Using Concept Mapping Strategies to Support teacher Professional learning and the Assessment of Student Understanding

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ABSTRACT

Two applications of concept mapping are described in this paper. The first relates to the use of concept maps by primary and secondary teachers as a focus for collaborative professional learning activities in mathematics and science. The second describes a classroom application of how concept maps prepared by primary and secondary students can be used to document developing understandings of some science concepts. Students collaboratively prepared a number of concept maps and these were analysed using a cognitive structural model called the Structure of the Observed Learning Outcome (SOLO) model. The SOLO model is an analytical tool that has the potential to distinguish qualitatively different levels of responses to a task along a developmental continuum.

For the teacher professional learning application, teachers worked collaboratively 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.

The focus for the classroom application of concept mapping was whether or not descriptors for distinctly different groups of concept maps can be developed from the perspective of a cognitive structural model. Such a focus has the potential to supplement investigations that have focused on the structural changes that can be observed in concept maps over time. A brief overview of the model is provided and a number of maps are discussed in terms of the holistic arrangement of concepts.

[Key words] Concept maps, the SOLO model, professional development, developmental understandings

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I. INTRODUCTION

This section provides relevant background by addressing three areas. The first relates to the educational context that forms the background for this paper. The second provides outlines the basis of concept mapping as a learning tool, and the third section introduces the cognitive structural model that can be used to analyse the quality of concept maps.

1. The Educational Context

Increasing prominence within the Australian teaching and learning context has been given to professional teaching standards that describe the attributes of teachers at key career stages. The implementation of a nationally consistent set of teaching standards from 2011 has provided an important framework for informing beginning and experienced teachers who wish to develop their teaching practice or to plan for ongoing professional development (Teaching Australia, 2007; Pegg, McPhan, Mowbray & Lynch, 2010). 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.

An additional dimension to the professional learning priorities for teachers within the Australian context has been provided by the findings of two recent national surveys. In documenting rural teachers’ ‘voices’, the lack of professional connectedness and feelings of isolation have been identified amongst their significant concerns (Lyons, Cooksey, Panizzon, Parnell & Pegg, 2006). In addition, teachers acknowledged that the learning needs of students in rural areas were often difficult of meet because of limited access to a broad range of alternative and extension learning activities. The need for collaboration with colleagues in order to update professional knowledge or for mentoring purposes has also been identified as a key
concern for teachers regardless of the geographic region in which they teach (Pegg, McPhan, Mowbray & Lynch, 2010). This issue was identified both by teachers who were the only teacher in their discipline/subject area at their school – as in the case of isolated or regional schools, and by teachers who were part of large subject departments – as in the case of large metropolitan and non-metropolitan centres.

For both uses of concept mapping discussed, the educational context comprised two small rural schools, one a primary school and the other a primary-secondary combined school. Whilst teachers within each of these schools were part of well-established collegial networks locally, they also acknowledged a sense of professional isolation in terms of meeting their own professional development needs within their respective discipline areas and also for trialling a range of strategies for enhancing student learning outcomes.

2. Concept Mapping

The structural basis of concept mapping is based on Ausubel’s meaningful learning theory that proposes learners’ cognitive structures to be hierarchically organized. More general, superordinate concepts subsume 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 & Canas, 2008). Hattie’s synthesis of over 800 meta-analyses related to student achievement places concept mapping in the ‘exciting’ category. They are listed as one of the influences that can have a great impact on student achievement outcomes, with an effect size of 0.57 (Hattie, 2009).

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.

3. The SOLO Model

The SOLO model is a post-Piagetian analytical tool that has the potential to
distinguish qualitatively different levels of response to a task along a developmental
continuum. The SOLO classification scheme refers to the Structure of the Observed
Learning Outcome (Biggs & Collis, 1982). Coding a response - rather than a
student, according to the SOLO model requires a consideration, firstly, of the nature
of the elements that are used and the complexity of the operations which can be
applied to those elements. Such a consideration gives rise, firstly, to modes of
thinking that are related to the abstractness of thinking. There are five main modes
of cognitive functioning within the SOLO model and these are currently referred to
as (1) sensorimotor - acquiring motor skills; (2) ikonic - thinking intuitively; (3)
concrete symbolic - representing concepts using different symbol systems; (4)
formal; and (5) post-formal - manipulating theoretical constructs. Secondly, as an
individual becomes more and more familiar with the elements and operations within
a mode, a pattern of response structure becomes apparent according to the ease with
which students process cues, something that may be related to working memory.

In general, most primary and secondary school students interpret phenomena or
undertake tasks within the concrete symbolic mode. This mode is the prime focus
for the compulsory school years. As a consequence, during these school years,
concrete symbolic is referred to as the target mode (Biggs & Collis, 1989). The goal
in any target mode is to raise the level of functioning to the point where responses
can be made at a level of sophistication that indicates that the quality of learning
which has taken place is adequate or that a skill has been practised sufficiently
(Biggs & Collis, 1991). A consideration of increasing complexity gives rise to the
second feature of the model, namely levels of responses. There are five main levels
of responding within the model: Prestructural (P) – no use of elements which belong to the mode in question; Unistructural (U) – identification of one relevant element of the required mode; Multistructural (M) – thinking about two or more pieces of information relevant to the target mode; Relational (R) – the relationships between separate pieces of information have been considered to produce an integrated understanding; Extended Abstract (EA) – a transition to a new mode of thinking through the use of material which is new or of increased abstraction.

Of the five SOLO levels, three constitute a learning cycle within a particular mode, namely, unistructural, multistructural and relational, whilst the other two, pre-structural and extended abstract, lie outside this mode (Biggs & Collis, 1982, 1989). The model proposed (Biggs & Collis, 1991) brings together successively the cyclical nature of learning (levels) and the hierarchical nature of cognitive development (modes). Inherent in the learning cycle is a sequence from low competence (novice learner) to expertise (Biggs & Collis, 1989) with each level being an indicator of how far learning has progressed towards competence. The sequential progression through the learning cycle, with progression towards modes of higher abstraction in an ‘onwards and ever upwards’ process has been termed the course of optimal (cognitive) development (Biggs & Collis, 1989). In later developments of the SOLO model, the notion of the course of optimal development has undergone refinements to incorporate linear development within a mode and development across modes (Collis, 1988; Biggs & Collis, 1989). In addition, the notion of the U-M-R learning cycle has been refined to incorporate multiple cycles within a mode (e.g., Collis, Jones, Watson, Sprod & Fraser, 1998; Panizzon, 1997; Pegg, 2003).

II. Concept Maps and Teacher Professional learning

This section provides three examples of collaboratively prepared concept maps that were used by teachers to support their professional learning. In particular, the activities provided opportunities for teachers from different discipline areas to share ideas in a collaborative context.
[Figure 1] provides an overview of teachers’ organisational approach to a specific problem related to perimeter and area. The focus activity provided data about the dimensions of a rectangle from which a comparison was required of its area with that of a square.

![Figure 1] Concept Map About Area  [Figure 2] Concept Map About Substances

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 students in 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. In particular, teachers considered options that would support students’ understanding and completion of such a problem. Representative comments included:

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.

[Figure 2] 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 (11-12 years of age). 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. 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, part of which is provided below.

Teacher 1: … 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 seawater and our activity would be to dissolve salt in water to demonstrate that dissolving action.

Teacher 2: I like the jelly one … because salt water doesn’t sound as attractive in comparison.

Teacher 3: 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 1: There are more factors there; it’s not only the dissolving.

[Figure 3] details the conceptual structure that represented one group of teachers’
collective understanding about the topic ‘sound’ for introduction to students in the upper primary Years of schooling (11-12 years of age).

[Figure 3] Concept Map About Sound

The discussion that took place about this map focused on its breakdown into conceptual and concrete aspects of sound. Teachers thought that the way each of these were detailed had implications for the learning experiences that might be planned for students. They acknowledged the three main conceptual areas covered in the concept map, namely, ‘amplification,’ ‘resonance’ and ‘pitch.’ Their inclusion raised some points for consideration, the first of which relates to the sequence in which they might be presented. Teachers drew attention to the absence of links between the sections of the map in which these three concepts occur, asking whether or not they would be presented independently. Where concrete aspects of sound were included (i.e., strings), there was agreement that the inclusion of ‘thickness’ and ‘length’ provided ideal contexts for developing practical learning experiences that would enable students to investigate variations in sounds produced.
Teachers also identified areas of the topic that would need to be consolidated before student learning took place. For example, it was decided that the concept of ‘pitch’ could be elaborated further, rather than being described as high and low only. Also, it was decided that the proposition that “sound has resonance” needed to be revised to make it more readily understood by students.

Teachers demonstrated that they could effectively document their discussions using the concept mapping strategy. Important elements of mapping were present in their maps, including branching points and cross-links. They were able to use the maps as a focus for sharing ideas about the sequencing of material, the selection of relevant concepts, and the revision of their own content knowledge in such a way that would support student learning.

### III. Distinctly different concept maps

This section provides examples of student prepared concept maps with associated discussion in terms of the SOLO model. The maps were prepared collaboratively by groups comprising 3-4 students from the upper primary, middle secondary senior secondary Years using 20 words about ‘matter’. Reference is made in this section to an ‘expert’ map. The ‘expert’ was a post-graduate student with a background in the physical sciences and some familiarity with concept mapping. The ‘themes’ refer to the way concepts were grouped using the same words provided to the students and they were identified as: the classification of matter; changes of state; kinetic-molecular behaviour of particles; an atomic description of matter.

The way each of the concepts is placed separately around the main concept in [Figure 4] provides an example of a structurally discrete map. Single words have been selected from each of the four ‘expert’ map themes, however these themes are not developed.
The main feature of this map is the presentation of discrete pieces of information, ordered as single propositions incorporating the same link term throughout. The construction of a generalizable proposition (one that is part of an agreed shared language within a discipline, such as science) is almost coincidental, suggesting that students have focused more on the correct appearance of a proposition than on the propositions themselves. In SOLO terms, this suggests an Ikonic mode of thinking.

[Figure 5] provides an example of a multiple strand map. Based on 9 of the 20 terms provided, one strand describes changes of state whilst the second strand makes reference to an atomic view of matter. The separation of this information into two thematic strands suggests that students may have made decisions about the underlying meaning of each strand. Whilst students may have been able to use the map structure to distinguish between different themes, the main feature of this map is the sequential presentation of information. One theme is stated and then students have begun again to present new information. In SOLO terms, such a treatment is consistent with a multistructural level.
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[Figure 5] Concept Map About Matter (#2)

In the right hand strand, students indicated that they could recognize changes of state that involve heating and cooling, applying this to liquids and gases, respectively. Even though ‘solid’ was included in the map, it has not been incorporated into the changes of state theme. There are two possible explanations for the absence of this link. One is that students cannot use a concept in multiple contexts: students may not have recognized that ‘solid’ has a meaning within a changes of state theme and an atomic view of matter theme. Secondly, the physical (visual) separation of a concept has possibly prevented students identifying a conceptual link. The complexity of this map may be related to the number of elements which students can consider concurrently, namely, creating propositions and using the structural components of a concept map.

In [Figure 6] the arrangement of concepts provides another example of a multiple strand map with words grouped according to all four ‘expert’ map themes. The sequencing of these words, however, is different from the previous example. Here, they take the form of separate groups of propositions. The ‘flow’ of the left hand strand of this map is not continuous as it can be written out as four statements, each of which is about a different aspect of matter. This strand does not therefore
convey understanding about a single theme. Rather, it represents the listing of different aspects of matter. The first of the statements uses the concept ‘charged’ in an everyday context, as has ‘neutral’ in the next proposition. The next statement, on initial inspection, indicates a faulty proposition. This reference to evaporation, however, could represent the recollection of observations made about the appearance of frozen objects when removed from a freezer. As a consequence, the underlying meaning of this statement is not immediately apparent and it imparts a context-specific nature or personally relevant meaning to the strand.

The second strand in this map can also be written as a number of separate statements, the main focus of which is changes of state. This theme is conveyed using six concepts in a continuous way and there is no need to repeat the main concept in order to make a proposition meaningful. After this sequence of propositions, a different theme is introduced, that of atoms. The meaning conveyed by both groups of propositions is generalizable. In SOLO terms, the way students have been able to maintain the ‘flow’ of concepts is consistent with a relational level of thinking. This map reflects another aspect of applying the model, namely that a level is assigned to a response on the basis of its most complex feature. This map reflects both individual and scientific perspectives, with the later taken as the more complex.

[Figure 7] provides an example of a complex map based on terms associated with each of the four themes of the ‘expert’ map. The underlying structure of this map incorporates the use of strands to integrate themes with no interruption to the ‘flow’ of meaning. In addition, cross-links are used to detail the reversible processes associated with changes of state. Statements are made about the behaviour of particles when heated or cooled, and the concept ‘particle’ has been used as a focal point for making a distinction between kinetic and atomic aspects of matter. In SOLO terms, the features in this map make it consistent with a relational level of thinking at a complex level.
The selection of maps about matter illustrates some distinctive features that reflect the quality of concept maps. The first relates to the holistic arrangement of concepts that leads to descriptions, such as, discrete, multiple strand or complex. The second feature relates to the grouping of propositions that can range from single propositions only through to those groupings that comprise cross-linked strands or where individual strands are made up of sequential ‘themes’. The third feature of the maps is linked to the way groups of propositions generate meaning. Differences between maps can be identified on the basis of the use of individual pieces of information, the use of linked ideas or themes, or the use of the shared language of the discipline of science. The variation in structural complexity provides a basis for using the SOLO model to formulate descriptions of categories for distinctly different maps that might form a developmental sequence.

[Figure 7] Concept Map About Matter (#4)
IV. Discussion

This paper provided a number of instances where concept maps have been used to provide teachers with an opportunity for collaborative professional discourse and learning, and to investigate the quality of student learning. In terms of acquiring the technique of concept mapping, teachers and students demonstrated that they could effectively document their discussions and ideas using this strategy in a collaborative setting. Important elements of mapping present in their maps included branching points and cross-links, features that reflect more complex thinking. In addition, the application of the SOLO model has provided an indication that the quality of maps can be interpreted from a developmental perspective.

In terms of the themes for the ISFIRE-2 conference, concept mapping has the potential to provide teachers and students with direct benefits in three areas. As support for students’ academic achievement, whether they are used as a planning tool by teachers or as a strategy to evaluate learning, concept maps provide a tangible representation of the structure of material to be used in teaching as well and also as a graphical ‘snapshot’ of the organisation of students’ conceptual understanding acquired during learning. As a way of enhancing curriculum and instruction, concept maps have an informing role for teachers in the identification of aspects of subject knowledge or content sequencing that may need to be further refined prior to instruction. For students, they provide an alternative to the more traditional ways – such as, pen and paper tests, of documenting their ideas and understandings. Concept maps also foster teacher collaboration as the preparation of maps along with their associated discussion and critiquing amongst peers provides a non-threatening context for the sharing of ideas.
REFERENCES


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