VISUAL REPRESENTATION OF THE SYLLABUS CONTENT ABOUT 'DATA'

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Concept maps (cmaps) are graphical tools that illustrate complex networks of interconnections between concepts. These can be used to illustrate the concept connections implicit in teaching syllabus content thus facilitating sense-making and meaningful learning. This paper sheds some light upon pre-service teachers' understanding of the interconnectedness of basic concepts for the topic of 'Data' as evidenced in their construction of comprehensive cmaps. The illustrative networks designed by pre-service teachers were analyzed in relation to what connections were made and the quality of statements between connecting links/nodes. The results showed the variety and complexity of the interconnectedness of pre-service teachers' understanding of the concepts. Implications for both teaching and research are provided.

INTRODUCTION

Meaningful learning takes place by the assimilation of new concepts and propositions into existing concepts in an individual's cognitive structure (Ausubel, 2000). The necessity of representing learners' conceptual understanding gave birth to the idea of representing an individual's knowledge in the form of a hierarchical concept map (Novak, 1990). Concept maps (cmaps) are graphical tools that allow the illustration of complex networks of interconnections between concepts. Concept mapping, therefore, can serve as a template or scaffold to help teachers and learners organize and structure knowledge. To be most effective this structure must be built up in small increments of interacting concepts.

It is critical that pre-service teachers develop a deep understanding of the interconnectedness of concepts in the syllabus that they will be required to implement for their students' learning. The construction of a concept map could allow a pre-service teacher to illustrate the interconnectedness of her/his own understanding of the relationships among concepts. We investigated how concept maps can be used to help pre-service teachers to illustrate the connections between concepts. Such concept mapping activity would provide insight into the pre-service teachers' understanding of concepts through the way they organize the complex connections between concepts. The research reported in this paper is based on the research of Afamasaga-Fuata and Reading (2007). The aim of this paper is to investigate the complexity and the interconnectedness of pre-service teachers' understanding of concepts as represented in cmaps. This is important because teachers should develop a sense of a connected understanding (Wilensky, 1997) about the topic of 'Data' before they began teaching the subject themselves.

CONTEXT

At an Australian regional university, first year pre-service teachers, who were destined to deliver the content of the K-6 Mathematics Syllabus (NSWBOS, 2002) in the state of New South Wales, studied a mathematics education course. The part of this course relevant to the reported research was a lecture followed by a workshop in each of two successive weeks. The week one lecture introduced the pre-service teachers to concept maps (cmaps) by providing professional reading and details about cmap construction, with relevant activities. A following workshop focused on drawing cmaps. The pre-service teachers had drawn cmaps in other courses, but had not used them to represent mathematical concepts. The pre-service teachers co-constructed cmaps, helping each other as they struggled with the process of building a good hierarchical organization. Cmaps were revised after class-level discussions about cross-links between concepts.

The week two lecture focused on chance and probability and in the following workshop pre-service teachers were engaged in problems concerning chance and data, and asked to draw construct-map cmaps (Ruiz-Primo, 2004), i.e., cmaps for which concepts are provided. The pre-service teachers were given a list of 37 concepts from the data section of the syllabus. They had prior knowledge of most or all of the concepts but not necessarily the connections between the

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concepts. First, they rank-ordered the concepts to help them begin the cmap construction. Second, they engaged in activities that helped them to recognize how concepts were related. Finally, they constructed a cmap, illustrating their own understanding of the connections among key concepts.

Cmaps consist of *nodes* (correspond to concepts), *links* (arcs/edges) or *connecting lines* (show a relationship between the concepts), and words on the connecting line, referred to as *linking words* or *linking phrases*, specifying the nature of the connections between the concepts. The inclusion of linking words indicates the interconnectedness of a learner's understanding. The pre-service teachers were instructed to: (a) include linking words or phrases that connect concepts (nodes) to show the relationship between two concepts; and (b) connect concepts in a hierarchical structure from the most inclusive, most general concepts to the less general concepts.

METHODOLOGY

The pre-service teachers were studying in three separate groups (now referred to as A, B and C). The groups were conducted by different lecturers and at different times. During the week two workshop the pre-service students were expected to construct paper-based concept maps individually. The interconnections of concepts in the cmaps were analysed using six criteria (Table 1) based on those used by Afamasaga-Fuata and Reading (2007). The criteria were used to investigate: inclusion of the given concepts (RC1); hierarchical organization of the concepts from more general to less general (RC3, RC4, RC5); and how linking words were used to describe the connections (RC6). Thus the emphasis of the analysis was placed on the indicators of rich and meaningful connections to shed light on the depth and connectedness of understanding. Qualitatively each map was analyzed to determine whether there was adequate structuring of the cmap. Quantitatively, the six criteria were applied to each cmap. The two researchers individually rated each criterion, compared ratings, and negotiated disputed ratings.

Table 1. Criteria for coding the cmaps

Criteria	Description	Rating
RC1	Content - inclusion of given concepts	3 = majority, 2 = some, 1= few
RC2	Hierarchy – concepts organized from most inclusive to least inclusive	3 = majority, 2 = some, 1= few
RC3	Links/Node - computed average number of links per node	3 = more than 1.2, 2 = from 1.2 to 1.0, 1= less than 1
RC4	Branching - count of nodes with more than 2 outgoing links	3 = more than 7, 2 = from 7 to 5, 1= less than 5
RC5	Merging – count of nodes with more than one incoming link	3 = more than 6, 2 = from 6 to 4, 1= less than 4
RC6	Linking words - quality of linking words	3 = mostly deep, 2 = mixture, 1 = mostly superficial

RESULTS

Although the 74 pre-service teachers were expected to construct the cmaps individually, those in Group A and Group C constructed the cmaps in small (less than five pre-service teachers) groups. This resulted in 30 cmaps being available for analysis, comprising 4, 18 and 8 from Groups A, B and C respectively. Although they had been asked to construct cmaps some pre-service teachers constructed mind maps. A mind map represents ideas arranged around a central key idea and does not shown interconnections of ideas, whereas cmaps represent the connections between concepts in a more diverse pattern.

The cmaps that were produced were qualitatively sorted into three categories: *Category 1* - mind maps that grouped concepts and had no connecting lines to show relationships between concepts; *Category 2* - mind maps that were transitional to cmaps because concepts were still grouped and some concepts were connected to other concepts; and *Category 3* - cmaps with ungrouped concepts suitably connected. All maps in the first two categories were produced by groups of pre-service teachers rather than independently. Due to the non-connected nature of the maps in the first two categories, they could not be analysed using the criteria in Table 1 and so were only analysed qualitatively.

The six *Category 1* mind maps presented the concepts in groups, some of which had a suitable concept placed at the top of the group, as a heading. The number of groups ranged from three to seven. Although the groups would suggest that the pre-service teachers recognised a connection between the concepts within each group, there were no attempts to link the groups of concepts or show the nature of any connections within the group. Some maps had a group that appeared to be 'left-over' concepts, i.e., concepts that were difficult to place in the other groups that had been created. For the weakest mind maps the logic used to create the groups was very difficult to determine.

The four *Category 2* maps were transitional between mind maps and cmaps. They were not cmaps because there was still grouping of concepts. However, the statistical basis for the grouping of concepts was clearer and some groups were connected in a linear order indicating a sense of statistical process. This was considered as a transitional step towards cmap representation because although the concepts were still grouped some lines were included as connecting links. Individual concepts were used as key central concepts, for example, on one map some concepts representing different levels of probability were grouped under the heading "probability". This could be considered as a transitional step to identifying key nodes for a cmap.

The 20 *Category 3* cmaps were coded against the six criteria (Table 1) and the number of pre-service teachers achieving each rating level for each criterion (except for RC5 and RC6) are presented in Table 2. Only six cmaps showed any merging but in each case there were fewer than 4 merges and hence all cmaps were rated as 1 on RC5. No cmaps had linking words on the connecting lines and hence all were rated at level 1 on RC6. Even, the branching (RC4) had 85% at level 1. This indicates that the cmaps had only limited representation of connections and interconnections of concepts. Very few of the cmaps were at the most desirable level (3) even for the more basic criteria (RC1, RC2 and RC3).

Table 2. Number of cmaps (n=20) at each rating level for criteria

Criteria	3	2	1
RC1	2 (10%)	14 (70%)	4 (20%)
RC2	3 (15%)	13 (65%)	4 (20%)
RC3	1 (5%)	6 (30%)	13 (65%)
RC4	0 (0%)	3 (15%)	17 (85%)

DISCUSSION

The representation of concepts in the mind maps of the first two categories indicated some level of understanding of the concepts because concepts have been grouped together. However, the variety of groupings that were formed suggested that there were differences between pre-service teachers in the mental linking of the concepts that was taking place. The poorer maps in *Category 1* did not represent direct links between concepts, thus it was difficult to determine exactly what mental links were developed between concepts. The representations suggested that pre-service teachers were grouping the concepts based around either (i) the levels of likelihood of chance, or (ii) the terminology of occurrence. The better maps in Category 2 provided a glimpse into links between groups of concepts. This should be encouraged as a first step towards the linking of individual concepts.

The variety of cmaps in *Category 3* indicated that pre-service teachers' understanding of concepts was limited. The majority of pre-service teachers struggled to meaningfully include all the concepts (content) as nodes. This limited the amount of understanding that could be demonstrated. They also had difficulties in positioning the concepts hierarchically to illustrate relative inclusivity. There was lack of recognition of the notion of "equal generality". The latter indicates that cmaps demonstrated "more inclusive" and "less inclusive" concepts but no concepts of equal status.

Deep understanding requires an interconnectedness of concepts, which is better demonstrated by the number of links per node. Pre-service teachers showed limited representation of interconnections of concepts. Moreover, the majority of cmaps demonstrated low ratings for the cognitive processes of *progressive reconciliation* (branching a number of concepts from a single concept) and *integrative reconciliation* (merging of many concepts into a single concept). The latter indicates a poor and sometimes a disconnected knowledge of interconnections, as illustrated

by the low structural complexity of the cmaps. Overall, pre-service teachers were not able to represent the interconnections of their understanding about the topic of "Data".

The expression of interconnections (the quality of *linking words*) is the criterion that is most reflective of understanding. No pre-service teachers illustrated the nature of the link between concepts, as evidenced in the lack of *linking words* on the connecting lines in all cmaps. This was disappointing and indicated that pre-service teachers either did not understand the interconnections, or found it difficult to articulate their understanding. This result is consistent with Afamasaga-Fuata and Reading's (2007) finding that pre-service teachers were not good at expressing their understandings of interconnections in the linking words or phrases.

There are two limitations of this study that should be considered when interpreting the results. First, the pre-service teachers had not drawn many cmaps prior to these workshops. As with all developing skills, limitations in cmapping skills itself may have reduced the effectiveness of representing the interconnectedness of understanding. Second, some of the cmaps were constructed by groups rather than individuals and it may have been difficult for the pre-service teachers to come to agreement about the nature of the connections because individuals can form very different mental links of concept connections. Despite the limitations, the cmaps that were produced do provide some insight into the early stages of the process of connecting the various concepts in the 'Data' component of the syllabus.

IMPLICATIONS

It is vital for educators to spend time in their education courses assisting pre-service teachers to develop a connected view of the syllabus content to be presented when teaching students. Cmap construction can be used to check whether pre-service teachers are able to form a connected view of the syllabus content. Provided that pre-service teachers have had sufficient experience in constructing representations of multiple connections between concepts, there is the potential for the cmaps to illustrate their understanding of concept interconnection. It is critical, though, that educators focus on supporting pre-service teachers in developing linking words or phrases to clarify the relationships between concepts that have been illustrated in the cmap.

Research is needed to determine the nature of the pre-service teachers' difficulty in representing the connections between content in the statistics section of the mathematics syllabus and their difficulty in verbalizing the nature of the links represented. Research is also needed to investigate the impact of instruction on pre-service teachers' cognitive structures and how well their changing understanding is represented in cmaps drawn at different times during their training. Concepts maps are a powerful tool being used with increased frequency by students in the classroom and it is time that our pre-service teachers were also able to benefit from the advantages of concept maps to assist their learning.

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