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CONCEPT MAPPING AND MOVING FORWARD AS A COMMUNITY OF LEARNERS

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Abstract. This paper describes some examples of how a group of teachers came together as a community of learners to plan for the implementation of an innovative teaching and learning strategy. Concept mapping was the strategy and none of the teachers had prior experience in its classroom application. During a twelve-month project the teachers, who taught both primary and secondary students, completed professional development activities to become familiar with the technique. These included a variety of mapping tasks that enabled teachers to reflect on their practice and to share ideas before introducing the strategy as part of their teaching. A review of teachers' feedback indicated that the professional development activities undertaken provided quality support for the introduction of an innovative teaching and learning strategy.

1 Introduction

In the Australian teaching and learning context, professional teaching standards which describe the attributes of teachers at key career stages are becoming increasingly important as frameworks for informing beginning and experienced teachers who wish to develop their teaching practice or to plan for ongoing professional development (e.g., Teaching Australia, 2007). Professional associations have also developed standards that describe aspects of professional knowledge, professional practice, and professional attributes of excellent teachers in the respective disciplines. The mathematics and science standards (AAMT, 2007; ASTA, 2007), for example, refer to the way excellent teachers: (1) seek out effective strategies and techniques for teaching and learning; (2) engage in professional development that is collegial; (3) actively explore new teaching ideas; and (4) initiate purposeful dialogue with students about their subject.

This paper reports some data from an Australian Schools Innovation in Science, Technology and Mathematics (ASISTM) project in mathematics and science based on the introduction to concept mapping to primary and secondary teachers who had no previous experience in concept mapping. Relevant to the Project were a number of the ASISTM aims, namely:

1. to encourage innovation by (a) fostering a culture of innovation in schools; (b) improved levels of coordination of science/mathematics teaching and learning between primary and secondary schools; and (c) increased collaboration between schools and universities; and
2. to promote world class teaching and learning through (a) changes and improvements in teachers' approaches to, and techniques in, teaching science/mathematics; and (b) enhanced student interest and engagement in science/mathematics learning (ASISTM, 2007).

The Project introduced hierarchical concept maps to teachers and students as meta-cognitive tools, firstly, to foster critical inquiry and competence in analysing mathematics and science content embedded in problems and activities and, secondly, to address students' mathematical and scientific literacy needs. To ensure the sustainability of innovation, teachers were trained first with appropriate support over a term before classroom trials. For teachers to assimilate innovative approaches, an important aspect to consider is their preparedness to take part in reflective practice and to share emerging understandings with peers within a community of learners. Hence, this paper focuses on some of the outcomes of the processes intended to support the teachers as learners of innovative strategies, reflective practitioners in a community of learners, and as classroom implementers of innovation. The focus questions guiding this paper are:

1. What are some of the issues and concerns raised by teachers when introduced to an innovation, such as concept mapping?
2. What processes did teachers go through to resolve these issues?
3. In what ways did concept mapping provide a useful planning tool for teachers?

2 Professional Development

An important characteristic of a successful professional development program, as articulated by Loughran & Gunstone (1997), is *working with*, rather than *doing to*, *teachers* by considering two contextual influences. First, the difficulty of sustaining professional learning in schools due to the uncertainties of professional practice. Second, teachers need to constantly refine their approaches to ensure pedagogical practices are meaningfully

applied and developed to support student learning. Clarke and Clarke (2007), recognising teachers' central role, proposed *ten key principles* to increase the likelihood of long-term and effective professional development and to identify the processes teachers engage with during associated programs. For example, addressing the principle of "issues of concern and interest, largely (but not exclusively) identified by the teachers themselves, and involve a degree of choice for participants" (Clarke & Clarke, 2007, p1) translates into negotiating the content and structure of professional development with teachers. Failure to place teachers as the central agents to reform practice or implement innovations, can only lead to disappointment in the achievement of positive outcomes (Van Driel, Beijaard & Verloop, 2001).

A four-point-scheme working-model for professional development, identified by Black and Wiliam (1998) with communities of learners who reflect on their practice for development, include (1) the provision of support for teachers to work together, (2) teachers incorporating ideas into classroom practice; (3) balancing the requirements of curriculum imperatives and meaningful learning; and (4) teachers receiving feedback from peer/external review of their practice. Overall, to guide development within the teaching profession, Crowther, Kaagan, Ferguson and Hann (2002) propose that teachers need to be supported to embrace learning, participation, collaboration, cooperation and activism.

3 Concept Mapping in Innovation

Ausubel's meaningful learning theory proposes that learners' cognitive structures are hierarchically organized with more general, superordinate concepts subsuming less general and more specific concepts by progressive differentiation and/or integrative reconciliation (Ausubel, 2000; Novak & Gowin, 1984). Through maps/diagrams, students illustrate publicly their interpretation and understanding of a topic/problem. Concept maps are hierarchical networks of interconnecting concepts (nodes) with linking words describing the nature of interconnections (Novak, 2002; Schmittau, 2004). Concept maps provide a metacognitive tool that can be used by teachers and students alike to organize and reflect on their knowledge (e.g., Conlon, 2004; Fellows, 1993; Fraser & Edwards, 1987; Novak, 1998; Novak & Cañas, 2008). Since the original work of Novak and Gowin (1984), methods for the analysis of concept maps have incorporated both quantitative and qualitative procedures. Each procedure provides different information about the quality of concept maps although each is directed towards obtaining a tangible representation of cognitive structure. Concept maps, together with the discussion that surrounds their preparation, provide an ideal reflective context for teachers as they interpret a new teaching and learning strategy, and plan for its implementation.

4 Methodology

A two-day professional development workshop (October 2005) introduced ten teachers, from two independent primary and central schools, to the innovative strategies of concept mapping and vee diagrams in mathematics and science. Presentations were interactive allowing teachers to field questions for clarifications of issues and ideas and to critique presented maps/diagrams. The emphasis was to illustrate the innovative ideas through examples of maps/diagrams previously constructed by secondary students and student-teachers to illustrate applications (a) in *learning* such as analysis of problems and activities including illustration and communication of one's understanding, and (b) in *planning* instruction such as teaching sequences, lesson plans and learning activities.

Small group activities invited the teachers to work cooperatively to co-construct concept maps by brainstorming ideas, compiling concept lists, organizing concepts into meaningful hierarchies, linking concepts, and including 'linking words' describing meanings of inter-connections. Teachers practised concept mapping techniques in activities related to syllabus outcomes, specific problems, structured activities, and textbook extracts. Group presentations and peer critiques followed each activity and these provided critical feedback to further improve the hierarchical organisation of concepts.

During the professional development sessions, participants reflectively considered how they might incorporate concept maps into future planning and classroom activities. Teachers also experimented with maps before meeting again in reflection sessions. The presented data includes exemplars of concept maps constructed during the workshop, negotiated during reflection sessions and constructed by primary students during classroom trials.

5 Results: Selected Concept Maps

The material presented is framed around the three different roles enacted by teachers during the Project, namely, teachers as learners of innovation, reflective practitioners in a community of learners, and classroom implementers of innovation. Material is drawn from teacher comments and samples of concept maps related to both mathematics and science topics.

5.1 Teachers as Learners of Innovation

After initial introductory sessions on the rationale and techniques for the preparation of concept maps, teachers worked in small groups on a number of tasks in three areas. The first was related to syllabus interpretation during which teachers interpreted the requirements of the syllabus and organised these requirements into a concept map. The second related to the conceptual knowledge required for a specific problem about comparing the area of a rectangle and a square. The third was about the conceptual knowledge for a specific topic during which teachers discussed collaboratively the essential concepts needed to introduce a teaching sequence about 'substances'. Each of these tasks is discussed briefly in terms of the potential benefits to the teachers as a community of learners.

5.1.1 Syllabus Interpretation

Figure 1 illustrates primary teachers' planning concept map about 'Number' for students in the middle years of primary schooling based on syllabus material.

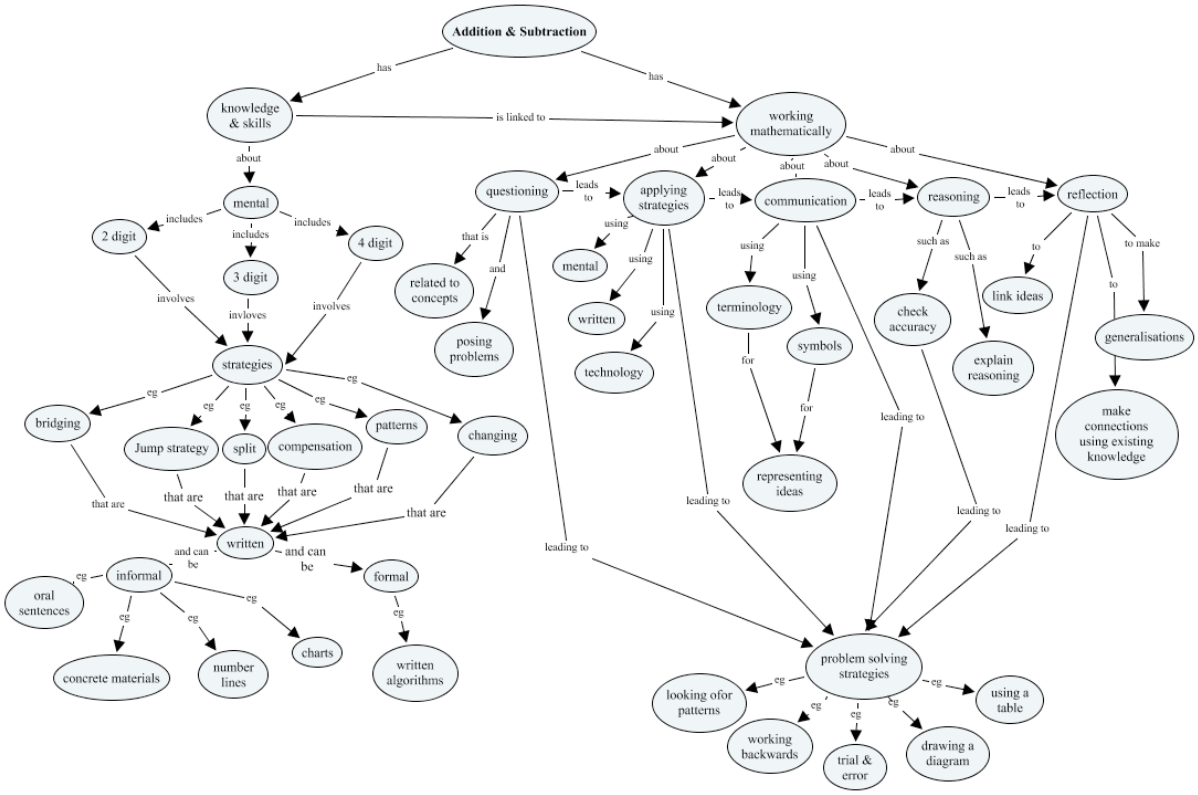

Figure 1 Concept Map for 'Number' Prepared Collaboratively by Teachers

The discussion which followed the presentation of this map highlighted two aspects of working as a community of learners: Firstly, the use of concept maps as an advance organiser provided a framework for discussion; and secondly, the discussion provided an opportunity for sharing ideas that reinforced good practice.

> *Presenter: We would begin with the two digit numbers and work our way through and build on that to the three and then the four. Once they've got the mental strategies in place we can then start to put it into the written from and written can be informal of formal. On the informal side, we looked at oral sentences where*

children explain what they are doing using concrete materials such as open number lines … but on the formal side we would look at the written algorithm… where we go from here you would have to do a concept map for two digits, then another for three …

Teacher: They make excellent scope and sequence statements.

Teacher: The structure … would be a series of lessons say over two weeks …

Teacher: You could photocopy a number of these and for each sequence of lessons highlight the relevant parts.

5.1.2 Specific Problems

Figure 2 provides an overview of teachers' beliefs about a specific problem related to area and perimeter. The problem provided data about the dimensions of a rectangle from which a comparison was required of its area with that of a square of identical perimeter.

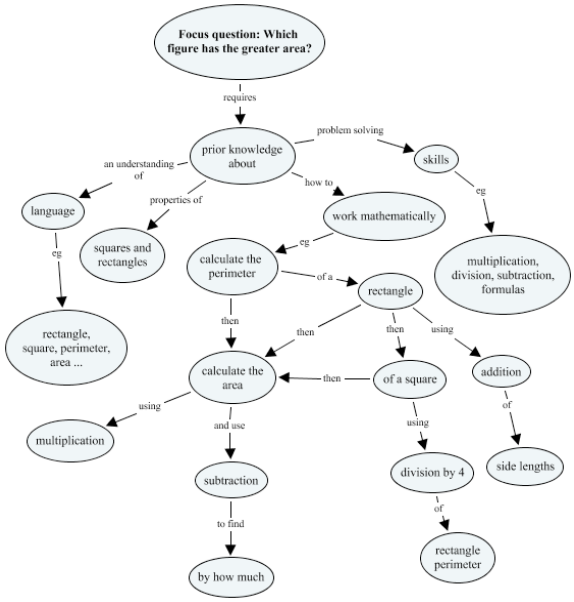

Figure 2 Concept Map for and Area and Perimeter Problem Prepared Collaboratively by Teachers

The concept map illustrates progressive differentiation of the focus question into the language, knowledge and skills, working mathematically, and prior knowledge needed to complete the question. The second half of the map describes the process of obtaining an answer based on a synthesis of an understanding of rectangles and squares. Much of the discussion about this problem focused on how different year levels would approach it. The majority of comments focused on the section of the map related to prior knowledge about rectangles and squares, and language. Representative comments included:

You could get them to solve it in the lower stages (middle primary years) if you gave them a picture of the rectangle and of the square. They could then compare the areas.

A lot of kids in my Year 6 class couldn't actually read that … I have to be more visual for them.

My children will have trouble with the language … perimeter, area, greater – my kids just say 'bigger than'. As for 'figure', they would use the word 'shape.'

I'd have to scaffold that … because they could understand the question, but they would get completely lost as to where to start. They can't break it down.

I'd still use the same wording with my class but go through the whole thing and make sure they understood what area was, what a rectangle was, what perimeter was, what I meant by figure and by greater. So that would be the first part of the problem.

I had a very algebraic solution, but that is for Stage 4 or 5 (middle secondary years of schooling) … using formulae. It depends on the class. If I have a Year 7, then I have to use diagrams.

5.1.3 Specific Topics

Figure 3 details the relevant content that one group of teachers regarded as important when starting a topic about substances with students in the later years of primary schooling.

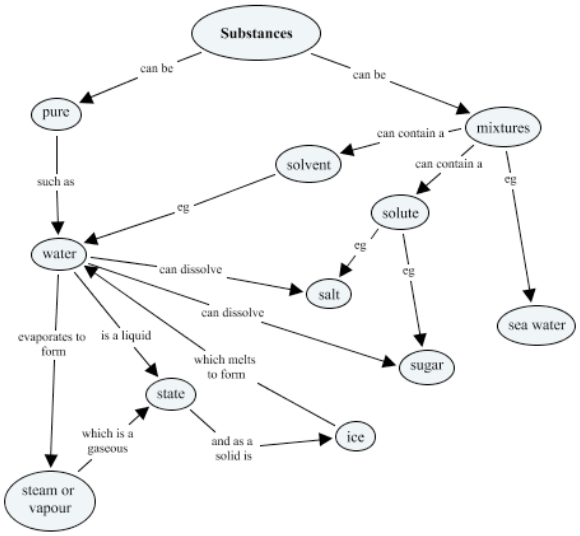

Figure 3 Concept Map for the Topic 'Substances' Prepared Collaboratively by Teachers

During discussions about this map as it was being prepared, the teachers had agreed that they wanted to focus on the essential difference(s) between pure substances and mixtures. They wanted to do this by selecting a substance with which students were familiar and which could be used in simple activities. The structure of the map reflects these priorities: the terms 'pure' and 'mixtures' placed at the top and, as they are differentiated, the term 'water' is given prominence through the use of cross-links.

5.2 Teachers as Reflective Practitioners

Two examples of reflective practice are provided here. The first relates to feedback teachers provided in a group setting when concept maps were discussed during presentations, i.e., peer critiquing. The second relates to how one teacher considered modifications to the planning of an activity as a way of engaging students as fully as possible. The first reflective example relates to the concept map in Figure 3 (Substances) prepared for students in the later primary years of schooling. Part of the discussion during the group presentation of this map included a justification of the uses of 'water', 'sugar' and 'salt' as exemplars for dissolving. This was continued in the discussion which followed.

Presenter: … we would use the example of water because that's familiar to everyone and water can dissolve sugar which is a solute or can dissolve salt which is another solute and salt with water is sea water and our activity would be to dissolve salt in water to demonstrate that dissolving action. And make a product they could relate to as well.

Teacher: I think you should remember the milo thing

Teachers: That's a good one, because they could drink it at the end.

Teacher: I like the jelly one … because salt water doesn't sound as attractive in comparison.

Presenter: We were trying to think of something with the sugar and the water … cordial would also have been a good one. But I like the jelly crystal idea …

Teacher: But it's a complex one.

Presenter: The trouble with the jelly crystal one though is it forms into a mixture but then it forms into a solid sort of thing.

Teacher: There are more factors there; it's not only the dissolving.

The second example of reflecting on practice related to how to contextualise a problem for students. One of the schools involved in the project had a predominantly aboriginal population. As part of using concept maps as a planning tool to introduce a lesson on measurement to upper primary students. The lesson activities were based on the use of road maps and the teacher had extracted the relevant syllabus knowledge and skills for the activity including drawing on prior knowledge of working mathematically. When presenting the overview of the activities to other teachers, the following comments were included:

… we're looking at abbreviations of kilometres and metres, and we will be recording lengths or distances using metres or kilometres that are included in the knowledge and skills. I would include aboriginal language and tribal boundaries, like for example it says how far from Tenterfield. I would say how far from Goombangui Country down to Bunjalung Country; and how far is it from Taree, which is in the Biripai area, to Kempsey, which is going back to Dunguddy Tribal land …

There are three key aspects to moving forward as a community of learners embedded in these two examples. Firstly peer critiquing provides an opportunity to discuss prepared maps in a non-threatening setting where teachers could share ideas and discuss how they might be included. Secondly, additional strategies for engaging students can be shared, e.g., the use of cultural contexts. Thirdly, examples that might present conceptual problems for students, such as dissolving leading to the formation of a solid, can be discussed fully.

5.3 Teachers as Classroom Implementers of Innovation

Throughout the project, teachers selected opportunities to introduce concept mapping as a stand-alone activity and as a component of preparing vee diagrams. These activities were carried out with classes in the primary and secondary years, and for both mathematics and science topics. The example provided in Figure 4 was prepared collaboratively by a group of three students in the middle primary years and offers some insights into the structure of their knowledge.

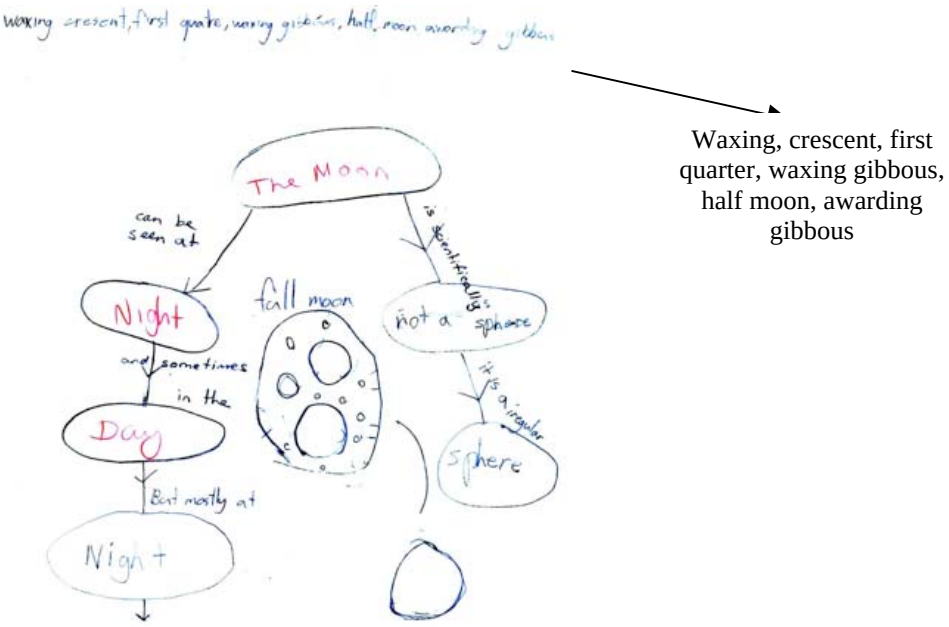

Figure 4 Concept Map of 'The Moon' Prepared Collaboratively by Year 3 Primary Students

The map and the discussions that took place during its preparation provide some important feedback for teaching and learning. Firstly, the fundamental unit for preparing a concept map, namely the proposition, has been successfully used by this group of students. Secondly, the students have written a number of concepts about the moon at the top of the map but have not incorporated them into the map. This absence suggests that students may be able to remember individual pieces of information about the moon, but they cannot yet apply them to this particular task. A further indication of the lack of consolidation of new information can be found in the use of the term 'awarding gibbous' which may be how 'waning gibbous' has been recalled. Thirdly, the students have incorporated a picture of the moon as they see it. These points suggest that, although concept mapping can be used successfully with this age group, the outcome of the activity provides some important feedback about the extent to which new terminology has been incorporated into students' existing knowledge structure.

Some representative comments from the students' conversation as they prepared this map further illustrate the separation (for students) of prior knowledge – or existing conceptual structure, new information, and the outcome of a learning task.

- *The moon is interestingly made of cheese … it has different shapes.*
- *The moon comes out at night mostly … and sometimes at daytime.*
- *We might not know the shape of the moon … and there is a man in the moon.*
- *The moon has magma and nuclear.*
- *The moon moves … and circles the moon for 24 hours.*

6 Summary of Findings

The project was guided by three key questions framed around how teachers would respond to an innovative teaching and learning strategy, how teachers might resolve identified issues, and how teachers would perceive the effectiveness of concept mapping as a planning tool. From the examples presented in this paper, some preliminary answers can be put forward. Firstly, teachers recognised the benefits of using concept maps and they created a non-threatening environment in which they openly discussed the learning of a new technique and were prepared to present their initial maps for peer discussion. They produced a number of detailed maps for different contexts and use them to resolve problems that they perceived students would experience. Concept maps were produced as an advance organiser for a syllabus topic (Number) that led to discussions about how student learning might be sequenced. Maps were also produced that outlined the conceptual structure for the introduction of a new topic (Substances). Teachers also used maps to identify the essential knowledge and skills that students would need to solve a particular problem in mathematics (perimeter and area problem).

Secondly, the extended discussions during presentations (peer critiquing) enabled teachers to share their knowledge, as well as add to and refine constructed maps. Through sustained conversations about subject matter and listening to each other's views about the important knowledge and skills that students need to acquire, teachers had the time to reflect and to gain a deeper understanding of their practice. Thirdly, teachers found concept maps a valuable way of documenting consensus amongst peers and for summarising the requirements of syllabus documents. Most importantly, in the context of a new strategy, collaboration, sharing knowledge and documentation were modelled by teachers in a way that provided them with the confidence to introduce concept mapping into their classes. Some comments taken from the teachers' reflection sessions qualify these points:

> *To make them (concept maps) relevant, you need to ensure that you begin them at the right level.*
>
> *I'm beginning to see their applicability more when working collaboratively with teachers to keep them aware of language difficulties etc.*
>
> *I feel that concept maps are a great tool for planning – for working out what the key concepts are and for knowing where you are wanting to head with the unit.*

In addition, four characteristics of exemplary practice were identified in the professional standards for mathematics and science teachers. Teachers who took part in the study indicated that the professional development activities based around the implementation of concept maps supported those characteristics, thus providing an informed basis for further work in these areas, namely:

- As an effective strategy for teaching and learning: *Concept maps are a great way to organise your ideas;*

- For providing opportunities to engage in professional development that is collegial: *We realised the importance of collaborative work and that working as part of a team could give more satisfaction;*
- In finding ways to actively explore new teaching ideas: *It helps to be able to break the information to be taught into little pieces;* and
- For initiating purposeful dialogue with students about their subject: *Concept maps are helpful for students to organise their learning.*

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