Concept Maps: Theory, Methodology, Technology
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CONCEPT MAPPING IN THE TEACHING OF PHYSICAL SCIENCE: ASSESSMENT OF REAL WORLD APPLICATIONS OF WAVE ENERGY BY PRE-SERVICE TEACHERS NEGOTIATING CONCEPT UNDERSTANDING

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Abstract Understanding the relationship between sound, light, and electricity can be a very challenging topic for pre-service students in a physical science class at the undergraduate level. Traditional lecture materials usually present this material as discrete topics. For this reason concept maps were used to develop an instructional unit on wave energy. Hands-on lab activities, and interactive computer simulations additionally supplemented instruction for each section of the unit. The effects of the use of concept maps were determined by a pre-post-test design. In addition to fill-in-the blank concept maps, students were asked to create group and individual concept maps, which were used to track their understanding of these concepts. The way this knowledge was applied largely depended on the students' understanding of electromagnetism. In particular it was observed that the participating pre-service students demonstrated capacity for distinguishing between the different conceptions of application of wave energy. Only students with a developed capacity for distinguishing between models were able to reason in a logical manner. They recognized the limits of models and were not only able to specifically designate changes from models and levels of models, but also to apply these in an accurate manner.

1 Introduction

Understanding the relationship between sound, light, and electricity can be a very challenging topic for pre-service students in a physical science class at the undergraduate level. For this reason an instructional unit-using concept maps on wave energy was developed. Hands-on lab activities, and interactive computer simulations additionally supplemented instruction for each section of the unit.

These pre-service students were enrolled in an Integrated Sciences: Physical Science course, a pre-service teacher science course in the Early Childhood Special Education program at a College in Central Georgia. They were involved in a two-week-long thematic learning unit to examine the relationship between different forms of wave energy. In order to answer the question "how do we make science real", pre-service students were required to build an electromagnet to power either a bell or a light bulb. The pre-service students had been introduced to the concepts of Wave Energy in their undergraduate classroom.

Besides analyzing the overall effects of using concept maps to enhance pre-service student understanding, the evaluation tracked their ability to successfully apply their understanding to the real-world use of wave energy. The study examined the following scientific question: What is the impact of concept mapping used by pre-service students on the comprehension of the basic concept of wave energy? The research was based on the hypothesis that pre-service students, who have developed an understanding between alternative conceptions, use models confidently and appropriately in the context of wave energy, while pre-service students without this capacity for distinguishing between alternative conceptions are not able to explain wave energy consistently.

Teaching science to elementary pre-service teachers typically involves boosting their self-efficacy towards science, overcoming popular misconceptions and content inaccuracy, and helping them develop scientific reasoning in order to engage in problem-solving by using methods of science inquiry. Communicating scientific ideas in the absence of a real-world context leaves pre-service teachers with a superficial understanding of the relevance of science in everyday life. Whereas, being able to visualize their own learning about physical science principles fundamental to wave energy and applying their understanding to find a real-world situation becomes a creative act, involving real-world experiences filtered through developing understandings translated into new teaching possibilities.

2 Theoretical Framework

Concept mapping in its elemental form is a learner-centered process. The process of constructing a concept map is a powerful learning strategy that forces the learner to actively think about the relationship between the terms. This makes concept mapping especially suited to science education as the learners often perceive, incorrectly, that studying science means simply memorizing facts (Dorough and Rye, 1997). The versatility of concept mapping allows use both for instruction (Martin, 1994; Mason, 1992) and for assessment (Stoddart et al., 2000;

Schau et al., 2001). The instructor can thus implement concept mapping based on the area that best suits the topic and the learning environment.

An increasing number of studies highlight the use of fill-in-the-blank concept mapping in identifying students' prior understanding of a particular topic (Yin *et al*. 2005). In addition, concept maps can also be used to promote cooperative learning. During group concept mapping students work in small groups and discuss their understanding of a topic and then collaborate together to produce a group concept map. This approach engages students in discourse about the concepts and encourages students to articulate their thoughts about, and experiences with, the concepts (van Boxtel *et al*, 2002). Since the group of students work on the same map, it helps strengthen interdependency and negotiation between the collaborating students.

Fill-in-the-blank concept maps can be used as 'advance organizers' and formative assessment of student conceptual understanding. Teachers/students can construct a concept map, which focuses on content in the upcoming lessons. This allows individuals to identify the connections between their existing conceptions and the new material being introduced. With concept maps, information can be presented in a concise manner without the loss of complexity and meaning. The visual presentation allows the students and teachers to accurately identify the relationship between different topics without the dense presentation of words and verbal compositions (Gul and Boman, 2006).

3 Methods

Pre-service students' understanding about the unit on wave energy was determined by a pre-post-test design. In addition to fill-in-the-blank concept maps, students were asked to co-construct concept maps, which were used to track application to a real-world model construction. A total of 64 pre-service students from 5 different sections of the course participated in the study; so the pre-post test analysis consisted of a total of 128 fill-in-the-blank concept maps and 64 co-constructed maps. These students were enrolled in 5 different sections of the course over a period of three semesters, between Fall 2010 through Fall 2011. For the purpose of analysis, the student concept maps were sorted into two groups: Group A, were concept maps from students who were able to successfully complete the final lab activity; and Group B, were concept maps from students who were unable to successfully complete the final lab activity.

The fill-in-the-blank concept maps to be worked on by the pre-service students consisted of 10 sets of propositions, which had been extrapolated from a feasibility study with previous-groups of pre-service students. Recent research has shown that the more constrained the map structure, of fill-in-the-blank maps, the higher was the reliability correlating to other forms of classroom assessments (Schau et al., 2001). For the purposes of this study, the fill-in-the-blank student map scores were appreciable when compared to co-constructed concept maps and the final lab activity.

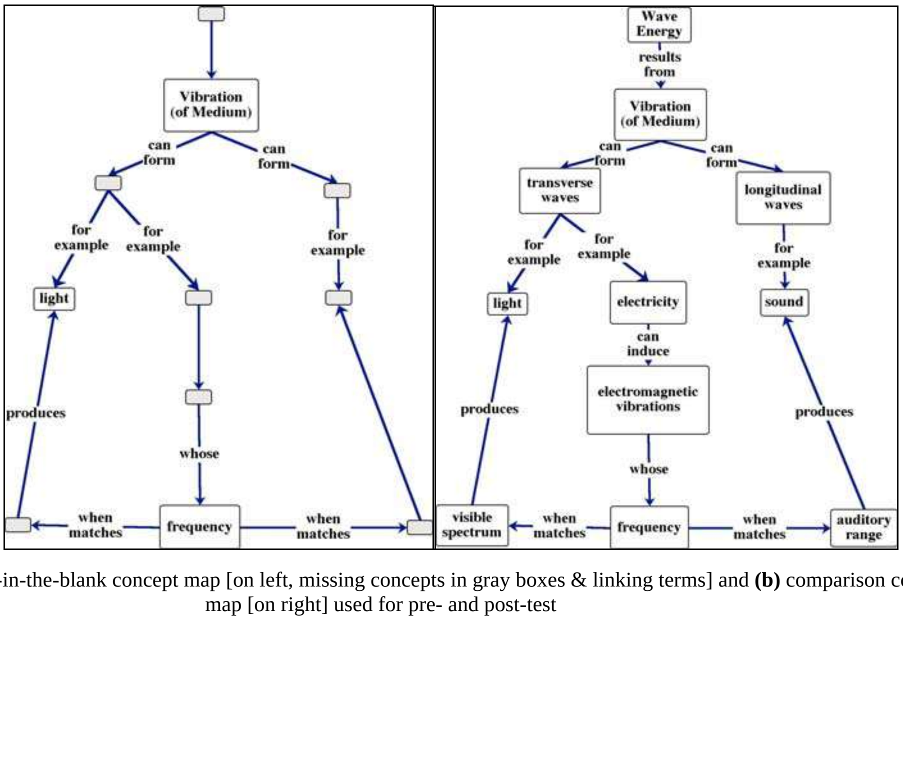

Figure 1: (a) Sample fill-in-the-blank concept map [on left, missing concepts in gray boxes & linking terms] and **(b)** comparison completed map [on right] used for pre- and post-test

The participating students were asked to fill-in either terms and/or linking terms. Sample templates of fill-in-the-blank maps and completed expert map used for the pre- and post-test were generated according to Figure 1a & 1b. Data from individual student fill-in-the blank concept maps were then analyzed based on their contents, and the structural parameters of the student maps based on accuracy of propositions were compared to the completed expert map. During the implementation of the unit, participants were also exposed to hands-on activities on each sub-topic for example light and electricity. Student comprehension of relationship between concepts regarding wave energy was measured by whether they could translate their understanding directly as applied to the lab activity of building an electromagnet without instructor guidance. The lab activity was conducted during class under strict guidelines to use only the materials provided by the instructor.

4 Results

In the pre-test, students in Group B demonstrated only rudimentary knowledge of wave energy; yet, the concepts of energy transfer were linked by logically correct propositions. The expressed knowledge was however reproduced from the students' rote knowledge. Students in Group B were not familiar with the formation of magnetic energy due to electricity. The propositions connecting the concepts confirm misconceptions regarding visible electromagnetic waves (Figure 2). The post-test and co-constructed maps show that structural development of concepts is evidently triggered by the ability to visualize concept understanding (Figure 3).

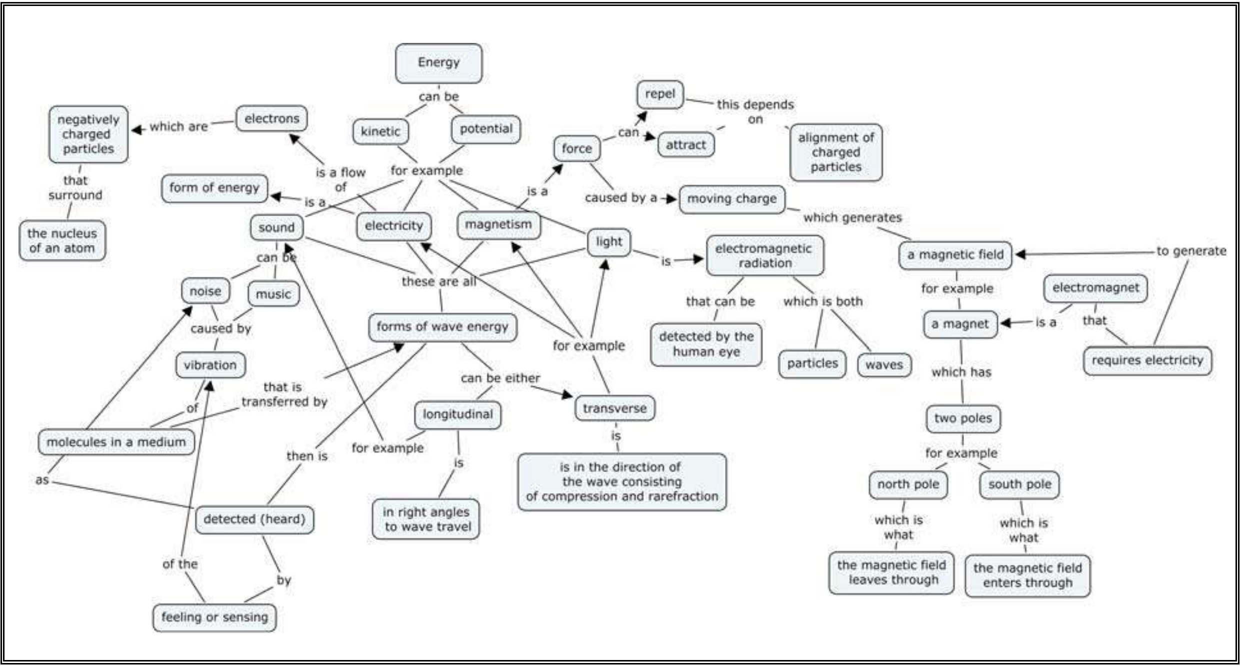

Figure 2: Example of a concept map co-constructed by students from Group B.

The comparison of propositional knowledge between the different types of concept maps (fill-in-the-blank and co-constructed) indicates that there was not only a highly significant increase in knowledge for each group of students, but also that this knowledge was consolidated. The analysis of student knowledge/understanding focused on concepts used for both types of concept maps, i.e. fill-in-the-blanks and co-constructed, were specific to concepts related to wave energy and allowed for a valid comparison of the accuracy of propositional knowledge presented in the student concept maps. Accurate relationships between concepts related to wave energy provided the degree of student understanding about these concepts. The consolidation of this knowledge largely depended on whether the pre-service students were able to accurately build an electromagnet and harness the energy to either ring a bell or light a bulb (Figure 3).

Analysis of the pre-test concept map shows evidence that students find it challenging to connect the different aspects of wave energy (Figure 3: Group B, n=50). Only those pre-service students, who had developed a deeper understanding of relationship between concepts were able to correctly apply their knowledge to accurately complete the required lab activity (Figure 3: Group A, n=14). They were consistently able to build an electromagnet, without instructor-guidance, and apply the electromagnetic energy to power the bell/bulb. Group A pre-service students were able to construct an electromagnet, present their propositions in a logical manner (Figure 4), recognize the limits of models and in levels of models, by applying their understanding to harness electric magnetic energy.

Pre-service students (Group B), without this capacity for recognizing the transformation between different types of wave energy were unable to successfully complete the lab activity (kept searching for a magnet among their lab materials to use in their model) and showed inconsistent patterns of explanation more frequently than pre-service students who exhibited a deeper understanding (Group A). This also correlated to the higher percentage of correctly marked propositions in Group A post-test concept maps.

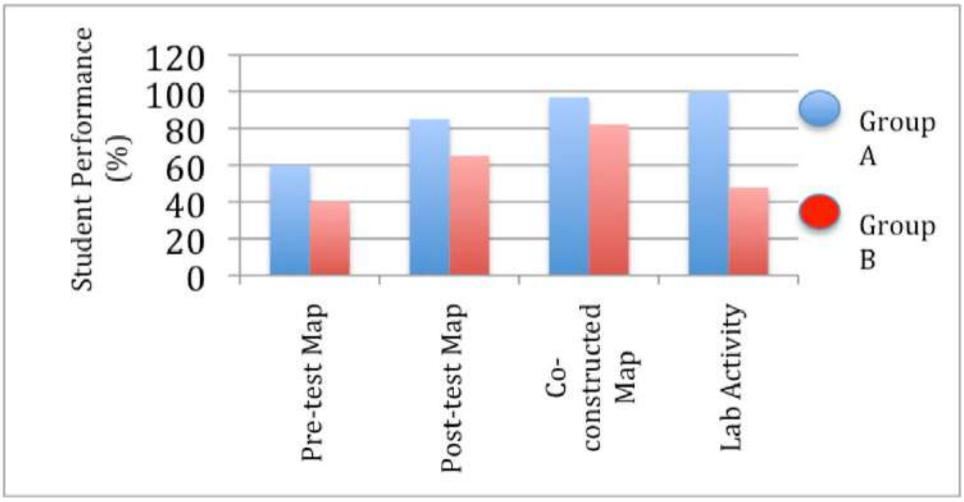

Figure 3: Graph showing pre-service student understanding of concepts as related to wave energy. Group A represents students successful in lab activity and Group B represents students unsuccessful in lab activity.

End-of-term course evaluations suggest that 100% of students from Group A and 50% of students from Group B reported that they benefitted from using the concept maps to monitor their own learning. About a third of the students from Group B indicated that they found concept mapping challenging and not helpful to their learning because the course material in itself was challenging. The last 20% students from Group B did not responded to the end-of-term course evaluations. All students who responded to the course evaluation reported that engaging in group discussions, while co-constructing the concept maps, helped them figure out gaps in their understanding of wave energy.

5 Conclusions and implications

The findings of this study confirm the positive impact of knowledge visualization for introductory survey courses at the undergraduate level. The capacity demonstrated by the pre-service students for distinguishing the relationship between the different forms of wave energy is of critical importance. Pre-service teachers, especially training to teach in elementary classrooms, are key in introducing science concepts accurately at the elementary school level. Therefore, more attention should be paid to the development of meta-conceptual awareness in physical science classes, so that the relationship and interdependence between concepts can be discussed and re-examined.

There is no shortage of new developments in the world of science education, to help teachers teach new information to students in a way that promotes meaningful learning. However, many of the tools required for teaching science require additional resources and a large amount of time for re-tooling and implementation. These factors often create challenges and constraints for classroom teachers. While concept mapping can offer a technique for revealing students' cognitive structure, the instructor and learner need to be well trained in the art of concept mapping before it can easily be subsumed within present classroom constraints.

What concept mapping is, is an alternative way of representing scientific knowledge differing from the usual written text in that information is presented in a hierarchical manner. Concept mapping gives students the freedom to answer a specific focus question using concepts that they understand and hence encourages meaningful learning. Concept maps are extremely versatile and can be used both for instruction and assessment.

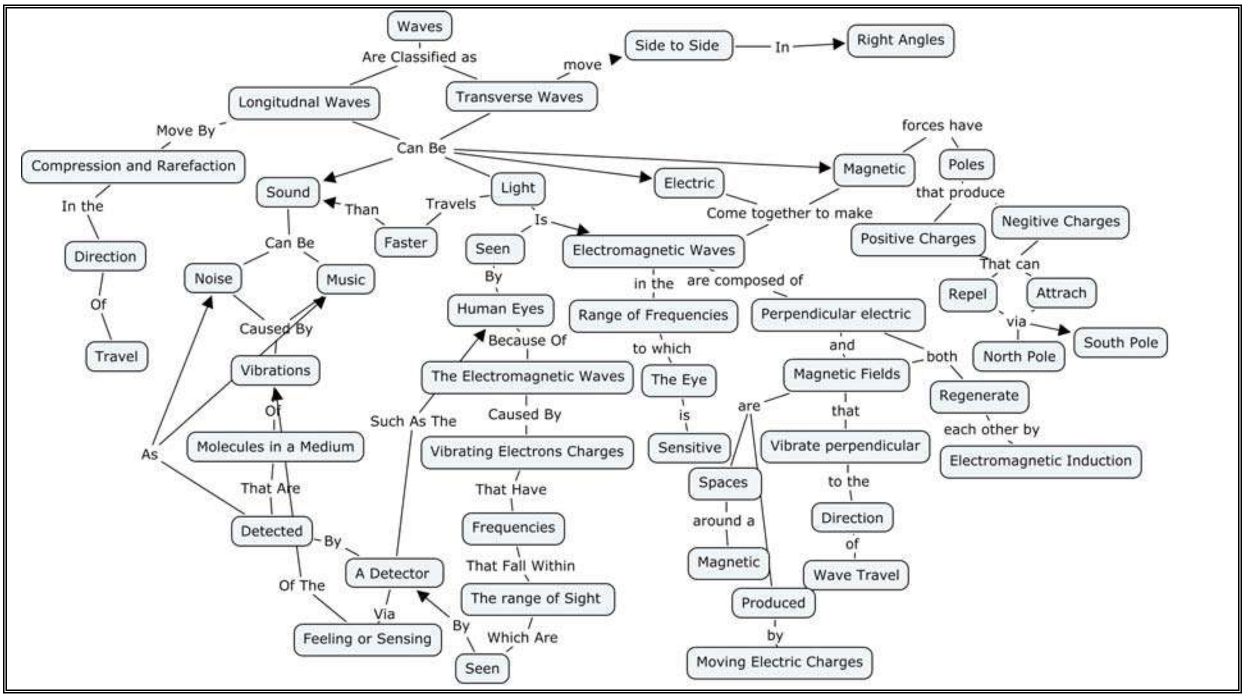

Figure 4: Example of a concept map co-constructed by students from Group A.

This study suggests that Concept Mapping can serve as a useful tool in science education by helping students to understand concepts more easily, link prior understanding to new knowledge and represent their understanding of those concepts. The majority of pre-service student participants reacted positively to the use of concept maps and felt that it has several benefits to their own learning and for their future career in teaching. The findings from this study show that it is of advantage that discussions based on co-construction of concept maps are implemented in introductory science courses, especially physical science, and that the students have the opportunity to scrutinize the limits of their understanding by visualizing their own learning through concept application.

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