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THE NATURE OF THIRD GRADE STUDENTS' EXPERIENCES WITH CONCEPT MAPS TO SUPPORT LEARNING OF SCIENCE CONCEPTS

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Abstract. To support and improve effective science teaching, educators need methods to reveal student understandings and misconceptions of science concepts and to offer all students an opportunity to reflect on their own knowledge construction and organization. Students can benefit by engaging in scientific activities where they build personal connections between what is learned and their own experiences. Integrating student-constructed concept mapping into the science curriculum can reveal to both students and teachers the conceptual organization and understanding of science content, which can assist in building connections between concepts and personal experiences. This paper describes how a class of third grade students used concept maps to understand science concepts through revision of content and structure as new ideas occurred to them during class discussions and interviews. This paper also reports how students' understandings and misconceptions were revealed through their construction of concept maps over time. Students were introduced to concept maps at the onset of a year-long science unit on watershed systems. Students then went on to build a series of concept maps over the course of the science unit using a software program. Each concept map built upon the previous map in the sequence for a total of seven maps per student. A concept map evaluative rubric displayed changes over time in students' concept map structure and content. A formal assessment of watershed concepts was implemented four times during the course of the science unit. Data suggests that by working on concept maps in science class, students were able to reflect on their work and to appropriately revise their knowledge construction and content.

1 Introduction

The study of student misconceptions in science has been the topic of discourse and investigation by the National Research Council (2007), and others in the fields of education and social sciences (Novak & Cañas, 2008; Smith, diSessa, & Roschelle, 1993). Smith *et al* (1993) uses the term misconception "to designate a student conception that produces a systematic pattern of errors" (p.119). Misconceptions for many science concepts have been recognized over the past 20 years in the literature and some of these misconceptions have been demonstrated to be well established within a student's cognitive structure, resisting even innovative teaching (Chi, 2005). When children harbor perceptions about specific objects or events in their lives, and those perceptions are at odds with scientific knowledge, challenges to resolving those specific misconceptions can result (Smith, diSessa, & Roschelle, 1993). However, children's misconceptions can present a roadmap for guiding a student from a series of misconceptions to a more authentic understanding of that particular domain (NRC, 2007). The assumptions about the natural world that young children bring to the classroom can provide jumping off points for science instructors as they create and leverage a bridge to new knowledge from established understandings (Lederman, Lederman, & Bell, 2004).

Student-constructed concept maps can support cognitive change, leading to meaningful learning within the domain of the natural sciences (Jonassen, Howland & Mara, 1999; Hay, Kinchin, & Lygo-Baker, 2008; Novak, 2002) from which the learner is then able to construct new understanding (Ausubel, Novak & Hanesian, 1978; Novak, 2002). Constructivism, where all experience filters through the existing lens (perspective) of the learner, supports knowledge modification over replacement, a process which guides the learner in restructuring understandings (Smith, diSessa, & Roschelle, 1993). Constructivism supports knowledge modification over replacement guiding the learner in restructuring their understandings. Gains in proficiency have more to do with cognitive restructuring than with the accumulation of discrete facts. Through becoming aware of how students construct understanding of science concepts, teachers might be able to intercede where misconceptions override content. Using information made available from a student's concept map, a teacher may intervene so conceptual knowledge can be grounded in scientifically valid understanding, which can lead to meaningful learning.

2 Background

2.1 Student Misconceptions

Children are likely to bring preconceived ideas to their school experiences about how the world around them works. These understandings can conflict with scientific teachings at times. It is not always easy for the teacher to discern student misconceptions. Children might appear to understand and accept a new explanation for an observed event while maintaining their original mental model of the phenomenon. An example of a concept about which students in this study were unclear was the water-table. This concept, within the context of the watershed study, came up many times. However, it existed in an abstract nature to most children; the phrase 'water-table' represents an idea and is that idea. Young children do not have prior experience or personal knowledge of a water-table. However, they may have personal experience of drought and flooding. The teacher worked at tying those ideas together for students to make the connection between classroom content and personal experience. The NRC (2007) suggests in order for children to develop a conceptual framework embracing new and possibly conflicting notions about the world, they need to "break out of their familiar frame and reorganize a body of knowledge" (p.120).

Children's conceptual knowledge builds on prior experiences, personal knowledge and understandings, a process which provides foundational platforms upon which subsequent knowledge is constructed. Children acquire new information through direct experiences and classroom teachings. Children then endeavor to create coherent explanations reflecting earlier ontological understandings of the mechanisms and classification of things. Misconceptions arise as children work to conflate earlier conceptual understanding with scientific knowledge that is not always intuitive, such as the notion of 'force'. Children often conceptualize force as something associated with movement. The notion of equilibrium does not connect with an understanding of force. When more than one observable force acts on an object, children often perceive the actions as either winning or losing (NRC, 2007).

2.2 Meaningful Learning

Meaningful learning refers the quality of knowledge-building that humans experience, beginning at birth. Research into meaningful learning and retention is typically focused on how meanings are constructed and then incorporated into existing cognitive structure (Ausubel, 1963). Meaningful learning has been proposed as necessary in order for cognitive growth and change to occur. According to Ausubel's learning theory, cognitive structure is organized hierarchically.The most inclusive and general concepts are positioned at the apex in the hierarchical structure of knowledge, while the less inclusive and more specific ideas and subconcepts are incorporated or subsumed within the more inclusive ones. Meaningful learning occurs when new ideas are able to be subsumed under already existing or anchoring ideas. Through subsumption, ideas that were initally dissociable from established knowledge units in the hierarchical knowledge structure are able to be retained and assimilated into the existing knowledge units. The desired outcome is for the learner to gain meaningful and useful knowledge from which to construct new understanding (Ausubel, Novak & Hanesian, 1978; Novak, 2002).

The single most important factor influencing learning (learning is defined for these purposes as *acquisition, retention and transferability of knowledge*) is the learner's prior knowledge, meaning what he or she already knows or thinks to be valid (Ausubel, 2000, Novak & Gowin, 1984). Using student-created concept maps, this information can be made available to the teacher.

2.3 Concept Maps & the Facilitation of Meaningful Learning

Concept maps are representational models of knowledge structures which can be constructed either with paper and pencil, or through the use of a computer-based software or online program. Included in these maps are nodes or bubbles housing concepts (ideas); connecting lines indicating a relationship between concepts; and linking words or phrases placed on connecting lines describing a connection between the two concepts, creating a propositional statement (Novak, 2002; Novak & Cañas, 2008). Propositions, also known as *semantic units or units of meaning* (Novak; Novak & Cañas), are made up of at least two linked concepts, along with linking words which create a complete or meaningful thought. Concept map structures can be created as *spokes, chains,* or *networks* (Hay, Kinchin, & Lyogo-Baker, 2008). Learning becomes visible through the use of student-created concept maps, as each concept map shape can reveal conceptual understanding of the learner. Thus, a concept map created with hierarchical structures is indicative of a hierarchical cognitive structure and of material subsumed onto already existing concepts (Novak & Cañas).

Inspiration® software technology was used for this project. Students would log onto the software and locate their most recent concept map in the files. To add, revise or rearrange a concept map, students would click on icon/tools displayed at the top of the open file window, or on the bottom of the page for additions and changes to the current cmap displayed. The program's procedures were intuitive for most students. Overall, students had familiarity with word processing and using the laptops for a variety of research and writing activities.

3 Method

3.1 Research Approach & Design

One third-grade classroom in a small rural elementary school (K-8) was the setting for this study, which lasted for six months of the school year (November – April). The participating classroom teacher (‘the teacher') taught all the science units over the course of the school year. All students received training on the construction of concept maps using paper and pencil first, then the software. The teacher received instruction before the beginning of the study on the use of the software technology, constructing concept maps, and was given a brief introduction to the theoretic framework underpinning the study.

Data were collected from three different sources, science class observations, student and teacher interviews (occurring three times) and artifacts. The study incorporated a What I **K**now, What I **W**ant to Know, What I **L**earned (K-W-L) chart as a tool to access student prior knowledge; a pre and post science unit assessment comprised of a collection of selected responses and short answers; and a concept map evaluative rubric (after Novak and Gowin [1984] and Hay and Kinchin [2008]).

The students’ first encounter with building concept maps was paper and pencil followed by the use of a concept mapping software program. Student ideas were included in their concept maps, and the structural organization of the map displayed how information was organized hierarchically and connected to other concepts.

Using information made available from students’ maps, the teacher intervened so concepts based in scientifically valid understanding occurred. This, in turn, contributed to a more grounded foundation of understanding as evaluated through techniques described in the following section, a process which provided additional support to students’ learning as science concepts build upon prior understanding.

3.2 Concept Map Evaluative Rubric (CMER)

The Concept Map Evaluative Rubric (CMER) (after Novak and Gowin [1984] and Hay and Kinchin [2008]) was a tool used to record changes over time on student-constructed concept maps. The CMER displayed changes in structure, content and scientific conceptions for each participating student. The CMER captured snapshots of each student’s perceptions of science content by recording frequencies of concepts, lines, and linking words (valid linking words and clearly stated propositions). The rubric also noted hierarchical structure for each concept map. Three raters evaluated each concept map. One of the raters was a science content expert who evaluated each map for science content validity. The other two raters, a non-participating teacher within the school, and the author, scored each concept map for structure and qualitative changes in hierarchical levels and concept validity.

3.3 Assessment

The assessment protocol used throughout this study was a set of questions on general watershed concepts. Some questions named specific bodies of water in the region, while others were of a more general nature. The children took the assessment four times during the science unit (September, December, and twice in April). Questions were constructed to test student knowledge, comprehension, application, and analysis of watershed concepts. Types of questions included short answers, true/false, multiple choice, and interpretive exercise. The assessment was a way to gauge application of learned concepts in a more formalized context while applying test-taking skills.

3.4 Accessing Prior Knowledge

K-W-L charts tapped into students’ prior knowledge about watersheds. The teacher conducted a whole-class K-W-L chart-building activity at the beginning of the watershed study in the fall (Table 1, left-hand column). K-W-L charts were then revisited in February, and again in April. Children received their own copy of the original chart with the class information on it. They filled in the What I **L**earned column in February. In April, using the same chart, students added onto what they had listed in February. The middle column (What I **W**ant to Know) was included in April. This gave the students an opportunity to reflect on their then-current fund of knowledge and subsequently to apply their own personal connections to watersheds and the learned content to target specific areas for further investigations.

KWL: A Watershed		
What I **K**now (November 2010)	What I **W**ant to Know (April 2011)	What I **L**earned (February & April 2011)
It has something to do with water A shed with water inside A windmill A shed with things we use on the water The name of a boat Shedding water Like a greenhouse with barrels of water	What would happen if one of the steps of the water cycle was taken out? Why doesn't the ocean overflow? What percent of water is saltwater? Why do lakes and rivers connect? I want to know why they named it the watershed? Why do people dirty up our watershed?	I learned about biomagnification And precipitation, evaporation, condensation, H_2O, and water cycle, and zones (Feb. 2011) I learned that what we thought it[watershed] was, was not true. That a watershed is mostly ridgelines. I learned that where ever you are, you are in a watershed. I know about pollution, oil, water, sun, food, people, life in the ocean, ponds, lakes, rivers, fish, animals, estuaries, anadromous and catadromous fish. Biodiversity, eutrophication, ecology, nonpoint pollution and point-source pollution (April 2011)

Table 1. What I **K**now, What I **W**ant to Know, What I **L**earned chart

4 Results

The students' process of creating, recognizing, and building connections within their concept maps (cmap) provided the means for the teacher to identify student misconceptions. The content and structure of their concept maps revealed their understandings of what they were learning. Students' personal connections to science content occurred in class and one-on-one discussions, and were displayed in concept map structure and content. Once misconceptions were identified by the teacher via concept map structure, content, and student discussion, she re-taught and re-contextualized the science concepts. Re-contextualizing the concept involved embedding the idea within a learning situation connected to the student's personal experience and prior knowledge. Through class discussion and probing questions on the teacher's part, she was able to determine whether knowledge modification had occurred in the student's understanding of the misconception. Structure and content of the student's follow-up cmap would contribute to the teacher's data on how content was being understood and connected to already embedded knowledge.

Through the process of building concept maps, the connections among watershed concepts and between concepts and personal knowledge became apparent to the students. During interviews and class discussions, students shared their perception behind each connection created in a particular concept map. This process provided a window of opportunity for both student and teacher to view the hierarchical organization as best representing each child's knowledge structure. Established information bits in concept maps were used as anchors for adding onto and building extensions using new information. Four examples of student-constructed concept maps (and associated interviews) are included in the following sections.

4.1 Rachel's Concept Maps

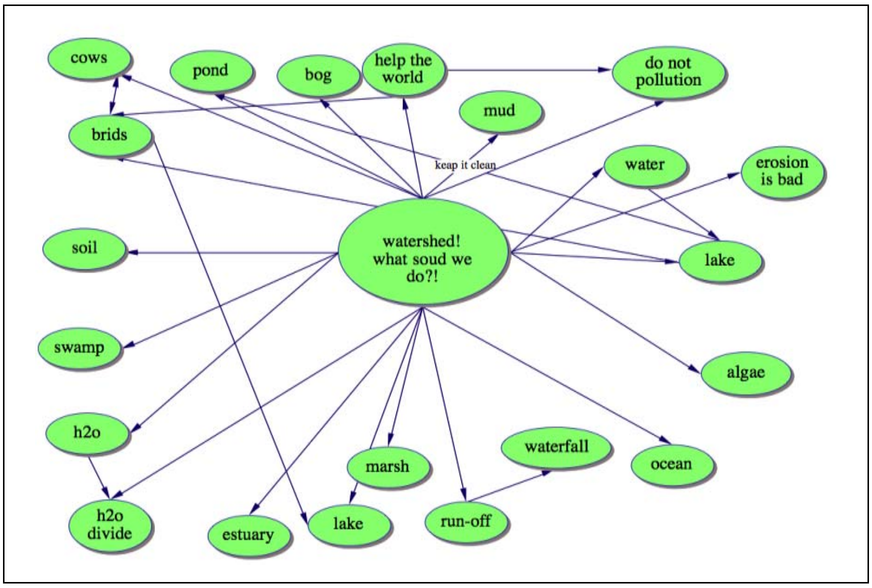

Figure 1. Rachel's Concept Map 1 (first)

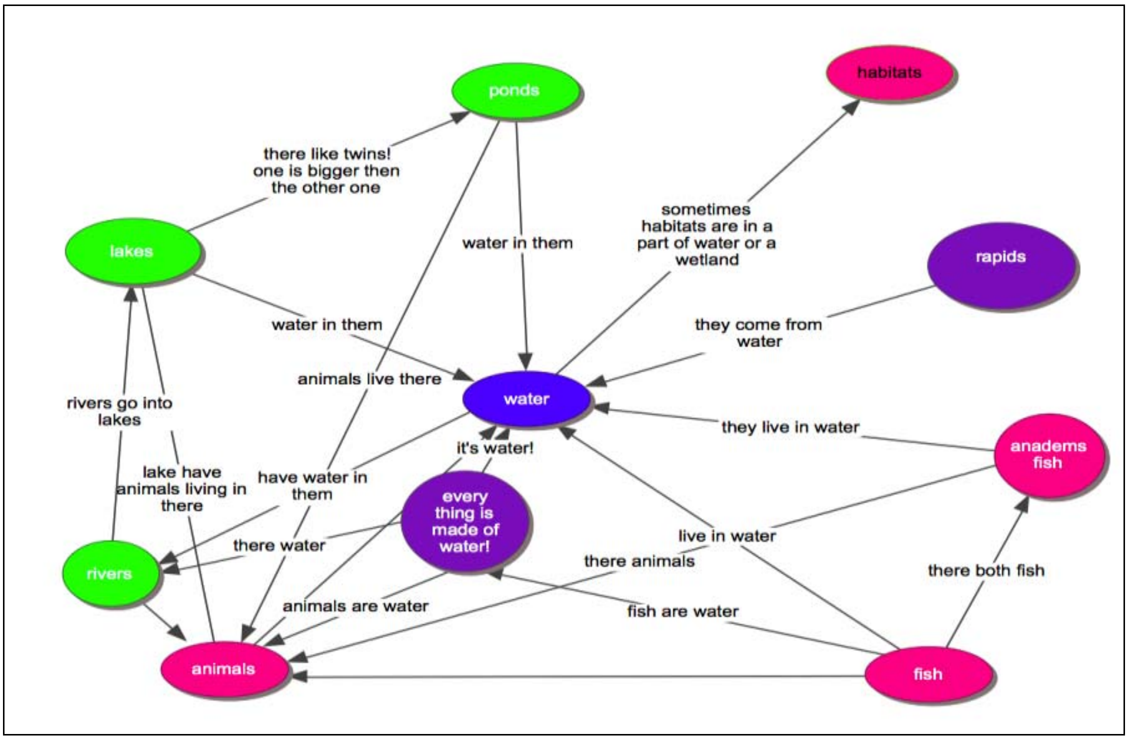

Figure 2. Rachel's Concept Map 7 (final)

4.2 Interview Excerpt with Rachel (1/25/11)

Rachel: I knew that everything would connect to watershed and then I had to think what would they be connected to, so I thought of all these different things and when I thought about them, I had to add new ones too [ideas]. I thought of new ones too, its like, um well the fertilizer would go with food 'cause fertilizer is food for the soil so those three would go together and then the cows would go with the food 'cause cows eat food and the cow…
Interviewer: Explain connections between ponds and oceans.
Rachel: They are both bodies of waters and so is lakes so those three connect and so does that does too 'cause a bog is a part of a water [bog and watershed].
Rachel: But I think a bog and a lake would be connected because they are sort of like the same thing.
Interviewer So a bog and a lake are connected because they are similar?
Rachel: Yes.
Interviewer: In what ways are they similar?
Rachel: Well, um, well they both are like, um I forget the question [question is repeated], well, I think they could connect to each other like they could run into each other, like a bog is like a lake because it has um... like what was I going to say, a bog is like a lake, they have lots of plants together - and they can both be muddy probably, sort of connected. Well, then I thought that mud and bog would probably go together because bogs can be muddy like on the bottom.
Interviewer: What is the water-table?
Rachel: It's like a um, sort of like, um..., the water-table is sort of like, I can picture it in my head I just don't know.

4.3 Critique of Rachel's Interview

Rachel's understanding of watersheds at this point in the study was revealed through her comments on her map content and structure. Her map was a *spoke* shape, with most of her ideas radiating out from or into the central theme of watersheds. Her map structure shows her centralized perception of the information she was learning. She was in the process of organizing all the watershed ideas as they connected to her main idea. Rachel included everything she had learned so far about watersheds in the first map. Hierarchical structure and organization of concepts were not apparent in her initial concept map. The connections she created and then explained in this interview excerpt show how Rachel's understanding of watershed-related ideas, as they connected and related to the watershed, had not evolved beyond her conviction that all her concepts were connected to the watershed with equal importance and validity. There was little variation in how things connected to her central idea. Her final concept map revealed an organized hierarchy of ideas as they connected with her central idea of water, which had grown out of her initial thinking on watersheds.

The process students experienced as they built and revised concept maps helped them make sense of their newly acquired knowledge on watersheds. Experimenting with ideas and the connections to other ideas allowed for comparisons among concepts, which in turn helped students develop an awareness of the attributes of each idea, the similarities and differences, and how one thing connects to another thing.

4.4 Anne's Concept Maps

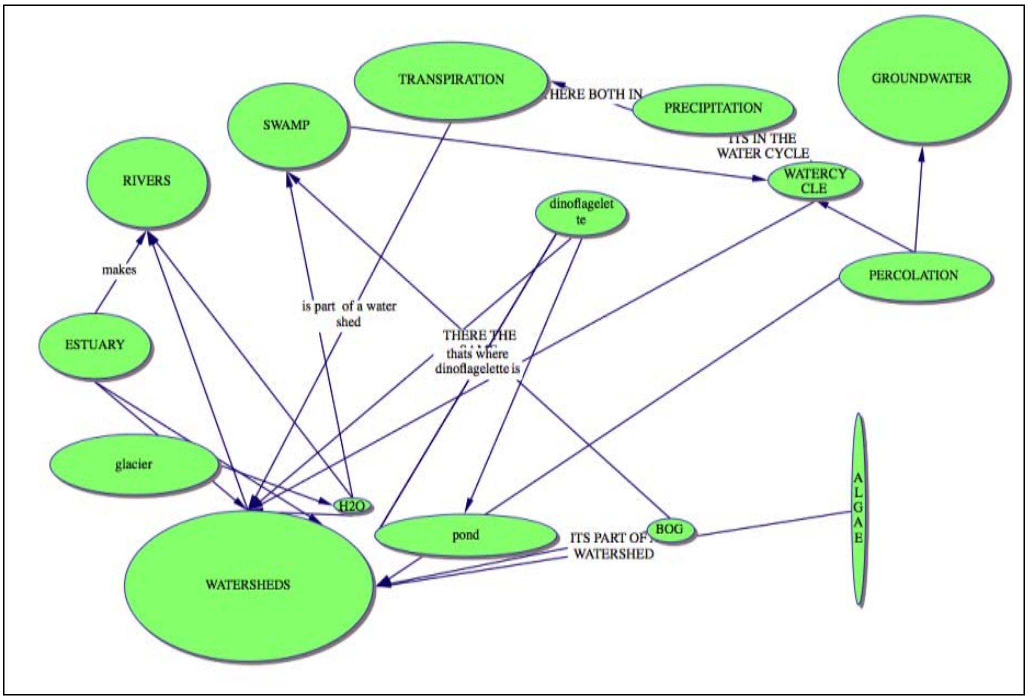

Figure 3. Anne's Concept Map 1 (first)

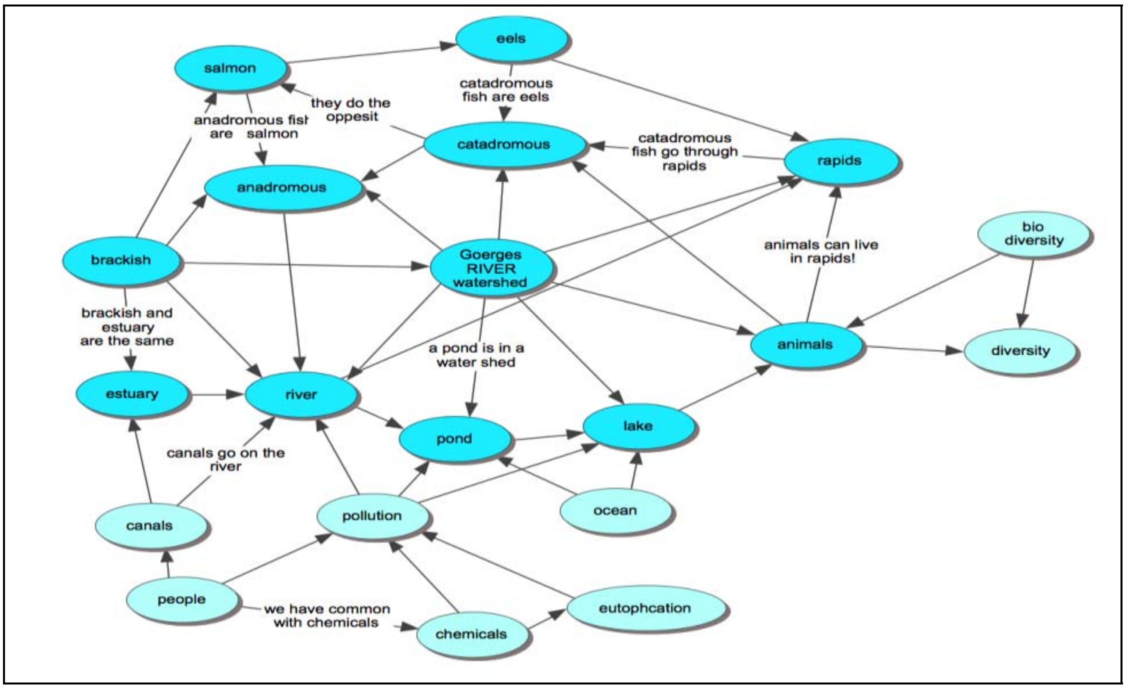

Figure 4. Anne's Concept Map 7 (final)

4.5 Critique of Anne's Concept Maps

Anne's concept maps developed from *spoke* shape to *network* shape over the course of the science study. Her content as well as structure were complex with many thoughtful concepts and connections. Anne was one of the few in her class who developed her concept maps with linking words. Her final map contained several hierarchical levels of information. Her color-coding used two colors on her final map but they were appropriate to her scheme of understanding of what she had created.

During one of Anne's interviews (4/29/11), she shared her perspective on creating concept maps.
Anne:…it's kind of like a puzzle of figuring what goes with what and all that."
Interviewer: "How did you figure or what process did you use when you were putting your puzzle together?"
Anne: "I just put one [bubble] on there and thought about it and put another one on there [bubble] and I thought about that one and then, well, just put some on that that I really thought were interesting and then I would see if they [ideas] would go together."
Interviewer: "How did you decide what goes with something?"
Anne: "I was thinking 'cause I had chemicals and biomagnification and then I thought about it and yeah, that would be kinda the same so I put that there."

5 Discussion

This work's theoretical premise that student-constructed concept maps when used in science class for the duration of a science unit supports student learning while providing a window into student cognitive organization and understanding, is primarily founded upon the work of Novak (2002), Ausubel (1963, 2000), Kinchin (2000) and is supported by the empirical outcomes of this research project.

This study blended the use of prior knowledge and concept mapping for both displaying student misconceptions and aiding the student in achieving gains towards meaningful learning in science class.
To support effective science teaching, educators need methods to reveal student understandings and misconceptions of science concepts, which can offer all students an opportunity to reflect on their own knowledge construction and organization. By using student-created concept maps developed and revised over time in science class, students experienced those opportunities to reflect on their own knowledge organization. The teacher was also provided with a pedagogical tool for displaying student misconceptions within the content and structure of each student's concept map.

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