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USING CONCEPT MAPS AS AN ASSESSMENT TOOL TO INVESTIGATE CONCEPTUAL CHANGE IN PRE-SERVICE TEACHER KNOWLEDGE OF BUOYANCY

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Abstract. This manuscript is part of a larger study that examined the content knowledge of 33 science teachers about the topic of Earth's processes. Teacher content knowledge was examined using pre/post concept maps and used total proposition accuracy scores to conduct a paired sample *t*-Test. Using the superordinate concept as the starting point; the participant map was scored against the expert map utilizing the proposition (concept-linking word-concept) as the unit of knowledge to be scored. Three scores were generated: (1) Total number of correct hierarchical propositions originating from the superordinate concept; (2) Total number of correct non-hierarchical propositions which do not linearly originate/ connect to the superordinate concept; and (3) A combined score for the total number of correct hierarchical and non-hierarchical propositions. Results of the paired sample *t*-test demonstrate a statistically significant difference between the total proposition accuracy scores for pre/post concept maps (t = -4.219, p < .000) with the instructional intervention larger for post-S map scores (M = 7.64; SD = 8.007) than for pre-S map scores (M = 2.30; SD = 4.104). The effect size as measured using Cohen's d was shown to be large (.84). Participant non-hierarchical knowledge also increased, on the post S map scores although this increase was not significant (t = -1.582, p < .123) with the instructional intervention larger for post-S map scores (M = 8.42; SD = 5.151) than for pre- S map scores (M = 6.12; SD = 5,213). The effect size as measured using Cohen's d was shown to be medium (.44). The combined score was statistically significant t = -5.438, p < .000) with the instructional intervention larger for post-S map scores (M = 15.45; SD = 7.467) than for pre- S map scores (M = 8.42; SD = 7.172). Cohen's d effect size was large (.96).
Keywords: Concept Mapping, Buoyancy, Science Education, Pre-service teacher, Elementary Teacher Content Knowledge.

1 Introduction

Research findings show that students have preconceptions about science concepts before they enter the classroom and these preconceptions originate from prior learning experiences and real-word interactions (Abell, 2007; Duit & Treagust, 2003). The current paradigm of science education attempts to address these preconceptions through the encouragement of student-centered learning experiences in which the teacher provides engaging content, inquiry-based problems, and constructive feedback based on prior knowledge (American Association for the Advancement of Science, 2009; National Research Council, 1996, 2000; NSTA, 1990; Stoddard, et al., 2000). Although the literature shows that implicit metacognitive developmental benefits result from this type of teaching and learning, few publications focus on the quality of the facilitator through the lens of how conceptual change occurs and results from specific educational interventions (Case & Gunstone, 2006; Cooper, 2007; Swanson, 1990; Taconis, Fergusen-Hessler, & Broekkamp, 2001; White & Gunstone, 1989).

Identifying misconceptions about buoyancy has been the topic of investigation in several research studies (Biddulph & Osborne, 1984; Halford, Brown, & Thompson, 1986; Havu-Nuutinen, 2005; Hsin & Wu, 2011; Yin et al., 2008), but most have centered on how young children understand the observation of floating and sinking. There is a gap in the research concerning how pre-service teachers understand the observation of floating and sinking as it relates to the scientific concept of buoyancy. This study investigated pre-service science teachers and identified the misconceptions they have about buoyancy as a scientific concept. It will also reveal how their cognitive structures, as they relate to buoyancy, were manipulated by exposure to an inquiry-based intervention in a pre-service teacher education program. Seeing as schools are charged with the responsibility of disseminating knowledge and developing students' cognitive abilities and frameworks through a variety of activities and experiences, it is important to evaluate how and if these interventions influence student understandings. Furthermore, it is important that teachers address misconceptions at early ages to avoid a cyclical precipitation of misunderstandings in society. This requires teachers to have accurate understandings of the topics they present.

2 Purpose of the Study

The purpose of this study was to identify conceptual understandings of buoyancy among pre-service teachers and present evidence of measurable conceptual change as a result of an educational intervention. In a broad sense, it aimed to contribute to current research about how individuals understand buoyancy and how a particular age group internalizes and assimilates new knowledge into prior understandings. Conceptual understandings and conceptual changes were measured using concept mapping and summative assessment scores. In terms of a measurable or objective outcome, this study sought to provide a reflective evaluation of how a particular teacher education program is addressing conceptual understandings and preparing teachers to convey buoyancy to students.

There are three research questions that guided the literature review, methodology, analysis, and discussion for this study. They included:

1. What conceptions are present within pre-service teacher understandings of buoyancy?
    a. What conceptions are accurate, according to current scientific knowledge?
    b. What conceptions are inaccurate, according to current scientific knowledge?

2. How does a 5E intervention influence pre-service teacher conceptual understanding of buoyancy?
    a. What conceptions are present before an intervention?
    b. What conceptions are present after an intervention?
    c. Is there a statistically significant difference between pre- and post-concept maps?

3. How can pre-service teacher education programs improve student understandings of buoyancy?

3 Methodology

This project used the following data points: (1) pre/post concept maps; (2) semi-structured interviews; (3) mid-term exam questions and scores; and, (4) final exam questions and scores. As previously referenced, the study was seeking to identify conceptions and examine conceptual change that resulted from an educational intervention. All data points, with the exception of the pre-concept maps, were collected after an instructional intervention that was designed using the 5E Model.

Students enrolled in a science methods course for pre-service teachers at a research institution in Texas were participants in this research study. All participants were high school graduates and seeking to obtain secondary or elementary teaching certification in Texas. The total sample consisted of 55 individuals, of which four were male. Prior to enrolling in the methods course, it was required that all participants complete their required core and academic major science courses. All except for seven participants earned credit in a conceptual physic course at the same institution as the science methods course or a community college. Six of the seven not earning credit in conceptual physics earned credit in an algebra-based Physics I at the same institution as the science methods course or a community college. Only one participant had not earned credit in a physics course at the college level. Thus, all except one were exposed to the topic of study, buoyancy, in a college-level course prior to this study. A majority of participants earned an A or B in their first or final attempt in conceptual physics course or algebra-based Physics I (87%). Twenty-six percent of participants repeated a conceptual physic course or Physics I.

All instructors of the science methods course were aware of the four factors that impact the effectiveness of concept map construction: how it is constructed, overall structure, inclusion of attributes, and, accuracy and quality of included information (Yin & Shavelson, 2008). Teacher knowledge of concept map construction influences how the students perceive the activity and execute the creation of acceptable concept maps (Wallace & Mintzes, 1990). In order to ensure all participants were exposed to the proper design and attributes for effective concept mapping, according to Novak (2010), all teachers incorporated concept mapping as an evaluative tool for lessons that preceded the introduction of buoyancy, including density. This allowed teacher feedback about concept map design prior to the buoyancy lesson and, more importantly, the pre-concept map construction that was used for this study. All participants were also provided instruction and experience with CmapTools, a shareware concept mapping program that provides consistent structure and organization for evaluation of knowledge constructs (Cañas et al., 2003; Novak 2010). CmapTools has been used in many educational and corporate settings to quickly and effectively present relationships between concepts (Coffey et al., 2003; Ryve, 2004; Van Zele, Lenaerts, & Wieme, 2004).

Before the 5E Model lesson, all participants were asked to create a concept map that included buoyancy as the central topic. Following the recommendation of Yin et al. (2005), participants were not provided concepts or linking words/phrases. This type of a concept map, a ‘c-map’, increases the validity of the output because participants are entirely responsible for using their understandings to produce related concepts and the appropriate linking words/phrases. It also provides an effective way to assess their conceptual understanding (Ruiz-Primo & Shavelson, 1996; Yin et al., 2005). Similar to the pre-concept map, all participants were asked to construct concept maps with buoyancy as the central topic after the lesson.

Three researchers composed a scoring committee and individually scored the pre and post concept maps by counting valid and total propositions. Propositions were considered 'valid' if they reflected an understanding of the scientific concept of buoyancy and were presented consistent with the concept map structure and attributes presented to students and outlined by Novak (2010). Using a consensus method, researchers discussed and agreed on final scores for each concept map. The final score for each concept map involved the agreed upon count of accurate or correct propositions. Pre- and post-scores were analyzed using a two-tailed paired *t*-test in SPSS 20.0 to reveal if a change resulted from the intervention.

Prior to scoring the concept maps, each participant was interviewed by the scoring committee. Using a semi-structured method, participants were asked to explain their concept maps. This provided an opportunity for them to explain the misconceptions and understandings present among the pieces of their concept maps. Interviews were transcribed and thematically coded using consensus model with the same three researchers. Accurate conceptions and misconceptions drove the coding process. Frequencies were analyzed using descriptive statistics in SPSS 20.0.

4 Results and Conclusions

The researchers extracted seventeen concepts related to buoyancy from the interviews and concept maps: buoyancy is not the same as density, surface area, gravity, opposing forces, buoyant force, floating and sinking, volume, pressure, relationship exists between density, weight, displacement, density of the fluid, density of the object, Archimedes Principal, fluids, mass, and a balanced load in a floating object. The majority of students did not include many of these terms in their pre-concept maps (M = 3.21; SD = 1.34) or post-concept maps (M= 5.74; SD = 1.71). Furthermore, only 30.9% of participants included one or more correct proposition on their pre-concept map (M = 0.51; SD = 0.87) and 58.2% on their post-concept map (M =1.25; SD = 1.54). A statistically significant difference exists between the total number of related terms accurately and inaccurately included in pre- and post-concept maps, $t(54) = -6.144$, $p < .001$. Also, the results from a paired t-test for the educational intervention indicated a statistically significant difference between the number of accurate inclusions of related terms on pre- and post-concept maps, $t(54) = -3.504$, $p = 0.001$. Although an increase in accurate conceptions of buoyancy related topics resulted from the intervention, the researchers concluded that a need for remediation exists for pre-service science teachers as it relates to their understanding of buoyancy.

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