A descriptive study of pre-service science teachers' misconceptions about sinking–floating

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Received 3 Oct., 2015
Revised 29 Dec., 2015

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Abstract

The purpose of this study is twofold. Firstly, it attempts to determine the pre-service science teachers' misconceptions about floating and sinking. Secondly, it aims to reveal the level of pre-service science teachers' misconceptions, scientific knowledge, lack of knowledge, and lack of confidence related to floating and sinking. To conduct the study, a diagnostic instrument of sinking and floating (DISF) with three tiers was developed and used. The three tiers were used to calculate a KR-20 reliability coefficient of 0.804 for the scientific knowledge and a KR-20 reliability coefficient of 0.768 for the misconceptions. The data was collected from 377 pre-service science teachers from three different universities in Turkey. 74 misconceptions about floating and sinking were found. These misconceptions were classified under seven categories. The results of the study demonstrated that the pre-service science teachers had many misconceptions, low scientific knowledge level, and low confidence level in their knowledge about floating and sinking.

Keywords: Floating and sinking, buoyant force, pressure, density, misconception

Introduction

The meanings attributed to the concepts have been changed and developed because of the rapidly changing developments in scientific knowledge. Not only does this situation lead conceptual learning to be one of the most important subjects in science education, but also increases the importance of research in this area (Joung, 2009). The studies have shown that there are a lot of factors that affect the students' concept learning (Kiray, Gok, & Bozkir, 2015).

Experience is the one of the most important factors. Before coming to the classroom, the students have prior experiences of the world resulting from their previous interactions, which affect their learning during their education at school (Yin, Tomita, & Shavelson, 2008). Along with the students' incorrect prior knowledge gained from real-life experiences and observations, teachers' incorrect descriptions in the school, the reflection of the authors' misinformation in textbooks, and the daily misuse of the scientific concepts may cause students to ascribe different meanings to the scientific concepts (Unal & Costu, 2005; Sahin & Cepni, 2011). Students' mistaken "scientific" knowledge is called misconceptions, misunderstandings, alternative frames, or alternative conceptions (Arslan, Cigdemoglu, & Moseley, 2012). Although there are many studies that deal with a specific science concept (Kirbulut & Beeth, 2013), this study focused on the pre-service science teachers' misconceptions of scientific concepts related to floating and sinking.

The floating and sinking misconceptions

Even though the students have encountered the topic of floating and sinking, they still have many misconceptions about it. The content is quite complex as it is associated with many content areas. In order for students to understand the floating–sinking topic, they should comprehend pressure, pressure force, density, buoyancy, buoyant force, balanced and unbalanced force, gravity, weight, and the principle of Archimedes (Bulunuz, Bulunuz, Karagoz, & Tavsanli, 2016, Cepni, Ayas, Johnson, & Turgut, 1997; Heywood & Parker, 2001; Hewit, 2002; Leuchter, Saalbach, & Hardy, 2014; Moore & Harrison, 2014; She, 2002; Yin, Tomita, & Shavelson, 2008; Yin, Tomita, & Shavelson, 2014). One of the most fundamental misconceptions related to floating and sinking arises from deciding if the matter can float or sink.

To determine whether an object floats or sinks, the density of the liquid and the density of the object should be compared (Kawasaki, Herrenkohl, & Yeary, 2004). This approach is called, "relative density approach" (RDA) in this study. Even though RDA is the most widely used approach to teach the floating and sinking content, the students still have misconceptions about it because of the misconceptions about the objects' density (Arce, Bodner, & Hutchinson, 2014). The studies have shown that the students assume that the change in density of a liquid induces change in buoyancy of an object; the density of a floating object is more than the density of a sinking object, and the density of an object hanging in a liquid is equal to a floating object's density (Unal, 2008). Also, they consider that when an object's density increases, the buoyancy of the object always decreases, (She, 2002) and objects that are covered by the liquid have always the same density (Unal & Costu, 2005). In addition to the above misconceptions regarding RDA, the students have the misconceptions about the forces that act on the floating and sinking objects.

The students consider the forces that impact the objects to understand the topic of floating and sinking (Heywood & Parker, 2001). In other words, the students use reasoning about the balanced and unbalanced forces (Moore & Harrison, 2004). Relative Force Approach (RFA) is defined as the comparison of the magnitude of an object's weight with the magnitude of the object's buoyant force in this study. The students usually are not aware of the RFA (Relative Force Approach) that compares the magnitude of the objects' weights with the magnitude of the buoyant force. The students should master the principles of Archimedes to comprehend RFA.

According to the principles of Archimedes, the magnitude of the upward buoyant force, which is applied on a sinking object or floating object, is equal to the magnitude of the liquid's weight that the body displaces. This principle applies to both the floating and sinking objects. However, there is a special case for the floating objects. When an object floats in a liquid, the magnitude of the buoyant force is equal to the magnitude of the overflowing liquid's weight and object's weight (Besson, 2004; Hewit, 2002). For a sinking object, only the magnitude of the buoyant force is equal to the magnitude of the weight of the overflowing liquid, and the magnitude of the object's weight is greater than the buoyant force. This situation may lead to students having a misconception about the content (MEB, 2006).

Some of the misconceptions are that the heavy objects displace more liquid than the light objects, and the sinking objects displace less liquid than the objects hanging in liquid (Cepni & Sahin, 2012; She, 2002). In addition, the hollow objects relocate more liquid (i.e., boat-shaped objects) than the solid objects, and the floating objects relocate more the liquid volume because of their big surface areas (Hewit, 2002; She, 2002).

The students have several misconceptions about overflowing liquid, the effects of the volume, or amount of the liquid when determining if an object floats or sinks. First, they believe that the volume of the liquid determines whether an object sinks or floats (Cepni & Sahin, 2012; Unal & Costu, 2005; Unal, 2008). Second, they assume that when the volume of a liquid in a container is increased, the volume of submerged part of a floating object increases (Unal, 2008). Third, they deem that an object would float if the object's volume and weight increases (Cepni & Sahin, 2012; Yin, Tomita, & Shavelson, 2008). These misconceptions affect the students' understanding the floating and sinking content.

Furthermore, the students develop misconceptions about the buoyant force. Many students think that if the volume of an object increases, the buoyant force increases. The students also believe that the buoyant force would be greater when a floating object (out of water) crosses a deep place than when the object crosses a shallow place (Cepni & Sahin, 2012; Unal & Costu, 2005; Unal, 2008). Similarly, the students think that when the volume of the liquid decreases, the buoyant force decreases, too, if the greater the floating part (out of water) of an object, the greater its buoyancy (Cepni & Sahin, 2012; Unal, 2008). Moreover, the students believe that the buoyant force of the sinking objects is greater than the buoyant force of the floating objects (Cepni & Sahin, 2012; Unal & Costu, 2005) and the buoyant force only affects the floating objects and does not affect the sinking objects (Cepni & Sahin, 2012).

The students also have a hard time comprehending the pressure force (Psillos, 1999), which causes misconceptions about floating and sinking. The *buoyancy* is the net force between the pressure force applied to the object from the bottom and the pressure force exerted the object on the top (Besson, 2004; Hewit, 2002). An object floats if the magnitude of the buoyant force is equal to the weight of the object. The misconception about this topic affects the students' understanding of the pressure force, the buoyant force, and floating and sinking. Even, some students may develop the misconception that the amount of the liquid affects the pressure force of the object (Besson, 2004). Similarly, many students have misconceptions related to the impact of the pressure force on an object because they do not count the force that affects an object in a liquid from either bottom or top. The students do not recognize that the pressure forces cause the buoyant force (Besson, 2004).

The other misconception held by the students is about how an object's shape affects whether the object floats or sinks. The most common misconceptions about floating and sinking are related to an object's size, weight, or shapes. The students decide whether an object floats or sinks by considering the object's weight or mass (Cepni & Sahin, 2012; Leuchter, Saalbach, & Hardy, 2014; Moore & Harrison, 2004; Unal & Costu, 2005). For instance, many students expect that a big piece of wood would sink, yet a small piece of iron would float (Leuchter, Saalbach, & Hardy, 2014). The students' prior experiences cause them to think that the weight or volume of an object determines whether the object floats or sinks. The students use faulty reasoning to determine whether an object floats or sinks by considering the shape of a ship, as a giant ship floats on the sea (Havu-Nuutinen, 2005; She, 2002; Tao, Oliver, & Venville, 2012). Additionally, the students believe that if an object sinks, the object's weight is greater than water (Ozsevgenc & Cepni, 2006) and that if the weight of the liquid is equal to the object's weight, the object sinks (Havu-Nuutinen, 2005). They also assume that while a small and light object floats, a heavy object sinks (Cepni et al., 2010; Cepni & Sahin, 2012; Kang et al., 2005; Moore & Harrison, 2004; Yin, Tomita, & Shavelson, 2008).

The students also have misconceptions related to the objects' shapes and features. Several studies have shown that the students believe that the objects float because of their shapes (Havu-Nuuiten, 2005; She, 2002); the objects with holes or empty objects always float (Havu-Nuuiten, 2005; Moore & Harrison, 2004; She, 2002), and the solid or hollow objects sink (Havu-Nuuiten, 2005; Yin, Tomita, & Shavelson, 2008). Moreover, they consider that when a floating object is cut into two parts, the parts would sink (Unal & Costu, 2005). The flat objects float (Yin, Tomita, & Shavelson, 2008), and an object with a hole sinks (Havu-Nuuiten, 2005; Unal & Costu, 2005), such as while a can floats, a closed cab sinks (She, 2002).

Furthermore, the studies have shown that the students believe that the way an object is dropped into the liquid affects whether an object sinks or floats. The students believe that vertical objects sink, and the horizontal objects float (Yin, Tomita, & Shavelson, 2008). In addition placing an object on its sharp edge causes it to sink while placing the object on its wide edge causes it to float (Kıray, 2010; Yin, Tomita, & Shavelson, 2008). Additionally, the students believe that the soft objects float while the rigid objects sink (Moore & Harrison, 2004; Yin, Tomita, & Shavelson, 2008).

Importance of the Study

The students and teachers' conceptual understanding, teaching, and learning of these concepts have been one of the most important parts of research in science education for the last thirty years (Duit & Treagust, 2003). The majority of the researches about conceptual learning have focused on the students' comprehension of scientific concepts, even though many teachers and students develop misconceptions. The teachers reinforce these misconceptions by reflecting them in their lesson plans and teaching (Arslan, Cigdemoglu, & Moseley, 2012); therefore, it is important to determine the pre-service science teachers' misconceptions and correct them. In the literature, the misconceptions about floating and sinking were determined by asking multiple-choice questions and open-ended questions. In this study, the authors investigated the pre-service science teachers' misconceptions about floating and sinking using a three-tier test. The study sought to answer the following two questions:

1. What were the pre-service science teachers' misconceptions related to floating and sinking?
2. What were the levels of pre-service science teachers' scientific knowledge, lack of knowledge, lack of confidence, and misconceptions about floating and sinking?

Methodology

Instruments

Three-Tier Tests

In literature, misconceptions are usually measured using either two-tier or three-tier tests. The two-tier tests that were used to investigate the students' conceptual knowledge became quite popular when they emerged. Therefore, in the past, the researchers used two-tier tests quite often to determine the students' misconceptions in the science field (Caleon & Subramaniam, 2010). However, nowadays the researchers use these tests as a preliminary stage to develop three-tier tests so that they can differentiate the students' lack of knowledge from their misconceptions.

One of the biggest problems, when detecting the misconceptions, is the researchers' inability to differentiate misconceptions from error. According to Eryilmaz and Surmeli (2002), all misconceptions are an error, but not all errors are a misconception. Errors must be differentiated from misconceptions because the lack of knowledge can cause errors (Kutluay, 2005). The two-tier tests are devoid of features that make this fine distinction. As a result, the adding of the third tier to the test may clarify whether the students' errors are caused by lack of knowledge or misconception (Hasan, Bagayoko, & Kelley, 1999; Pesman & Eryilmaz, 2010).

The first tier of the three-tier test is called the content tier. This tier depicts the respondents' descriptive knowledge. The second tier —the reason tier—evaluates the students' mental model. Finally, the third tier—confidence tier—measures the students' confidence in their answers (Caleon & Subramaniam, 2010). In other words, if a student gives an incorrect answer in the first or second tier or both of them and the student feels confident in their answer, the student is considered to have a misconception about the topic (Kutluay, 2005). Table 1 shows the possibilities based on the students' responses to the three-tier tests.

Table 1: All possibilities of responses

First tier	Second tier	Third tier	Categories
Correct	Correct	Certain	Scientific knowledge
Correct	Incorrect	Certain	Misconception (false positive)
Incorrect	Correct	Certain	Misconception (false negative)
Incorrect	Incorrect	Certain	Misconception
Correct	Correct	Uncertain	Lucky guess, lack of confidence
Correct	Incorrect	Uncertain	Lack of knowledge

Incorrect	Correct	Uncertain	Lack of knowledge
Incorrect	Incorrect	Uncertain	Lack of knowledge

*Arslan, Cigdemoglu,& Moseley (2012)

Diagnostic Instrument of Sinking and Floating (DISF)

To understand the pre-service teachers' misconceptions related to floating and sinking, the test included open-ended questions. When creating the questions, the following resources were used: the pre-service teachers' difficulties related to floating and sinking, alternative concepts, and misconceptions from literature, lesson observations, and open-ended physic exam questions from the first year of college. The questions were piloted with 38 different pre-service science teachers who learned the floating and sinking topic. In order to elaborate on their answers, the author interviewed 12 students face-to-face. Considering the students' answers, the open-ended questions in the first tier were transformed into three-choice questions. When developing the second tier of the test, a short space was left to ask the student give an explanation and reasoning for their choice. This phase of the test was administered to 24 students. These students participated in the focus-group interviews. The students' discussions and reasoning were recorded using a video camera during the focus groups. The data collected from the second phase of the study was converted to the multiple-choice one-answer questions tests. The first and second tiers of the test contain subconcepts related to floating and sinking. Table 2 presents the categorization of the concepts and subconcepts measured by DSIF.

Table2: The concepts and misconceptions related to floating and sinking measured with DISF

Concepts related with sinking and floating in DISF													
	Buoyant Force	Pressure/Pressure Force	RDA	Density	RFA	Amount/ level of liquid	Mass or weight of solid	Mass/ weight of liquid	Volume of solid	Volume of liquid	Position in liquid	Hard or soft	Shape of object
1	✓*					✓*							
2	✓	✓		✓		✓*							
3	✓*	✓		✓*	✓*								
4				✓*			✓*		✓*				✓*
5				✓*			✓*		✓*				✓*
6				✓*			✓*						✓*
7	✓			✓*			✓		✓		✓*		

8	√	√		√*					√		√*		
9	√	√		√*								√*	
10	√			√*			√		√			√*	
11	√	√		√*		√*				√			
12	√	√	√*	√*									
13	√	√*											
14	√		√*	√*	√*			√*	√*				
15	√*		√*	√*									
16	√*				√*								
17	√		√*	√*			√	√	√				
18	√	√*											
19	√	√*											
20	√*					√*							
21	√*				√*								

√Both two tiers   *Only first tiers

Before conducting the pilot study, a third tier was added to ask the pre-service science teachers if they were sure of their answers. Four different experts evaluated the test, and then the test was revised based on their feedback and comments. The latest version of the test was administered to six sophomore, junior, and senior pre-service science teachers, and the researcher made small revisions based on their comments. A language expert checked the language and grammar of the test. Also, the students checked the ambiguity of the language or terms. At the final stage, the test was called Diagnostic of Instrument of Sinking and Floating (DISF). The test measured the 74 misconceptions related to floating and sinking.

Reliability

DISF were used to measure both the students' misconceptions and their levels of scientific knowledge. Therefore, the reliability of the three-tier DISF was calculated in two ways.

Reliability 1: Reliability of Scientific Knowledge Test

The first type of reliability coefficient of DISF was calculated according to the students' scores from all three tiers, and the KR-20 coefficient was 0.804. The reliability coefficient was calculated to discover the students' scientific knowledge about floating and sinking.

Reliability 2: Reliability of Misconception Test

The second reliability coefficient of DSIF was calculated to catch on the students' misconceptions by looking at the relationship between the students' incorrect answers to questions in the first or second tiers, or both tiers and their lack of confidence in their answers. The test's reliability coefficient of misconception KR-20 was 0.768. This coefficient was valid when using the test to find out the students' misconceptions about floating and sinking.

Validity

There are three quantitative methods to measure the test's validity.

Validity 1: Construct Validity

Construct validity, the confidence tier, was calculated as a correlation coefficient among the first two tiers of the test and third tier. When a student got a high score from the first tiers of the test, the student must have confidence in his or her answers. In other words, there must be a statistically significant correlation between the first two tiers and the third tier (Arslan et al., 2012; Cataloglu, 2002). The test's construct validity was $r=0.51$ ($p<.05$). After administering the test, the researcher conducted face-to-face interviews with 10 students. To form the test's construct validity, the students' test answers were compared with their interviews.

Validity 2: Exploratory Factor Analyses

The questions in the test contain the misconceptions from the literature. Table 2 shows the questions' factors that were measured using the first and second tiers. Based on the factor analysis results, the questions were regrouped and renamed in accordance with the dominant feature in the question stem (see Table3). The KMO value of the test is 0.794 based on the total score of the factor analysis and this value shows the appropriateness of the data. The factor analysis shows that the eigenfactor value for all questions is higher than 1 and there are seven categories in the test. Table 3 presents the factors and loadings.

Table3. The factor loadings of DISF

	Amount/ level of liquid	Shape of objects	RFA	Position in liquid	Hard/soft objects	RDA	Pressure force
2	0.720						
20	0.620						
1	0.598						
11	0.468						
5		0.739					
6		0.707					
4		0.601					
16			0.711				
21			0.660				
3			0.542				
14			0.476				
7				0.809			
8				0.731			
9					0.711		
10					0.686		
15						0.679	
17						0.560	
12						0.518	
13							0.761
19							0.467
18							0.460

Validity 3: Content Validity

Content validity was examined for the false negative and false positive probability.

False Negative: Hestenes and Halloun (1995) define false negative as the wrong answers that are given by the students who provide right reasoning. The rule of thumb for false negative is less than 10%. In this study, the students' false negative score was 3.40%.

False Positive: Hestenes and Halloun (1995) define false positive as the wrong answers that are given by the students who do not provide right reasoning. They state that it is not possible to determine a fixed minimum score for false positive because the students' false positive may be made through guesswork (Pesman, 2005). As a result, the chance of success may vary by the number of options in the first tier. In this study, the chance of students' random-answer probability should be less than 33.3% as the first tier questions have three choices. The calculated false positive value is 20.1% for this study.

Participants

The test was administered to 377 senior pre-service science teachers from three different universities in Turkey. The participants' age range was 21–25; there were 253 female and 124 male participants.

Data Collection and Analyses

The pre-service science teachers took the test one month before they graduated. They had two minutes for each question, for a total of 42 minutes. The frequency and percentages of the data were calculated. In the first phase of the study, 21 questions were developed. The questions were grouped under seven categories to measure the pre-service science teachers' levels of scientific knowledge, lack of knowledge, misconceptions, and lack of confidence based on the criteria (see Table 1). In the second phase of the study, the percentages of the 74 misconceptions were obtained by matching the three tiers. If there was more than one match, the average of the percentages were calculated; if there was only one match, the percentage value was used (See Table 5).

Results and Discussions

Table 4 presents the pre-service science teachers' conceptual understanding of floating and sinking based on the subcategories of the test.

Table 4: The Pre-Service Science Teachers' Understanding of Sinking and Floating

% Correct responses								
Content area	**DISF item**	**Only First tiers**	**Both two tiers**	**All three tiers**	**Scientific knowledge**	**Misconception**	**Lack of confidence**	**Lack of knowledge**
Category1: Amount/ level of liquid	1	65.7	63.3	55.9	55.9	25.9	7.4	10.6
	2	70.5	67.9	57.5	57.5	21.4	10.3	10.6
	11	79.3	72.1	62.5	62.5	14.5	9.5	13.2
	20	76.9	71.6	58.3	58.3	12.2	13.2	16.18
Mean (%)	**Factor1**	**73.1**	**68.7**	**58.5**	**58.5**	**18.5**	**10.1**	**12.6**

Category2: Shape of objects	4	68.1	54.3	40.3	40.3	23.6	14	22.0
	5	51.9	18.3	13.5	13.5	45.0	4.7	36.6
	6	38.9	28.3	19.0	19.0	31.8	9.2	39.7
Mean (%)	**Factor2**	**53.0**	**33.6**	**24.2**	**24.2**	**33.5**	**9.3**	**32.8**
Category3: RFA	3	16.1	10.0	6.3	6.3	70.8	3.7	19.0
	14	35.0	28.9	19.8	19.8	39.7	9.0	31.3
	16	35.5	24.4	18.0	18.0	46.9	6.3	28.6
	21	46.1	41.9	28.6	28.6	33.6	13.2	24.4
Mean (%)	**Factor4**	**33.2**	**26.3**	**18.1**	**18.1**	**47.8**	**8.0**	**25.8**
Category4: surface area/ position in liquid	7	70.0	64.9	54.1	54.1	19.0	10.8	15.9
	8	61.2	51.9	41.1	41.1	29.7	10.8	18.3
Mean (%)	**Factor6**	**65.6**	**58.4**	**47.6**	**47.6**	**24.4**	**10.8**	**17.1**
Category5: Hard–soft	9	52.5	44.2	37.9	37.9	33.6	6.3	22.0
	10	62.8	37.6	23.3	23.3	31.2	14.3	31.0
Mean (%)	**Factor5**	**57.6**	**40.9**	**30.6**	**30.6**	**32.4**	**10.3**	**26.5**
Category6: RDA	12	61.0	53.3	46.9	46.9	27.3	6.3	19.3
	15	54.3	49.0	39.2	39.2	28.6	9.8	22.3
	17	87.0	54.3	48.8	48.8	32.6	5.5	13.0
Mean (%)	**Factor3**	**68.1**	**50.9**	**44.9**	**44.9**	**29.5**	**7.2**	**18.2**
Category7: Pressure force	13	24.6	14.8	11.1	11.1	57.2	3.7	27.8
	18	57.2	46.1	31.8	31.8	25.4	14.3	28.3
	19	35.8	22.2	12.2	12.2	41.6	10.0	36.1
Mean (%)	**Factor7**	**39.2**	**27.7**	**18.3**	**18.3**	**41.4**	**9.3**	**30.7**

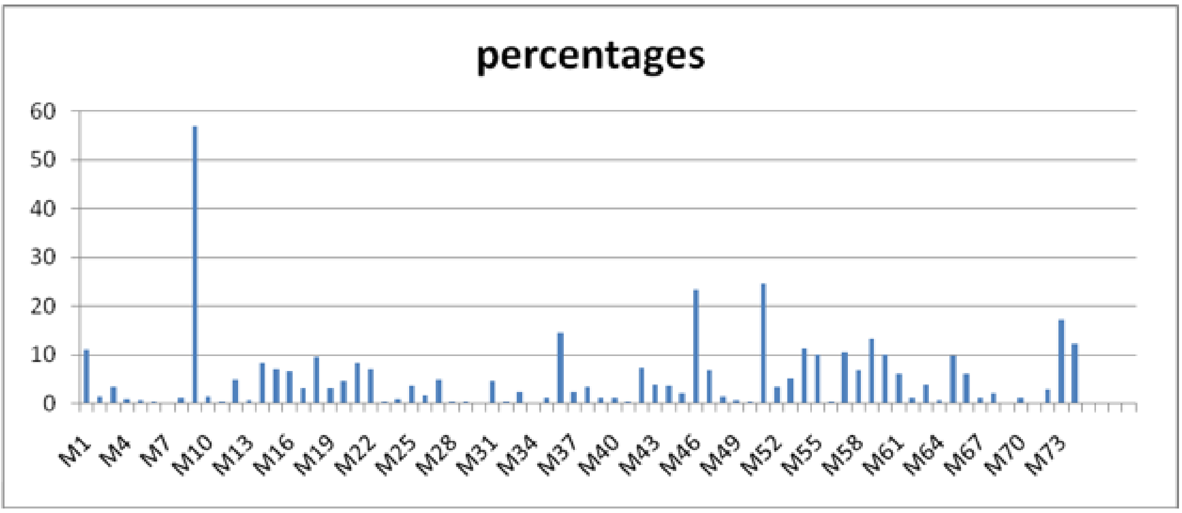
Table 5 shows the percentile values of 74 misconceptions that were grouped under seven categories.

Table 5. Percentage of misconceptions.

N=377	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**
Mean	42	5.5	12.4	3.5	3	1.5	0.5	4	215	5
%	11.14	1.45	3.28	0.92	0.79	0.39	0.13	1.06	57.02	1.32
N=377	**M11**	**M12**	**M13**	**M14**	**M15**	**M16**	**M17**	**M18**	**M19**	**M20**
Mean	2	18	3	31	27	25	12	36	12	17
%	0.53	4.77	0.79	8.22	7.16	6.63	3.18	9.54	3.18	4.50
N=377	**M21**	**M22**	**M23**	**M24**	**M25**	**M26**	**M27**	**M28**	**M29**	**M30**

Mean	31	27	2	3,5	14	6	18	2	2	1
%	8.22	7.16	0.53	0.92	3.71	1.59	4.77	0.53	0.53	0.26
N=377	**M31**	**M32**	**M33**	**M34**	**M35**	**M36**	**M37**	**M38**	**M439**	**M40**
Mean	17	2	9	0,5	4	55	9	13	4	4
%	4.50	0.53	2.38	0.13	1.06	14.58	2.38	3.44	1.06	1.06
N=377	**M41**	**M42**	**M43**	**M44**	**M45**	**M46**	**M47**	**M48**	**M49**	**M50**
Mean	2	28	15	14	8	88	26	5	3	2
%	0.53	7.42	3.97	3.71	2.12	23.34	6.89	1.32	0.79	0.53
N=377	**M51**	**M52**	**M53**	**M54**	**M55**	**M56**	**M57**	**M58**	**M59**	**M60**
Mean	93	13	19	43	38	2	40	26	50	38
%	24.66	3.44	5.03	11.40	10.07	0.53	10.61	6.89	13.26	10.07
N=377	**M61**	**M62**	**M63**	**M64**	**M65**	**M66**	**M67**	**M68**	**M69**	**M70**
Mean	23	4	15	3	37	23	4	8	0	4
%	6.10	1.06	3.97	0.79	9.81	6.10	1.06	2.12	0	1.06
N=377	**M71**	**M72**	**M73**	**M74**						
Mean	1	11	65	46						
%	0.26	2.91	17.24	12.20						

Graph 1 shows the graphic representation of the 74 misconceptions, which were based on the percentages in Table 5.



Graph 1. Percentages of misconceptions

Category1: Amount/Level of Liquid

The pre-service science teachers had the lowest levels of misconceptions in this category, as seen in Table 4. Except the misconception of M1 (11.14%), the other misconceptions are vanishingly small. The other misconceptions are M2 (1.45%), M3 (3.28%), M4 (0.92%), M5 (0.79%), M6 (0.39%), M7 (0.13%), and M8 (1.06%). Compared to the other studies in the literature, the percentiles in this category is relatively low. Unal and Costu (2005) demonstrated that 70% of the 8th-grade Turkish students had the misconception that the volume of the liquid would determine whether an object would float or sink. In addition, another study conducted by Unal (2008) confirmed this finding and found that 64% of the students in Turkey had the same misconception. Based on these findings, even though the majority of the 8th-grade students in Turkey had the misconception that the liquid amount/volume affects the buoyant force, this percentage was relatively lower for the pre-service science teachers. The percentage for lack of confidence (10.1%) was higher than 10%; this finding showed that the pre-service science teachers did not have enough confidence in their knowledge. However, the pre-service teachers had the highest percentage of scientific knowledge (58.5%) in this category. Furthermore, the pre-service teachers had the lowest percentages (12.6%) for lack of knowledge in this category.

Table 6. The pre-service science teachers' misconceptions related to the "amount/level of liquid" category

List of Misconceptions	Three tier
M1.When the depth of a liquid increases, the magnitude of the buoyant force increases.	1.1.b, 1.2.b, 1.3.a 20.1.c, 20.2.e, 20.3.a
M2.When the depth of a liquid decreases, the magnitude of the buoyant force increases.	1.1.a, 1.2.c, 1.3.a 20.1.b, 20.2.d, 20.3.a
M3.When the amount of the liquid increases, the magnitude of the buoyant force increases/when the amount of the liquid decreases, the magnitude of the buoyant force decreases.	1.1.b, 1.2.d, 1.3.a 1.1.b, 1.2.e, 1.3.a 2.1.a, 2.2.a, 2.3.a 11.1.a, 11.2.a, 11.3.a 20.1.c, 20.2.a, 20.3.a
M4.When the amount of the liquid increases, the magnitude of the buoyant force decreases.	2.1.b, 2.2.b, 2.3.a 20.1.b, 20.2.b, 20.3.a
M5.When the volume of the liquid increases, the magnitude of the net pressure force increases, too.	2.1.a, 2.2.d, 2.3.a 2.1.b, 2.2.d, 2.3.a 11.1.c, 11.2.b, 11.3.a
M6.When the volume of the liquid increases, the magnitude of the net pressure force decreases.	2.1.a, 2.2.e, 2.3.a 2.1.b, 2.2.e, 2.3.a
M7.When the amount of the liquid increases, the density of the liquid decreases.	2.1.a, 2.2.f, 2.3.a 2.1.b, 2.2.f, 2.3.a
M8.When the amount of the liquid increases, the density of the liquid increases.	2.1.a, 2.2.g, 2.3.a 2.1.b, 2.2.g, 2.3.a 11.1.a, 11.2.c, 11.3.a

Category 2: Shape of Objects

In contrast to Category 1, the pre-service science teachers had the highest lack of knowledge scores (32.8%) in this category. The pre-service science teachers' levels of scientific knowledge were 24.2% while their lack of confidence percentage was 9.3%. The Turkish science curricula do not cover the topic of how the objects' shapes affect their floating and sinking (MEB, 2006; MEB, 2013), and the college physics courses mostly cover the formulas. As a result, the pre-service science teachers have a low level of knowledge and a high level of misconceptions in this area. The pre-service science teachers' level of misconception was 33.5%, which ranked third. Category 2 had 16 misconceptions. These misconceptions were predominantly related to mass, weight, volume, and change in density as well as the conformational changes that occur in a solid body. However, the pre-service teachers' misconceptions in this category were less than 10%. The misconceptions held by more than 5% of the pre-service science teachers were M14 (8.22%), M15 (7.16%), M16 (6.63%), M18 (9.54%), M21 (8.22%), and M22 (7.16%). The misconceptions held by less than 5% of the pre-service science teachers were M12 (4.77%), M13 (0.79%), M17 (3.18%), M19 (3.18%), M20 (4.50%), M23 (0.53%), M24 (0.92%), and M25 (3.71%). The misconceptions that emerged in this study also were encountered in the following studies: Çepni et al. (2010); Çepni & Şahin (2012); Havu-Nuutinen(2005); Kang et al.(2005); Leuchter, Saalbach, & Hardy (2014); Moore, & Harrison(2004); Parker, & Heywood (2000); She (2002); Tao, Oliver, & Venville(2012); Unal & Costu (2005); and Yin, Tomita, & Shavelson (2008). However, some of these studies presented the findings in percentages.

Parker and Heywood's (2000) study is one of the studies that presented the misconceptions in percentiles. In their study, Post Graduate Certificate in Education (PGCE), when the students determined whether an object would sink or float, 75% of the students considered the shape of the object, 50% of them considered if an object had a hole, 43.2% of them considered whether an object was hollow, 59.1% of them considered the weight of the objects, and 2% of them considered the volume of the object. In She's (2002) study, 15% of the students believed that the shape of an object determines whether the object would float or sink while 5% of the students claimed that boat-shaped objects float because they're hollow, and solid objects would sink because of their weight. Moreover, Unal and Costu (2005) pointed out that when 8th-grade students decide whether an object would float or sink, 55% of the students consider the volume of the object, 47% of them consider the weight of the object, and 13% of them looked at the shape of the object. Also, in Unal and Costu's (2005) study, 41% of the students had the misconception that if you made a hole through the object, it would sink. Even though the majority of the misconceptions in Category 2 were described in the literature, their percentiles were relatively low because the misconceptions were determined using the three-tier test. As the three-tier test measures the students' responses at three level, the rate of misconceptions are lower than the studies that used different methods (Eryılmaz, 2010). Based on the results, RFA was the most common misconception held by the pre-service science teachers.

Table 7. The pre-service science teachers' misconceptions related to the "shape of objects" category

List of Misconceptions	Three tier
M12.When two floating objects are combined as a block, the block sinks because of the increase in its mass.	4.1.b, 4.2.a, 4.3.a
M13.When two floating objects are combined as a block, the block sinks because of the increase in its volume.	4.1.b, 4.2.e, 4.3.a 4.1.b, 4.2.b, 4.3.a
M14.When two floating objects (a portion above the liquid) with the same density are combined as a block, the block hangs in the liquid because of the increase in its density.	4.1.c, 4.2.d, 4.3.a
M15.If you make a hole through the solid object, it sinks because of filled liquid through the hole.	5.1.b, 5.2.a, 5.3.a
M16.If you make a hole through the solid object (a portion above the liquid), it will be hanging in the liquid because of the decrease in its volume.	5.1.c, 5.2.b, 5.3.a
M17.If you make a hole through the solid object (a portion above the liquid), it sinks because of the increase in its density.	5.1.b, 5.2,c, 5.3.a
M18.If you make a hole through the solid object (a portion above the liquid), the floating part in the liquid increases because of the decrease in its density.	5.1.a, 5.2.d, 5.3.a
M19.If you make a hole through the solid object (a portion above the liquid), the floating part (out of water) decreases because of the decrease in mass.	5.1.a, 5.2.f, 5.3.a
M20.If you make a hole through the solid object (a portion above the liquid), the floating part (out of water) increases because of the decrease in volume.	5.1.a, 5.2.g, 5.3.a
M21.When the objects are carved from the upper part, they float because of the decrease in density.	6.1.a, 6.2.a, 6.3.a
M22.When the solid object (a portion above the liquid) are carved from the upper part, they hang in the liquid because of the decrease in mass.	6.1.c, 6.2.b, 6.3.a
M23.When the solid object (a portion above the liquid) are carved from the upper part, they sink because of the increase in density.	6.1.b, 6.2.c, 6.3.a
M24.The surface area of the carved objects increase, so does the magnitude of the buoyant force.	6.1.a, 6.2.e, 6.3.a 6.1.c, 6.2.e, 6.3.a
M25.A carved object will be filled with air, so it will float.	6.1.a, 6.2.f, 6.3.a

Category 3: RFA

The pre-service science teachers got the highest level of misconception (47.8%) in this category. M9 (57.02) was the highest level of misconception about the magnitude of the buoyant force of the hanging objects and weight, which was quite high when compared to the other misconceptions in this category. The other misconceptions with the highest levels of percentages were M59 (13.26%), M60 (10.02%), M61 (6.10%), M73 (17.24%), and M74 (12.20%). In Unal and Costu's (2005) study, they found that 26% of the 8th-grade students thought that when two objects at the same mass were put into a liquid, the buoyancy of the object hanging in the liquid is more than that of the floating object. 54% of them believed that when the density of the liquid increased, the buoyant force would increase, too. Both the pre-service science teachers and the 8th-grade students had the misconception about the buoyancy of the floating objects and the objects hanging in a liquid. The other misconception in this category was about the principle of Archimedes.

The RFA category included the questions related to the principle of Archimedes. More than 10% of the pre-service science teachers had the misconceptions of M54 (11.40%) and M55 (10.07%), which were related to the weight of the objects, the weight of the overflowing liquid, and the magnitude of the buoyant force. Unal and Costu (2005) indicated that 41% of the 8th-grade students held the misconception that the magnitude of the buoyant force of an object hanging in a liquid was more than the magnitude of the weight of the liquid overflowing. The other misconceptions related to RFA were M10 (1.32%), M11 (0.53%), M56 (0.53%), and M72 (2.91%). Especially, the pre-service science teachers confused RFA with RDA when interpreting the magnitude of the buoyant force of a floating object. Apaydin (2014) found that the 8th-grade students not only confused the concepts of RDA with RFA, which were defined in this study, but they were also not aware of the forces' impact on the floating or sinking objects. In addition, Unal and Costu (2005) pointed out that 19% of the 8th-grade students in Turkey considered the density as a force exerted on the object from the bottom. This study confirmed these findings: the pre-service science teachers held misconceptions like the 8th-grade students in Turkey.

The pre-service teachers had the highest levels of misconceptions, the lowest levels of scientific knowledge (18.1%), and quite high lack of knowledge scores (25.8%) as RFA was one of the hardest topics that the pre-service science teachers had trouble with. However, the pre-service teachers reported high lack of confidence scores (8%). This finding showed that the pre-service teachers' high level of confidence led them to have high levels of misconceptions. Contrariwise, the pre-service science teachers got high lack of confidence scores in Category 4.

Table 8. The pre-service science teachers' misconceptions related to the "RFA (relative force approach) category

List of Misconceptions	Three tier
M9. When the density of a liquid increases, the magnitude of the buoyant force that acts on a hanging object in a liquid increases.	3.1.a, 3.2.b, 3.3.a
M10.When the density of a liquid increases, the magnitude of the buoyant force that acts on a hanging object in a liquid decreases.	3.1.b, 3.2.a, 3.3.a
M11.When the pressure increases, the magnitude of the buoyant force decreases; when the pressure decreases, the magnitude of the buoyant force increases.	3.1.b,3 .2.d, 3.3.a 3.1.a, 3.2.e, 3.3. a
M54.When two different liquids overflow from the overflowing container, the one with bigger volume always weighs more.	14.1.b, 14.2.a, 14.3.a
M55.When two different liquids overflow from the overflowing container, the one with bigger density always weighs more.	14.1.a, 14.2.b, 14.3.a
M56. The weight of the liquid that is overflown by a floating object that has less submerged portion is less than the amount of the liquid that has more submerged portion in the liquid.	14.1.a, 14.2.d, 14.3.a
M59.When two objects float in the same liquid, the object that is close to the bottom will be affected by more buoyant force.	16.1.c,16.2.a,16.3.a
M60.When two objects with an equal mass float in a liquid, the magnitude of the buoyant force of the one that is closer to the bottom is less than the magnitude of the buoyant force of the other one.	16.1.a, 16.2.b, 16.3.a
M61.When two objects with equal mass float in a liquid, the magnitude of the buoyant force of the one that floats (out of water or a portion above the liquid) is more than the magnitude of the buoyant force of the one that hang in the liquid.	16.1.a,16.2.c, 16.3.a
M72.A floating object's weight is more than the buoyancy of the object.	21.1.c, 23.2.a, 23.3.a
M73.The weight of a sinking object is less than the buoyancy of the floating object.	21.1.b, 23.2.b, 23.3.a
M74.A floating object's buoyant force is greater than the object's weight.	21.1.b, 23.2.d, 23.3.a

Category 4: Surface Area and Position in Liquid

The pre-service science teachers got the highest lack of confidence scores (10.8%) in this category. This topic is not part of the science curriculum (MEB, 2006; MEB, 2013); the pre-service science teachers may not feel confident in their answers as they encountered the content for the first time. Besides, the findings showed that the pre-service science teachers used their scientific knowledge to answer the questions in this category. The pre-service teachers had quite high levels of scientific knowledge (47.6%), and they got quite high lack of knowledge scores (17.1%) and low levels of misconceptions (24.4%), compared to the other areas. In this category, the pre-service teachers had the second-lowest levels of misconceptions. The pre-service teachers' misconceptions were M26 (1.59%), M27 (4.77%), M28 (0.53%), M29 (0.53%), M30 (0.26%), M31 (4.50%), M32 (0.53%), M33 (2.38%), M34 (0.13%), and M35 (1.06%). Even though the pre-service teachers had all these misconceptions, the percentages for each misconception were low. Parker and Heywood (2000) found that 11.4% of the PGCE students had misconceptions about how an object is placed; 72.7% of them had the misconception that the buoyant force that acts on the objects' surface would affect whether an object sinks or floats. The results of a study conducted by She (2002) showed that 25% of the students had the misconception that if the contact surface area of the object with water increases, the magnitude of the buoyant force would decrease. She (2002) also determined the misconception of M35 in this study. However, only 1.06% of the pre-service science teachers held this misconception. Similar to Category 4, the pre-service science teachers had high lack of confidence scores in the soft- and hard-object topic.

Table 9. The pre-service science teachers' misconceptions related to the "Surface area and position in liquid" category

List of Misconceptions	Three tier
M26.The sharp edge of an object makes it sink.	7.1.b, 7.2.a, 7.3.a
M27. The magnitude of the buoyant force of a sharp edge of an object is less than that of a flat object.	7.1.b, 7.2.b, 7.3.a
M.28.When the flat surface of a cone-shaped floating object (out of water) is flipped horizontally, the object sinks because of the increase in the floating part in the liquid.	7.1.b, 7.2.f, 7.3.a
M.29.When the flat surface of a cone-shaped floating object (out of water) is flipped horizontally, the object floats because of the increase in the object's density.	7.1.c, 7.2.e, 7.3.a
M.30.When the flat surface of a cone-shaped floating object (out of water) is flipped horizontally, the object sinks because of the increase in the volume of sinking part.	7.1.b, 7.2.c, 7.3.a
M31.When an object is dropped off in a liquid vertically, the magnitude of the buoyant force of the object is bigger than when the object is dropped off horizontally.	8.1.a, 8.2.a, 8.3.a
M32.When an object is dropped off in a liquid vertically, the magnitude of the buoyant force of the object will be less than when the object is dropped off in horizontally.	8.1.b, 8.2.b, 8.3.a
M33.When a horizontal object is dropped off liquid vertically, the object does not sink because they apply less pressure.	8.1.a, 8.2.c, 8.3.a 8.1.c, 8.2.c, 8.3.a
M34.When a horizontal object is dropped off in a liquid vertically, the object's density decreases.	8.1.a, 8.2.e, 8.3.a 8.1.c, 8.2.e, 8.3.a
M35.When an object is dropped in water horizontally, it will sink; when the object is dropped vertically, it will float because dropping vertically increases its volume.	8.1.a, 8.2.f, 8.3.a 8.1.c, 8.2.f, 8.3.a

Category 5: Hard and Soft Objects

The pre-service science teachers' lack of confidence percentage was 10.3% in this category. Like Category 4, this topic is not a part of science curricula. Therefore, the pre-service science teachers may not feel confident when they are answering the questions because they are not familiar with the topic. The pre-service science teachers' levels of scientific knowledge were 30.6%, their lack-of-knowledge scores were 26.5%, and their levels of misconceptions were 32.4%. M36 (14.58%) and M46 (23.34%) were the two highest levels of misconceptions held by the pre-service science teachers in this category. M42 (7.42%) was the third-highest levels of misconception, which was that putting the soft objects on the top of the hard objects increases the buoyant force. The other misconceptions in Category 5 were M37 (2.38%), M38 (3.44%), M39 (1.06%), M40 (1.06%), M41 (0.53%), M43 (3.97%), M44 (3.71%), and M45 (2.12%). According to the studies, the 8th-grade students believed that the soft objects would float and the rigid objects would sink (Moore & Harrison, 2004; Yin, Tomita, & Shavelson, 2014). In addition, the misconception that the soft objects would sink was more common than the misconception that the rigid objects would sink. The pre-service science teachers had lower levels of confidence in Category 6 than Category 4 and Category 5.

Table 10. The pre-service science teachers' misconceptions related to the "Hard & soft objects" category

List of Misconceptions	Three tier
M36.Soft objects float out of water or a portion above the liquid.	9.1.a, 9.2.a, 9.3.a
M37.Soft objects would hang in a liquid.	9.1.c, 9.2.b, 9.3.a
M38.The hard objects sink because their density is higher than the soft objects.	9.1.a, 9.2.c, 9.3.a
M39.Soft objects sink because of their density.	9.1.b, 9.2.d, 9.3.a
M40.The magnitude of the soft objects' buoyant force is greater than the hard objects.	9.1.a, 9.2.f, 9.3.a 9.1.c, 9.2.f, 9.3.a
M41.The magnitude of the soft objects' pressure force is more than the hard objects' pressure force.	9.1.a, 9.2.g, 9.3.a 9.1.c, 9.2.g, 9.3.a
M42. When the soft objects are added to the floating hard objects in a closed container, the closed container sinks because the magnitude of the buoyant force decreases.	10.1.b, 10.2.a, 10.3.a
M43.When the soft objects are added to the floating hard objects in a closed container, the density of the closed container decreases, so the closed container floats.	10.1.a, 10.2.b, 10.3.a 10.1.c, 10.2.b, 10.3.a
M44.When the soft objects are added to the sinking hard objects in a closed container, the closed container floats because of the increased the magnitude of the closed container's buoyant force.	10.1.a, 10.2.c, 10.3.a 10.1.c, 10.2.c, 10.3.a
M45.When the soft objects are added to the sinking hard objects in a closed container, the volume of the closed container increases, so the object floats.	10.1.a, 10.2.d, 10.3.a 10.1.c, 10.2.d, 10.3.a
M46.When the soft objects are added to the floating hard objects in a closed container, the density of the closed container increases, so the closed container sinks.	10.1.b, 10.2.e, 10.3.a

Category 6: RDA

The pre-service teachers reported the lowest lack of confidence scores (7.2%) in this category. Almost all science curricula and the textbooks that were written based on them include a section on RDA. The students may feel comfortable when answering the RDA questions as they come across with it quite often (Yin et al, 2014).

Compared to the other categories, this category ranks in the middle in terms of levels of scientific knowledge (44.9%), lack of knowledge scores (18.2%), and levels of misconceptions (29.5%). The RDA category included nine different misconceptions. The highest levels of misconceptions that the pre-service teachers held were M57 (10.61%), M47 (6.89%), and M58 (6.89%). The other misconceptions held by less than 5% of the pre-service teachers were M48 (1.32%), M49 (6.89%), M50 (0.53%), M62 (1.06%), M63 (3.97%), and M64 (0.79%).

When making a decision about whether an object floats or sinks, compared to RFA (where students compare forces), the pre-service science teachers had fewer misconceptions about RDA (where students compare density). Even though this topic was a part of all science curricula, the pre-service science teachers had quite high levels of misconceptions. Because the students used rote memorization for RDA instead of in-depth thinking (Yin et al., 2014), they treated RDA as density and made decisions by only looking either at the object's density or the liquid's density. She (2002) claimed that 5% of the students made a decision about whether a can would float or sink based on the water's density. In addition, the students had misconceptions related to comparing the density of objects and liquids.

Unal and Costu (2005) found that 8% of the 8th-grade students had the misconception that the density of a hanging object is equal to the density of a floating object, and 6% of them held the misconception that the density of a hanging object is equal to the density of a sinking object. In the same study, 45% of the students had the misconception that the density of a floating object is more than that of a sinking object and an object hanging in a liquid. 6% of the students had the misconception that the density of an object hanging in a liquid is less than the density of the liquid.

Table 11. The pre-service science teachers' misconceptions related to the "RDA (relative density approach)" category

List of Misconceptions	Three tier
M47.When comparing two liquids with different densities, the buoyancy of the one with low density will be more.	12.1.a, 12.2.a, 12.3.a 15.1.b, 15.2.d, 15.3.a
M48.Only an object's density determines if the object floats or sinks.	12.1.c, 12.2.b, 12.3.a
M49.When compared to two liquids with different densities, the magnitude of the pressure force of one with low density will be more.	12.1.a, 12.2.d, 12.3.a 12.1.c, 12.2.d, 12.3.a
M50.The buoyancy of an object is not related to the liquid's density.	12.1.c, 12.2.e, 12.3.a
M57.The density of the liquid does not affect the buoyancy of the sinking objects.	15.1.a, 15.2.a, 15.3.a
M58. Despite the density of the liquid, the buoyant force remains the same for all sinking objects.	15.1.a, 15.2.c, 15.3.a
M62.Objects that are covered by the liquid have always the same density.	17.1.a, 17.2.c, 17.3.a
M63.The objects with low density have more buoyant force.	17.1.b, 17.2.d, 17.3.a
M64.When an object has a bigger volume, they float because they also have big density.	17.1.c, 17.2.e, 17.3.a

Category 7: Pressure Force

The pre-service science teachers had high levels of misconceptions in this category. The pre-service science teachers had the second-highest levels of misconceptions (41.4%) and the second-lowest levels of scientific knowledge (18.3%) after RFA. The pre-service science teachers' lack of knowledge level was 30.7%, and lack of confidence level was 9.3%. In this study, M51 (24.66%) was the second-highest levels of misconception held by the pre-service teacher M9. The other highest levels of misconceptions were M53 (5.03%), M65 (9.81%), and M66 (6.10%). The other misconceptions that were less than 5% were M52 (3.44%), M67 (1.06%), M68 (2.12%), M70 (1.06%), and M71 (0.26%). Besson (2004) in his study asked the students a hanging fish's pressure in the open sea and the pressure of a fish hanging in a cave at the bottom of the sea at the same elevation. 25% of the college students held the belief that the pressure in the open sea would be greater than the cave while 8% of them believed that the pressure in a cave would be greater. Considering the students' misconceptions about the pressure, the students may have misconceptions related to sinking and floating and pressure force. Besides, 12% of the students in Besson's study were aware that the buoyant force is a result of the pressure forces. These findings verify that the pressure force is a difficult subject for students.

Table 12. The pre-service science teachers' misconceptions related to the "pressure force" category

List of Misconceptions	Three tier
M51.The magnitude of the pressure forces that acts on a hanging object in a liquid would be same.	13.1.c, 13.2.a, 13.3.a 13.1.c, 13.2.e, 13.3.a 19.1.c, 19.2.a, 19.3.a 19.1.c, 19.2.d, 19.3.a
M52.The magnitude of the pressure force from the top of an object hanging in a liquid is more than the magnitude of the pressure force from the bottom.	13.1.a, 13.2.b, 13.3.a 13.1.a, 13.2.f, 13.3.a 19.1.a, 19.2.e, 19.3.a
M53.The magnitude of the pressure force from the bottom of an object hanging in a liquid is more than the magnitude of the pressure force from the top of the object because the object's weight and the object' buoyant force affect the bottom of the object.	13.1.b, 13.2.d, 13.3.a
M65.When the amount of the liquid is more on a floating object, the magnitude of the pressure force is more, too.	18.1.a, 18.2.a, 18.3.a
M66.Because of the weight of both rocks and water, the magnitude of the pressure force of a fish that is located in a cave under a sea is more than the pressure force of a fish that floats in an open sea under same depth.	18.1.b, 18.2.c, 18.3.a
M67. When two identical objects are put into liquid, the one with more liquid at the top of the object has the greater magnitude of the pressure forces than the one with less liquid at the top of the object	18.1.a, 18.2.d, 18.3.a
M68.The buoyant force does not impact the objects hanging in a liquid.	18.1.c, 18.2.e, 18.3.a
M69.Because the density of water in a cave under the sea is less than the density of water in the open sea, the magnitude of the pressure force impacts a fish in a cave undersea is less, too.	18.1.a, 18.2.f, 18.3.a
M70.The magnitude of the pressure force of a floating object acting on the upper part is more than the magnitude of the pressure force acting on the bottom part because the weight of water above is less.	19.1.a, 19.2.b, 19.3.a
M71.Because the pressure force and the weight direction are reversed, the magnitude of the pressure force acting on the bottom is less than the upper.	19.1.a, 19.2.c, 19.3.a

Conclusion

This study measured the pre-service science teachers' scientific knowledge level, lack of knowledge level, lack of confidence level, and misconception level related to floating and sinking. Compared to the other studies in the literature that used different methods, the ratio of the misconceptions was relatively low because the three-tier misconception test was able to differentiate misconceptions by considering the students' level of scientific knowledge, lack of knowledge scores, and lack of confidence scores. The students' low scores on the third tier distinguished the students' lack of knowledge from their misconceptions (see Table 4). In addition, the "relative force approach" was defined for the first time in this study.

Relative force approach is the type of topic about which the majority of the teachers have misconceptions. The pre-service teachers had high levels of misconceptions, high lack of knowledge scores, and low levels of scientific knowledge about the buoyancy of an object. The most striking finding in this study was that the majority of the pre-service science teachers did not know that the magnitude of the buoyant force of a floating object was equal to the object's magnitude of weight. A similar situation is also true for the relationships between the pressure force, the buoyant force, and sinking and floating.

The pre-service science teachers' second-highest level of misconception was about the relationship between the buoyant force and pressure force. In addition, the pre-service science teachers had the second-lowest levels of scientific knowledge in the pressure force topic. The scientific knowledge missed by the pre-service science teachers was that an object would float if the buoyancy force exerted on it by the fluid balanced its weight. This finding showed that the pre-service science teachers either did not know the relationship between the buoyant force and the pressure force or used faulty reasoning. Based on these findings, when teaching the floating-sinking topic, the teachers should place a special emphasis on RFA and pressure force. The findings related to RDA were also quite important.

Even though RDA was a part of science curricula and textbooks, the pre-service teachers used rote memorization to answer the questions in this study. The pre-service science teachers had the tendency to use only the liquid's density instead of comparing the liquid and objects' densities. Besides, the majority of the pre-service science teachers in this study had the misconception of using RDA as density. Although RDA was included in many resources (i.e., textbooks and research), during the development of the three-tier test, the factor analysis, which was conducted using SPSS, revealed the objects' shape, their hardness or softness, and the drop-off position as separate factors. In this study, the pre-service science teachers, similar to the RDA category, had faulty reasoning. On the basis of this faulty reasoning, the pre-service teachers did not fully master RDA.

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