Concept Maps: Theory, Methodology, Technology
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CONCEPT MAPPING IN MIDDLE SCHOOL MATHEMATICS

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Abstract. *Concept Mapping in Middle School Mathematics* (CMMSM) is a developing mathematics intervention designed to increase the likelihood of success in Algebra I for sixth-, seventh-, and eighth-grade students from low-income neighborhoods. The intervention uses concept mapping to strengthen teacher understanding of the connections among mathematical concepts and to bring meaningful learning of connected concepts to their classrooms. This study details the progress of one group of 17 teachers as they learn to use CmapTools™ to connect ideas in planning instruction using activities and textbook units.

1 Introduction: Teaching and Learning Algebra I

Algebra I is a gatekeeper subject for the secondary mathematics curriculum. According to the American Association for the Advancement of Science (1998) and the National Research Council (1996), Algebra I is essential for success in college mathematics and science courses, and, in Florida, it is a high school graduation requirement. Despite the clarion call for reform in approaches to teaching and in the content of mathematics in U.S. schools, there still exists a significant gap in U.S. student performance, internationally. The Florida Department of Education reports that only 59% of Florida's eighth graders were performing at or above grade level on the mathematics portion of the 2005 *Florida Comprehensive Assessment Test* (FCAT). Furthermore, FCAT results for the intervention middle schools indicate that 30% or fewer of the eighth graders were performing at grade level in mathematics.

Teachers play a role critical to student performance; however, there is wide variation in the effectiveness of teachers. Instructional strategies often lack the incorporation of research on cognition, which frequently results in teaching for low levels of knowledge. Emphasis on facts and recall of facts in quizzes shows not only the difficulty of teaching and testing for fundamental understanding, but also the probability that most teachers do not know how to teach for higher levels of thinking (Goodlad, 1984). With little or no time spent on the development of important, organizing ideas, there is often only superficial coverage of facts before moving on to the next topic (Bransford, Brown, & Cocking, 1999; Schmidt, 1997).

Advances in the neurological understanding of how meaningful learning occurs have implications for both teachers and students. Meaningful learning is the basis for building knowledge structures and posits that learners create new concepts and propositions by integrating new information into existing knowledge (Novak & Cañas, 2006). Furthermore, the National Academy of Sciences (2002) identified seven key principles of learning that substantially contribute to the acquisition of new knowledge. Two of the seven directly address meaningful learning and state that learning occurs when new and existing knowledge is structured around major concepts and principles of the discipline and that learners use what they already know to construct new knowledge.

2 The Intervention: Concept Mapping in Middle School Mathematics

In fall 2004, the Florida Institute of Education at the University of North Florida refocused its existing middle school mathematics program to emphasize student preparation for Algebra I. First, the research team developed a set of *expert* concept maps describing the relationships among the defining *Big Ideas* of Algebra I. Then the research team formulated the *Concept Mapping in Middle School Mathematics* (CMMSM) intervention which uses concept mapping to effect change, assist mathematics teachers in making connections among concepts, and provide teachers with a tool and instructional strategies to aid students in making meaningful mathematic connections. A more detailed overview of CMMSM is provided in Figure 1.

When meaningful learning occurs, relationships between concepts become more explicit, more precise, and better integrated with other concepts and propositions. This *progressive differentiation* of conceptual and propositional meanings, results in more precise and/or more elaborate ideas (Ausubel 1968). Concept maps are, therefore, valuable to document growth in students' conceptual understanding and as a process of sharing knowledge with a wide age range of learners (Cañas, et al., 2004).
Note: CmapTools™ was used for concept mapping in CMMSM.

2.1 *The Participants*

A middle school serving low-income neighborhoods in each of two counties, one urban and one rural, agreed to participate in CMMSM. The urban middle school enrolls predominately Black children and the rural middle school enrolls predominately White children of farmworkers. Professional development activities for the mathematics teachers in the two middle schools include four all-day workshops to learn to use Cmap Tools™ and concept mapping for lesson planning, instruction, and assessment of student progress. CMMSM workshops strengthen the teachers' understanding of mathematical concepts and the connections between them. Two-week summer camps, held at the participating schools in June, are planned with the purpose of motivating selected students toward mathematics, science, and technology (MST) careers and toward enrollment in college preparatory mathematics and science courses. During late spring and early summer, teachers will work to plan the activities for the summer camps. The development and delivery of camp activities will provide further concept mapping experiences for the middle school teachers.

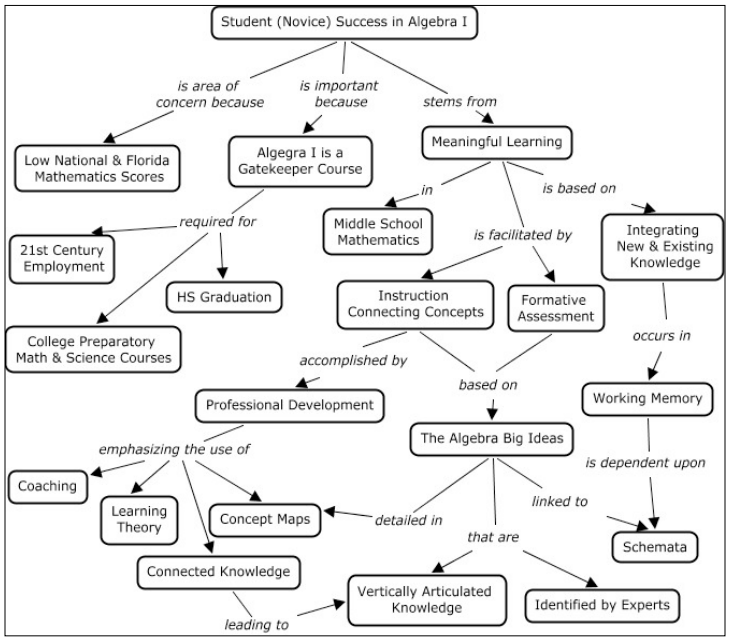

Figure 1. *Detailed concept map of CMMSM.*

3 Workshop Progress: The Rural Middle School Mathematics Teachers

The first four teacher workshops were held in the rural county during February and March 2006. The first workshop provided an introduction to the CMMSM intervention and concept mapping in general. Participants in the second workshop were provided a *parking lot* of concepts taken from a master map on the properties of addition of real numbers and, in turn, were asked to develop their own concept maps. Figure 2 shows the work of two teacher groups. Both maps show linear concept strings that read as sentences rather than using cross-linked connections. For example, both groups made a string of the concepts *addition of numbers or adding numbers*; *any pair of numbers, a and b*; *a single number called the sum of a and b*; *a+b*; and *a plus b*; however, the order of the concepts is different in the two strings. The concept map on the left starts with the global concept, *addition of numbers or adding numbers*, and uses a top-down hierarchy, while the concept map on the right starts with the more specific concept *any pair of numbers, a and b*, and uses a bottom-up hierarchy to attain the global concept. Both concept maps have focus questions which were provided and both show linking words and structure. Additionally, both groups were also using the exercise as an opportunity to explore the design palette of the CmapTools ™; however, their use of color has been omitted.

Participants in the third workshop were asked to think about activities that would help students understand the concept, one million. The groups used concept maps to plan the activities. Most groups made maps that reflected the process to complete the activity rather than linking the mathematical concepts embedded in the activity. The concept map titled *Million Wheelin* shown in Figure 3 is missing a focus question, but does show a hierarchy, structure, and linking words. Additionally, the map shows an effort that could easily link to the mathematical concepts *rotation*, *diameter*, *circumference*, *distance*, *inches*, *miles*, *conversion of measurement units*, and *comparison*.

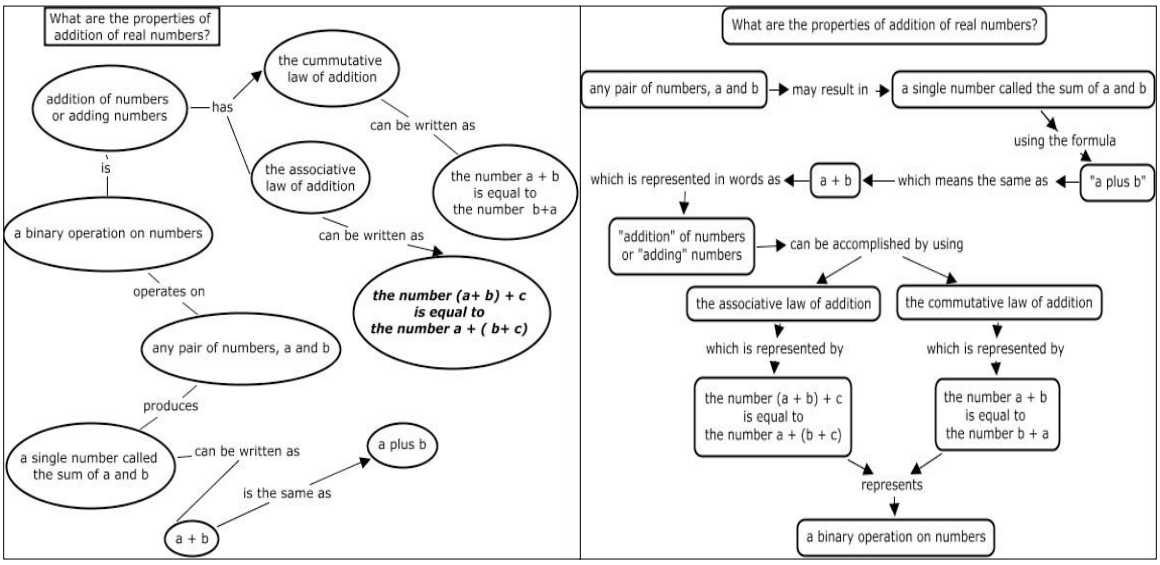

Figure 2*. Teacher-produced concept maps from the second workshop.*

Participants in the final early spring workshop were asked to use concept mapping to plan a textbook chapter. Teachers first made a parking lot using the vocabulary and objectives of the chapter. Figure 4 shows the incomplete work of one of the teachers. The teacher appears conflicted about the hierarchy of the concepts as evidenced by the placement of the concept *Algebraic Inequalities,* but there are appropriate connections between the concepts. There is little doubt the concept mapping exercise is forcing this teacher to grapple with the connections between the mathematical concepts presented in the chapter and that that struggle will benefit her students. The teacher is focusing on the connections between the concepts and is using a top-down hierarchy and cross-connecting links.

4 Discussion: Progress of Professional Development

Over the four workshops the teachers made strides in both the use of the CmapTools ™ and the quality of their concept maps. After using concept mapping over time, teachers commented they appreciate concept mapping as an effective tool for concept development and teacher planning. One teacher, in reference to parking lots, indicated she "liked the idea of using concept maps as a word wall" while another "realized you can do a KWL exercise with students to create a parking lot of concepts to help students identify and add concepts as the year progresses." Teachers also thought concept mapping is "a good way to keep focused on big ideas and review connections," and one teacher linked concept mapping directly to student learning by indicating it is a "great planning tool and with little addition would be a good study guide." The idea of helping individuals make connections is essential in learning mathematics. It constitutes a key charge to teachers in the *National Council of Teachers of Mathematics Curriculum and Evaluation Standards* - teachers must help their students understand such

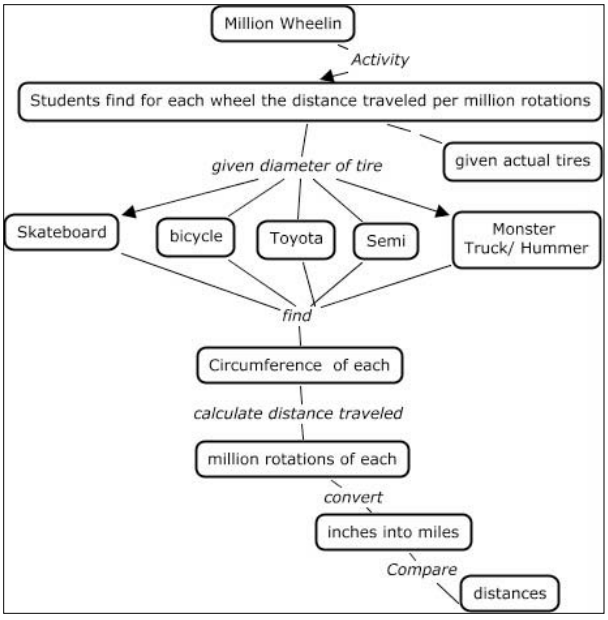

Figure 3. *Teacher-produced concept map from the third workshop*

connections, and to do so the teachers must first have a clear understanding of the connections. In fact one teacher stated that the workshop experiences "helped my team to see first-hand how cmaps can change our thinking and our approach to a topic."

There is reason to believe the teachers from the rural middle school involved in CMMSM workshops will continue to develop their expertise with the CmapTools ™. Four more workshops are planned in April/May for the teachers from the urban middle school. The workshop content will be modified based on teacher feedback and discussion among the research team and the project evaluators about the professional development outcomes. Additionally, the early summer workshops designed to develop activities for the summer camps involving students will provide further practice and shared experiences for the teachers.

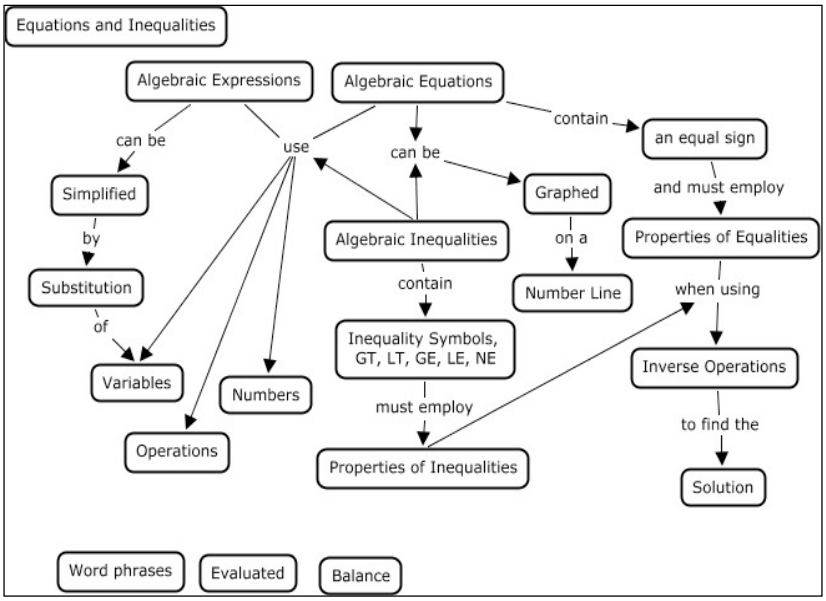

Figure 4. *Teacher-produced concept map from the fourth workshop.*

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