**Conservation of Substance**

**Materials**

Two equal balls of clay, and a small amount of clay on the side.

**Procedure**

1. Present the two balls of clay. Say Are these balls of clay the same size? If the student says no, then say Then please make them the same size. Allow the student to add or subtract clay until satisfied that the balls are equal.

2. Smash one ball into a pancake shape. Say Does one of these have more clay than the other, or do both balls have the same amount? Record the student’s response.

3. Say Can you tell me or show me how you know this is true? Record the student’s response.

**Interpretation**

Students show conservation of substance if their response indicates an awareness that the two amounts of clay must be equal because nothing has been added or subtracted in the transformation. Examples include:

• Statements such as “Changing shape doesn’t change the amount” or “You didn’t add any more clay, so they’re both still the same.”

• Behaviors such as rolling the pancake back into a ball, or flattening the ball into a pancake so that both pieces of clay appear equal again.

Students show a lack of conservation if they say the two pieces of clay are different in amount and justify that conclusion on the basis of the clay’s appearance. Examples include:

• Statements such as “The ball is taller” or “The pancake is skinnier.”

• Behaviors such as adding more clay to one in order to make the two pieces the “same” again.

Conservation of substance appears early in concrete operations, usually when children are about 6 or 7 years old.

**Conservation of Displaced Volume**

**Materials**

• Two equal balls of clay, and a small amount of clay on the side.

• Two glasses containing equal amounts of water.

• Two rubber bands.

• A table knife.

**Procedure**

1. Present the two glasses of water, with one rubber band around each glass at the level of the water’s surface. Say Do both glasses have the same amount of water? If the student says no, say Then please make them the same and allow the student to pour water from one glass to the other until satisfied that the amounts are equal.

2. Present the two balls of clay. Say Are these balls of clay the same size? If the student says no, then say Then please make them the same size. Allow the student to add or subtract clay until satisfied that the balls are equal.

3. Place one ball of clay into a glass of water as the student watches. Say Did you see the water go up? Let’s move the rubber band to the place where the top of the water is. Move the rubber band to the level of the water’s surface.

4. Take the second ball of clay and second glass of water. Say I’m going to cut this ball of clay into two pieces. Using the knife, cut the ball into two approximately equal pieces.

5. Say How far do you think the water in this glass will go up when I put the two pieces of clay into it? Please move the rubber band up to the spot where you think the water will go. Allow the student to adjust the rubber band until satisfied with its location.

6. Say Tell me why you put the rubber band where you did. Record the student’s response.

7. Say Let’s see what happens. Drop the two pieces of clay into the glass. Say Were you right? Record the student’s response.

8. Say The water in this glass is the same height as the water in the other glass. Can you explain why that is? Record the student’s response.

**Interpretation**

Students show conservation of displaced volume if their response indicates an awareness that the same amount of water is being displaced in each glass. Examples include:

• Placing the rubber band on the second glass at a level equal with the rubber band on the first glass.

• Statements such as “There’s the same amount of clay in each glass.” Statements like these are considered to indicate conservation even if the student’s original prediction was incorrect.

Students show a lack of conservation if they predict that the water in the second glass will rise to a different height than that in the first glass and if they cannot later justify why the two heights are the same. Examples include:

• Placing the rubber band of the second glass higher or lower than that of the first glass.

• Statements such as “There is more clay in the second glass” or “The pieces in the second glass are smaller.”

Conservation of displaced volume appears later than most other forms of conservation, usually not until age 11 or 12 at the earliest (Linn & Pulos, 1983; Sund, 1976).

**Proportional Reasoning**

**Materials**

• A piece of poster board or large sheet of thick paper, with a stick figure drawn on each side. One figure, labeled “Mr. Little,” is 20 cms tall. The other figure, labeled “Mr. Big,” is 35 cm tall.

• Two thin pieces of wood (such as slats or dowels) at least 45 cm (18 inches) long. One (the “greenie” ruler) is marked in green ink at 5-cm intervals. The other (the “reddie” ruler) is marked in red ink at 2-cm intervals.

• A pencil.

• A sheet of blank paper.

**Procedure**

1. Place the greenie and reddie rulers out of sight. Show the student the two stick figures. Say Here is Mr. Little, and here is Mr. Big. I want you to measure how tall they are.

2. Show the student the greenie ruler. Say Here is a special ruler from the planet Xeron. People on planet Xeron don’t measure with centimeters or inches, they measure with units they call “greenies.” Give the greenie ruler to the student. Say I’d like you to measure how many greenies tall Mr. Little is. Let the student measure Mr. Little, assisting if necessary, until a height of 4 greenies is obtained.

3. Say Now I’d like you to measure how many greenies tall Mr. Big is. Let the student measure Mr. Big, assisting if necessary, until a height of 7 greenies is obtained.

4. Remove the greenie ruler from sight, and bring out the reddie ruler. Say Here is a ruler from the planet Phylus. People on planet Phylus measure with units they call “reddies.” Give the reddie ruler to the student. Say I’d like you to measure how many reddies tall Mr. Little is. Let the student measure Mr. Little, assisting if necessary, until a height of 10 reddies is obtained.

5. Remove the reddie ruler from sight. Say Now let’s review what we know so far. Mr. Little is 4 greenies tall and Mr. Big is 7 greenies tall. Mr. Little is 10 reddies tall. Without measuring, see if you can figure out how tall Mr. Big must be in reddies. Give the student the pencil and blank paper. Say You may use pencil and paper if you wish. Allow the student to work as long as necessary.

6. After the student gives you a prediction for Mr. Big’s height in reddies, say How did you arrive at that answer? Record the student’s response.

7. Give the student the picture of Mr. Big and the reddie ruler. Say Now measure Mr. Big to see if you are right. Let the student measure Mr. Big, assisting if necessary, until a height of 171/2 reddies is obtained. Say Mr. Big is 171/2 reddies tall. Can you tell me why that is the correct answer? Record the student’s response.

**Interpretation**

Students show proportional reasoning if their response indicates the use of multiplication, division, ratios, or fractions. Examples include:

• The correct answer of 171/2.

• Statements such as “The ratio of Mr. Big to Mr. Little in reddies is the same as the ratio in greenies” or “4 is to 7 as 10 is to 171/2” or “10 is 2.5 times 4, so the answer must be 2.5 times 7.” Statements like these indicate proportional reasoning even if the student’s original prediction was incorrect.

Students show a lack of proportional reasoning if they use addition or subtraction to obtain an answer and if they cannot later explain how the correct answer is obtained. Examples include:

• An incorrect answer (often “13”).

• Statements such as “The difference between 4 and 7 is 3, so I added 3 to 10 and got 13” or “4 plus 6 equal 10, so I added 6 to 7.”

Proportional reasoning is one aspect of formal operational thinking.