Cubes & Liquids Scoring Guide

The following are the **operational learning goals** to be assessed:

- Distinguishes Observation from Inference
- Technical Description
- Density of Solid Objects – Coordinates Mass and Volume
- Density of Liquids – Coordinates Mass and Volume
- Classification Scheme (2X2) to Organize Relevant Factors
- Proportional Reasoning -- Coordinating Solid and Liquid Densities

Each **Learning Goal** contains sections entitled Where to Look and Criteria. Descriptions of each Level are provided.

First let us consider **Density.**

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Density – General Considerations

Criteria:

- Any term referring to mass, weight, heaviness, amount of matter etc. is acceptable as an indicator that **mass** is being considered. However the student must be speaking of the mass of one of the objects under consideration - not just in the abstract.

- Any term referring to shape, size, volume, surface area etc is acceptable as an indicator that **volume** is being considered. However the student must be speaking of the volume of one of the objects under consideration not just in the abstract

- In the case of volume it is important however to distinguish between ***size*** *used to differentiate the two cubes* and the consideration of ***size*** *as a factor in floating and sinking*. Only the second is acceptable in rating performance on this objective. Example: “The smaller one looks lighter and so I think it will float.“ Here size is used as a distinguishing property but not with reference to volume as a causal factor.

- The use of a formula, e.g. D=M/V or the term 'density' is unacceptable for either mass or volume unless the student decomposes the formula and refers to the actual mass and volume of the objects under consideration.

Distinguishes Observation from Inference

Where to Look: OBSERVATIONS 1, 2, 3, 4

Criteria:

- Student must respond to all 4 OBSERVATION sections
- Student responses in the OBSERVATION sections must strictly be descriptions of what was observed. They should contain no inferences, explanations or beliefs. A typical unwarranted inference is that the liquid in the beakers is water.

Level 1: Records observations; makes no unnecessary inferences

- Student must respond to all 4 OBSERVATION sections, *and*
- Student responses in the OBSERVATION section are strictly descriptions of what was observed. They contain no inferences, explanations or beliefs.

Level 0: Makes inferences where only observations are called for

- Fails to record 4 observations, *or*
- Inferences that go beyond the simple descriptions required in the OBSERVATION section:
  - "The cube sank to the bottom because it is heavy"
  - "The liquid pushes the object up"
  - “The smaller cube was placed in the 'water'”

Technical Description

Where to Look: OBSERVATIONS 1, 2, 3, 4

Definition: The critical actions and objects of the demonstration/experiment are described so that a person who is not present could reconstruct the event.

Criteria: **CRITICAL ACTIONS AND OBJECTS for Cubes and Liquids:**

- *Experiment 1* – Specify that an object was placed in a beaker of liquid. The result.
- *Experiment 2* – Specify **which** object was placed in a beaker. The result.
- *Experiment 3* -- Specify **which** object was placed in **which** beaker. The result.
- *Experiment 4* -- Specify **which** object was placed in **which** beaker. The result.
- The action (i.e. of placing the object in the beaker) must be stated.
- The result (floating or sinking) must be stated.
- "Container of Liquid", "Beaker", "Container", "Jar," etc. or even "Liquid" are to be considered equivalent and acceptable responses for "Beaker of Liquid."

Level 2: **The student must indicate the critical actions and objects in all of the above experiments (4/4 correct)**

Level 1: **The student fails to provide the required details above for one experiment (3/4 correct)**

Level 0: **The student fails to provide the required details above for more than one experiment (2/4 or less correct)**

Density of Solid Objects – Coordinates Mass and Volume

Where to Look: PREDICTIONS and REASONS FOR PREDICTIONS

Criteria:

- Explicitly and correctly relates the mass and the volume of the solid objects in predicting and explaining the behavior of cubes in liquids.
- Makes correct judgments/predictions and supplies correct reasoning in all cases.

Level 2: Correctly coordinates mass and volume of solid objects

Version A (Large cube first and sinks—alcohol in 1st beaker)

Prediction 1 – Not enough information
Prediction 2 – The cube will sink
Prediction 3 – Not enough information
Prediction 4 – The cube will sink *or* not enough information

Version B (Large cube first and floats—water in 1st beaker)

Prediction 1 – Not enough information
Prediction 2 – Not enough information *or* the cube will sink
Prediction 3 – Not enough information
Prediction 4 – The cube will sink

Level 1: Attempts to coordinate mass and volume of solid objects

- **Must have prediction 2 correct in Version A *or* prediction 4 correct in Version B.**
- A blank response to one or more REASONS for PREDICTIONS means the student can earn no higher than a rating of '1' because a '2' requires that all items must be correct.
- Explicitly relates the mass and the volume of the solid object in predicting and explaining the behavior of the cubes in liquids. Does not make correct judgments/predictions in all cases.
- **Example:** "If it weighs the same in a smaller space, then the density is greater than the large cube."

Level 0: Does not coordinate mass and volume of solid objects

- **Examples:**
  - "It's floating because it has air in it."
  - "I don't know if it's made of metal or wood, so I can't tell if it will float or sink."

Density of Liquids – Coordinates Mass and Volume

Where to Look: THOUGHT EXPERIMENT 2

Level 2: Correctly coordinates mass and volume of liquid

- Explicitly and **correctly** relates mass and volume of the liquid in predicting and explaining the behavior of cubes in liquids

Level 1: Attempts to coordinate mass and volume of liquid

- Explicitly relates mass and volume of the liquid in predicting and explaining the behavior of the cubes in liquids

Level 0: Does not coordinate mass and volume in explaining the behavior of the cubes in liquids

- A blank response to THOUGHT EXPERIMENT #2 is score of '0' on *Conceptualizes Density of Liquids*.

Classification Scheme (2X2) to Organize Relevant Factors

Where to Look: THOUGHT EXPERIMENT 1

Criteria: Specifies how a lighter mystery cube would behave in each of the two liquids AND specifies how a heavier mystery cube would behave in each of the two liquids. Four conditions must be referred to for a complete classification scheme.

Level 2: Forms a COMPLETE classification scheme including all levels of both factors

- Specifies how a lighter mystery cube would behave in each of the two liquids AND specifies how a heavier mystery cube would behave in each of the two liquids. Four conditions must be referred to for a complete classification scheme.
- Respondents must supply the reasons for each of their predictions, but the reasons do not have to be correct.

Level 1: Forms an INCOMPLETE classification scheme including all levels of 1 factor

- Any one of the following possibilities will constitute an INCOMPLETE classification scheme:
    1. The behavior of the lighter mystery cube in both beakers
    2. The behavior of the heavier mystery cube in both beakers
    3. The behavior of both mystery cubes in one beaker

Level 0: Does not form a scheme to classify objects

Proportional Reasoning – Coordinating Solid and Liquid Densities

Where to look: **Thought Experiment 2**. If not there, also check **Thought Experiment 1.**

Definition: Proportional Reasoning is the application of multiplication or division, fractions or ratios in order to coordinate properties of the solid object and liquids.

Criteria: In order to show proportional reasoning, the respondent must:

- Decompose the liquid into its mass and volume, and do one of the following:
  1. Relate mass and volume of the liquid using multiplication or division, fractions or ratios in order to coordinate properties of the solid object and liquids (e.g. "2 gm/cc").
  2. Provide a correct numerical or algebraic answer to the question.
  3. The ratio relationship may not appear visibly as a mathematical formula but is implied in a verbal answer (e.g. "1 cm^3 of the liquid must weigh more than 2 grams").

Level 2: **Correctly coordinates 2 ratios**

- Successfully uses multiplication or division, fractions or ratios in order to coordinate properties of the solid object and liquids.
- Examples:
  - "If the mass of the cube is 2 g for a cube 1 cm on a side, the liquid would have to have a mass of 2g or more for a 1 ml or 1 cm^3 of the liquid."
  - "The ratio of the mass to volume would need to be more than the metal cube in order for the metal cube to float."
  - "1000 ml of the liquid would have to weigh more than 2000g."
  - "For 1 cm^3 the liquid must be weighted at more than 2 g."

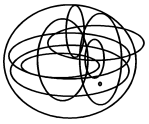
Level 1: **Attempts to coordinate ratios**

- Uses multiplication or division, fractions or ratios in order to coordinate properties of the solid object and liquid but does not succeed in solving the problem.
- Examples:
  - "The volume and the mass of the liquid would have to be more than the volume and mass of the cube."
  - "The mystery liquid must have a volume of less than 1 and a mass less than 2 grams" (response form shows various algebraic formulas and ratios).

- "The liquid must have more atoms in a given volume than the cube." [While this answer may not be conceptually correct it is mathematically correct.]

Level 0: Does NOT attempt to coordinate ratios

- Either does not form ratios *or* does not relate the solid to the liquid
- Examples:
  - "The mystery liquid must be thicker so that it can be able to keep the small cube up."
  - "The liquid would have to be heavier than the cube."
  - "I believe the cube would have to be a light material and the liquid to be normal. Mercury would be perfect."
  - "The water must have more volume than the cube."
  - "The properties must be that the volume is small and the mass is big. It would have to be a mass of 3 or more and a volume of $2cm^3$."



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