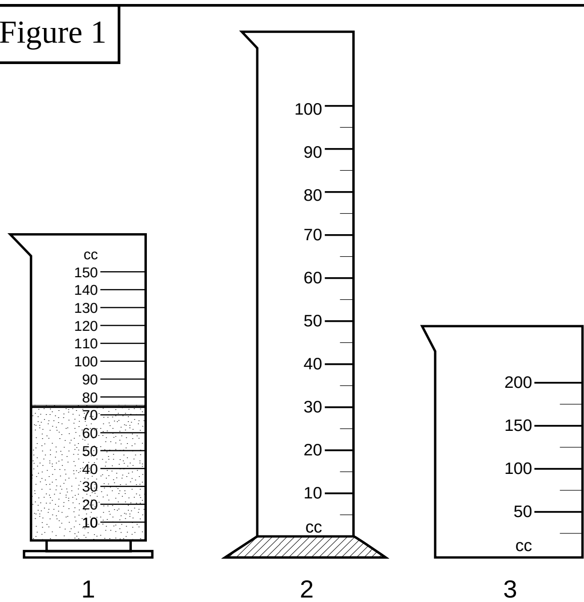
Marshmallows vs. Containers

Teacher Lab Discussion

Figure 1



Overview

This exercise focuses on one of the classic experiments of Piaget, the Swiss epistemologist: the conservation of volume. Piaget used three different containers. For our purpose, let's call them container 1, container 2, and container 3 as shown in Figure 1. Water from container 1 was poured into the narrower container 2 and then into the wider container 3. Piaget found that 4 to 6 year olds thought that container 2 contained more water than container 1 (and container 3 less), because, as Piaget noted:

> *...the water in B[2] is higher than it was in A[1]; therefore it increased in quantity, regardless of the fact that it is the same water that has merely been poured from one container to another."*

However, by the age of 7 or 8, Piaget found that

> *...the child says: "It is the same water," "It has only been poured," "Nothing has been taken away or added," "You can put the water in B [2] back into A where it was before," "The water is higher but the glass is narrower, so it is the same amount."*

These results of Piaget have been confirmed many times over, and in some tests that we ran, children who were a good deal older still confused height with volume, saying that container 2 held the most water and container 3 the least. Clearly then, we should work on this conceptual difficulty in the first and second grades (when children are 6 and 7) and help the children "see" conservation of volume as Piaget's 3rd graders did.

This particular version of Piaget's experiment was developed by one of our TIMS teachers, Mrs. Judy Rader, when she was a 2nd grade teacher at the Gladstone School in Chicago. Instead of water, which is hard to use, she used small marshmallows. She carefully cut three different cups so that the tallest did NOT have the biggest volume. The children then poured marshmallows into each cup until the cups were full and then proceeded to count and record the number of marshmallows in each container.

Picture, Data Table, and Graph

Louise's picture is shown in Figure 2. She and her partner are busy counting marshmallows. The

Figure 2

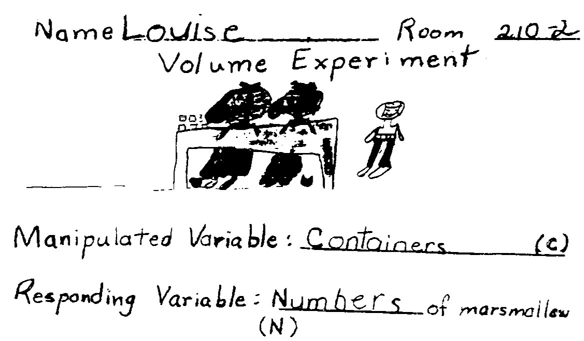
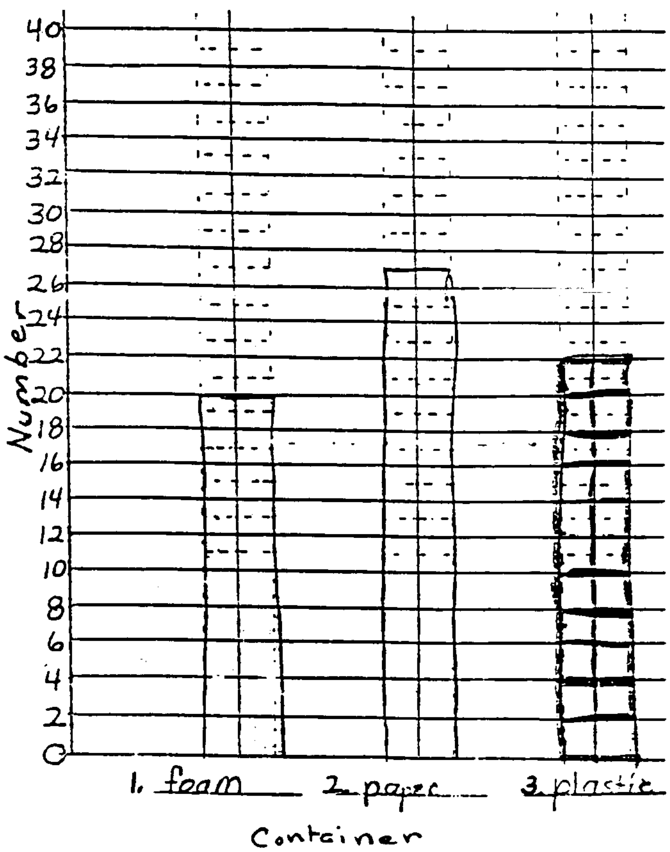


Figure 3

C	N
1. Foam	20
2. paper	27
3. plastic	22

Figure 5



cups are numbered 1, 2, and 3, and Mrs. Rader is standing in the background keeping an eye on things. In **Question 1,** Louise correctly identified the manipulated variable as the "containers." The "type of container" would also have been acceptable. The responding variable, in **Question 2**, is the number of marshmallows. We show Louise's answers in Figure 7.

Louise's data table is shown in Figure 3. Mrs. Rader wrote in the names of the cups, and Louise wrote in the numbers.

To make your life easier, TIMS has three containers all ready to go. These are the 150 cc graduated cylinder (container 1 in Figure 1), the 100 cc cylinder (container 2), and the 250 cc beaker (container 3). You can use marshmallows, dried beans, or dried peas to fill the containers. What you use depends on how high the children can count. Using Brown's Best Large Lima Beans (1-lb bag), it took approximately 130 beans to fill container 1; 100 to fill container 2; and 220 to fill container 3. The results are shown in Figure 4. In the process of counting, the children have a nice opportunity to sort in groups of 10 and then add up the number of groups plus the remainder to find the total number of objects in the containers. Clearly, the bigger the volume of the object used to fill the containers, the fewer objects the children have to count. One advantage of the marshmallows is that the children can have a treat and eat them after the experiment. Maybe that will help them remember conservation of volume!

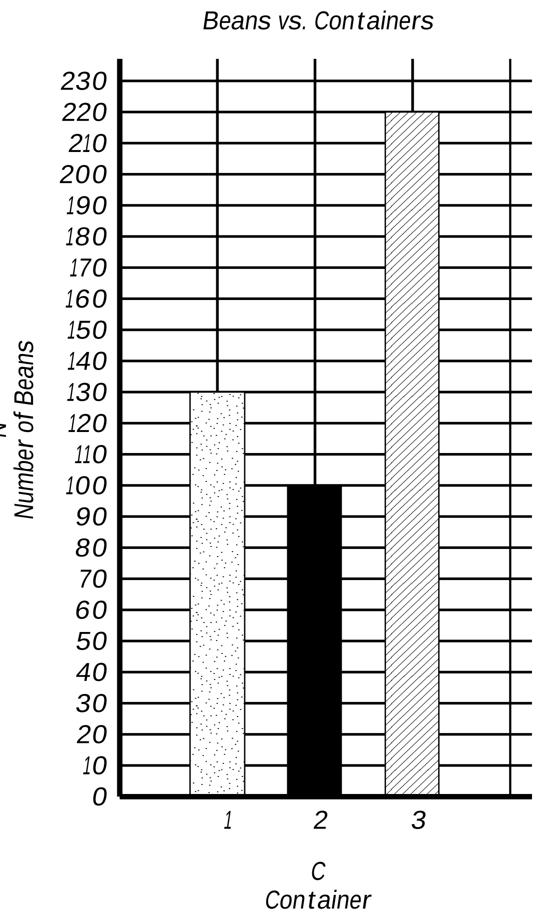
Figure 4

Table I

C Container	N Number of Beans
1	130
2	100
3	220

Louise's graph is shown in Figure 5. Mrs. Rader set up the graph so the children had to count by 2's in order to plot the data and had to interpolate odd numbers, like N = 27. If you use the TIMS containers, then you would probably have to skip count by 5 or 10 to accommodate the large numbers of marshmallows or beans. If you use the Brown's

Figure 6



Best Large Lima Beans, then your graph using the TIMS containers will look like the one in Figure 6.

Comprehension Questions

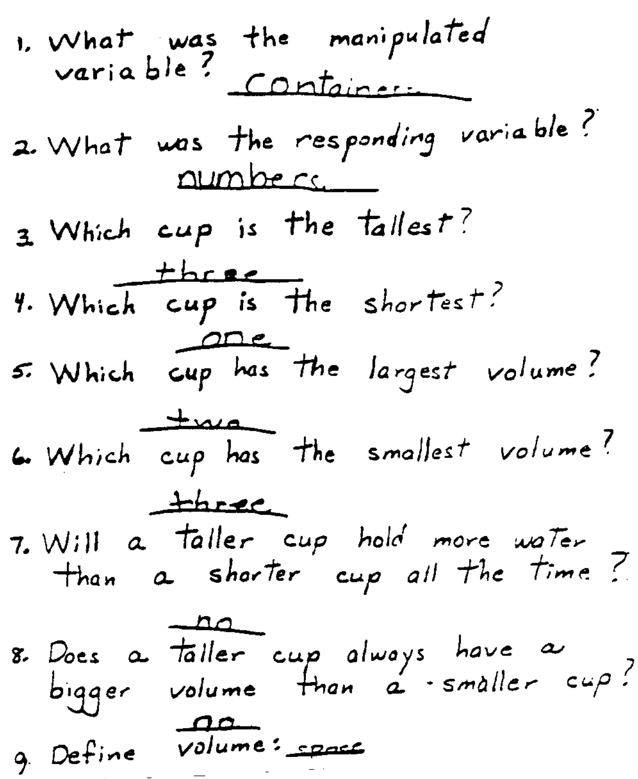
In Figure 7 we reproduce Mrs. Rader's set of comprehension questions and Louise's answers. As you can see the first questions were very simple: "What is the manipulated variable?" "What is the responding variable?" "Which cup is the tallest?" "Which cup is the smallest?" But then comes the key question: "Which cup has the largest volume?" Judy said that chaos then ensued. The children just could not believe that the tallest cup did not hold the most marshmallows. A great hubbub and discussion took place, and in several instances the experiment was tried again to "make sure." The children wanted to focus on the one dimension of height and were forgetting about the other two dimensions which defined the width of the cups, just as Piaget said! This is a common problem with not only children, but also with high school children and adults. When more than one variable is involved, they will often focus on only one and conveniently ignore the other. This certainly simplifies the problem, but unfortunately it simplifies it right out of existence. Later, when we study velocity and density, we shall see that the same kind of problem recurs.

We modified Mrs. Rader's questions slightly. We shall go over all comprehension questions here, using the data from the TIMS containers shown in Figure 1, and the large lima beans.

Questions 3 and **4** ask the children to identify the tallest and shortest containers. Container 2 is clearly the tallest; in fact, it is much taller than the other containers. Container 3 is distinctly shorter than either Container 1 or 2.

Now comes the fun. The answer to **Question 5**, "Which container holds the most objects?" will be container 3, the *shortest*. This is the setup for the key question, **Question 6**, " Which container has

Figure 7


1. What was the manipulated variable? Container
2. What was the responding variable? numbers
3. Which cup is the tallest? three
4. Which cup is the shortest? one
5. Which cup has the largest volume? two
6. Which cup has the smallest volume? three
7. Will a taller cup hold more water than a shorter cup all the time? no
8. Does a taller cup always have a bigger volume than a smaller cup? no
9. Define volume: space

the largest volume?" The answer, of course, is container 3. Will the children see this? Will chaos ensue? "Stay tuned," as they say. We further muddy the water by asking in **Question 7**, which container has the smallest volume. That will be container 2, but that is also the tallest. So the tallest holds the least and the shortest the most.

The children have been concentrating on beans, peas, or marshmallows. In **Question 8**, we try to be a little tricky. They are asked to anticipate whether a taller container will hold more *water* than a shorter container. This requires the children to generalize their understanding of volume. Filling the containers with water should make no difference. A taller cup still may *not* hold more water than a shorter cup; the children have seen the same situation for beans!

In **Question 9** we make the transition from beans and water to volume in general. The children are asked to explain if a taller cup will always have a bigger volume than a shorter cup. As Louise answers, "No." Why? She might have answered, "Because we have just seen it."

Question 10 refers to Marisa's 3 containers. These containers act as a check against what the children have just observed. They are asked to predict which of Marisa's containers will hold the most water and which will hold the least. Since Marisa's container 1 holds the most beans, it has the biggest volume and should also hold the most water. Container 3, even though it is the tallest, holds the least water because it holds the fewest beans.

Believe it or not, many of our pilot test teachers complained that the lab was too short. They suggested we add some quantitative questions that involve addition and subtraction. The next three questions are our response to that request. Between Unifix cubes, hundreds charts, beans, counting down, counting up, etc., there are many strategies the children can use to solve the problems. We suggest letting them find one with which they feel most comfortable and working with it.

In **Question 11**, Marisa pours the beans from container 1 into an empty container 3. We ask the children if the beans will overflow container 3 (**Question 11a**). Since 62 beans is greater than 29 beans, it certainly will. By how much is harder to answer. They can use subtraction by counting down from 62 to 29, or by counting up from 29 to 62. For example, in the latter they can add 1 to 29 to make 30, then 10 more to make 40, 10 more to make 50, and 10 more to make 60, and then 2 more to make 62. So, there will be

1 + 10 + 10 + 10 + 2 = 33 beans

left over (**Question 11b**). No formal algorithm is needed in any of the three problems. Fingers will do nicely.

In **Question 12**, we ask if the beans from container 2 and container 3 can fit into an empty container 1. As in Question 11, there are lots of strategies the children can use. They can add 43 beans to 29 beans and see if the sum exceeds 62 beans. Or they can pour container 2 into container 1 and find that there is still room for 19 more beans. Since container 3 holds 29 beans, we cannot make it and the answer is no.

Question 13 is harder still. We show three full container 3's. Marisa pours them into an empty container 1 until it is full. First we ask how many of the container 3's will be empty. A little addition shows that two of them will be but not the third since two of them hold

29 + 29 = 58 beans.

We then ask how many beans will be left in the container 3's. We need 4 more beans to fill container 1, so

29 – 4 = 25 beans

will be left over. A multiple step logic problem. Great.

Finally, we repeat Mrs. Rader's last question in **Question 14,** "What is volume?" Louise's answer was "space," which is short and to the point. We hope the children will get the point of the lesson, too.

Summary

This experiment makes a direct assault on the conceptual problem of associating volume with just the height of a container. Three containers are chosen that give results that should confound the children's expectations. Using marshmallows or beans gives the children a more concrete volume measure than water. But the children are asked to use inductive logic and make the step from the particular situation with marshmallows to the idea of volume.

This one experiment will not turn the children into believers of conservation of volume, but it is a beginning. As you can see by Louise's answers to the last few questions, they at least suspended disbelief and put down the correct answers. One must pursue this concept for them by trying it again with water later in the year or in the next grade.

Materials per Team

- sufficient small marshmallows or Brown's Best Large Lima Beans to fill the 250 cc beaker
- 1 TIMS 100 cc graduated cylinder, 1 TIMS 150 cc graduated cylinder, and 1 TIMS 250 cc beaker, or 1 tall, narrow container, 1 short, wide container, and 1 other container with a different shape

References

[1]Piaget, Jean and Inhelder, Barbel. *The Psychology of the Child.* New York: Basic Books, Inc., 1965.