USING CONCEPT MAPS TO ASSESS SCIENCE KNOWLEDGE OF PRE-SERVICE ELEMENTARY METHODS STUDENTS

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Abstract

The purpose of this study was observing the initial state of the pre-service elementary students' content knowledge in science. Concept maps are designed to demonstrate the prior knowledge students have acquired around a variety of topics (Ruiz-Primo & Shavelson, 1996) as well as providing a valid assessment tool that is respectful of nontraditional learners who may have previously avoided the topics being assessed due to lack of understanding (Hough et al. 2007). Pre-service students were given a blank sheet of paper and asked to make a concept map with science as the central node. The results indicate that elementary pre-service students have less breadth and less organized science content knowledge than their secondary counterparts.

Keywords:

Introduction

As a Science Educator concerned about the current state of science teaching at the elementary level and in charge of the science teaching methods classes in the School of Education, I am interested in how to evaluate the level of conceptual understanding in science that my students enter the course with. Most of my students are in the master's program for teacher certification and so have previously received their BA or BS degree from another institution of higher education. Some students enter the course with masters' level or higher degrees and considerable experience in the world of work outside of academia. This also means that they have taken their science classes somewhere else and more often than not, it was years ago. (the state requires that aspiring K-8 educators need only take 2 science classes with no labs. The 2 classes can be any random non-related courses, that may or may not have anything to do with the subject matter children in elementary school need to study.) To my way of thinking, this is not an adequate preparation for the needs of our elementary children, who are growing up in a world that is more and more driven by science and a society that requires a more scientifically literate public to make the choices that will guide us into a sustainable future.

With this in mind, educators need to find out what these pre-service teachers know or even think about science without giving them a tedious initial assessment that they will see no value in. Subjecting pre-service elementary teachers to a multiple choice, short answer, fill in the blank type of rote recall test that limits the possible responses they can give or constricts the breadth of their answers to just spewing out memorized terms is not the answer. It is important to know what the students think about when they hear the term science and at the same time get some insight into how deeply they know science concepts and how well these thoughts are organized. Educators need to be responsive to the fact that they are teaching adults, many of whom are second-career professionals, and deserve to feel that they are being respected as experienced learners. In addition, because most students at the

graduate level are highly motivated to learn the practical aspects of teaching science and not a lot of extraneous material, it is important to use a type of assessment that is not often taught in science methods classes but would be of use to the students in their profession. There is only one science methods class for all of the pre-service secondary or pre-service elementary students, so an assessment is needed that is flexible enough to allow students from any of the science disciplines to demonstrate their content knowledge and at a range of levels of understanding. Greene et al (2013) had a similar set of criteria and settled on the use of concept maps as the assessment method that would meet all of these needs. Concept maps combine assessment and learning that is also applicable to many domains (Beaudry & Wilson, 2010). Concept maps are designed to demonstrate the prior knowledge students have acquired around a variety of topics (Ruiz-Primo & Shavelson, 1996) as well as providing a valid assessment tool that is respectful of nontraditional learners who may have previously avoided the topics being assessed due to lack of understanding (Hough et al. 2007).

The next question is how to evaluate or score the concept maps that the students have produced. There have been many articles written about how this might be accomplished, many of which use mathematical formulas that give weight to the various components of the concept map. (see for example: (Besterfield-Sacre et al. 2004 ; Van Zele et al. 2004 ; Yin et al. 2005) Many of the studies provided the mappers with a list of concepts to be filled in and linked, and many used a rubric to assess the constructions. For this study a blank sheet of paper was provided to the students and they were asked to construct a map without a list of prompts. Yin et al. (2005) suggest that these open format type of concept maps may be better at demonstrating partial knowledge and revealing misconceptions. Greene et al (2013) used a simple method of counting concepts (or nodes), links, and "chunks" (nodes that were grouped together by at least two connections (Greene et al 2013, Hough et al 2007)), calculating the mean and comparing the means pre and post treatment. The overall number of nodes and links closely paralleled each other and were used to demonstrate the changes in content knowledge. Greene et al. (2013) found these factors (counting nodes and links) to be appropriate evidence to compare the participants content knowledge when assessing a professional development program, and so this is the basis of the current study using concept mapping and counting concepts as a way of evaluating the initial knowledge of the students entering the elementary science methods classes. Since these two parameters paralleled each other in the Greene et al (2013) study the current study also used the counting of the concepts or nodes as a basis of comparison between the elementary pre-service teachers and their pre-service secondary science counterparts.

The purpose of this study was observing the initial state of the pre-service elementary students' content knowledge in science. It would not be appropriate to compare the elementary pre-service students' knowledge to that of an expert as we are not expecting them to be experts in science, but there is another group that this study could readily compare them to, the secondary pre-service science students. The secondary pre-service students have a bachelor's degree with a major in a science field. Both sets of students have gone through the same admissions process including a transcript review and a personal interview. The elementary pre-service students must also have a bachelor's degree but it may or may not be in a science-related field.

The question that this study desired to answer was: What is the initial state of science content knowledge of pre-service elementary students? In order to answer this question the study compared the pre-service elementary student concept maps to concept maps made by secondary science pre-service students. The study hypothesized that the elementary pre-service students would have less science content knowledge than the secondary pre-service students and that the knowledge would not be as well organized.

You would not expect the elementary pre-service students to have the same degree of depth of knowledge as their secondary counterparts, but you would expect them to have the same breadth of knowledge as elementary teachers need to be able to teach a wider range of science topics (for example: see NGSS Lead States 2013, in Physical Science, Life Science, Earth Systems Science, and Engineering Design) where as the secondary pre-service teachers only need to teach or be knowledgeable about one subject in depth. This makes the counting of the nodes, links and "chunks" a good measure of comparison between the two groups which looks at the big ideas that the pre-service students thinks of.

Methodology

The concept mapping approach that met the requirements of the study was to give the pre-service students a blank sheet of paper and ask them to make a concept map with science as the central over-arching concept. Ruiz-Primo et al (2001) describe this type of concept map construction to be appropriate for evaluating the participant's knowledge structures and their prior knowledge. The pre-service students are first asked if they know what a concept map is and how to make one. The instructor then demonstrated how to make a concept map by completing an example with them before having the pre-service teachers start their own maps. The students are allowed to make a free flowing map that can start at any point on the paper and go in any direction. By not requiring the participants to make a hierarchical concept map, it allows them to quickly and easily demonstrate their thinking about the general topic of science without the distraction of getting the map right.

On the first day of class, the pre-service teachers are provided with a brief description of what a concept map is, starting with a concept such as dog or frog as the central node to build off of. The class did a brainstorm of ideas/concepts and the instructor demonstrated how to organize them around the starting node. (This was done either on the board, computer, or overhead) Without any further emphasis on the process of making a concept map, the instructor distributed a blank sheet of white paper and instructed the group to make a concept map that has science as its central node. The pre-service teachers were given approximately 15 minutes to work on this map, or until they seemed to reach a plateau of writing. The papers were then collected.

Table 1 below explains the factors that were analyzed on each of the concept maps produced by the students during the first week of class. 54 elementary pre-service and 22 secondary pre-service student concept maps were collected and analyzed for this study.

Table 1: Definition of factors (adapted from Greene, et al)

Factor	Definition
Nodes	Concepts on the map not including the given starting concept
Links	Connecting words or phrases
Chunks	Nodes with two or more connected nodes leading from them

Results and Discussion

Table 2 shows the means and standard deviations for the concept maps made by the elementary and secondary pre-service teachers who were enrolled in the science methods classes. The individual scores were analyzed using excel to find the mean and standard deviation for each group and the t-test function (1 tail, type 3) was used to find the p-value for the comparisons of the elementary to the secondary group means.

Table 2: means and standard deviation between Elementary and Secondary entry maps and t-test, p value.

Factor	Certification Level	mean	SD	t	p
Nodes	Elementary Secondary	21.3 35.7	9.3 14.9	4.09	.0001
Links	Elementary Secondary	3.13 8.86	5.53 11.71	2.36	.0211
Chunks	Elementary Secondary	3.66 8.48	2.88 3.71	4.96	.000004

The idea of counting "chunks" as a way of assessing how the pre-service students organize their understanding of the concepts was an approach taken directly from Greene et al, 2013. Their work demonstrated how this was a valid approach to looking at student conceptual understanding through the use of concept maps, and how to evaluate those maps (Greene, et al, 2013). Novak & Canas (2008) in discussing the theory behind concept maps, describes how meaningful learning requires well-organized knowledge that would lead us to interpret concept maps with more chunks to mean that the author of the map has experienced more meaningful learning in science. Students whose knowledge is more highly organized also allows them to more easily recall this knowledge at a later time (Turns et al, 2000). One of the central conclusions of "How People Learn" (Bransford et al 2000) in regards to teachers and teaching is that teachers need expertise in subject matter content. Further, How People Learn goes on to discuss that "subject matter expertise requires well-organized knowledge of content" p. 242. We would hope therefore, that all of our pre-service teachers would have their concept maps organized in chunks indicating that their concept knowledge is well organized and can be easily recalled when needed. This would be true for both elementary and secondary pre-service teachers.

Being able to utilize such a straight-forward method of evaluating concept maps, such as counting nodes and chunks, makes them all the more valuable as a means of observing participants' concept knowledge and how well it is organized. In our study, all three factors show a significant difference with $p<.03$ between the secondary science pre-service teachers and the elementary pre-service teachers, with chunks and nodes significant at $p\leq.0001$. This would indicate that the elementary pre-service teachers have a lower command of science content knowledge than their secondary science counterparts, as seen in the lower mean of the number of nodes on their concept maps (21.3 vs. 35.7, $t=4.09$, $p\leq.0001$). This would be expected as many elementary teachers tend to shy away from math and science. Elementary teachers in grades K-8 however are expected to be able to teach a wide variety of science concepts (see for example NRC 1996, NRC 2011, & NGSS Lead States 2013) covering topics such as energy, force and motion, earth and space science and life science (NRC 2011, NGSS Lead States 2013). The significantly lower mean in the score for chunks (3.66 vs. 8.48, $t=4.96$, $p\leq .000004$) indicates that the content knowledge that the elementary pre-service teachers do have is much less organized and therefore less well understood (Greene et al, 2013). When content knowledge is not well organized, it is more difficult to recall (NRC 2005, Bransford et al, 2000) and would make the teaching of that knowledge also more difficult. With limited depth and breadth of science knowledge, it is not surprising that many if not most elementary teachers are reluctant to take on the teaching of science in their classrooms. Many elementary schools in the area have all but eliminated science from their curricula in favor of teaching more math and literacy. With the increasing need of STEM educated workers in the United States, it is imperative that we start teaching our students science at an early age by teachers who have a solid science background.

These findings indicate that we need to provide increased meaningful professional development in science for our pre-service elementary education students. It would reasonably follow that meaningful professional development in science content should also be available for in-service practicing elementary teachers as well

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