Using Concept Maps to Reveal Prospective Elementary Teachers' Knowledge of Buoyancy

Karthigeyan Subramaniam
University of North Texas, USA

Benjamin Kirby
Jesuit College Preparatory School of Dallas, USA

Pamela Harrell,
University of North Texas, USA

Christopher Long
University of North Texas, USA

Abstract

The purpose of this exploratory qualitative study was to investigate prospective elementary teachers' conceptual understanding of buoyancy. Specifically, the study aimed to identify the scientifically accepted conceptions, and misconceptions that preservice teachers hold about buoyancy using an instructional intervention. Presently, there is a gap in the research literature concerning how preservice teachers understand floating and sinking as it relates to the scientific concept of buoyancy. Conceptions were analyzed using pre/post concept maps, and interviews. Findings showed that preservice teachers had scientifically accepted conceptions and misconceptions about buoyancy as a force and that both conceptions interacted with associated concepts of buoyancy (gravity, weight, mass, density, etc.). Overall, preservice teachers showed a significant deficiency in their content knowledge of buoyancy at the end of the study. Implications include (1) the need for teacher educators to review the science content courses prospective teachers are required to take for certification; and, (2) the need for elementary teachers to understand the concept of buoyancy and all related concepts in order to develop and implement curricula related to the topic of buoyancy.

Keywords: Pre-Service Teachers**,** Buoyancy, Conceptions, Concept Maps, Misconceptions

Please address any correspondence to: Karthigeyan.Subramaniam@unt.edu

Introduction

The purpose of this exploratory qualitative study was to investigate prospective elementary teachers' conceptual understanding of buoyancy. Specifically, the study aimed to identify the scientifically accepted conceptions, and misconceptions that prospective elementary teachers hold about buoyancy using an instructional intervention. This investigation is part of a series of studies conducted by the authors (Harrell & Subramaniam, 2014a, 2014b; Kirby, 2016; Subramaniam & Harrell, 2013) contributing to the research stream on prospective teachers' knowledge of physical science concepts. This study was also part of a larger study that utilized a mixed methods approach to the phenomenon under investigation. The study presented in the article is the qualitative component of the mixed methods study.

Conceptual understanding of scientific concepts, like buoyancy, is essential to understanding the nature of science and the ways by which different aspects of the environment interact (Driver, 1996; Gilbert, Osborne, & Fensham, 1982; Wee, 2012). For teachers, inservice and preservice alike, a scientifically accepted conceptual understanding of buoyancy enables the effective teaching of the concept to students. Studies investigating the impact of teachers' educational background on student achievement and the development of student academic skills have resulted in a variety of policy and pedagogical recommendations (Connor, Son, Hindman, & Morrison, 2005; Duncan, et al., 2007; Early et al., 2002; Van Driel & Berry, 2012). The importance of content knowledge and teaching methods is important for teachers and preservice programs to consider and, according to research, both are important and must be developed in tandem (Davis & Petish, 2005). The research question that guided this study was: What conceptions do prospective elementary teachers have about buoyancy?

Significance of Study

The significance of the study is two-fold. First, the study provides data about accurate conceptions, and misconceptions that prospective elementary teachers have for the topic of buoyancy. Identifying conceptions about buoyancy has been the topic of investigation in several research studies (Halford, Brown, & Thompson, 1986; Havu-Nuutinen, 2005; Hsin & Wu, 2011) but most of these studies are centered on how young children understand buoyancy in relation to floating and sinking. Presently, there is a gap in the research literature concerning how prospective elementary teachers understand floating and sinking as it relates to the scientific concept of buoyancy.

Second, this study can be used to examine degree plan coursework for prospective K-6 teachers and possibly redesign such degree plans in an effort to better prepare teachers with the fundamental conceptual understandings of science content they will be expected to teach in elementary grades. As teacher preparation programs are charged with the development of teacher content knowledge as well as pedagogical content knowledge, it is important to evaluate the outcome of these programs as they ultimately affect the fundamental understandings of student learning.

Teacher's knowledge and understanding of scientific concepts is pertinent in helping students bridge the gap between the everyday knowledge they bring to the classroom and the scientific knowledge teachers desire students to acquire (Driver, 1996). That is, student content and cognitive development is tethered to the ability of the teacher to facilitate experiences with accurate scientific explanations and representations for students to experience and internalize (Anderson & Helms, 2001; Hewson & Thorley, 1989; Vosniadou, 1994, 2003; Wee, 2012). As teachers have an important role in students' formation and refinement of accurate scientific concepts, it is important that preservice teacher programs strive to develop teachers who acquire scientific knowledge about important fundamental concepts, which can in turn be packaged within pedagogical content knowledge needed to instruct students' in today's science classrooms.

Perspectives on Conceptions and Misconceptions

Students develop either accurate conceptions or misconceptions when exposed to concepts in academic environments and everyday experiences (Novak, 2010). Accurate conceptions are those based on factual details and meanings that also reflect the conceptions accepted by scientists (Keeley, 2012). In addition to being correctly defined, accurate conceptions are integrated into the hierarchically organized cognitive structure of the student (Kikas, 2004) in a manner that requires and reflects a genuinely accurate understanding of the concept and all related concepts. On the other hand, misconceptions, according to scholars (Subramaniam & Harrell, 2013; Chi, 2005; Keeley, 2012) do not cohere with the accepted scientific definition, are trivial, and are inappropriately organized into the cognitive structure. For example, Chi (2005) states that misconceptions are "inaccurate or incomplete isolated pieces of knowledge" (p. 162). According to Subramaniam and Harrell (2013) both conceptions and misconceptions (1) are part of one's knowledge system that involves many interrelated concepts that are used to make sense of one's experiences, and (2) can be expressed as explanations. Explanations, derived from one's knowledge system, can reflect an accumulation of memorized, factual and conceptual details organized in a meaningful framework to scientifically explain a natural phenomenon. Explanations can also reflect concepts derived from everyday experiences and inaccurate or incomplete isolated pieces of knowledge – misconceptions - loosely connected to explain a natural phenomenon. According to Chi (2005), explanations composed of misconceptions are naive explanations or fragmented explanations or alternative explanations.

Perspectives on Buoyancy

Scientific Conceptions

Buoyancy is an upward force that acts on an object in a fluid and determines whether the object will rise, sink, or remain static in a fluid (Giambattista, Richardson, & Richards, 2010). As seen in the free body diagram presented in Figure 1, the buoyant force (F_B) and the object's weight (Fg) directly oppose each other and their relationship determines the position of the object in the fluid. Thus, the phenomena of floating and sinking respectively are manifestations of the relationship between weight of the object and the buoyant force (Giambattista et al., 2010; Kariotogloy, Koumaras, & Psillos, 1993; Rowell & Dawson, 1977a, 1977b). In other words, if an object's weight is greater than the buoyant force, the object will sink (negative buoyancy); if an object's weight is less than the buoyant force the object will float (positive buoyancy); and if the object's weight is equal to the buoyant force the object will not sink nor float but remain submerged in a position (neutral buoyancy).

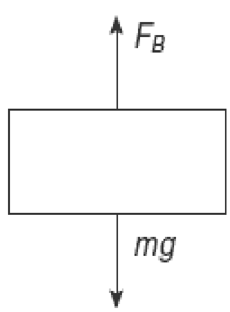

Figure 1. Free-Body Diagram: Opposing Forces on an Object in a Fluid

The aforementioned is mathematically conceptualized by Archimedes' principle: $F_B = (\rho_{\text{fluid}})(V_{\text{object}})(g)$. The mathematical representation states that the buoyant force is equal to the product of the fluid density (ρ_{fluid}), object volume (V_{object}) and gravity (g) (Dijksterhuis, 1988). As evident from the formula for calculating buoyancy, an object's mass, and density do not determine the buoyant force. Moreover, an object that rises in a fluid will have a greater buoyant force than the product of the object's weight and gravity (*mg*).

Learning about buoyancy and floating or sinking requires a student to have accurate conceptions of mass, volume, and density in order to fully develop an accurate conception of buoyant force and the formula for calculating the value. The terms are related and dependent on one another. Using the aforementioned definition of buoyancy, it is important that students be able to integrate multiple dimensions in order to accurately and completely understand why things float and sink. Although it can be considered a single concept, buoyancy relies on a conceptual understanding of connected physical science concepts. For example, the accurate conception of Archimedes Principle, an important application of buoyant force, requires the accurate conception of volume, density and gravity. An accurate conception of Archimedes principle summarized in the formula $F_B = (\rho_{\text{fluid}})(V_{\text{object}})(g)$ would reveal connections consistent with the direct relationships between buoyant force and fluid density, buoyant force and object volume, and buoyant force and gravity (Dijksterhuis, 1988).

Misconceptions

The literature indicates that K-6 students have misconceptions about floating and sinking, which directly and indirectly leads to misconceptions about buoyancy. For example, K-6 students who are challenged in relating density, weight and matter (Halford et al., 1986; Kohn, 1993; Rappolt-Schlichtmann, Tenenbaum, Koepke, & Fischer, 2007), did not understand floating and sinking in terms of relationships between scientific concepts (density, weight and matter) (Hsin & Wu, 2011), and did not connect floating, sinking, and other concepts (density, weight, and matter) (Butts, Hofman, & Anderson, 1993).

Additionally, literature indicates that students in higher grades are challenged by the concepts involving multiple dimensions and forces (density, weight, buoyancy, mass, and matter) (Smith, Carey & Wiser, 1985). Similarly, pre-service teachers did not understand the concepts surrounding fluids (Greenwood, 1996), did not understand the concepts of density and buoyancy sufficiently to identify relationships (Stepans, Dyche, & Beiswenger, 1988), and are challenged when explanations require mathematics (Dawkins, Dickerson, McKinnet, & Butler, 2008).

Method

Participants

The 55 participants (51 females and 4 males) in this study were prospective elementary teachers enrolled in a K-6 teacher preparation program at a large university in the southwest. At the time of this study, participants were taking the science methods course prior to student teaching. Participants had also completed required core courses and academic major science courses prior to enrolling in the science methods course. The Institutional Review Board (IRB) at the institution approved the collection and use of data in this study. All information and artifacts that could identify the participants of this study were kept in a place accessible only to the researchers.

Data was collected from participants enrolled in four sections of an elementary science methods course. These sections were taught by the authors of the study, one author taught two sections while the other authors each taught one section. The science methods courses were framed by Constructivist principles and the 5E Learning Cycle model. The science methods course curriculum included lessons on pedagogy and assessments and also specific lessons on dissolving, density, and buoyancy.

Data Collection

This study used the following data sets: (1) pre-concept maps; (2) post-concept maps; and (3) semi-structured interviews. In order to ensure all participants were exposed to the proper design and attributes for effective concept mapping (Novak, 2010), all the course instructors incorporated concept mapping as an evaluative tool for lessons that preceded the introduction of the topic on buoyancy. This allowed for course instructor feedback about concept map design prior to the buoyancy lesson and, more importantly, the pre-concept map construction that was used for this study. Prior to collection of concept maps, participants in the study were provided instruction and practice with CmapTools (a shareware concept mapping program) to construct concept maps that aligned with the structure and organization for evaluation of knowledge constructs represented on concept maps as advocated by scholars (Cañas, Hill, & Lott, 2003; Coffey et al., 2003; Harrell & Subramaniam, 2015; Novak, 2010; Ryve, 2004; Van Zele, Lenaerts, & Wieme, 2004). Instruction and practice also included the suggestions from the research of Moon, Hoffman, Novak, and Cañas (2011) and the protocol suggested by Harrell & Subramaniam (2015) for the construction of concept maps. That is, the pertinent need for participants constructing concept maps to include directional arrows on all linking lines, thereby providing the authors access to participants' understandings of the relationships between concepts and enabling authors to validate to the propositions resulting from concepts and linking lines. This instruction about concept mapping was also done to ensure that data collected for this study would not be impacted by participants not being able to interact with the concept mapping collection instrument. The data would not be accurate if the participants were not informed on the process for creating a concept map; their understandings would not be reflected on the maps because of their inability to construct a concept map and not because of their lack of understanding. Moreover, this issue would render the analysis of the concept map uninformed of the true understandings of the participants' conceptual understanding of buoyancy.

To the same end, all course instructors of the science methods sections were made aware of the four factors that impact the effectiveness of concept map construction: (1) how the map is constructed, (2) overall structure, (3) inclusion of attributes, and, (4) accuracy and quality of included information (Yin & Shavelson, 2008). This coheres with the contention that teachers' knowledge of concept map construction influences how participants perceive the activity and execute the creation of acceptable concept maps (Harrell & Subramaniam, 2015).

The first data set collected were the pre-concept maps. Each participant was asked to create a concept map that included buoyancy as the central topic. Following the recommendation of Yin, Vanides, Ruiz-Primo, Ayala & Shavelson, (2005), participants were not provided concepts or linking words/phrases. This type of a concept map, a 'Cmap', increases the validity of the output because the 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 conceptual understanding (Ruiz-Primo & Shavelson, 1996; Yin et al., 2005). Following the pre-concept map collection, participants experienced the lesson on buoyancy framed by the 5E Learning Cycle (Bybee et al., 2006). Similar to the pre-concept map, all participants were asked to construct concept maps with buoyancy as the central topic after the instructional intervention was completed. The same concept mapping requirements (e.g., directional arrows and linking words) were requested of the participants.

All data sets were collected in a sequence. The pre-concept maps allowed the researcher to have an understanding of participants' prior knowledge, and the post-maps revealed the manipulations of pre-existing understandings or the assimilation of new concepts or linking words. While it remained possible that all participants were not fully utilizing the various components laid out by Novak (2010) and Moon et al., (2011) for concept map construction, interviews were conducted to provide insights into their understandings of buoyancy based on their pre- and post-concept maps

Instructional Intervention

The 5E Learning Cycle, developed by the Biological Science Curriculum Study (BSCS) (Bybee et al., 2006) was used as the framework for the instructional intervention. The 5E Learning Cycle is an inquiry-oriented method develops and that provides contexts for students to explicate and expose their prior content knowledge. Driver (1989), for instance, contends that the BSCS model "involves an interaction between the schemes in pupils' heads and the experiences provided" (p. 27) and thus provides foundational platforms for the students and teachers to engage with prior knowledge.

The instructional intervention consisted of the five phases: Engage, Explore, Explain, Elaborate, and Evaluate. The phases were designed to construct and apply buoyancy and related concepts. The Engage stage was initiated by a discussion about how cargo ships made of steel and other metals float rather than sink. This discussion included both photos of cargo ships and videos of cargo ships. Participants were asked to discuss and write their possible explanations wherein the explanations were noted for usage or absence of concepts related to buoyancy.

The Explore stage consisted of participants in groups making models of cargo ships with aluminum foil and using pennies as the cargo. Participants then placed their models in fish tanks filled with water to observe if their models floated or sank. Participants had the option of placing more pennies into their cargo ship models to test if their cargo ship models sank after a certain number of pennies were placed in their cargo ship models. Participant were specifically asked to explain their observations of floating and sinking of their cargo ship models.

Prior to direct instruction on the topic of buoyancy in the Explain phase, participants were giving time to present their explanations of floating and sinking using their cargo ship models. Direct instruction was used in the Explain stage to present the lesson on buoyancy thereby (introducing and) reviewing the scientific concepts of buoyancy, buoyant forces, floating, sinking, gravity, weight, gravity, density of fluid, density of object, mass, displacement, and surface area. Direct instruction included definitions, descriptions, exemplars and non-exemplars of the scientific concepts.

During the Elaborate phase, participants revisited their prior knowledge about cargo ships based on their discussions and written responses from the Engage phase. Participants read and reread their written explanations and applied their knowledge of buoyancy from the Explore and Explain phases to reconstruct their explanations. For the Evaluation stage, participants were given a worksheet that asked knowledge and application questions: (1) What is the buoyancy?, (2) Explain how substances denser than water like cargo ships made of steel can still float, (3) Explain the difference between density and buoyancy, and (4) Explain the relationship between buoyancy, floating, and sinking.

The data sets collected after the intervention were strategic in that they provided an opportunity for triangulation of themes. It also reinforced any generalizations extracted from the post-concept maps because, as noted by Cohen, Manion and Morrison (2000) extrapolating themes from one source does not provide a full understanding. The subsequent sections will further detail these data sets and how the data sets were used in the analysis process.

Pre- and Post- Concept Maps

Three of the authors, as a scoring committee, individually and collectively, evaluated the pre- and post-concept maps. The authors collected the frequency of total and valid propositions presented in each concept map. 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 participants and outlined by Novak (2010), and Harrell and Subramaniam (2015). Using a consensus method, the authors discussed and agreed on final scores for each concept map.

Semi-structured Interviews

Prior to scoring the concept maps, each participant was interviewed by the authors of the study. Using a semi-structured interview method, participants were asked to explain the information presented in each of their pre- and post- concept maps. This provided an opportunity for participants to explain the concepts and propositions within their concept maps. Participants were also asked questions about the structure of their concept map and how it incorporated the various details outlined by Novak (2010) and Moon et al., (2011). In some instances, participants expressed confusion about the various components they drew in their concept maps which solidified their accurate understanding of buoyancy or further enhanced the evidence that misconceptions existed within their understanding. Each of the interviews was recorded and transcribed. Accurate conceptions and misconceptions drove the coding process. The authors evaluated each transcript for information reflecting an understanding of the concept of buoyancy, in addition to any related concept (e.g., gravity and weight).

Data Analysis

Authors reviewed each participant's concept map and created a list of the concepts in each participant's explanation of buoyancy including accurate conceptions and misconceptions. The accurate conceptions and misconceptions were coded for frequency counts. This was done after the interviews occurred so participants could clarify their construction of the concept maps and the content or concepts they provided within the concept maps, and interviews. The following concepts, density, surface area, gravity, opposing forces, buoyant force, floating and sinking, volume, pressure, relative density, weight displacement, density of the object, density of the fluid, Archimedes principle, fluid properties, mass, and a balanced load, were outlined and used by the authors to analyze, understand and explain buoyancy as used by participants in their concept maps and other data. Frequency counts were performed on the pre- and post-concept maps to identify how often buoyancy and its related concepts were included in each of the respective concept maps.

Figure 2 provides samples of both pre- and post- concept maps and how they were analyzed.

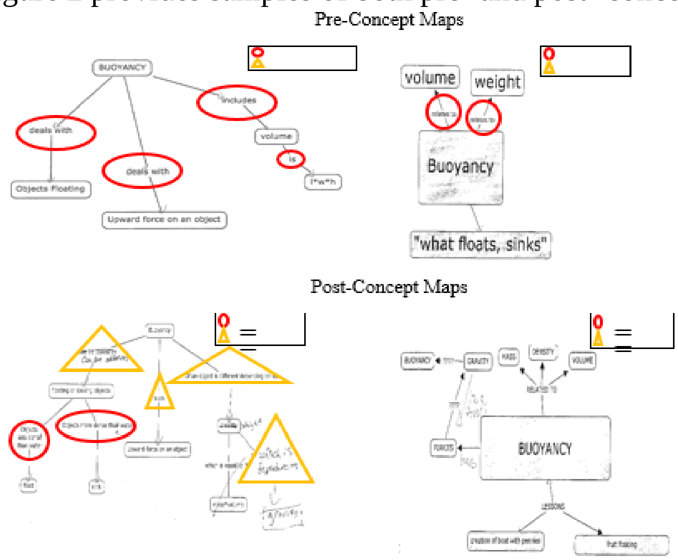

Figure 2. Samples of Pre- and Post- Concept Maps

Findings

The frequency counts of the related concepts together with valid propositions and invalid propositions within the concept maps gave insights into the participants' conceptual understandings of buoyancy before and after a 5E Learning Cycle instructional intervention. Related concepts were included in this study because, as noted in the review of the literature, each of the related concepts is fundamental to understanding the concept of buoyancy. For example, one cannot fully understand or explain buoyancy without grasping the influence gravity has on an object in a fluid. To that end, the frequency counts included both the number of concept maps that included the related concepts and the number of concept maps that did not include the respective related concepts.

Table 1 focuses on the pre-concept maps and, in addition to showing the concepts that were not included in participants' concept maps and provides a detailed account of the concepts included on participants' concept maps. Moreover, it outlines if the concepts were included in a way that demonstrated a scientifically accurate understanding or a misconception. The individual frequency was divided by the total number of participants to report a percentage of participants with included concepts in each respective category. For example, the concept of gravity had a frequency of three. The frequency was divided by the total number of participants (n = 55) and multiplied by 100 to obtain the percentage value of 6%. As previously noted, the number of concept maps on which each of the related concepts was absent was also considered. This information, as it related to the pre-concept maps, is included in the "Not Included" column of Table 1. From this information, one can see that density was not included on any of the pre-concept maps from this study.

Table 1
Frequencies and Percentages of Participants' Accurate Conceptions and Misconceptions on Pre-Concept Maps for the concept of Buoyancy (n=55).

Related Concept	Accurate Conception	Misconception	Not Included
Density.	0 (0%)	0 (0%)	55 (100%)
Surface Area.	1 (2%)	2 (4%)	52 (95%)
Gravity.	3 (6%)	2 (4%)	50 (91%)
Opposing Forces.	2 (4%)	0 (0%)	53 (96%)
Buoyant Force.	9 (16%)	11 (20%)	35 (64%)
Floating and Sinking.	4 (7%)	39 (71%)	12 (22%)
Volume.	0 (0%)	7 (13%)	48 (87%)
Pressure.	1 (2%)	1 (2%)	53 (96%)
Relative Density.	0 (0%)	1 (2%)	54 (98%)
Weight.	2 (4%)	8 (15%)	45 (82%)
Displacement.	1 (2%)	4 (7%)	50 (91%)
Density of Fluid.	2 (4%)	22 (40%)	31 (56%)
Density of Object.	1 (2%)	27 (49%)	27 (49%)
Archimedes Principle.	0 (0%)	1 (2%)	54 (98%)
Fluid Properties.	2 (4%)	10 (18%)	43 (78%)
Mass.	0 (0%)	13 (24%)	42 (76%)
Balanced Load.	0 (0%)	1 (2%)	53 (96%)

Table 2 includes a similar analysis of the post-concept maps and the frequencies of inclusion for each of the related concepts. Continuing with the related concept of density, only one participant included density on their post-concept map, and it revealed a misconception about buoyancy. As previously noted, the number of concept maps was considered, even when there were absent concepts. This information, as it relates to the pre-concept maps, is found in the "Not Included" column of Table 2. From this information, one can see that all of the related concepts were at least included on each of the post-concept maps from this study.

A comparison between the scientifically correct conceptions and misconceptions that were included in participants' pre- and post-concept maps is shown in Table 3 shows the changes observed between the concept maps. For example, there was an increase of eight participants (14% of participants) who included gravity in their post-concept maps, as only three participants (2% of participants) correctly included gravity in the pre-concept maps and 11 participants (20% of participants) correctly included gravity in the post-concept maps. Likewise, a change in 12 participants (22% of participants) was observed between the concepts for floating and sinking. 39 participants (71%) included floating and sinking in their pre-concept maps in a way that reflected a misconception and this was reduced to 27 participants (49%) in the post-concept maps.

Overall, when compared to the pre-concept maps, participants increased their association between related concepts of buoyancy and the concept of buoyancy on concept maps created after the instructional intervention. Furthermore, when compared to pre-concept maps, participants increased their accuracy in associating related concepts and buoyancy on concept maps created after the instructional intervention. When compared to pre-concept maps, there was an increase in the number of misconceptions present within the conceptual frameworks of the participants, as they relate to buoyancy, as evidenced in concept maps created after the instructional intervention.

Table 2

Frequencies and Percentages of Participants' Conceptions and Misconceptions on Post-Concept Maps for the concept of Buoyancy (n=55).

Included Concept	Scientifically Correct	Misconception	Not Included
Density	0 (0%)	1 (2%)	54 (98%)
Surface Area	6 (11%)	16 (29%)	33 (60%)
Gravity	11 (20%)	12 (22%)	32 (58%)
Opposing Forces	6 (11%)	0 (0%)	49 (89%)
Buoyant Force	20 (36%)	14 (26%)	21 (38%)
Floating and Sinking	5 (9%)	27 (49%)	23 (42%)
Volume	0 (0%)	10 (18%)	45 (82%)
Pressure	2 (4%)	0 (0%)	53 (96%)

Relative Density	1 (2%)	0 (0%)	54 (98%)
Weight	5 (9%)	13 (24%)	37 (67%)
Displacement	3 (6%)	16 (29%)	36 (66%)
Density of Fluid	2 (4%)	31 (56%)	22 (40%)
Density of Object	2 (4%)	34 (62%)	19 (35%)
Archimedes principle	2 (4%)	6 (11%)	47 (86%)
Fluid Properties	2 (4%)	4 (7%)	49 (89%)
Mass	1 (2%)	14 (26%)	40 (73%)
Balanced Load	1 (2%)	2 (4%)	52 (95%)

Table 3

Frequency Counts: Scientifically Correct Concepts and Misconceptions on Pre- and Post-Concept Maps.

	Scientifically Correct			Misconceptions		
Included Concept	Pre-Concept Maps	Post-Concept Maps	Change	Pre-Concept Maps	Post-Concept Maps	Change
Density	0 (0%)	0 (0%)	--	0 (0%)	1 (2%)	1 (2%)
Surface Area	1 (2%)	6 (11%)	5 (9%)	2 (4%)	16 (29%)	14 (25%)
Gravity	3 (6%)	11 (20%)	8 (14%)	2 (4%)	12 (22%)	10 (18%)
Opposing Forces	2 (4%)	6 (11%)	4 (7%)	0 (0%)	0 (0%)	--
Buoyant Force	9 (16%)	20 (36%)	11 (20%)	11 (20%)	14 (26%)	3 (6%)
Floating and Sinking	4 (7%)	5 (9%)	1 (2%)	39 (71%)	27 (49%)	-12 (22%)
Volume	0 (0%)	0 (0%)	--	7 (13%)	10 (18%)	3 (5%)
Pressure	1 (2%)	2 (4%)	1 (2%)	1 (2%)	0 (0%)	-1 (2%)
Relative Density	0 (0%)	1 (2%)	1 (2%)	1 (2%)	0 (0%)	-1 (2%)
Weight	2 (4%)	5 (9%)	3 (5%)	8 (15%)	13 (24%)	5 (9%)
Displacement	1 (2%)	3 (6%)	2 (4%)	4 (7%)	16 (29%)	12 (22%)
Density of Fluid	2 (4%)	2 (4%)	--	22 (40%)	31 (56%)	9 (16%)
Density of Object	1 (2%)	2 (4%)	1 (2%)	27 (49%)	34 (62%)	7 (13%)
Archimedes principle	0 (0%)	2 (4%)	2 (4%)	1 (2%)	6 (11%)	5 (9%)
Fluid Properties	2 (4%)	2 (4%)	--	10 (18%)	4 (7%)	-6 (11%)
Mass	0 (0%)	1 (2%)	1 (2%)	13 (24%)	14 (26%)	1 (2%)
Balanced Load	0 (0%)	1 (2%)	1 (2%)	1 (2%)	2 (4%)	1 (2%)

After analyzing the data sets, it was evident that participants included in this study lacked a scientifically acceptable conceptual understanding of buoyancy before the instructional intervention. As observed in the post-concept maps, participants included more related concepts in their knowledge structure for buoyancy but a large gap between the scientific definition of buoyancy and the ways by which the participants were presenting the information was evident. When asked to explain buoyancy in the interviews and concept maps, many of the participants resorted to only talking about floating and sinking in a liquid. Although the instructional intervention alleviated some of the serious gaps in participants' conceptual understanding of buoyancy, it was apparent from the midterm examination drawings that some misconceptions still persisted in participants' understanding of buoyancy.

Discussion and Conclusion

This study focused on identifying participants conceptions of buoyancy, before and after the instructional intervention. The findings revealed that participants' understandings of buoyancy cohered with those in preschool and elementary age children (Grimellini-Tomasini et al., 1990; Halford et al., 1986; Hsin & Wu, 2011; Rappolt-Schlichtmann et al., 2007;). Additionally, participants' prior knowledge of buoyancy was similar to the challenges preschoolers faced when dealing with floating and sinking, specifically, these included the understanding of weight and volume (Kohn, 1993), mass and weight (Rappolt-Schlichtmann et al., 2007), properties of matter (Au, 1994), and general scientific concepts (Grimmellini Tomasini et al., 1990).

Findings also revealed that several of the related concepts increased in their frequency during the study (e.g., gravity between pre-concept maps and the drawings) and that some of the related concepts decreased (e.g., fluid properties between the pre-concept maps and post-concept maps). This revealed that some clarity was provided in the instructional intervention that encouraged the participants to remove connections or assimilate new understandings. Overall, there was an increase in the total number of concepts that were related or connected to buoyancy by the end of the study.

The increase of 92 concepts included in the post-concept maps, when compared to the pre-concept maps, suggests that the instructional intervention was successful in providing new connections or reminding participants of connections they learned or experienced prior to the study. As noted by the concept map format used in this study, conclusions about conceptual frameworks can be drawn from the ways by which participants connect concepts and linking words in concept maps. One possible scenario that led to the increased number of concepts included in a post-concept map was a participant recalling a concept or connection from a prior experience as a result of the instructional intervention. For example, if a participant experienced a lesson during their high school curriculum or perquisite coursework that included the relationships between buoyancy, floating, sinking, and density, but the participant did not recall it during the pre-concept map, the connection could have been reconfirmed during the instructional intervention and reflected in the post-concept map. The instructional intervention, as visually observed by the authors, included a discussion about the connection between these terms. The intervention might have provided an opportunity to recall prior knowledge and reconnect concepts in a way that reflected accuracy or a misconception in the post-concept map. Additionally, it is possible that the instructional intervention provided new connections and concepts that were not explored in prior experiences. Each of the participants had different experiences with the concept of buoyancy prior to the study and prerequisite coursework, there was no part of this study that explored how each of the prior experiences impacted each individual. Furthermore, situations could have occurred during the prerequisite course, such as an individual being absent from coursework that covered the related concepts. This would be evidenced by a detailed evaluation of individual participants and their responses to each of the research components.

Several of the related concepts provided by the participants were not present in any part of the literature review or, per the scientific definitions, directly connected to the concept of buoyancy (Giambattista et al., 2010; Kariotogloy et al., 1993; Rowell & Dawson, 1977a, 1977b). For example, pressure, water level, and inertia were included in the concept maps and, as such, connected to buoyancy within the schema of the participants who included it. The inclusion of these concepts without an expansive display of the relationships is considered a misconception because of absence of direct linkages to buoyancy. Including these concepts in the concept maps possibly reveals that the responsible participants were searching for scientific concepts to connect with buoyancy and those words or concepts might have been referenced or introduced by a prior experience incorrectly.

There was also evidence that accurate conceptions of buoyancy were present within the conceptual frameworks of a small group of participants; however, robust prior knowledge and understandings associated with the related concepts were not evident. Moreover, there were gaps in their conceptual frameworks about the concept of buoyancy before and after the instructional intervention. Some of these gaps, per the scientific definition of buoyancy, should be considered significant. For example, the fact that none of the participants included opposing forces in their pre-concept maps in a way that revealed an accurate understanding was concerning. As outlined in the definition of buoyancy in the literature review, the scientific concept of buoyancy centers on the presence of opposing forces (Giambattista et al., 2010).

Conclusion

Based on the findings of this study, it is evident that participants had weak prior conceptual understandings of buoyancy and misconceptions that impacted the ways they understood and linked concepts related to the scientific definition of buoyancy. Buoyancy is the concept that involves an upward buoyant force in a fluid and how it opposes the force of gravity. Furthermore, the relative density of the fluid and the volume of the object play a significant role in buoyancy because, as noted by Dijksterhuis (1988), the formula for calculating buoyant force is the following: $F_B = (\rho_{\text{fluid}})(V_{\text{object}})(g)$. Based on the findings of the study, participants do not fully understand the components of the formula: density, gravity, or volume. This leads to significant gaps in their ability to understand the elementary concepts of buoyancy and thus, floating and sinking. The elements of the buoyancy formula are introduced on a basic level in preschool education, and are revisited throughout elementary, middle, secondary, and post-secondary curricula. Per the research and educational curricula on physical sciences, understanding the concept of buoyancy requires a solid framework that includes the following: density, surface area, gravity, opposing forces, buoyant force, floating and sinking, volume, pressure, relative density, weight displacement, density of the object, density of the fluid, Archimedes principle, fluid properties, mass, and a balanced load. The fact that many of the participants had a preschool level understanding of buoyancy leads one to question the scaffolding present within the educational systems experienced by the participants. Moreover, one must question if the foundational concepts were introduced initially and revisited annually in ways that addressed misconceptions and concretized accurate scientific understandings. The participants in this study did not accurately connect all of these concepts to buoyancy in way that would permit one to state that the teachers are adequately prepared to instruct students on buoyancy.

Implications

This study revealed a significant deficiency in content knowledge, as it relates to buoyancy, within the cognitive structures of preservice teachers. Thus, it is appropriate that one implication be the review of the course content knowledge required of teachers obtaining teaching certification and placement in school classrooms. In regards to buoyancy, it is essential that elementary teachers understand the concept and all related concepts in order to develop and implement curricula related to buoyancy and floating and sinking. Although all participants completed a conceptual physics course or similar prerequisite, this study should provide support for reviewing the science content-level required for teachers considering the responsibility of providing accurate information to students and being prepared to remediate their misconceptions.

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