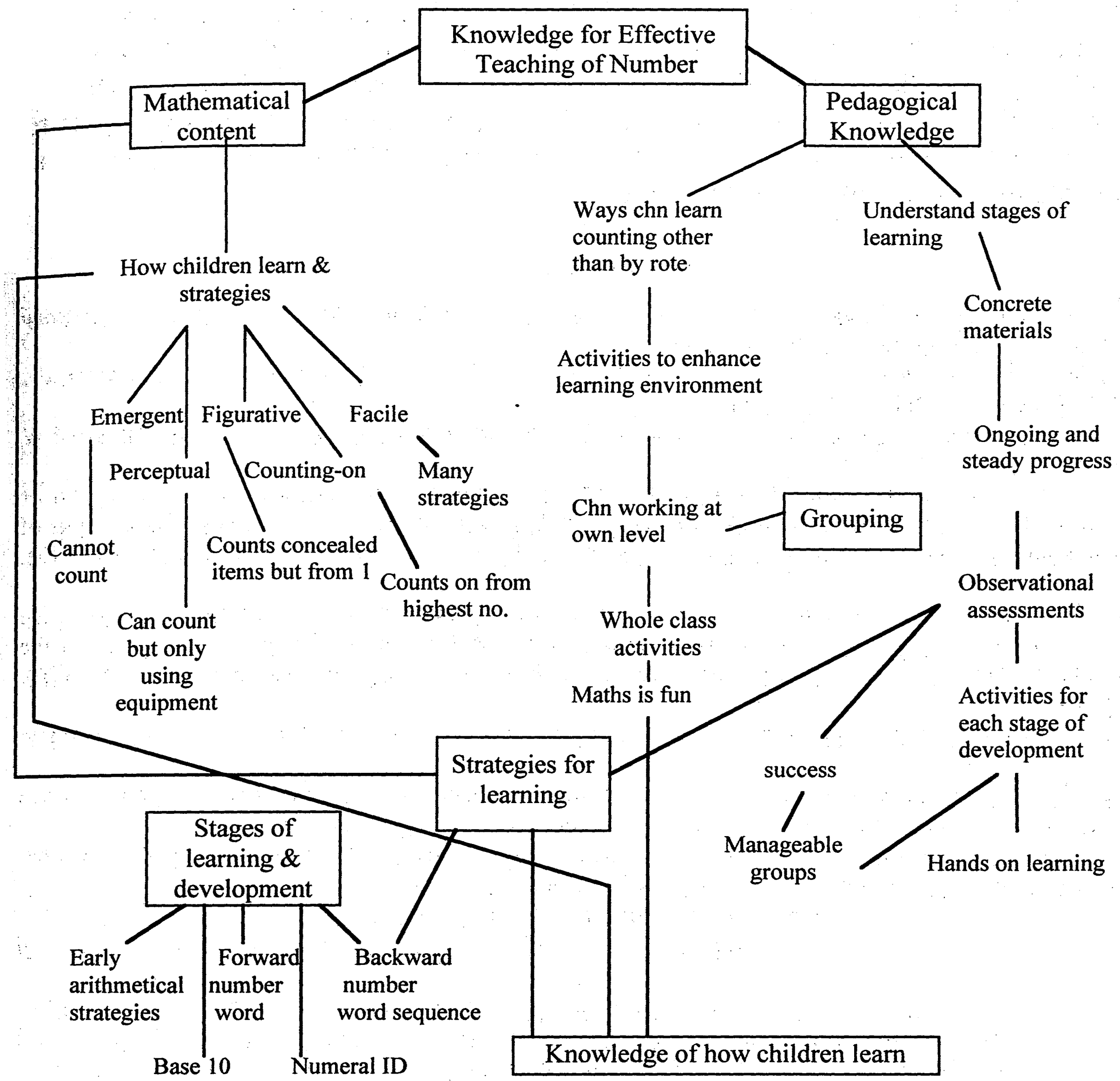

Figure 2. Concept map constructed by Theresa during the second concept mapping session

The refocusing of attention towards children's cognition was noted in the second concept maps of many teachers. This is evident from a comparison of the means presented in Table 1. Theresa's initial map (Figure 1) was quite typical of other teachers' maps in that it does not contain any reference to children's cognition. However, her second map (Figure 2) contains 3 key nodes and 19 node links in respect to this type of knowledge. This indicates a major reconceptualisation of her view towards teaching mathematics.

Another trend in concept map changes is the slight increase in the level of integration between the different types of knowledge. This is evidenced by the increase in the frequency of crosslinks. While the number of crosslinks increased overall, concept maps constructed by three teachers contained no crosslinks even after the second mapping session. These teachers tended to be those who had experienced CMIT for a shorter period of time.

Summary and Conclusion

The evidence derived from an analysis of the concept maps indicates that Count Me In Too *did* have an impact on the professional knowledge of teachers. In particular, there was an increase in teachers' knowledge of how children learn mathematics and, to a lesser extent, their pedagogical knowledge. This was evident in the second concept mapping exercise which indicated an increase in the frequency of key nodes and node links associated with these two types of knowledge. The fact that the degree of knowledge integration only increased slightly from the first to the second mapping exercise overall, demonstrates how difficult it is to achieve such an outcome even by classroom-based professional development programs that are implemented over an extended period of time.

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