Problematic issue for students: Does it sink or float?

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Contents

Abstract

The aim of this study is to investigate grade-eight students' conceptions of sinking and floating. Firstly, semi-structured interviews were conducted with 12 students to determine students' difficulties and to develop a multiple-choice diagnostic test. In designing the content of the interview questions, grade-eight science curriculum, research on students' understanding of the subject, and primary school science teachers' views were taken into account. A diagnostic MCQ test was developed and administered to 108 students to determine the extent of the misconceptions revealed from the students' responses in the interviews. From the data, it was found that primary school students' misconceptions on sinking and floating, determined by earlier studies, were also held by grade-eight students in this study. In this paper, we have discussed the reasons that may lead to misconceptions and what should be done as science educators or teachers. Moreover, a sample activity, designed to remediate the misconception that mass or weight determines whether an object sinks or floats, was presented for researchers and teachers' use at the end of the paper.

Key Words: Science Education, Misconceptions, Sinking and Floating, Science Activities

Introduction

Much research has indicated that students enter their classrooms with ideas about science that have been influenced by their prior experiences, textbooks, teachers' explanations, or everyday language (Osborne, 1982; Nakleh, 1992; Fleer, 1999; Palmer, 2001; Coştu & Ayas, 2005; Çalık & Ayas, 2005). According to the constructivist view, students often construct their own knowledge and theories about how the natural world works. Therefore, their construction of knowledge or theories may sometimes be contrary to those of scientists (Osborne and Wittrock, 1983; Bodner, 1986; Geelan, 1995). Such views or conceptions have been called misconceptions, preconceptions, alternative frameworks, naïve conceptions or common sense conceptions (Driver & Erickson, 1983; Treagust, 1988; Nakleh, 1992).

Over the last two decades, educators have shown great interest in identifying students' misconceptions about various science phenomena, either prior to or following an instruction. One of the areas that science education and cognitive development research have studied is floatation. Students' views on floatation were first reported by Inhelder and Piaget (1958). They revealed that because the formulation of floatation rules requires advanced reasoning skills, it may not be understood by students and it is possible for students to have misunderstandings. Rowell and Dawson (1977a, 1977b, 1981) carried out studies related to the results of Piaget's work to elicit students' understanding and help them improve their understanding of the phenomenon of floatation. In addition, there are numerous studies reporting students' misconceptions and investigating the effectiveness of alternative teaching models for floatation and related concepts (Simington, 1983; Biddulph and Osborne, 1984; Smith, Carey, & Wiser, 1985; Halford, Brown, & Thompson, 1986; Smith, Snir & Grosslight, 1992; Hewson & Hewson, 1993; Kariotogloy, Koumaras, & Psillos, 1993).

Although there have been many studies on students' conceptions of sinking and floating in the international science literature, few studies are available in Turkey. Gürdal and Macaroğlu (1997) investigated fifth grade students' conceptions of sinking, floating and the Archimedes principle. They also discussed how to teach these phenomena by taking into account primary school students' cognitive skills. Their study revealed that as students did not give correct response to any test item, they couldn't construct scientific understanding about these concepts. Macaroğlu and Şentürk (2001) also carried out a study to elicit fourth grade students' understanding of the floatation. They found that students could not identify whether a material sank or floated, because of their non-scientific rules for sinking and floating.

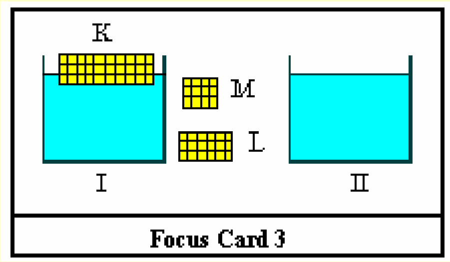
Although there are some studies investigating primary school students' conceptions of sinking and floating, similar studies on grade-eight students' conceptions have not been studied so far in Turkey. As the Archimedes principle and other related concepts are first introduced to students at the seventh grade, one important question should be asked whether students still hold their earlier misconceptions or alternative ideas even after formal instruction in class. Therefore, this study aimed to investigate Turkish grade-eight students' conceptions, understandings and misunderstandings of sinking and floating concepts.

Methodology

Instruments

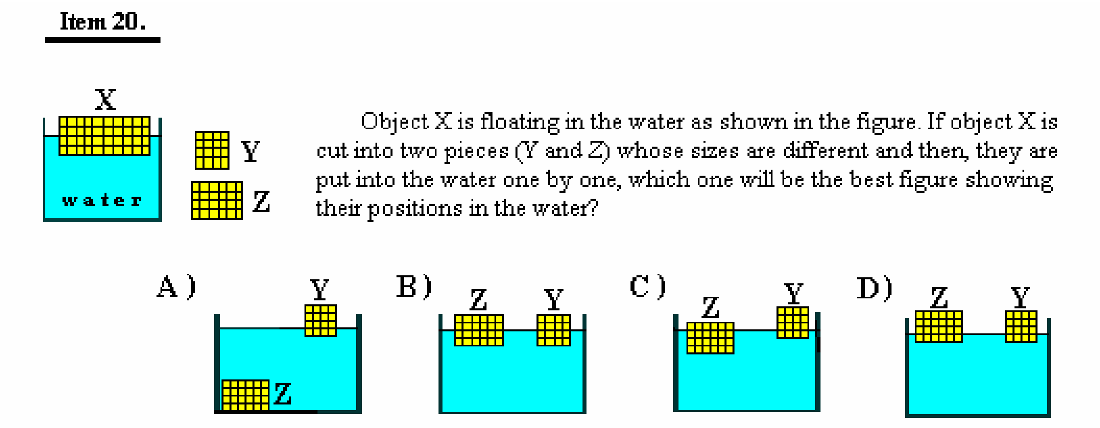
In this study, semi-structured interviews and a Sinking and Floating Conceptual Test (SFCT) comprising 20 multiple-choice questions were developed and used to collect data.

The content of the semi-structured interview protocol was designed by taking into consideration the propositional statements given in the curriculum, the results of earlier studies and teachers' comments. The aim of the semi structured interviews was to reveal misconceptions held by the students. Therefore, in the semi structured interview, students were first given nine focus cards and asked to respond the questions on them. When explaining their ideas, their understanding was investigated more deeply by means of follow-up questions. One of the focus cards and its focus question used in the study is presented below:



Object K is floating in a liquid as shown in the first figure. If object K is divided into two pieces (M and L) whose sizes are different from each other and then, they are put into the same liquid, what do you predict will be their positions? Will they sink or float? Please explain your reasons.

To determine how widespread the misconceptions revealed from the students' responses in the interviews was, a multiple-choice diagnostic test (SFCT) was developed and administered. Each question had four choices which included the correct answer and three misconceptions revealed from the interviews, a literature review or teachers' views. One of the test items is presented below. Content validity for the test instrument was ensured by basing the test's construction on a previously validated list of propositions that represented primary science curriculum and reviews by three science educators and three experienced primary school science teachers. Cronbach alpha-reliability coefficient was measured 0.74 for the test by means of SPSS 10 TM.



Sample

This study was conducted during the spring term of 2004. Semi structured interviews were conducted with 12 grade-eight students who participated in these sessions voluntarily and then, SFCT was administered to a total of 108 grade-eight students from four different classes of science lessons instructed by two different teachers from a public primary school in Trabzon.

Process

The methodology of the research is summarized in Figure 1.

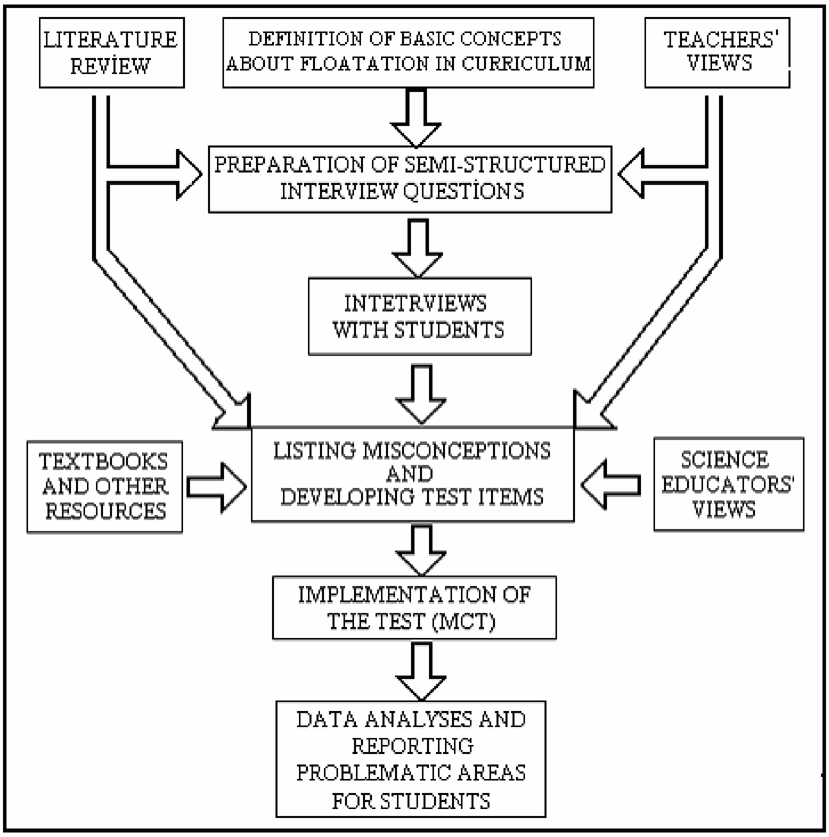


Figure 1. The research methodology: stages of the study

To define concept boundaries related to sinking and floating, the primary science curriculum was examined. Before attempting to identify students' misconceptions on sinking and floating, problematic areas reported in related literature were defined. Furthermore, primary school science teachers were interviewed for identifying their students' difficulties about these concepts. By considering the propositional statements in the curriculum, the results from earlier studies and the teachers' comments, focus cards and the content of semi-structured interview protocol were organized. All interviews were audio-taped. After the interviews, they were fully transcribed and analyzed to list students' misconceptions on the phenomena under investigation.

In the second stage, a multiple-choice diagnostic test (SFCT) was developed. During this process, suggestions from three science educators and three primary science teachers were taken into account. In addition to this, science textbooks and other useful resources were also used. After the administration of SFCT, the students' responses were analyzed. In the analyses process, items of the instrument were evaluated for both correct and incorrect responses. The frequencies and percentages of choices that were given by the students as correct answers for the questions were calculated for each of the test items. The results of this process were given in Table 1. And then, students' misconceptions and the percentages of students who had these misconceptions for each of the test items were defined and presented in Table 2. Analyses of incorrect responses selected by the students provided data on students' misconceptions related to items.

The choices of some test items include more than one misconception. Simultaneously, a misconception was used in more than one choice of the same question. When calculating the percentages of students who had this misconception, we considered the total of the students whose choices included that misconception. Therefore, in grouping misconceptions, the choices of the test items were used more than once in the same questions.

Results and discussion

The frequencies and percentages of the students' responses to SFCT items are represented in Table 1.

Table 1. The frequencies and the percentages of the students' responses to SFCT (n=108)

Item	Correct choice	A		B		C		D		No response	
		f	%	*f*	%	*f*	%	*f*	%	*f*	%
1	**D**	-	-	-	-	10	9	**98**	**91**	-	-
2	**C**	16	15	7	66	**16**	**15**	4	4	-	-
3	**A**	**59**	**55**	10	9	18	17	21	19	-	-

4	**A**	**44**	**41**	49	45	6	6	9	8	-	-
5	**B**	-	-	**57**	**53**	7	6	44	41	-	-
6	**B**	20	19	**48**	**44**	12	11	28	26	-	-
7	**D**	43	40	14	13	8	7	**43**	**40**	-	-
8	**C**	-	-	12	11	**64**	**59**	32	30	-	-
9	**A**	**38**	**35**	32	30	21	19	17	16	-	-
10	**A**	**44**	**41**	27	25	8	7	25	23	4	4
11	**D**	17	16	38	35	34	31	**19**	**18**	-	-
12	**B**	5	5	**67**	**62**	25	23	11	10	-	-
13	**C**	33	31	25	23	**36**	**33**	12	11	2	2
14	**D**	39	36	27	25	12	11	**30**	**28**	-	-
15	**B**	17	16	**15**	**14**	42	39	34	31	-	-
16	**C**	16	15	17	16	**54**	**50**	14	13	7	6
17	**A**	**34**	**31**	19	18	45	42	10	9	-	-
18	**A**	**67**	**62**	14	13	-	-	24	22	3	3
19	**D**	20	19	12	11	13	12	**63**	**58**	-	-
20	**B**	20	19	**51**	**47**	35	32	2	2	-	-

* The frequencies and the percentages of student choosing the correct answer are shown in bold.

From the analyses of the students' responses to the test items 2, 7, 15 and 20, it is clear that most of the students had the misconception that weight or mass determines whether an object sinks or floats. The percentages of the students who had this misconception were in the range of 40-66% for different items (see Table 2). It is possible to conclude that students probably construct some non-scientific rules guided by their limited daily life experiences. This misconception may stem from both students' lack of knowledge and their inaccurate generalization.

Another misconception revealed in the study was that the volume of an object determines whether it will sink or float (see items 1, 2, 15 and 20 in Table 2). The percentages of the students whose choice includes this misconception were in the range of 19-55% for different items. This misconception may also result from students' lack of the concept of density and their over generalization of experiences in daily life.

The majority of the students think that the volume of a liquid in a container determines whether an object sinks or floats. This misconception was revealed from the students' responses to items 9, 16 and 17. The percentage of the students whose choice on those items includes this misconception, were 35%, 50% and 69% respectively. According to the students who had this misconception, when the level of the liquid in a container is increased, a sinking object will float and the volume of its sinking part will decrease. This misconception may also stem from students' previous experiences. Although a child could not float a toy boat in a bowl because of its height, he could float it in a pool. Therefore, students erroneously conclude that the volume of a liquid in a container determines whether an object sinks or floats.

Table 2. The percentage of students who gave the correct response and those who had misconceptions for each item

Item No	Students Giving Correct Responses (%)	Propositional Statements (Content of Test Items)	Students' Misconceptions and Difficulties
1	91	Deciding whether an object sinks or floats by regarding its position in a liquid	*Objects which are hanging on in a liquid are named as sinking objects because they are covered by the liquid (9%)
2	15	Identification of the factors influencing whether an object sinks or floats in a liquid	*Volume determines if an object will sink or float (19%) *Weight determines if an object will sink or float (66%) *The volume of the liquid determines if an object will sink or float (70%)
3	55	Description of the concept of density	*Density is the weight of an object (9%) *Density is the weight of an object in a liquid (17%) *Density is the force that pushes an object up (19%)
4	41	Comparison of different objects' densities by regarding their positions in a liquid	*The density of an object hanging in a liquid is equal to that of a floating object (8%) *The density of an object hanging in a liquid is equal to the density of a sinking object (6%) *The density of a floating object is more than that of a sinking object and an object hanging in a liquid (45%)
5	53	Making a connection between the buoyancy	*The density of an object hanging in a liquid is less than the density of the liquid (6%)

		which affects an object and the weight of the liquid overflowing	*The buoyancy of an object which is hanging in a liquid is more than the weight of the liquid overflowing (41%)
6	44	Comparison of the densities of different objects, whose masses are the same but volumes and buoyancies are different from each other	*The density of an object hanging in a liquid is equal to that of a floating object (19%) *When two objects at the same mass are put into a liquid, the buoyancy on the object hanging in the liquid is more than that on floating object (26%)
7	40	Understanding the reasons why objects may have different positions in a liquid, although they are made of the same matter and their masses and densities are equal	*The mass of an object determines whether it will sink or float (40%) *When two objects of the same mass are put into a liquid, a geometrical shaped one will float, but the other having no geometrical shape will sink (13%)
8	59	Determination of the processes to make a floating object sink	*When the container is shaken, the floating object will sink (11%) *If you make a hole through the object, it will sink (41%)
9	35	Comprehension of the reason why an object may have different positions in two different liquids	*Because the volume of the liquid affects buoyancy, the volume of the sinking part of the objects in a container filled with a little liquid is more than another with more liquid (46%) *Because the volume of the liquid in the container is little and insufficient, the volume of the sinking part of an object is more than that in another container (35%)
10	41	Calculation and comparison of the buoyancies of objects whose weight and volume of the sinking parts are the same	*The greater the floating part (out of water) of an object, the greater its buoyancy (30%) *When comparing buoyancies affecting three objects one of which sinks, another floats and the other hangs in a liquid, the buoyancy of the sinking object is more than the others (25%) *Not making the connection between the volume of sinking part of an object and its buoyancy (59%)
11	18	Putting the solutions (liquids) in order, according to their densities by regarding of solvent and solute quantities	*Making wrong connections between the solvent and solute quantities of solutions and their densities (82%)
12	62	Identification and comparison of the densities of different liquids, which don't mix with each other, by regarding their positions	* Making wrong connections between the densities of different liquids and their positions in a container (38%)

		in a container	
13	33	Interpretation of how the volume of the sinking part of an object and its buoyancy changes when a liquid which is less dense is poured into the container filled with a more dense liquid	*When the densities of the liquid changes, the buoyancy of an object changes too (54%) *The volume of the sinking part of an object becomes less when a liquid which is less dense is poured into the container filled with a more dense liquid (34%)
14	28	Interpretation of how the water level in a container and the positions of the objects change when two objects, one of which is put on top of the other, and then put into the liquid one by one	*When two objects, one of which is put on the top of the other, is put into the liquid one by one, the position of the object which is beneath does not change (47%) *When two objects, one of which is put on the top of the other, are then put into the liquid one by one, the water level in the container does not change (36%)
15	14	Understanding the reasons why objects may have different positions in a liquid	*Weight determines if an object will sink or float (47%) *Volume determines if an object will sink or float (55%)
16	50	Understanding that the volume of a liquid in a container does not affect the position of the object in the liquid and its floatation	*When the volume of a liquid in a container is increased, the volume of the sinking part of an object will decrease (15%) *When the volume of a liquid in a container is increased, the volume of the sinking part of an object will increase, too (19%) * When the volume of a liquid in a container is decreased, a floating object will sink (13%)
17	31	Understanding the reasons why objects at the same volume may have different positions in a liquid	*The volume of a liquid in a container determines whether an object sinks or floats (69%) *Objects which have a hole will sink in the course of time because the liquid fills the hole (51%)
18	62	Interpretation of the last positions of two objects in a liquid when they are tied together by regarding their earlier positions in the liquid	*No interpretation of the position of objects, which are tied to each other, in a liquid by considering their earlier positions in the liquid (38%)
19	58	Interpretation of the densities of new objects which are formed by sticking an object on another object with regard to their positions in a liquid	*Objects which are covered by the liquid have always the same density (23%)

20	47	Identification of the positions of the pieces of the object in the liquid when a floating object is cut into parts of different sizes	*When a floating object is cut into two parts, the volume of the smaller sinking part will become less (53%) *When a floating object is cut into two parts, the bigger piece will sink or the volume of the sinking part will increase (51%)

*In some of the test items (e.g. items 2, 8, 9, 10), total percentages may not be %100 because two or more choices include the same misconception. Therefore, in grouping misconceptions and calculating their percentages, the choices of the test items were used more than once.

It was found that students had difficulties in understanding the concept of density. It was very clear from the students' responses to test items 3, 11, 12 and 14 (see Table 2) that the students could not understand it and thus, had some misconceptions. For example, more than 38% of students had difficulties in describing density and also definitions of densities of different objects. In addition to this, some students did not consider the density of the liquid when determining whether an object would sink or float (see items 8, 9 and 13 in Table 2). The percentages of the students whose choices were wrong for these items were 41%, 65% and 65% respectively.

Students' responses to items 4, 6 and 19 showed that they could not compare the density of different objects by regarding their positions in a liquid (see Table 2). The percentages of the students whose choices include misconceptions in this area were 59%, 56% and 42% respectively. The most common misconception held by the students in this area was that the density of an object hanging in a liquid is equal to that of a floating object or a sinking object. Moreover, some students made an incorrect connection between densities of the objects and their position in the liquid.

Another misconception revealed from the students' responses to the test items 3, 5, 6, 9 and 10 was that the students did not have a sound understanding of buoyancy. For example some students reported that the buoyancy of an object hanging in a liquid is more than the weight of the liquid overflowing. In addition, some students had the misconception that when two objects are put into a liquid, the buoyancy of the object hanging in the liquid is more than that of the floating object. In other words, students cannot make the connection between the volume of the sinking part of an object and its buoyancy.

It was revealed from the students' responses to test items 8 and 17 that found that some students believe that objects with holes will sink in the course of time, because the liquid fills the hole. This misconception was revealed from the students' responses to items 8 and 17 (41% and 51% respectively).

Students' responses to item 20 showed that some students could not identify the positions of the pieces in a liquid when a floating object is cut into parts of different size. Some students (53%) indicated that when a floating object is cut into two parts, the volume of the sinking part of the smaller piece will become less. Furthermore, 51% of them also reported that when a floating object is cut into two parts, the bigger piece will sink or the volume of the sinking part will increase.

Conclusion and implications

Students are first introduced to the Archimedes principle, buoyancy and other related concepts in the seventh grade. These results show that despite the formal instruction, Turkish eighth grade students still have difficulties in understanding sinking and floating, and have misconceptions about the phenomena as reported in the earlier studies involving primary school students.

Students cannot identify the factors influencing whether an object sinks or floats in a liquid. When deciding whether an object sinks or floats, they consider their mass, or volume instead of density. They also consider irrelevant factors such as whether it has a hole, its size or the volume of the liquid. When these misconceptions about sinking and floating are examined, it can be concluded that the reasons behind students' misconceptions are their construction of rules or theories by regarding their experiences in daily life, lack of knowledge and overgeneralization.

Results of the study showed that there are eight problematic areas where students commonly have difficulties and misconceptions. These are:

- Effect of the mass of an object on floatation
- Determination of the density of an object
- Effect of the density of an object on floatation
- Effect of the density of the liquid on floatation
- Effect of the volume of the liquid on floatation
- Calculation of the buoyancy applied by the liquid on an object
- Effect of a hole which is on the object on its floatation

- Effect of the size of an object on its floatation

The related literature has a range of reports that indicate students' misconceptions (Inhelder and Piaget, 1958; Smith, Carey, & Wiser, 1985; Smith, Snir & Grosslight, 1992; Kariotogloy, Koumaras, & Psillos, 1993; Macaroğlu and Şentürk, 2001). It is well known that misconceptions are pervasive, stable and often resistant to change through traditionally organized classroom instruction, and often held by students even after the formal science instruction (Driver and Erickson, 1983). Therefore, studies on misconceptions are important in revealing students' difficulties in conceptualizing new scientific knowledge and suggesting remediation ways. Teachers need to be alerted to students' difficulties in conceptualizing scientific knowledge and suggestions need to be made to them regarding more effective strategies for improving classroom instruction. Therefore, the results of this study are particularly significant especially for future studies that would suggest teaching strategies, including activities, to enable students to construct scientific understanding about the eight problematic areas reported above.

Considering the results, such suggestions also can be made:

- Before teaching the phenomena; concepts of mass, weight, volume and the concept of density and their differences should be clarified.
- When teaching sinking and floating, both factors that determine whether an object will sink or float and those that do not should be emphasized in the class.
- By considering that some students' cognitive skills may not develop in the expected time and they may not understand abstract concept and theories, this phenomenon should be taught in classes or labs through concrete activities.
- This study is the first step of an extensive effort whose aims are to identify students' misconceptions on floatation, to develop laboratory activities for remediation and to investigate effectiveness of this teaching strategy. In this effort, we developed eight activities to enhance students' understanding of sinking and floating and to remedy students' misconceptions about eight problematic areas reported in the study. One of the activities related to the misconception that mass or weight determines whether an object will sink or float is presented for science teachers, curriculum developers, researchers and the other science educators (Appendix 1).

- It is known that there are alternative strategies or tools for conceptual change such as concept mapping, computer aided instruction and conceptual change texts. Besides concrete laboratory activities, other effective teaching models including other strategies or tools should be developed and presented to teachers for their practice.

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Appendix 1

The lab activity to remedy the misconception that mass or weight determines whether an object will sink or float.

SINKING AND FLOATING

Activity 1. Effect of the mass of an object on floatation

Materials for Each Group:
- Electronic scale
- A large container
- A candle
- A marble
- A rubber ball

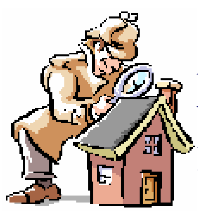
First Step: Weigh the masses of the candle, the marble and the rubber ball by using an electronic scale. Write down the masses of the objects in the table.

Objects	Weights
The candle	
The marble	
The rubber ball	

Predict which of the objects will sink or float. Please write down your prediction. Why do you think this? Please explain your reasons.

Second Step: Fill almost half of the container with water. Afterwards, put the candle, the marble and the rubber ball into the container gently. What did you observe? Which sank or floated? Please write down your observations.

Were your earlier predictions correct? Compare the differences between the predictions about which objects will sink or float and the result of the experiments. If there is a difference between your predictions and the results of experiment, what do you think your earlier predictions were incorrect?



Summarization Question (Discuss with members of your group): After the experiments, do you think that mass or weight determines whether an object will sink or float? Do heavier objects always sink, but lighter objects float?