Effectiveness of Direct Instruction and Guided Discovery Teaching Methods for Facilitating Young Children's Concepts

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Abstract

Researchers studying high school and college education have found that students learn more when they are led through activities that allow them to discover concepts for themselves (guided discovery) than from the presentation of concepts by an instructor (direct instruction). In order to examine the effects of these styles of teaching with younger children, this study compares how much preschool and kindergarten students learn about objects sinking and floating in water when they are taught using these two methods in two different orders. After a pretest assessment, thirty-five students from Carnegie Mellon University's Children's School were taught lessons via one of these methods and then tested again to compare the impact of each method on their correctness in predicting and explaining the sinking and floating of objects. Then each of the children was taught the same concepts using the teaching method by which they had not previously received instruction and a third assessment was conducted. In this study, challenges of keeping control variables constant in real teaching settings were found, including maintaining both the time of instruction and the number of times students were exposed to concepts in guided discovery and direct instruction lessons. Both learning effects and developmental differences were evident in this study, but there was no overall difference in students' gain scores based on the experimental manipulation. The preschool students did gain more than the kindergarten students on correctly predicting sinking and floating when the direct instruction lessons were presented before the guided discovery lessons but not when the order of lessons was reversed.

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Guided discovery is a teaching method where the teacher guides students through open ended activities in order to encourage them to discover concepts for themselves. When teachers give the students the information that they want to learn via methods such as lecture or teacher led demonstrations, they are using a direct instruction method of teaching. Both of these types of teaching methods are commonly used in practice, so it is important to understand their effectiveness in teaching concepts.

Studies have been performed to compare these teaching methods with college age students, but nothing has been published about studying this method with preschool age children. In a college level math course, it was found that the subjects who were taught the concepts by a guided discovery approach performed significantly better on the exams testing these concepts than students who learned the same concepts from the teacher directed lecture (Clute, 1984). It has also been found that students learned science concepts better via guided discovery rather than teacher based instruction (Yadav, 1984). This study had methodological problems because the different types of lessons were taught by different teachers without maintaining the same content, so the students may not been presented with the same information or learned the same concepts in both of the conditions.

Another drawback to the current literature is that experiments have not been performed testing whether guided discovery or direct instruction methods are effective for teaching young children. There could be several different factors that could cause one of these methods to be more effective in young children. It has been found that 7 to 10 year old children are not able to systematically study situations or make valid conclusions about scientific reasoning when they are not given direct instruction about designing experiments (Chen and Klahr, 1999). Young children might not have the cognitive facilities to abstract concepts as necessary with guided discovery instruction; they might need an instructor to point out the concepts. This situation could impair their ability to derive principles from experiments that they are designing and lead young children to learn more about concepts by direct instruction over guided discovery. It is also possible that young children do not have the attention necessary to learn from teacher instruction, which could lead to better results in the guided discovery method over the direct instruction method. This pattern of findings would mean that young children would be similar to adults in learning more via guided discovery as compared to direct instruction. It is one of the purposes of this experiment to determine whether students learn about the properties of objects that cause them to sink or float in water better when they are taught by either direct instruction or guided discovery.

The current literature also does not consider teachers using a combination of methods of guided discovery and direct instruction. Looking at how these methods interact is important because in school settings teachers often use a combination of teaching methods. It is possible that when the students are first allowed to discover concepts themselves about the properties of objects that cause them to sink or float in water, they could form a mental framework that would allow them to assimilate the information that they later received from the teacher's instruction. It is also possible that after the children learn the information from an instructor they know what concepts to look for when they are presented with guided discovery, which would allow them to learn more from this order of instruction. The second purpose of this study is aimed at determining whether students learn information better if they are first taught by direct instruction and then taught the same concepts by guided discovery or if they learn better via guided discovery followed by a direct instruction teaching the same concepts.

Sinking and Floating Concepts

Objects will sink or float based on whether they are more or less dense than water respectively. Density is defined as the ratio of weight of an object per unit volume of space it occupies. A decision tree, shown in Figure 1, maps one way to determine if an object will sink or float in water. Since density is too difficult a concept to teach a group of young children, two concepts of density were used in this study. The first branch in Figure 1 says that objects that are heavier than the water will sink and objects that are lighter than the water will float. This concept was taught to the children using demonstration objects that were approximately the same size and all with a spherical shape (heavy or light objects). From the second and third branches of Figure 1, heavy sealed cup-shaped objects will sink or float based on how they are oriented when they are placed into the water. These objects will sink when they are filled with water but float when they are oriented with the cupped end downward. A real life example of such an object would be a metal ship. If it were filled with water, it would sink; but while the outside of the ship is sealed and it is filled with air, it will float. Objects were used that could be made to float or sink depending on the orientation of how the students put them in the water (cupped-both objects). In order to teach children that there were some cup-shaped objects that were too light to sink even when they were filled with water, some cup-shaped objects were used that would always float (cupped-float objects). These objects would be categorized as lighter than the water from the first branch on the decision tree in Figure 1, which would mean that they should float.

Experimental Design

A diagram of the experimental design in shown in Figure 2. Students were first given pretests in order to assess how accurately they were able to predict and how well they could explain whether objects would sink or float before they were exposed to the lessons. Four groups of students, two consisting of four preschool children and two consisting of five kindergarten children, were instructed for two lessons by a Children's School teacher using the guided discovery method of teaching. The remaining groups of children, which were two groups with four preschool students and two groups of five kindergarten children, were taught two lessons by the same teacher by the direct instruction teaching method.

Within each of these groups, the students received two lessons using the same style of teaching. The first lesson in both sessions concerned teaching students that objects that are heavier than water sink while objects that are lighter than water float using the heavy and light objects. The second lesson in both sessions focused on learning about how some objects that were put into the water could be made to sink or float (cupped-both objects) and that some objects were too light to sink regardless of how they were put into the water (cupped-float objects). After each of the groups were taught two lessons with one of the teaching methods, the students were assessed using a midtest. This allowed us to compare what the students learned about accurately making predictions and explaining what they saw about sinking and floating when they were taught by either the direct instruction or the guided discovery method of teaching. Following the midtest, the students were taught two lessons using the teaching method to which they had not been previously exposed. These lessons were designed to teach the same concepts as the first set of lessons. These lessons were structured the same as the first set of lessons, but they used objects that the students had not seen in their previous set of lessons in order to try to keep the students engaged in the activity. Following all of the lessons, the students were administered a posttest in order to assess what they had learned following the combined order of instruction. This point of the design allowed us to compare whether the students were better able to predict and explain sinking and floating depending on the order that they were presented the lessons of guided discovery and direct instruction in order to learn more about the effects of combining these styles of teaching.

Method

Participants

Students

The participants are all students at the Children's School, which is an integral part of the Psychology Department at Carnegie Mellon University. The entire class of 20 kindergarten students participated in this study. The kindergarteners were initially randomly assigned to one of four groups such that two of the groups were taught by the guided discovery method first followed by direct instruction and two of the groups were taught by the direct instruction teaching method first and then by guided discovery. There were five kindergarten students in each of the lesson groups.

Having a group that was disruptive would impair the learning of all of the students in the group, so having groups that were less likely to have this issue was determined to be more important than having random assignment of the participants. Since the teachers were familiar with how all of the students interacted, they looked at the groups of students after the random assignment to see if they thought there would be any combination of students that might display behavior problems. None of the teachers were informed which of the groups would be in which experimental condition. In the kindergarten class, there were two male students who the teacher switched due to this issue. One student was in the group that was scheduled to receive direct instruction followed by guided discovery and the other student had been assigned to the guided discovery method first followed by the direct instruction method.

All fourteen four year olds and two of the three year old students who were in the extended morning preschool class participated in this study. The three year old students participated in order to make the number of students in the preschool group of sufficient size. The three year old children were chosen because they were students the teacher felt would be willing to participate in this extensive of a study. The three and four year old students will analyzed together as the preschool group of participants. The sixteen preschool children were each originally randomly assigned to be in one of four groups, with two groups designated to receive direct instruction first followed by guided discovery and two groups to be taught by guided discovery first and then direct instruction. There were four preschool children in each of the lesson groups.

As with the kindergarten children, the preschool teachers examined the randomly assigned groups to see if they felt that there would be any disruptive combinations. The teachers chose to switch the assignment of two of the male participants who were both in the guided discovery condition first followed by the direct instruction teaching method.

Teacher

A preschool teacher from the Children's School collaborated with the experimenter to teach all of the lessons in this study. This teacher has 18 years experience teaching preschool and elementary age children. She was one of the teachers for the extended morning preschool class from which the preschool students in this study were drawn. The teacher was also familiar with many of the kindergarten students from the prior year's preschool class and other visits to their current classroom. This arrangement allowed the lessons to be taught by an experienced teacher who was also familiar with the students in the study. All subsequent references to the teacher refer to this individual, while references to the experimenter indicate the author of this thesis.

Materials

In all parts of the study, including the lessons and assessments, shoebox style green bins of water were used for the sinking and floating of objects. All of the lessons and assessments were video taped on a VHS recorder, and the child's responses during the assessments was noted on a recording sheet by the experimenter. A sample of the recording sheet for Assessment Kit L can be seen in Appendix A. The recording sheets for the Assessment Kits M and N were analogous to Assessment Kit L. Of the objects that were used (heavy, light, cupped-both, and cupped-float), there were some objects that the students saw only in the assessments, some that they saw only in the lessons, and some that they saw in both. This distinction allowed for comparing how well students were able to perform on the assessments with objects that they had and had not previously seen in lessons, showing how well they were able to transfer their knowledge. The objects that were used in the heavy/light lessons are listed in Table 1, while the objects that were used in the cup-shaped lessons are given in Table 2. Within the heavy/light lesson, the objects were randomly assigned to either Lesson Kit A or B, such that there would be three heavy objects and three light objects in each of these lesson kits. The objects for the cup-shaped lessons were randomly assigned to either kit C or D such that there was one cupped-float object and five cupped-both objects. The five cupped-both objects in each lesson kit include one paper-like object (foil or wax paper), one malleable object (putty or clay), one bottle, one lid, and one closed object (jar or easter egg). The kits were designed to show the students the variety of objects that were cup-shaped or could be made into cup-shaped objects.

Within each of the lessons, the objects were originally randomly assigned to the order of presentation. This order was used in all instances except for the cup-shaped lesson kit C. In this case, the plastic lid was placed first so that the teacher would have an obvious example of an object that was cup-shaped and could be made to sink or float. Some of the objects in the chart, namely the clay, foil, wax paper, and putty are all able to be made into cup-shaped objects so that they can float, so they are not as obvious as the other objects. The order of the presentation of the objects remained consistent across all of the lessons; that order is listed in Tables 1 and 2.

Table 1

Objects in Heavy/Light Lesson Kits

Lesson Kit A	Object Type	Lesson Kit B	Object Type
Hard Boiled Egg*	Heavy	Balloon*	Light
Puff Ball*	Light	Candle*	Light
Sponge*	Light	Plastic Apple Ornament*	Light
Koch Ball*	Heavy	Rock*	Heavy
Carrot*	Heavy	Marble*	Heavy
Wooden Bead*	Light	Bell*	Heavy

*Indicates an object that was used in both the assessments and the lessons.

Table 2

Objects in Cup-Shaped Lesson Kits

Lesson Kit C	Object Type	Lesson Kit D	Object Type
Plastic Lid	Cupped-Both	Jar Lid	Cupped-Both
Clay	Cupped-Both	Wax Paper	Cupped-Both
Jar #2	Cupped-Both	Bottle #2	Cupped-Both
Plasitc Film Container*	Cupped-Float	Plastic Cup*	Cupped-Float
Bottle*	Cupped-Both	Putty*	Cupped-Both
Foil*	Cupped-Both	Easter Egg*	Cupped-Both

*Indicates an object that was used in both the assessments and the lessons.

The objects from the three different assessments are shown in Table 3. Each of the objects was randomly assigned to each of the assessment kits, subject to the constraint that there were four heavy objects, four light objects, two cupped-both objects and two cupped-float objects. For each assessment kit, the order of presentation was consistent across all groups of children and is the order that the objects are listed in Table 3. The students were each randomly assigned to one of three orders of presentation of the assessment kits L-M-N, M-N-L, or N-L-M representing the assessment received for the pretest-midtest-posttest series.

Table 3

Objects and Their Type in Assessment Kits

Assessment Kit L	Object Type	Assessment Kit M	Object Type
Olive	Heavy	Balloon*	Light
Rubber Basketball	Light	Bell*	Heavy
Marble*	Heavy	Bottle #1*	Cupped-Both
Jar #1	Cupped-Both	Carrot*	Heavy
Styrofoam Ball	Light	Cheese	Heavy
Plastic Cup*	Cupped-Float	Jack Ball	Light
Sponge*	Light	Ping-pong Ball	Light
Metal Ball	Heavy	Potato	Heavy
Candle*	Light	Puff Ball*	Light
Copy Paper	Cupped-Both	Putty*	Cupped-Both
Kooch Ball*	Heavy	Styrofoam Cup*	Cupped-Float

Assessment Kit N	Object Type
Cork	Float
Easter Egg*	Cupped-Both
Foil*	Cupped-Both
Golf Ball	Heavy
Grape	Heavy
Hard Boiled Egg*	Heavy
Nut	Light
Plastic Apple Ornament*	Light
Plastic Film Container*	Cupped-Float
Rock*	Heavy
Wooden Bead*	Light

*Indicates an object that was used in both the assessments and the lessons.

A diagram of the overall group design and random assignment is displayed in Figure 3. Each of the kindergarten children was randomly assigned to be in one of four groups numbered 1-4; as previously mentioned, two of the students were switched from random assignment due to behavior concerns. The preschool children were randomly assigned to be in one of four groups numbered 5-8. Each of the groups was then randomly assigned to be in either the direct instruction or the guided discovery condition first. Then within each age and teaching style group, the subjects were randomly assigned to receive one of the heavy/light lesson kits (A or B) and one of the cup-shaped lesson kits (C or D) first, so by default they would receive the other kit in the second session of lessons.

Procedure

Lessons

A complete script for all of the lessons, including the heavy/light and cup-shaped lesson for both the guided discovery and direct instruction conditions are listed in Appendix B, but the general procedures are given here. The experimenter was present in almost all of the lessons to oversee their video recording and to observe how the lessons went. Most of the time this did not seem to affect the students, which is likely due to the fact that the students were familiar with the experimenter at this time and because they are used to being observed in their classes. The teacher introduced the topic of discussion to the students (either the teaching of the heavy/light concepts or the cup-shaped objects).

For all of the lessons, the basic procedure started with the teacher bringing one of the groups of students into a room separate from the rest of the class during a free choice activity time. The teacher and the students were clustered around a bin of water. After discussing the concepts being taught in a particular lesson, the teacher passed each of the objects so that all children got to hold the object and then the students took turns putting the object into the water, with each student allowed at least one turn per lesson. This procedure allowed the students in both the guided discovery and the direct instruction conditions to have the same amount of hands on experience in order to try to engage the students in both of the lesson types. The teacher tried to have all of the guided discovery and direct instruction lessons last for approximately 15 minutes.

In the guided discovery condition, the teacher focused on asking the students what was happening and why. As an example, in the heavy/light lesson after an object had floated because it was light, the teacher asked, "Why do you think it floated?" The teacher tried to get the students to respond by saying that the object floated because it was light. In the direct instruction condition, the teacher explained what was happening to the students. For instance, in the heavy/light lesson when the students had made a light object float, the teacher said, "This is a light object, so it floats in the water."

Following each day of lessons, the teacher and experimenter had informal discussions about the experiences with different age children and the different teaching styles. Once all of the lessons were completed, the teacher, experimenter, and her advisor had a videotaped debriefing session to discuss the effects of the lessons qualitatively. These discussions are summarized in the results of the lessons section.

Assessments

A complete script of the assessments can be found in Appendix C, but the general procedure is outlined here. The experimenter took each child from the classroom individually and walked to the lab. The experimenter first asked the student to describe sinking and floating to make sure that the student understood what the terms meant. If the student was not able to explain the concepts, the experimenter would tell the student that when something sits at the top of the water it is floating and if something goes to the bottom of the water it is sinking.

The experimenter would first hand each of the objects to the student and ask the student whether he thought the object would sink or float and why. The child then put the object in the water. The experimenter asked the student if that is what he thought would happen, and why the student thought that the object sank or floated. The experimenter recorded all of the student's responses on paper and a video camera was set up to record the assessments as well.

Results

Lessons

From a qualitative look at the first session of lessons, it appeared that the students were more interested in the guided discovery lessons than the direct instruction lessons. This impression was especially true for the preschool students. They had short attention spans in both of the types of instruction, but they seemed more apt to be bored in the direct instruction condition. The teacher felt that the direct instruction condition was limiting to the students because they were not able to show what information they knew.

The students who had been taught by the guided discovery method of teaching in the first set of lessons and were in the direct instruction condition for the second session of lessons seemed to be less interested than the students who had received the conditions in the opposite order. The students who received the direct instruction condition second seemed even more distracted than the students who had received direct instruction in the first condition. This pattern could be because they had the comparison of the guided discovery in the first set of lessons.

Distraction in the direct instruction condition of the second session was particularly evident in the preschool children.

As part of the different methods of the lessons, the students were asked to make predictions in the guided discovery condition and they were told by the teacher what to expect in the direct instruction condition. The students who received the direct instruction condition second often spontaneously gave predictions about what was going to happen when they placed different objects in the water. This behavior is likely a carryover from how these students were used to making predictions in the context of the guided discovery lessons. Interestingly, the different styles of teaching can carryover, even when the teacher does not mean for this to be the case.

It was intended that the guided discovery and direct instruction lessons were the same in all respects except for the manner in which the information was presented to the students. However, the teacher found that she was not able to maintain the same amount of time for both of the conditions. In both sessions, the guided discovery lessons were longer than the direct instruction lessons. The teacher believed that this occurred because it took longer to get the students to give the desired response that was necessary for the guided discovery condition than to tell them the concepts as she did in the direct instruction condition. In future experiments, it would be better for the length of the lessons to be under better control.

One female four year old student was only present in one out of a total of four lessons, so data from this participant was not used in analysis. Two male students missed one of the lessons each, one because the teacher removed him due to behavior and one because he did not want to go to the activity. These students were included in the data analysis and the lessons that they were missed counted as an absence from the lesson. Overall, the students attended an average of

3.5 out of 4 lessons. One student attended only two of the lessons, but all of the other students were present at three or four of the lessons. Since absences from the lessons were infrequent, they are not expected to have a significant effect on the results.

In general, the teacher and the researcher felt that the students seemed to be understanding the ideas behind the lessons. Students in all of the conditions seemed to be learning information, the question is whether some students were learning more than others. Learning effects will be analyzed in the quantitative results from the assessments. If it is true that the students preferred the guided discovery condition over the direct instruction condition, the question would be whether they learned more in this condition.

Assessments

Scoring

The students' responses in the assessment section of the study were scored in order to evaluate their knowledge of and ability to predict and explain sinking and floating. Every student earned five scores for each of the 11 items for each assessment. After the student was handed an object but before she placed it in the water, she was asked to predict whether she thought it would sink or float when it was placed in the water. The correctness of this prediction (Right) was scored based on whether the student was correct in her prediction, including predicting either sinking or floating for the cupped-both objects which could be made to do both (received a score of 4), predicted both sinking and floating when the object only did one or the other (3), predicted sinking or floating incorrectly (2), or gave no prediction (1). For Right, students could receive a minimum score of 11 and a maximum score of 44.

The student was then asked to say why she thought the object would sink or float. These reasons were categorized along the concepts that were taught in the lessons (Why1). Students were given a score of 4 if they used a concept of the cup-shaped objects. This includes saying that the object was cup-shaped, it had edges, there was air or water inside one of the cup-shaped objects, or there was an opening that water could get into. Students received a score of 3 if they said that the object was heavy or light or said that there was air inside of the heavy/light objects. The children scored a 2 if they named the object itself or a property of an object that is irrelevant to sinking or floating (big, little) or said that they had seen the object sink or float before. If the student gave no response, said that they didn’t know why the object would sink or float, or said that they just knew that it would sink or float, they scored a 1 on Why1. The student’s 11 responses coded for Why1 can have a range of values from 11 to 44.

After the student had placed the object in the water, she was asked whether it did what she thought it would. If assessment of her own prediction was correct, she received a 3, incorrect she received a 2, and if she gave no response or had made no prediction she received a 1 for Assess. The variable Assess can range from 11 to 33. When the student placed the object in the water, she could make the cupped-both objects sink or float. When she would make the object do both she received a score of 2 for Both, otherwise she received a score of 1 in this category. After the student placed the object into the water, she was asked to explain why it sank or floated (Why2). This variable is coded in the same manner as Why1. The relative gains on these measures from the pretest to the midtest and the midtest to the posttest will be examined and will be referred to as Gain*variable* with *variable* being any of the above mentioned dependent variables.

Data Analysis

For all analyses an α value for significance of 0.05 will be used. If a result was not significant to this level, but to α value of 0.10, this will be described as a trend in a specified direction.

Sex Comparison. Overall sex comparisons were run for each of the times of testing (pretest, midtest, posttest). In ANOVA tests, no significant differences were found between the male and female students on any of the dependent variables (Right, Why1, Assess, Both, and Why2). At the time of the midtest, there was a trend that the male students performed better than the female students on Why1, $F(1, 33) = 3.10$, $p < 0.10$. Since this trend was not significant to the $\alpha = 0.05$ level and it was only evident in one variable at one point in time, sex was determined not to have a real affect on any of the variables of interest and was ignored throughout the rest of the analyses.

Pretest Performance. To test the equivalence of the experimental groupings, all of the dependent variables were measured at the pretest. All factors (Right, Why1, Assess, Both, and Why2) were tested by ANOVA for the pretest and found to have no significant difference between the conditions. All of the corresponding means and ANOVA data are shown in Table 4.

Table 4

Mean Values and Analysis of Variance for Pretest by Condition

	Condition M (SD)		
Variable (Range)	Guided Discovery First	Direct Instruction First	F[a]
Right (11-44)	37.3 (2.4)	37.6 (3.3)	0.10
Why1 (11-44)	25.5 (4.4)	25.4 (6.5)	0.01
Assess (11-33)	31.6 (2.0)	32.2 (1.7)	0.99
Both (11-13)	11.1 (0.5)	11.0 (0.0)	0.94
Why2 (11-44)	25.6 (5.3)	26.7 (5.7)	0.38

[a] The degrees of freedom for this column are 1, 33.

From Table 4, it is evident that the variable Right and Assess are close to ceiling values. This indicates that already at the time of the pretest, the students are correctly predicting whether objects will sink or float and assessing the correctness of their prediction after seeing what the object does in the water. There is little room for improvement on these measures with subsequent treatment. It appears that the variable Both is at the floor level, indicating that almost none of the students were making the cupped-shape objects both sink and float. Variables Why1 and Why2 both had intermediate values for their means.

Learning Effects At Different Times of Testing. By comparing the scores on all of the variables at each of the different times, we are able to see how much the students in all of the conditions learned from the lessons. See Table 5 for a the mean values and a summary of the significance level from the ANOVA analysis for each of the variables at each of the testing times.

Table 5

Means and Analysis of Variance Comparing Variables for Pretest, Midtest, and Posttest Data

	Time M (SD)			
Variable (Range)	Pretest	Midtest	Posttest	F[a]
Right (11-44)	37.4 (2.8)	36.7 (3.8)	37.7 (3.8)	0.64
Why1 (11-44)	25.5 (5.4)	28.7 (4.6)	29.5 (5.3)	5.84**
Assess (11-33)	31.9 (1.9)	31.9 (2.1)	32.0 (2.5)	0.03
Both (11-13)	11.1 (0.3)	11.8 (0.8)	12.3 (0.8)	23.36***
Why2 (11-44)	26.1 (5.4)	28.7 (5.3)	30.2 (4.7)	5.54**

[a] The degrees of freedom for this column are 2, 102.

** $p < 0.01$. *** $p < 0.001$.

Over time, the variables Right and Assess did not improve. This is likely a result of these variables being at the ceiling in the pretest. For Why1, the students improved significantly from the pretest to the midtest, but not from the midtest to the posttest, $F(2, 102) = 5.84$, $p < 0.01$. This means that the students were improving their prediction explanations from the pretest to the midtest, but not after this time. The mean values for Why1 at the midtest was 28.7. Although this does not seem close to the ceiling of 44, attaining the highest score of 44 requires using the logic of cup-shaped objects. They can even use this logic for why one of the heavy/light objects does not float (i.e., saying that an object floats because it does not have a hole that water can get in), though it seems less likely that they would use this type of explanation when they can sufficiently say that the object is sinking or floating because it is light. So the students may have been near an appropriate ceiling of at the time of the midtest, leaving no room for improvement.

A similar pattern was shown for students' evidence explanations (i.e., for an object sinking or floating after they had placed the object in the water). The difference in Why2 was found to be significant from the pretest to the midtest but not from the midtest to the posttest, $F(2, 102) = 5.54$, $p < 0.01$. This also could be a result of approaching the ceiling of the variable.

Students' increased number of times of making an object both sink or float (Both) was statistically significant over time and improved between all three of the times of assessment, $F(2, 102) = 23.36$, $p < 0.001$. This shows that the students were able to learn more about making an object both sink and float from both sessions of the lessons.

Age Effects. In order to better understand the effects of the different conditions, the responses of the preschool and kindergarten children were compared at each of the times of testing. Developmental differences between the age levels were seen throughout the study. The mean values for the variables are in Table 6, while the results of the test for ANOVA on all of these variables can be seen in Table 7.

At the time of the pretest, Both was the only variable that was not significantly different between the preschool and kindergarten children. Both was not significant because at the time of the pretest, almost none of the students made the objects both sink and float in the water. For the variables Right, Why1, Assess, and Why2, the kindergarten students scored better than the preschool students. The kindergarten students were better able to predict, assess their predictions, and explain the sinking and floating of objects before the lessons occurred.

Table 6

Mean Values and Standard Deviations Comparing Ages at Pretest, Midtest, and Posttest

		Time for Each Age Group M (SD)		
Variable	(Range)	Pretest	Midtest	Posttest
Right	(11-44)			
	Preschool	35.9 (2.6)**	35.5 (4.3)	37.8 (4.4)
	Kindergarten	38.6 (2.5)**	37.7 (3.1)	37.6 (3.4)
Why1	(11-44)			
	Preschool	23.0 (4.3)*	27.3 (4.8)	27.1 (5.4)*
	Kindergarten	27.4 (5.6)*	29.7 (4.4)	31.3 (4.6)*
Assess	(11-33)			
	Preschool	31.1 (1.8)*	31.0 (2.3)*	31.3 (2.7)
	Kindergarten	32.5 (1.7)*	32.5 (1.6)*	32.5 (2.3)
Both	(11-13)			
	Preschool	11.0 (0.0)	11.6 (0.6)	12.1 (0.8)
	Kindergarten	11.1 (0.5)	12.0 (0.8)	12.4 (0.8)
Why2	(11-44)			
	Preschool	23.5 (4.2)*	26.2 (5.0)*	27.1 (4.2)***
	Kindergarten	28.1 (5.6)*	30.6 (4.8)*	32.5 (3.8)***

* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

Table 7

Analysis of Variance Comparing Age at the Pretest, Midtest, and Posttest

Variable	F (pretest)	F (midtest)	F (posttest)
Right	8.97**	3.02	0.02
Why1	6.32*	2.22	6.14*
Assess	6.36*	5.35*	1.96
Both	0.74	1.87	0.60
Why2	6.93*	6.69*	15.47***

Note: The degrees of freedom for this table are 1, 33.

* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

At the time of the midtest, the kindergarten students were better able to Assess their own predictions and explain the objects sinking and floating after they had placed them in the water as shown in Table 6 and 7. The difference between the two age groups seemed to disappear as the scores of both groups of children came even closer to the ceiling value.

From Tables 6 and 7, the kindergarten students performed better on their explanations for sinking and floating after seeing the object float, but not before. At the time of the posttest, the kindergarten students performed better on both of these explanations.

Differences between the preschool and kindergarten students' knowledge of sinking and floating were evident in almost all domains at the time of the pretest. Many of these differences seemed to decrease at the midtest and the posttest, but these effects could be a result of the scoring system used for this analyses. It might not have been robust enough to differentiate between the kindergarten and the preschool students' knowledge.

Students' Gains in Scores Over Time. The relative gain in students' scores from the pretest to the midtest and the midtest to the posttest were computed by subtracting their score for the earlier test from their score at the later assessment. Similarly, the overall gain scores were calculated by subtracting the students' scores on all of the dependent measures at the pretest from their scores at the posttest. Note that, with this calculation, it is possible for students to receive a negative gain score. For all of the variables measured, both the relative and overall gains compared by the students' ages was insignificant as tested by an ANOVA. However, when the scores were split based on the order of presentation of the lesson style and the differences in gain were assessed based on the ages of the students, some interesting trends were evident.

The mean values showing the comparison of the different age students who received the guided discovery instruction first followed by direct instruction (GD→DI) and the direct instruction lessons first and then the guided discovery lessons (DI→GD) are shown in Table 8. The ANOVA results are shown in Table 9. In the condition where the direct instruction lessons were given first, the preschool students gained more than the kindergarten students in the variable Right from the midtest to the posttest, $F(1, 15) = 5.49$, $p < 0.05$. For the students who received the direct instruction lessons first, there was no difference between the preschool and kindergarten students' GainRight scores from the midtest to the posttest, $F(1, 16) = 0.16$, $p > 0.05$. It was also true that the preschool students gained more overall on the variable Right than the kindergarten students from the pretest to the posttest when the direct instruction lessons were presented before the guided discovery lessons, $F(1, 15) = 12.82$, $p < 0.01$, but not when the guided discovery lessons were presented first followed by direct instruction, $F(1, 16) = 0.17$, $p >$

0.05. None of the other comparisons between groups receiving lessons in different teaching methods were significant. Because significance was not reached for any of these variables for the gains from the pretest to the midtest, there was no effect of whether the students received guided discovery or direct instruction first.

Table 8

Mean Values and Standard Deviations Comparing Relative and Overall Gains

		Time for Each Age Group M (SD)		
Variable	(Range)	Pre to Midtest	Mid to Posttest	Pre to Posttest
GainRight	(-33 to 33)			
GD→DI				
	Preschool	-1.0 (5.0)	0.1 (5.3)	-0.9 (6.3)
	Kindergarten	1.0 (3.5)	-0.9 (5.6)	0.1 (3.8)
DI→GD				
	Preschool	0.3 (5.9)	4.7 (3.0)*	5.0 (3.8)**
	Kindergarten	-2.7 (3.6)	0.7 (3.6)*	-2.0 (4.1)**

GainWhy1	(-33 to 33)			
GD→DI				
	Preschool	2.1 (2.9)	1.0 (2.7)	3.1 (3.8)
	Kindergarten	2.4 (5.8)	1.4 (2.1)	3.8 (4.5)
DI→GD				
	Preschool	6.9 (5.6)[a]	-1.7 (7.6)	5.1 (8.9)
	Kindergarten	2.2 (4.7)[a]	1.8 (2.7)	4.0 (6.4)
GainAssess	(-22 to 22)			
GD→DI				
	Preschool	0.4 (2.7)	-0.8 (3.1)	-0.4 (2.8)
	Kindergarten	0.7 (1.9)	-0.6 (2.5)	0.1 (2.3)
DI→GD				
	Preschool	-0.6 (1.5)	1.6 (2.0)	1.0 (1.9)
	Kindergarten	-0.7 (2.5)	0.5 (2.6)	-0.2 (2.2)
GainBoth	(-2 to 2)			
GD→DI				
	Preschool	0.5 (0.5)	0.8 (0.9)	1.3 (0.9)
	Kindergarten	1.0 (0.8)	0.5 (0.7)	1.5 (0.7)
DI→GD				
	Preschool	0.7 (0.8)	0.3 (1.0)	1.0 (0.8)
	Kindergarten	0.7 (0.8)	0.3 (0.8)	1.0 (0.9)

GainWhy2	(-33 to 33)			
GD→DI				
	Preschool	2.8 (4.5)	2.1 (2.5)	4.9 (4.5)
	Kindergarten	2.3 (3.7)	2.3 (3.6)	4.6 (4.9)
DI→GD				
	Preschool	2.6 (3.9)	-0.4 (5.3)	2.1 (5.5)
	Kindergarten	2.8 (5.0)	1.4 (1.9)	4.2 (5.7)

[a]This statistic showed a trend with $p < 0.10$, but was not statistically significant.

* $p < 0.05$. ** $p < 0.01$. for this assessment test compared to others

Table 9

Analysis of Variance Comparing Age for Relative and Overall Gains

	Relative or Overall Gains		
Variable	F (pre to midtest)	F (mid to posttest)	F (pre to posttest)
GainRight			
GD→DI	0.99	0.16	0.17
DI→GD	1.67	5.94*	12.82**
GainWhy1			
GD→DI	0.02	0.13	0.11
DI→GD	3.43[a]	1.84	0.10

GainAssess			
GD→DI	0.10	0.01	0.15
DI→GD	0.01	0.86	1.36
GainBoth			
GD→DI	2.22	0.44	0.44
DI→GD	0.00	0.00	0.00
GainWhy2			
GD→DI	0.05	0.01	0.01
DI→GD	0.01	1.02	0.55

Note: The degrees of freedom for this table are 1, 33.

[a]This statistic showed a trend with $p < 0.10$, but was not statistically significant.

* $p < 0.05$. ** $p < 0.01$.

Discussion

This study focused on how effective guided discovery and direct instruction teaching methods are for teaching beginning science concepts to young children. The effects of these different teaching styles were investigated in classrooms of kindergarten and preschool children. The overall learning and the gain of the students scores were assessed to see what groups of children learned more from the lessons.

There was no significant difference between the scores of the students at the time of the pretest who were assigned to different conditions. All of the students were good at predicting whether an object would sink or float and assessing whether that prediction was correct after seeing the object sink or float, so the students did not have much room to improve upon subsequent testing. The students were able to correctly explain some of the reasons that objects would sink or float, but they scored at the floor level at making the cupped-both objects both sink and float.

From the pretest to the midtest, but not from the midtest to the posttest, learning effects were evident for the children's explanations for objects sinking and floating both before and after seeing them float. The children's explanation scores may have been approaching a ceiling at the time of the midtest. The children also made clear improvements in their ability to make cupped-both objects sink and float.

At the time of the pretest, the kindergarten students were performing better than the preschool students on all dependent measures except for making the object both sink and float. With instruction, the difference declined, and the kindergarten students were only performing better than the preschool students on both of the explanation measures the time of the midtest and posttest.

There was no difference between the gains of the preschool and kindergarten students when they received the guided discovery lessons before the direct instruction lessons. However, the preschool students gained more than the kindergarten students at correctly predicting the sinking and floating of objects from the midtest to the posttest and from the pretest to the posttest when they received the direct instruction lessons before the guided discovery lessons.

The students who received the guided discovery lessons first were the least interested during the direct instruction lessons that they received in the second session of lessons. This tendency was especially true for the preschool children. It is possible that this group of preschool children was so bored during their direct instruction lessons that they were not learning what the teacher was trying to teach them because of the contrast with this lesson style over the guided discovery lessons that they had already received at this time. It is possible that the kindergarten students were old enough that they could sit and listen to a teacher giving them information and learn the same amount of information as when they were being taught by the guided discovery teaching method.

It is also possible that the preschool students may have needed to receive the direct instruction from the teacher first in order to have a schema in which they could be thinking about the concepts in the guided discovery lessons. This effect might have occurred in the preschool students and not the kindergarten students because the preschool students were not as knowledgeable about the sinking and floating concepts under study. So it could be that when students are learning a concept that they do not know very much about, they initially need some direct instruction in order to develop a framework in which to think about the concepts of study.

In this study, it is possible that there were not more effects of the experimental variable because the teaching methods of the guided discovery and direct instruction lessons were not distinct enough. In future studies, it would be beneficial to make sure that these manipulations were strong in order to see sufficient effects. The contrast might also be improved by having more than just two lessons of each teaching style. Similarly, the students performed so well on some of the dependent variables at the time of the pretest, that there was little room for improvement. It would be better to be testing students on concepts that they did not know as well as these or to have more complicated assessments on which the students did not perform so well.

In future research, it would be interesting to learn more about the effects of combining different types of teaching methods. In this research, direct instruction and guided discovery were treated as occurring at different points in time. In most teaching settings, these methods of teaching are used in conjunction with one another within one lesson. It would be interesting to see what information students learn best by direct instruction and what is best learned via guided discovery in a more naturalistic teaching context.

This study helped to show some of the issues that arise with doing experimental research within the context of a classroom. It showed how difficult it is to keep all variables constant; a trade off was found between having guided discovery and direct instruction lessons the same length and having the concepts presented the same number of times. This problem arose because it took longer for the students to come up with a concept than for the teacher to directly tell them.

The preschool students were found to have improved more on correctly predicting objects' sinking or floating when they were in the direct instruction first followed by guided discovery, but not when the lessons were in the opposite order. This effect was not observed in the kindergarten students. This finding could be because the preschool students were younger and less willing to sit through the direct instruction lessons after they had been allowed freedom in the guided discovery lessons. It is also possible that the preschool students did not know as much about the concepts under study, so they needed the framework provided by the teacher instruction in order to learn from the guided discovery condition. Given that the teacher-researcher collaboration was so positive in this study, further exploration of the relationship between teaching methods and learning outcomes is both warranted and practically possible.

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Appendix A

<u>Sample Assessment Form</u>

Date: ___________________________ **Test:_______________________________**

Subject: ________________________ **Age: _______________________________**

Kit L		**Will it.....?**			**Thought?**		
Object	**Real**	**Sink**	**Float**	**Why?**	**Yes**	**No**	**Why?**
Olive	Sink						
Rubber Basketball	Float						
Marble	Sink						
Jar #1	Both						
Styrofoam Ball	Float						
Plastic Cup	Float						
Sponge	Float						
Metal Ball	Sink						
Candle	Float						
Copy Paper	Both						
Kooch Ball	Sink						

Appendix B

Lesson Scripts

For all of the lessons, the basic procedure started with the teacher bringing one of the groups of students into a room separate from the rest of the class during a free choice activity time. The teacher and the students were clustered around a bin of water. After discussing the concepts being taught in a particular lesson, the teacher passed each of the objects so that all children got to hold the object and then the students took turns putting the object into the water, with each student allowed at least one turn per lesson. This procedure allowed the students in both the guided discovery and the direct instruction conditions to have the same amount of hands on experience in order to try and engage the students in both of the lesson groups. The teacher tried to have all of the guided discovery and direct instruction lessons approximately 15 minutes.

Guided Discovery

In guided discovery learning, it is important that the teachers try to lead the students to concepts by asking them questions and suggesting ways of looking at an issue. The teacher was instructed to avoid directly telling the students an idea, but to ask them questions that will allow the students to discover the concepts for themselves. If the teacher is trying to direct the students along a path and the students are not able to get one concept, she can directly tell the students, but this is only to be used when deemed absolutely necessary by the teacher.

Heavy/Light Lesson.

The teacher introduced the lesson by asking the students, “When you put an object that is light into water, what would it do?” The teacher tried to get the students to respond that it would float using more questions if necessary. If the students were unable to come up with an answer themselves, then the teacher told the students that the object would float. Next the teacher asked the student, “When you put a heavy object in water, what would it do?” Again the teacher tried to get a response from the students that the object would sink in the water if it was heavy, with more prompts if necessary or else she told the students that the object would sink. The teacher went through each of the objects one by one with the students. For each object, the teacher asked the students whether they thought it would sink or float and why. After they had put each of the objects into the water, the teacher would ask, “Why do you think that floated/sank?” The teacher would try to get the students to reply by saying that the object floated or sank because it was light or heavy respectively. The teacher encouraged the students by asking them questions designed to get them to come up with explanations for their predictions. After the students are done testing all of the objects, the teacher encouraged them to separate the objects by saying, “Why don’t we separate all of the objects into piles of what sank and what floated.” Once that was done, the teacher asked, “What is the difference between the objects that floated and the objects that sank?” The teacher prompted the class until she got them to say that the heavy objects sank while the light objects floated.

Cup-shaped Lesson.

The teacher introduced the lesson by saying, “In the last lesson, we studied objects that floated and objects that sank. What was the difference between the objects that floated and objects that sank?” The teacher tried to prompt the students until they replied that the objects that are heavy sank while the objects that are light floated. The teacher then asked the students the question, “Are big trucks heavy?” The students should have replied that they are heavy or the teachers should have prompted them to say that they are. “Are big ships heavy?” the teacher asked and tried to get the students to reply yes to this question. The teacher asked the students, “Do big ships float?” and tried to induce the students to say yes to this. This contrast allowed the teacher to ask the students, “How do big ships that are heavy float?” The teacher allowed the students to try to answer this question. The correct answer is that big ships float because of the orientation of the way that they are put into the water. If the students are unable to answer the question (which is likely because this is a difficult question for students of this age), the teacher told them that it is because of the shape of the boat.

The teacher then went through each object in the lesson kit and asked the students whether they thought it would sink or float and why. In this lesson, there were five cup-shaped objects that can be make to sink or float (cupped-both object). Some of these objects included malleable (putty, clay) or paper-like objects (foil, wax paper) which can be made into a cup shape to float when the are placed into the water with the sealed cup side oriented downward. For each of the lessons, the teacher made sure that the students saw each of these five objects sinking and floating. In each of these lessons, there was also one cup-shaped object that is so light that it will always float, even when it is filled with water (cupped-float object). The teacher made sure that in each of these lessons the students saw the object float and then attempted to make it sink. At this point, the teacher asked the students, “Why do you think that this will only float?” The teacher tried to get the students to reply that this object will only float because it is so light. The teacher encouraged the students by asking them questions designed to get them to come up with explanations for their predictions. After the students were finished testing all of the objects, the teacher encouraged them to separate the objects and characterize them by saying “Why don’t we separate all of the objects into piles of what sank and what floated.” Once that was done the teacher asked, “What is the difference between the objects that floated and the objects that sank.” The teacher tried to get the students to talk about how they could change whether the objects sank or floated based on how they were oriented in the water.

Direct Instruction

The key aspect to this style of instruction is that the teacher was to tell the students the concepts for the lessons rather than having the students figure out the concepts for themselves.

Heavy/Light Lesson.

The teacher introduced the lesson by saying, “When things are heavier than water, they will usually sink to the bottom of a bowl of water. Usually things that are light will float on top of the water.”

The teacher went through each of the objects in the lesson. When she got to a light object she would name the object then say, “This is light, so it should float on the water.” She then passed the object around so that all of the students in the group could hold it to see that it was light and then allowed one of the students to place it into the water. The students were all allowed to see the object floating. “This is a light object, so it floats in the water.” For the heavy objects, after telling the students what the object was, the teacher said, “This is heavy, so it should sink in the water.” The object was passed around and placed in the water. When the students saw the objects sink, the teacher would say, “This is heavy, so it sank in water.” She proceeded through all of the objects so that each group saw three heavy objects sink and three light objects float.

Once the teacher went through all of the objects for a particular lesson, she finished by putting the objects into piles of objects that sank and objects that floated. “Let’s look at everything in the pile that floated. These are all light objects.” The teacher allowed all of the students to pick up some of the objects to confirm that this is true. “Now let’s look at the objects that sank. They are all heavy objects.” The teacher again allowed the students to pick up the objects to confirm that the objects that sank were heavy. The teacher concluded the lesson by saying, “Today we learned that objects that are light usually float while objects that are heavy usually sink.”

Cup-Shaped Lesson.

The teacher introduced the lesson by saying, “In the last lesson, we learned that objects that were heavy usually sink while objects that were light usually float. Sometimes this isn’t true. A big boat will float in the water, but it is very heavy. Today we will figure out why this happens. Here I have a (cupped-both object) that is heavy.” The teacher passed the cupped-both object around to the students to allow them to hold it to see how heavy it was. “From what we learned in our last lesson, we would expect this object to sink because it is heavy.” The teacher had one of the students place the cupped-both object into the water at a sideways orientation so that it sank to the bottom of the water. “This (cupped-both object) can sink to the bottom. But if we put it into the water in a different direction, we can get it to float on top of the water.” The teacher had one of the students place the cupped-both object into the water with the cupped end downward so it floated. The teacher would explain this by saying, “By changing the way we put the (cupped-both object) in, we can make it sink or float.” The teacher proceeds through the objects showing how each of the five cupped-both objects can be made to float or sink. These objects will also include a malleable object (clay, putty) and a paper-like object (foil, wax paper) that can be made into cup-shaped objects to float or sink depending on the orientation of the object. For each of the cupped-both objects, the teacher made sure that each group made the object sink and float.

Each of the lesson kits also had one cupped-float object which is so light that it will always float. The teacher got the students to try it by both ways that were previously able to get the cupped-both objects to sink and float. She will then explain to the students, “Some objects are so light that they will always float in the water, no matter what we change about them.”

The teacher concluded the lesson by saying, “Usually heavy objects sink and light objects float, but sometimes we can change things about objects to make them sink or float. This is just like the big ship that floats in water because it has a cupped bottom even though it is heavy.”

Appendix C

Assessment Script

The researcher went to the classroom to get a child. After choosing a child who is not engaged in an activity, the researcher told the child, “It is your turn to come play the sinking and floating game with me.” The researcher then led the child to the testing room where the child was asked to sit across a table from the researcher.

The researcher used the following dialogue with the student: “Hi (Student’s Name), my name is (Researcher’s Name). Today we are going to play the sinking and floating game. What happens when something floats in water?” If the student correctly answered the question by saying that the object will rest on the top of the water, the researcher replied by saying, “Right, when something floats it sits on top of the water.” If the student did not correctly answer the researcher, then the researcher said, “When something floats, it sits on top of the water.”

The researcher then asked the student, “What happens when something sinks in water?” If the student answered the researcher correctly by saying that the object will go to the bottom of the water, the researcher replied, “Right, when something sinks it goes to the bottom of water.” If the student did not correctly answer the researcher, then the researcher said, “When something sinks, it goes to the bottom of the water.”

The purpose of this initial dialogue is to ensure that the students are not confused about the concepts of sinking and floating. The student’s responses to the questions above were not used in the analysis.

The researcher gave the student the instructions, “I am going to show you some things and I would like you to tell me whether you think they would sink or float in water. Then you will put them in water to find out what happens.”

For each of eleven objects, the researcher handed the student an object and asked them, “Do you think this will sink or float?” After a response, the researcher asked, “Why?” then took the lid off the bin of water and instructed the child, “Okay. Now you can put it in the water. Is that what you thought would happen? Why do you think it sinks/floats?” At any of these points, if the child responds that they do not know, the researcher asked the question once more to see if the child would respond before recording a response from the child as, “I don’t know.”

All of the student’s responses were recorded by the experimenter on a recording sheet as well as by a video camera.

Footnotes

[1] An object is defined as the material the object is composed of plus any air or water contained within its volume. Note that the amount of air or water within the volume of an object can change when the conditions of the object are changed (i.e., the object is placed in water). This could cause an object to float on water for a while, then when the air is displaced by water, this could become heavier than the water and sink.

Figure Captions

Figure 1. Basic decision tree for non-mathematical sinking and floating judgments of objects[1].

Figure 2. General study design displaying the order of presentation of the different lesson styles to each age group of students.

Figure 3. Detailed study design, showing the assignment of each group of children to lesson kits for each style of teaching.

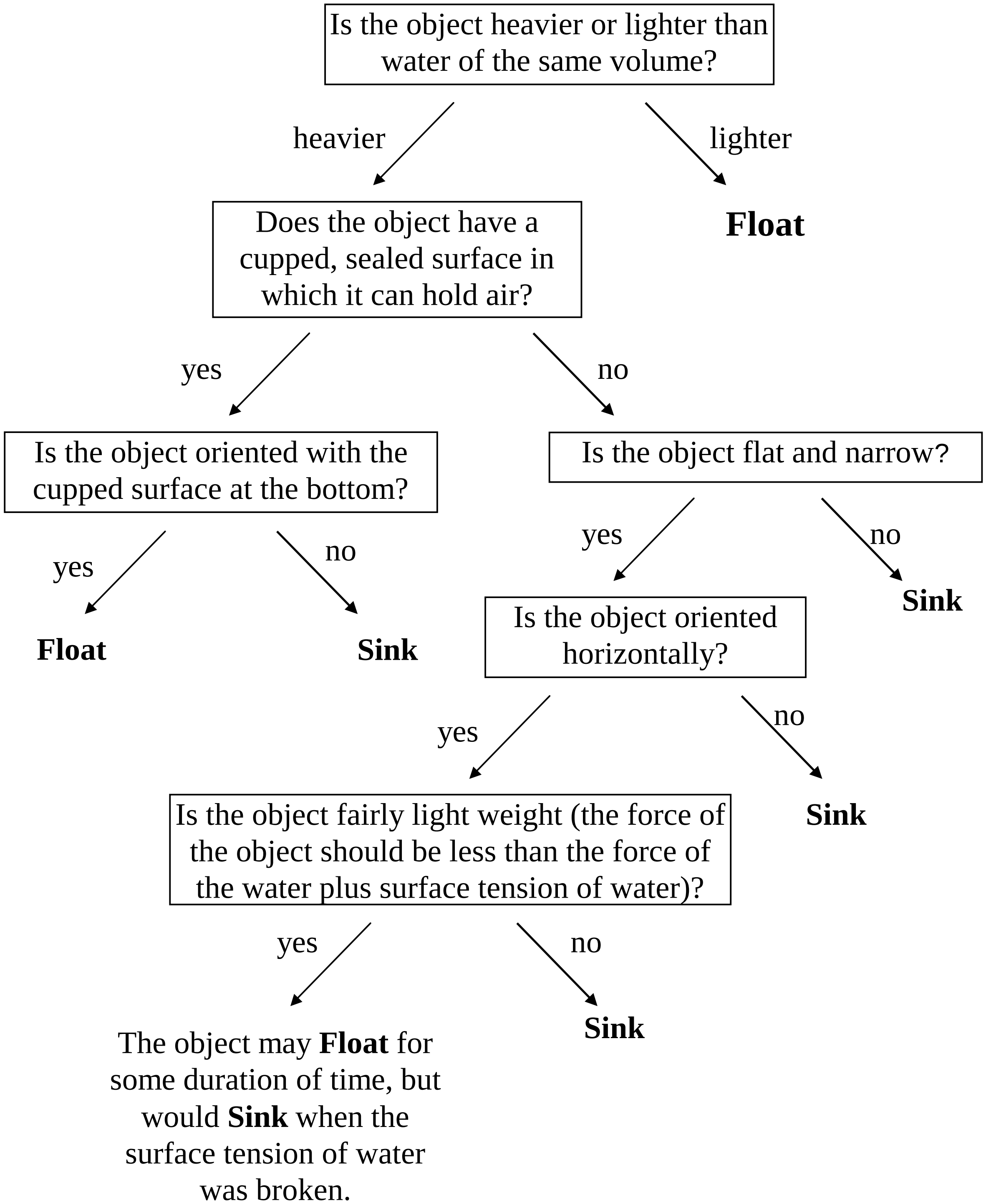
Is the object heavier or lighter than water of the same volume?
heavier
lighter
Float
Does the object have a cupped, sealed surface in which it can hold air?
yes
no
Is the object oriented with the cupped surface at the bottom?
Is the object flat and narrow?
yes
no
Float
Sink
yes
no
Sink
Is the object oriented horizontally?
yes
no
Sink
Is the object fairly light weight (the force of the object should be less than the force of the water plus surface tension of water)?
yes
no
Sink
The object may Float for some duration of time, but would Sink when the surface tension of water was broken.

Figure 1

	First Session (2 lessons)	Second Session (2 lessons)
Preschool	Guided Discovery	Direct Instruction
	Direct Instruction	Guided Discovery
Kindergarten	Guided Discovery	Direct Instruction
	Direct Instruction	Guided Discovery

Pre-Test Mid-Test Post-Test

Figure 2

	First Session (2 lessons)	Second Session (2 lessons)
Preschool	Guided Discovery	Direct Instruction
Group 5	Lesson Kits B and C	Lesson Kits A and D
Group 7	Lesson Kits A and D	Lesson Kits B and C
	Direct Instruction	Guided Discovery
Group 6	Lesson Kits A and C	Lesson Kits B and D
Group 8	Lesson Kits B and D	Lesson Kits A and C
Kindergarten	Guided Discovery	Direct Instruction
Group 2	Lesson Kits A and C	Lesson Kits B and D
Group 3	Lesson Kits B and D	Lesson Kits A and C
	Direct Instruction	Guided Discovery
Group 4	Lesson Kits A and D	Lesson Kits B and C
Group 1	Lesson Kits B and C	Lesson Kits A and D

Pre-Test ↑ Mid-Test ↑ Post-Test ↑

Figure 3