Using Concept Maps To Measure Undergraduates' Nature Of Science Conceptions During A Biology Course

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Abstract

The purpose of the study is to investigate what nature of science tenets undergraduate students integrate into concept maps throughout a semester. Nature of science refers to the epistemology of science, science as a way of knowing and includes the values and beliefs inherent to scientific knowledge (Lederman, 1992). The integration of nature of science tenets to classroom content will be reinforced using explicit-reflective instruction throughout the entire semester. Undergraduate students in a biology course will generate concept maps to review their nature of science understanding. Concept mapping will be used by the student to help understand what concepts are integrated into their cognitive structure of what they know about the tenets of nature of science.

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Student conceptions of nature of science [NOS] have been on the forefront of science education for decades (Abd-El-Khalick, Bell, & Lederman, 1998). Encouraging literacy and aptitude within the K-16 population continues to be the focus of reform efforts (AAAS, 1993). Thus, researchers have identified specific NOS tenets that are relevant, accessible, and considered important for increased literacy and aptitude. The nature of science aspects and associated dimensions that are emphasized in the present study are: "empirical, inferential, creative, theory-laden, tentative, myth of 'The Scientific Method', scientific theories, scientific laws, social dimensions of science, and social and cultural embededness of science " (Abd-El-Khalick, 2012). These aspects, while listed here, are not independent of each other. For example, scientific knowledge is inherently tentative because of the subjective, creative, socio/cultural, empirical and inferential nature of science. The human and social elements of the scientific enterprise necessarily influence what and how science is practiced and accepted. For meaningful understanding of NOS, learners need to understand connections across aspects (Abd-El-Khalick& Lederman, 2000; Lederman, 2007). While there is a list of these tenets to broaden the scientific scope of literacy and aptitude, simply knowing the list will not provide ample framework or context. More work is necessary to connect the list of concepts into a framework that is better understood for students.

Although some may argue how NOS should be represented in a classroom, all will probably agree that these aspects are important to integrate and assess in a science classroom, including biology classrooms. Studies have indicated that an explicit reflective approach is necessary to provide students context in understanding NOS (Akerson, Abd-El-Khalick, &

Lederman, 2000). However, few studies have been able to successfully show what cognitive structures students possess prior to an explicit reflective approach to learning NOS that is then embedded throughout the entire science course (Borda, Burgess, Plog, DeKalb, & Luce, 2009). Learners' cognitive structure of NOS conceptions may indicate how they see connections and relationships among aspects. A cognitive structure is a knowledge structure of an individual (Novak &Canas, 2006). Originally, a concept map was created to represent conceptual understanding of children (Novak &Canas, 2006). Using concept maps to dive into learners' conceptions of NOS may provide a better understanding of student cognitive structures they may have prior to instruction. This will benefit future work of how to integrate the NOS aspects and associated dimensions within a classroom. Furthermore, if NOS tenets exist in a student's understanding, there may be limited, relevant connections or relationships to other contexts. This study capturesundergraduates students' understanding of NOS and connections across aspects using four concept maps throughout a semester of undergraduate biology that included explicit reflective NOS instruction.

Methodology

Participants. The seventeen participants were of an undergraduate non-majors biology class from a Mid-western university. Some of the student participants were pre-service teachers. All the participants were in the same course and received the same instruction from the same instructor throughout the entire semester.

Context. The course is designed to help students utilize problem-solving techniques in a laboratory-based curriculum that promotes meaningful interrelationships of key biological concepts. The biological concepts start with NOS activities. Historical episodes were used teach cellular concepts including cell theory, genetics, molecular processes, and biotechnology. The

NOS activities challenged students' ideas by highlighting alternative conceptions of science while reinforcing NOS. By completing this course, the students have opportunities to connect biotechnology concepts to fundamental concepts and socioscientific issues.

Concept Mapping. During the first week of class, students were presented a PowerPoint of how to construct a concept map and reasons to construct a concept map. The presentation was given by the primary researcher. Pre-made concept maps in the presentation were used to help define and show good practices of the following: identifying key concepts to answer the question, hierarchy, merging, linking, and branching. This instruction encouraged student participation and reinforced how to make concept maps. The students practiced making a concept map by answering a non-science question. A worksheet guided them through the process of concept mapping by 1) listing concepts that come to mind when answering the question, 2) Ranking the concepts from general to specific, 3) Mapping the concepts using linking words and best practices discussed in the presentation. Peer feedback was used in their practice map. Then, students completed their first of four concept maps, answering the question "What is science?". Each time a student completed a map, they generated their own concepts from what they learned in class. Four maps were collected and analyzed from each student throughout the semester (N=17). The concept maps were completed four different times : at the beginning of the semester, after concept mapping instruction, post Nature of Science unit, and completed on the final class day prior to the last exam. All the maps were completed in class by the individual student and were not returned to the student.

Results

Data Analysis. All the concept maps were double blinded prior to review (names removed and map numbers removed). Each concept map was analyzed for hierarchy, merging, branching and number of concepts (Figure 1). For this paper, these are considered structural components of the concept map. A modified Novak and Gowin method (1984) was used to define how analysis might occur to analyze concept maps (Martin, Mintzes, &Clavijo, 2000; Quinn, Mintzes& Laws, 2004). Hierarchy refers to levels in a concept map. Merging occurs when two links from two concepts merge to one concept. Whereas, branching is identified with one concept branching into two concepts. Merging and branching suggest that the students understand relationships between the concepts. Concepts were counted as non-redundant concepts. To ensure inter-mapper reliability of .90, the fourth author who has experience in using concept maps analyzed the maps. The concept map data for each student for all four maps was analyzed using two-way repeated measures ANOVA (N=17). All the assumptions were assessed.

In addition, each concept map was analyzed for its NOSconcepts in specific terms. There were ten"consensus aspects of NOS and associated dimensions" that were reviewed from the literature to be significant to NOS understanding (Abd-El-Khalick, 2012). These terms and dimensions were explicit, reflectively used throughout the entire semester. The students were expected to know these aspects and were given in-class opportunities to apply these with biology key concepts. The NOS concept word/phrases were counted if they were located within the concept map. In addition, the idea of models in science was a strong component in the course and was a concept that was selected to be analyzed from the concept maps. The models concept was grouped within the NOS terminology to equal eleven components. The authors calculated the frequency of the terms per 17 mapsfor four maps events (Figure 2). The NOS terminology frequencies were totaled and analyzed using the two-way repeated measures ANOVA. By capturing a series of data throughout the semester using the concept maps, a trend of diversifying NOS concepts was observed.

Findings. Participants were asked to answer the question "What is science?" and draw four concept maps in a 15-week semester. The structural components means of Map 1 significantly increase before Map 2 (p<0.001), Map 3 (p<0.001), and Map 4 (p<0.001) (Figure 1). However, from Map 2 to Map 3 there is an increase in overall structural components mean and then a decrease from Map 3 to Map 4, (p=1; p=0.487, respectively). This decrease could be the result of students not changing their overall cognitive structure at this time of the semester. The hierarchy trend after the second map is similar to what was reported by Quinn, Mintzes, and Laws (2004).

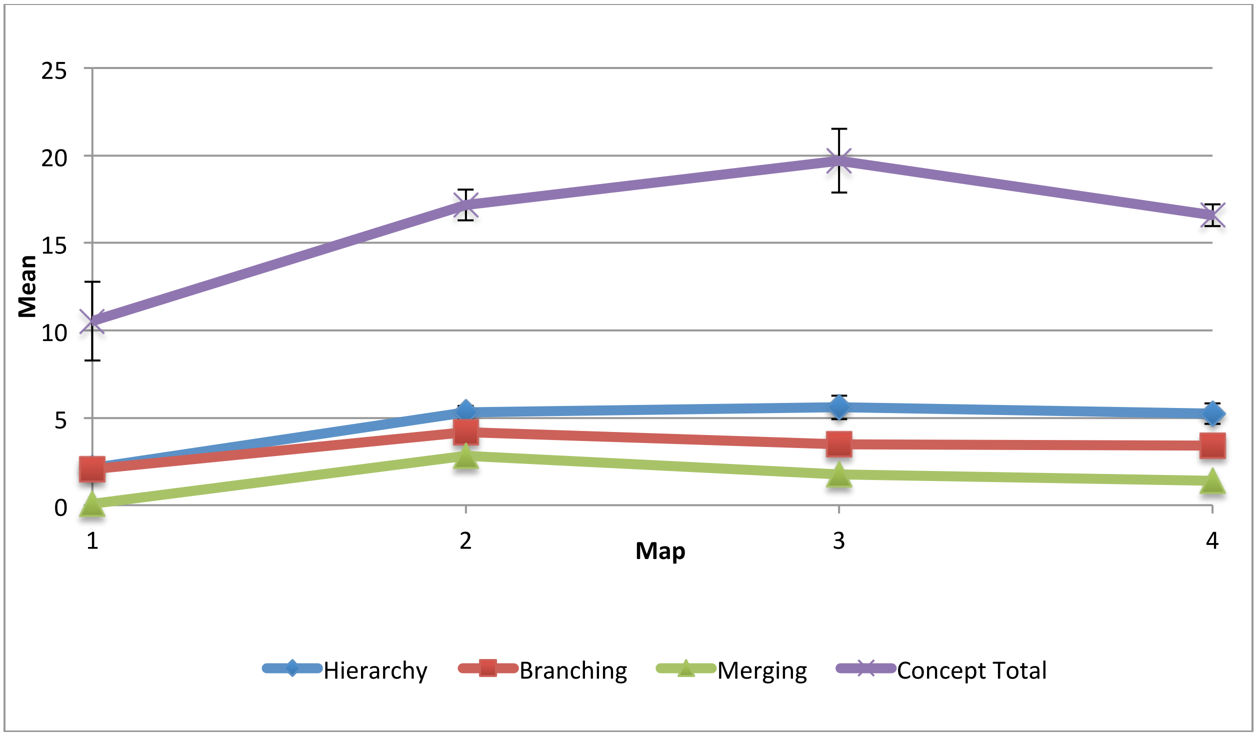

Figure 1. Structural analysis of the concept maps

Throughout the semester, the concept maps illustrated an increase of NOS terminology (Figure 2). Further analyses would yield a significant main effect in the NOS terminology and in the concept map times (Figure 2).In the first map, three of the eleven NOS terminologies were diagramed. In the final map, ten of the eleven NOS terminology categories were represented in the concept maps. The diversity of NOS terms increased as the semester progressed (Figure 2).

Means for the total number of NOS concepts in the concept maps were also significantly different between the four maps, $F(1.66, 26.71)=17$, $p<0.001$. This suggests that each time a concept map was created, the total NOS terms mean increased throughout the semester and were significantly different for each time a map was created.

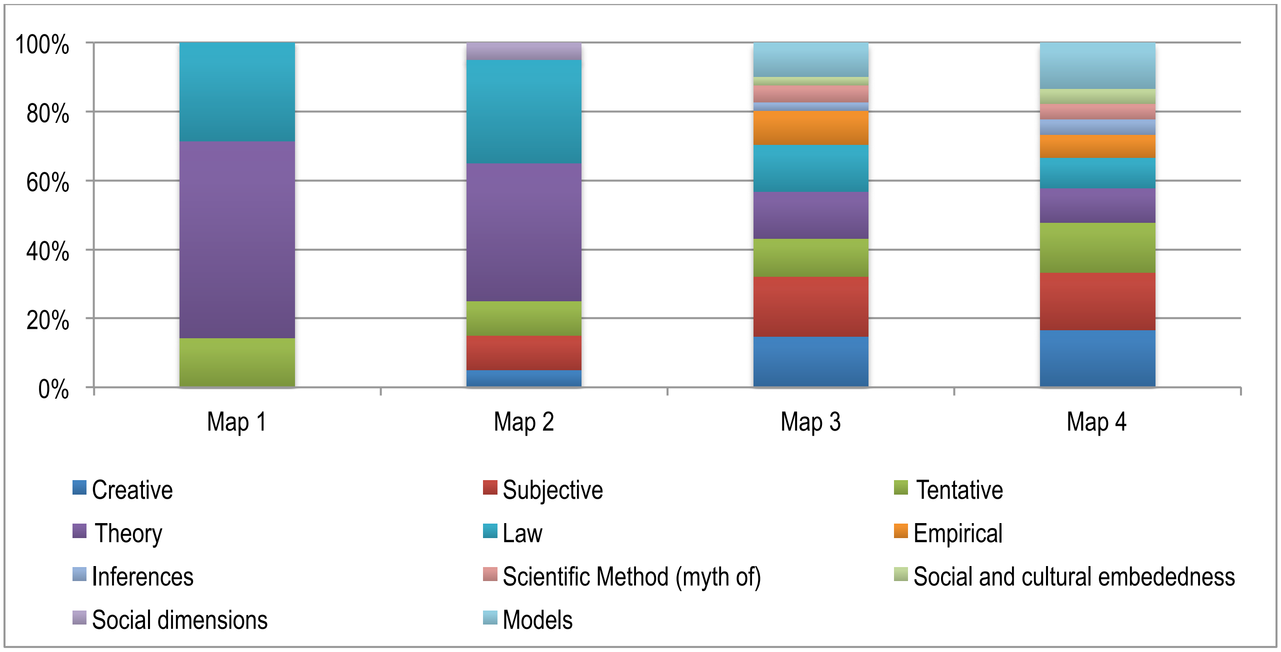

Figure 2. Frequency (% stacked) of NOS terminology within the concept maps (n=17). In the first map, only three of the eleven categories were identified, whereas in Map 4, ten of the eleven categories were identified. There was a significant main effect of NOS terminology $F(3.97, 63.59) = 4.78$, $p<0.001$.

Discussion

Overall, as the students' progressed throughout the semester, they were able to convey NOS understandings by identifying and increasing the number of NOS terms in their concept maps. This demonstrated the diversity of student NOS knowledge within their cognitive structure when asked "What is science?". This would imply that the students revised their knowledge structure unknowingly by including more NOS terminology each time they created a map during the semester. An interesting outcome was that students' increased the representation of NOS terms in their concept maps but did not increase the structural complexity (e.g. merging, branching) of the concepts maps. Future studies may be needed to understand why this occurred.

The contribution of this concept mapping research is far reaching, it illustrates what few studies have been able to show; learners' mental models of NOS terminology. This research is important for understanding the progression of meaningful learning in the biology classroom, including pre-service curriculum and in-service teacher training. The study captured learners' cognitive structures prior to an explicit reflective approach and also throughout the entire science course. Creating meaningful learning opportunities through an explicit reflective approach can benefit the student by diversifying their understanding of certain concepts. These concept maps diagram the cognitive structure of NOS conceptions and indicate how the learners' viewed connections and relationships among NOS tenets and biological processes and concepts. This study represents the first step to understanding how undergraduates' represent their NOS conceptions. The trends exhibited within this study can help provide future educators new ideas of how to capture meaningful learning. Concept mapping is one tool that can be used in educational research to capture students understanding of the content and relationships to various contexts.

One particular study had the two groups of students create a concept maps with one group given NOS concepts and the other group require to generate the NOS concepts to map (Merle-Johnson, Promyod, Cheng, &Hanuscin, 2010). The groups given the concepts focused more on the relationships between the NOS concepts, whereas the group required to generate the concepts provided insight into the prior knowledge and knowledge progression (Merle-Johnson et al., 2013). As students were required to generate their concepts and connections for this study, the diversity of NOS term was mapped.

Concept maps are a key to providing educators with insight into the thinking process involved in NOS comprehension. Further research is warranted to examine how learners are able to connect NOS to biology concepts. Such connections are a critical step in developing more sophisticated and meaningful conceptions between NOS *and* science (Krajewski& Schwartz, 2014; Schwartz & Lederman, 2002). For biology teachers who want to embed NOS within their biology curriculum, understanding such connections is essential (Krajewski& Schwartz, 2014).

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