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IMPACT CONCEPT MAPPING HAS ON PRE-SERVICE TEACHERS UNDERSTANDING OF SCIENCE CONTENT KNOWLEDGE AND DEVELOPMENT OF THEIR SCIENCE PEDAGOGY

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Abstract. The focus of this study is to support and improve the quality of teaching and learning of elementary teacher candidates in the physical and life sciences. Concept Mapping and Peer-Instruction (using ConcepTests) were used to model best practices in enhancing science concepts and processes at a conceptual level and to provide teacher candidates with a tool to enhance the learning environment and formative assessment of teaching and learning in their classrooms. Research indicates that an understanding of how students learn (or fail to learn) combined with appropriate cognitive tools, such as concept mapping, can create learning environments that produce improvements both in teacher preparation and their attitude toward teaching. The project aims to develop both an improved understanding of barriers to elementary teacher candidates learning physical and life science concepts as well as providing tools to help them surmount those barriers. The participants were pre-service candidates enrolled in the Macon State College (MSC) Early Childhood Education Program. The elementary schools where they conducted their field internships are in the neighboring school districts in Bibb and Houston counties. The use of ConcepTests and Concept Mapping provided a peer-supportive environment for pre-service candidates in which to develop a deeper knowledge of science concepts. Comparison of initial and final student concept maps suggests a moderate correlation between learning approach, development of concept knowledge and quality of knowledge organization.

1 Introduction

The objectives of the study were to: (1) allow teacher candidates to see concept mapping and peer-instruction practices proven to increase their conceptual understanding of physical and life science; (2) give teacher candidates the opportunity to use concept mapping as an organizing tool to engage in conversation in tandem with an expert, providing a deeper understanding of the implementation and use of this cognitive tool; and (3) provide teacher candidates the opportunity to apply concept mapping techniques to what they have learned and to receive immediate feedback while initially implementing the practice.

In the last two decades within all disciplines in science there has been an unequivocal shift in the goals of science teaching from helping students merely create a knowledge base of scientific facts to developing deeper understandings of major concepts within a particular discipline/domain of knowledge. This emphasis on conceptual understanding in science education reform has guided the development of standards and permeates all major science education reform policy (AAAS, 1989, 2001; NRC, 1996). However, this transition to teaching towards conceptual understanding presents a host of challenges both in theory and practice. More crucial is the fact that few if any students come to the study of physical and life science in college, without significant prior knowledge of the topic. Yet there is often little time invested by instructors in finding out the depth of their prior understanding, and more specifically any misconceptions and lack of understanding that might effect how they fit the new information they learn into their current cognitive framework.

Research has repeatedly pointed to teachers and the teaching environment as the key to improving student achievement. According to Darling-Hammond and colleagues (2001), studies have concluded that teacher qualifications (e.g. knowledge and expertise, education, and experience) "account for a larger share of the variance in students' achievement than any other single factor, including poverty, race, and parent education" (p. 10). One overriding feature that re-occurs throughout the literature as a paramount component of quality teacher preparation is the ability of teachers to "learn *about* practice *in* practice" (Darling-Hammond et al., 2001, p. 20). While theoretical instruction is important in building a foundation for teaching, adequate opportunities for teachers to apply the knowledge that they have learned is critical (Darling-Hammond et al., 2001; Gersten, Chard, & Baker, 2000). Critics accuse teacher preparation programs of not providing teachers with enough knowledge and practice with research-based strategies, hence the reason for a lack of implementation. One of six factors that Gersten and colleagues (2000) claim determines a teacher's sustained use of a practice is the teacher's ability to "understand and think through the instructional approach" and how it can be used. Given this framework, it becomes apparent that a teacher's level of knowledge about and experience with a given practice is directly related to his or her future implementation of that practice in the classroom.

Teaching methods, based on a careful consideration of constructivism in its epistemological, psychological and educational aspects, contrast with traditional ones. Gil-Perez (2002) indicates that it is not possible to change this behavior of the traditional teacher unless they change their epistemology, their ideas about how scientific knowledge is built, and their viewpoints about science. A constructivist learning environment is, according to Wilson (1996, p.194) “a place learners work together and support each other as they are using a variety of tools and sources of information, following the orientation of the learning purposes and the activities of problem solving”. Building such an environment has a lot to do with the way the teacher approaches teaching and learning.

One of the important requisites of such constructivist environments is that students cooperate with each other for the solution of the tasks, which are proposed to them. These tasks should be stimulating challenges for their learning and cognitive development. Having cooperative activities, when it takes place in an adequate environment, is enriching as it often leads to students’ meaningful learning (Soares, 2006). A concept map is a graphic organizer which uses visual representation to hierarchically organize a set of concepts, connected by descriptive words in order to build meaningful statements. Expressing meaningful relationships between concepts through a concept map reveals each student’s comprehension and knowledge structure (Novak & Gowin, 1984). The negotiation of ideas among students, on the basis of concept mapping individually and/or by groups, particularly, when monitored by the teacher, helps them deepen the knowledge upon which the maps are based. This allows students and teachers being able to glean the meanings of course materials (Novak & Gowin, 1984).

At Macon State College (MSC) we are designing and developing a new teacher preparation program with certification in elementary and special education. The science course content is aligned to the Georgia Performance Standards (GPS) for physical and life science for K-5. Our attempt is to provide a content-rich background for our Early Childhood majors in order for them to become conceptually engaged and be able to acquire critical thinking skills as they progress onto becoming teacher candidates in our program. This is crucial for our students especially with respect to Science, Technology, Engineering, and Mathematics (STEM) education. MSC is an open enrollment college, part of the University System of Georgia that historically, has a rather depressed academic profile especially with respect to the public schools and STEM education. Although teacher education coursework often use constructivist teaching strategies that are student-centered and model best practice, lack of prior preparation in science and content connection to the real-world often lead to a disengagement with science course content (Anagnostopoulos, Smith, & Basmadjian, 2007; Putnam & Borko, 2000). By integrating concept mapping within standards based curriculum, teacher candidates can learn course content and immediately see its application within the K-5 setting, providing them a strong foundation of how to apply knowledge learned in their coursework to unique and realistic instructional settings.

2 Theoretical Background

Conceptual understanding denotes a complex, multidimensional integration of information into a learner’s existing conceptual framework. Marzano and Kendall (2007) describe concepts to be synonymous with generalizations pertaining to disciplinary knowledge. In understanding science concepts this requires the organizing of ideas into principles and processes that are guided by these principles. This suggests that the acquisition of new knowledge and enriched understanding requires a balance between students’ prior and new understandings. In addition, it requires varied instruction and ongoing assessment during the course of instruction. The following four teaching strategies lend themselves to teaching towards knowledge enrichment based on conceptual understanding: (1) using different instructional strategies regarding topics chosen and time involved in teaching those concepts; (2) different approaches used to help students identify their prior understanding; (3) use of misconceptions as a diagnostic tool for assessment; and (4) using assessments designed to detect change in understanding.

The use of alternative conceptions and/or misconceptions to promote conceptual understanding has a long history in the teaching of science (Hestenes, Wells & Sawackhamer, 1992). Pintrich and colleagues (1993) indicate that the motivation to persist in the difficult process of constructing and organizing knowledge is related to the value of the task and to the student’s belief in the likelihood of success in internalizing knowledge. The value of a task can also be influenced by classroom contextual factors in the form of peer interactions that help create an environment of commitment to understanding. This can be achieved by integrating cooperative peer instruction in the form of ConcepTest, and class wide discussions through collaborative concept mapping.

ConcepTests (CT) were developed by Eric Mazur (1997) to help students confront misconceptions, and develop conceptual skills by defending their understanding about concepts in physics. The very nature of peer-guided discussions allows students to explore and confront their understanding and/or misconception. ConcepTests are designed to promote debate between peers thereby providing a safe scenario for conceptual shifts to occur in the relative absence of a grade.

The theoretical foundation of concept mapping rests upon the constructivist view of education and Ausubel's theory of meaningful learning (versus rote learning) (Heinze-Fry, 2004). Concept maps (CM) were developed as a metacognitive tool that help students understand the science they study by revealing gaps in understanding, identifying misconceptions, promoting reflective thinking, and facilitating shared understanding (Iuli & Hellden, 2004). Concept maps visually represent an individual's knowledge within a framework of concept relationships thereby allowing assessment of an individual's understanding. An instructional format with these components will provide teacher candidates with the opportunity to reflect on their own misconceptions, and to refine their own understanding by listening to one another's ideas and justifications and seeking clarifications. Pre-service teachers can construct concept maps that identify and define structural concepts based on their individual understanding and knowledge about curriculum and pedagogy. Concept mapping can be used to make explicit the relationship between principles, processes, and their conceptual content. Research on the current status of US elementary science curricula reveals considerable mismatch between science instruction and science concepts. Concept mapping can be used to bridge this gap by revealing to the teacher whether or not their students grasp both the concepts and procedures as an integrated whole. CT and CM techniques were used to identify teacher candidates' prior knowledge and provide them with a safe environment and the flexibility to probe, monitor, control, and reflect on their own learning

The Learning and Studying Questionnaire (LSQ) (Entwistle et. al., 2002) is a well-established survey instrument that examines students' approaches to learning and studying. Previous research by Iuli and Himangshu (2007) suggests the efficacy of using student approaches to learning to correlate concept-mapping data in undergraduate science. Improved map organization representing a more coherent understanding of relationships between concepts strongly correlates with a conceptual approach to learning. For most items on the LSQ, students respond on a 1-5 Likert scale (5=high). Subscales result from adding together the responses on the items in that subscale. Because change in conceptual understanding can be influenced by individual differences in approaches to learning as well as peer-interaction, LSQ scores were obtained to provide a measure of individual learning approaches. The differential between Deep versus Surface approach scores was used to group students as Deep, Surface or Mixed learners. Scoring was done using EXCEL 10.0.

3 Methodology and Materials

This pilot study was designed to provide an environment in which to test the impact of interactive teaching strategies on enhancing student conceptual understanding in an undergraduate science course designed for pre-service teacher training. The experimental design involved the use of CT and individual CM for teaching physical science concepts in a course designed for elementary science teachers based on GPS for elementary science. Development of conceptual understanding was compared between individual pre-service teacher concept maps at two different points, beginning (initial cmap), and end of semester (final cmap) and compared to a collaborative unit map which addresses a science theme using different disciplinary lenses for example physical science and earth science. The criteria for analysis of concept maps included number of accurately linked concepts, hierarchy and organization, presence of examples, and removal of misconceptions. In addition, the Learning and Studying Questionnaire (LSQ) was administered in order to group students as Deep, Surface, or Mixed (using both Deep and Surface methods) and data from ConcepTests was used to triangulate analysis of concept maps.

A base line of pre-service teacher candidates' understanding regarding physical science concepts was assessed pre-instruction by designing reading quizzes used to evaluate prior understanding. Change in pre-service teacher candidates' conceptual understanding was assessed at several points post-instruction by designing questions based on application of concepts. An item-analysis of questions missed by 50% or more of each group of students was used to design ConcepTests. In addition, sub-groups consisting of 2 pre-service candidates each were engaged in creating collaborative unit map regarding a science theme viewing concepts, processes and their applications from 2 disciplinary lenses, for example teaching Habitats of Georgia blending life science and earth science. Peer-instruction and guidance during both the ConcepTest and collaborative concept mapping activities provided a venue for addressing misconceptions and clarifying concept confusion.

Using this design, all pre-service candidates were trained in the use of concept mapping as well as provided with immediate feedback support. This design provided the potential to identify an effective method for impacting teacher preparation. The total number of pre-service teacher participants was 65 with $\alpha = .05$ and power = .80 the required sample size is about 28 participants per group. This was necessary for the observation of a moderate effect size ($\omega^2 = .06$; Cohen, 1988). As the intention of this pilot study was to generate a model for replication, a moderate effect size was required in order for the project to merit replication and further implementation of these teaching strategies.

4 Data Analyses

The sample population consisted of a total of 65 pre-service teachers, (59 females and 6 males), enrolled in the General Science for Elementary Teachers course at MSC. The LSQ distribution for this population is, 20% deep learners, 52% mixed learners, and 27% surface learners (Figure 1). ConceptTests correlated strongly (r (2) = 0.76, p<0.01) with concept maps of deep learners, and moderately (r (2) = 0.56, p<0.01) with concept maps of mixed and (r (2) = 0.52, p<0.01) surface learners.

LSQ Type	Concepts (% increase) (> 4 linkages)	Hierarchical (% increase)	Misconception (% decrease)
DEEP (n=13)	38	30	0
MIXED (n=35)	51	45	23
SURFACE (n=17)	35	53	29

Figure 1. Comparison between initial and final concept maps based on student approaches to learning.

For the majority of pre-service teachers in this study analysis of initial and final student maps reflected gains in number of concepts as well as depth of understanding (represented by linkages between concepts). Irrespective of the approach to learning, 75% of pre-service teachers demonstrated gains in conceptual understanding as measured by the end-of-semester maps (Figure 2). Moderate gains in increased number of linkages and hierarchical organization were observed in the concept maps from mixed (51%, 45%) and surface learners (35%, 53%), respectively. Deep learners showed a minimal increase of 38% with respect to number of linkages and 30% increase in hierarchical organization. With respect to absence of misconceptions, none of the concept maps constructed by deep learners had an misconceptions while maps from mixed and surface learners showed a 23% and 29% decrease in misconceptions, respectively, Figure 1. Overall analysis of individual student concept maps between the beginning (initial Cmap) and end of the semester (final Cmap) suggests: (1) Gains in understanding as denoted by 63% increase in hierarchical linkages, 75% increase in number of concept linkages (> 4) and 46% increase in examples provided to explain concept relationships and (2) Misconceptions and inaccuracies were reduced and clarified by 25%, (Figure 2).

Criteria	**Initial Cmap (n=65)**	**Final Cmap (n=65)**	**% Gain (+)/ Loss (-)**
Concepts Accurately Linked	2 linked concepts = 65 3 linked concepts = 52 4 linked concepts = 32 >4 linked concepts = 8	2 linked concepts = 65 3 linked concepts = 65 4 linked concepts = 54 >4 linked concepts = 57	2 linked concepts = 0% 3 linked concepts = + 46 4 linked concepts = +34 >4 linked concepts = +75
Hierarchical	16	57	+ 63
Examples Included	40	53	+ 46
Presence of Misconceptions/ Inaccuracies	35	8	- 25

Figure 2. Overall comparison between initial and final concept maps (n = 65).

Figures 3a. & 3b. provide an example of one pre-service teacher candidate's initial and final concept maps to show the progression of concept and hierarchy development. The following observation by this student is included as she described her attempts to create a concept map about motion and energy.

Being able to actually see the concepts arranged visually and being able to re-organize and link them again and again I realized I was trying to put too much that I was finding hard to link. I needed to revise my map and actually re-did it four or five times before I could use only the big ideas to connect motion and energy …. I think we try to link too many terms and that would be very difficult to teach especially to third graders. The concept map helped me understand what I was missing and how to connect the terms. It was also useful and less scary to work along my classmates as I continued to make my map better.

The above student transcript indicates that being able to visualize the organization of concepts provided a useful means of learning about her own understanding and that the refining process was important in identifying key concepts regarding motion and energy that helped her connect these concepts from both a physical science and a life science perspective. This pattern is apparent in the structure of the concept maps constructed by the mixed and surface learners.

3a.

3b

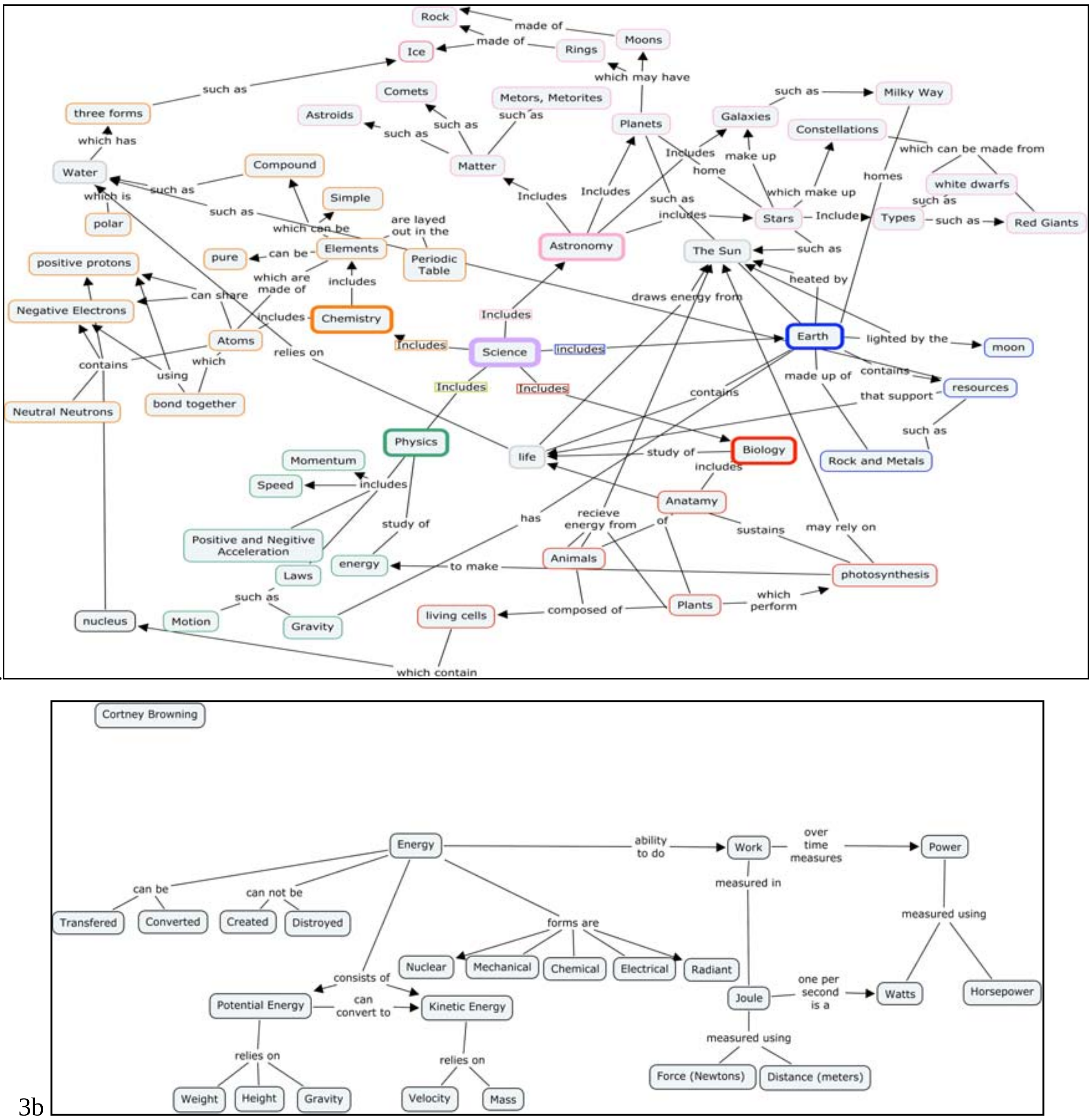

Figure 3. Maps a & b depict one pre-service teacher's development in hierarchy and concept accuracy between the beginning (a) and towards the end of the semester (b).

5 Results and Conclusion

Data analysis indicated a moderate correlation between individual approaches to learning and the growth observed in concept understanding in pre-service candidate maps between the beginning and end of semester. The moderate correlation between approaches to learning and the responses on the ConcepTests analysis for both mixed and surface learners correlates with the fact that only 3 pre-service candidates had any High School Physical Science prior to entering the EC program. Initially these student teachers were hesitant to defend their understanding of concepts but their discussions became more robust as they used the concept mapping process to guide their understanding or lack thereof. An overall increase in student confidence on an individual basis and classroom level as expected was represented in gains in conceptual understanding between the individual initial and final maps. In addition, end-of-term collaborative unit maps (data not included) each constructed by a pair of teacher candidates, for student teaching in a third grade classroom, indicated integrated content understanding, accuracy, and hierarchy not observed in initial individual concept maps.

6 Significance of Results

This is a first attempt to use different meta-cognitive strategies in concert to enhance student conceptual understanding in science in a standards-based Early Childhood teacher-training program. An overall increase in teaching confidence on an individual and classroom level basis was represented in gains in conceptual understanding between initial and final concept maps and the collaborative unit map. The use of peer-instruction through ConcepTests and collaborative concept mapping provided an environment that nurtured student engagement and enhanced conceptual understanding for the pre-service teacher candidates.

The broader impact of this project is the ability to change how pre-service teachers are prepared to teach science in the classroom. The costs are minimal and the potential impact is high. By capitalizing on existing technology, we can change the face of teacher preparation and ultimately improve student outcomes in STEM disciplines. In addition, we propose to extend this pilot study by supporting six teacher candidates as they develop their own teaching strategies and assessment methods during their clinical experience. Given the critical need for qualified teachers in the areas of mathematics and science, teacher preparation programs must work to ensure that new teachers entering the field are well-prepared and supported. The use of concept mapping and ConcepTesting offers a cost-effective means by which to provide pre-service teachers with the experiences and immediate supportive feedback that is crucial in improving content knowledge.

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