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ABSTRACT

The research described in this paper investigates the use of portfolio assessment techniques in middle school science classrooms. It explores how alternative assessment frameworks, such as portfolios, can be used by the classroom teacher and the students as an indicator of students' conceptual understanding and to facilitate changes in science learning environments where learners' development is promoted in the domains of epistemic, cognitive, and social goals. Interviews using the SEPIA (Science Education through Portfolio Instruction and Assessment) Student Interview, were conducted with 29 sixth-grade students selected from classes of 6 teachers in 5 schools in the same urban school district. The purpose of the interview was to develop a profile of students' conceptual understanding with respect to flotation and buoyancy; this understanding was assessed with respect to the three domains established within the conceptual framework of the lesson unit. Transcribed tapes were coded by use of concept maps which are an integral part of instruction. Results indicate that students' conceptual understanding of flotation and buoyancy in terms of operating forces was well established although relation to the underlying explanation in terms of water pressure and design features were underemphasized. A high percentage of students focused on vessel performance in water. Students' use of their portfolios during the interview suggest that certain portfolio items might be critical in bringing about effective instruction and assessment. Appendixes provide: The SEPIA Student Interview and Storyboards; concept maps; samples of student work; and forecast portfolio item. (Contains 17 references.) (ND)

Using Portfolios to Assess Students' Conceptual Understanding of Flotation and Buoyancy

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ABSTRACT

Interviews were conducted with 29 sixth-grade students selected from classes of 6 teachers in 5 schools in the same urban school district. The purpose of the interview was to develop a profile of students' conceptual understanding with respect to flotation and buoyancy. This understanding was assessed with respect to three domains established within the conceptual framework of the lesson unit. Transcribed tapes were coded by use of concept maps which are an integral part of instruction. Results indicate that students' conceptual understanding of flotation and buoyancy in terms of operating forces is well established although relation to the underlying explanation in terms of water pressure and design features is underemphasized. A high percentage of students focused on vessel performance in water. Students' use of their portfolios during the interview suggest that certain portfolio items might be critical in bringing about effective instruction and assessment. The investigation displays the use of portfolio assessment as an indicator of students' conceptual understanding.

Introduction

The adoption of curriculum and instruction models that are grounded in cognitive psychological theories requires a consistency with the other fundamental practices that characterize schools and schooling. In particular, assessment and feedback that students receive ought to be consonant with learning goals and outcomes (Messick, 1987). Fredrickson & Collins (1989) refer to this match between curriculum, instruction and assessment as *systemic validity*. The problem is that advances in assessment and evaluation have not kept pace with curriculum frameworks and models of instruction which seek to improve learners' subject matter reasoning, higher-order thinking skills and communication skills.

Resnick (1987) claims that what is tested in schools signals what is valued in the learning process. In her opinion, tests should go beyond mere illustration of the conceptual knowledge of students. Assessment practices which can be informative about the cognitive and metacognitive abilities of learners need to be developed. Such practices need to yield information about individual learner's representations of concepts, symbols and notations. The strategies that learners use to solve problems, process text, compose stories and construct explanations need to be accessed. Furthermore, prior ideas and conceptions that learners hold are important to determine since these can influence subsequent learning. The capacity to receive, process and apply information from each of these categories concerning learners' cognitive and metacognitive abilities, significantly enhances educational practices and assist learners in the attainment of educational outcomes (Bruer, 1993).

Having access to this information (i.e. via engaging students in tasks which make it possible to make an assessment of a reasoning, problem-solving or data analysis strategy) is both critical and essential for designing effective learning environments. Thus, recommendations for the development of alternative assessment strategies have stressed a review of what we assess and how we assess. The issues about *what* we assess are grounded in arguments from cognitive psychology such that expertise in a domain of knowledge requires the appropriation of select information-processing skills and motivations to learn. The issues surrounding *how* we assess concern what the purpose of the assessment is, who should have access to information resulting from assessment practices and how this information will be utilized.

In this paper, we address these issues on assessment as well as how curriculum and instruction can be aligned with assessment practices towards systemically valid practices of schooling. We approach these concerns by reporting a study that investigates the use of portfolio assessment techniques in middle school science classrooms. We are interested in how alternative assessment frameworks such as portfolios can be used by the classroom teacher and the students to facilitate changes in science learning environments where learners' development is promoted in three goal domains: epistemic goals, cognitive goals and social goals. In our view, the use of portfolios as an assessment tool includes but is not limited to an end-of-unit evaluation of learner outcomes. We advocate a daily interaction with the work students produce during the investigation of problem-based science units. We call this kind of teaching *Assessment Driven Instruction* (ADI) and our broader research program is one that seeks to understand how ADI influences teaching and learning in science classrooms. In this report of research, our focus is on an end-of-unit assessment of students' portfolio construction.

Review of Literature

Champagne and Newell (1994) identify three groups of performance assessments:

1) Academic performance assessments which include laboratory practicals and other closed-ended school problems
2) Authentic tasks which involve real-world, open-ended tasks (Baron, 1990; Raizen and Kaser, 1989)
3) Dynamic or developmental assessment which measures students' potential for change over time as determined by students' responses to feedback (Campione, 1990).

This partitioning of performance assessments is grounded in research by cognitive sciences, which has pointed to the domain-specific nature of higher-level thinking or reasoning (Glaser, 1984). Hence, the expanded role of performance assessment in science ought to take into consideration the nature of scientific knowledge acquisition and include areas of performance capabilities such as conceptual understanding, practical reasoning and scientific investigation (Champagne and Newell, 1994). The implication from cognitive research on learning and teaching (Glaser, 1984; Resnick, 1989; Klahr and Dunbar, 1988) is that these capabilities (conceptual understanding, practical reasoning and scientific investigation) are not mutually exclusive of one another. As such, there are interaction effects among the various cognitive processes. That is, both the conceptual and procedural knowledge demands needed to reason, problem solve or inquire in science are determined by the context in which the reasoning, problem solving or inquiry will take place. For instance, Gardner (1993), in arguing from his theory of multiple intelligences, advocates that thinking in context requires attention given to epistemic, notational and symbolic systems.

The generation of new assessment items and instruments (authentic tasks, dynamic assessment) and new strategies and formats (portfolios) can be seen as development which is grounded in our enriched understanding of what it means to reason scientifically. Since scientific reasoning occurs with domain-specific knowledge (Glaser, 1984; Voss, Wiley & Carretero, 1995) declarative what-we-know knowledge must be taught and assessed. However, declarative knowledge needs to be coupled with procedural or strategic how-we-know knowledge of the domain. In this sense, development of strategic knowledge becomes important when learning itself is treated as problem solving (Resnick and Glaser, 1976). Hence, learning in science and the development of scientific reasoning involves the restructuring of both declarative and procedural knowledge. Furthermore, development of learners' intentions, plans and mental efforts in problem solving need to be taken into consideration (Bereiter and Scardamalia, 1989).

Glaser (1994), in a keynote address delivered at the 23rd International Congress of Applied Psychology, offers a set of seven related emerging principles of instruction derived from learning theory that can be used to shape learning environments:

1. *Structured Knowledge* - "Instruction should foster increasingly articulated conceptual structures that enable inference and reasoning in various domains of knowledge and skill. Education that teaches isolated memorization of facts and definitions of concepts will not accomplish this purpose" (p 17).

2. *Use of Prior Knowledge and Cognitive Ability* - "[R]elevant prior knowledge and intuition of the learner is . . . an important source of cognitive ability that can support and scaffold new learning . . . . . the assessment and use of cognitive abilities that arise from specific knowledge can facilitate new learning in a particular domain" (p 18).

3. *Metacognition: Generative Cognitive Skill* - "[T]he use of generative self-regulatory cognitive strategies that enable individuals to reflect on, construct meaning from, and control their own activities . . . . is a significant dimension of evolving cognitive skill in learning from childhood onward. . . These cognitive skills are critical to develop in instructional situations

because they enhance the acquisition of knowledge by overseeing its use and by facilitating the transfer of knowledge to new situations . . . [T]hese skills provide learners with a sense of agency." (p 18).

4. *Active and Procedural Use of Knowledge in Meaningful Contexts* - "Learning activities must emphasize the acquisition of knowledge, but this information must be connected with the conditions of its use and procedures for it applicability. . . . School learning activities must be contextualized and situated so that the goals of the enterprise are apparent to the participants" (p 19).

5. *Social Participation and Social Cognition* - "The social display and social modeling of cognitive competence through group participations is a pervasive mechanism for the internalizations and acquisition of knowledge and skill in individuals. Learning environments that involve dialogue with teachers and between peers provide opportunities for learners to share, critique, think with, and add to a common knowledge base" (p 19).

6. *Holistic Situations for Learning* - "[L]earners understand the goals and meanings of an activity as they attain specific competencies. . . . [C]ompetence is best developed through learning that takes place in the course of supported cognitive apprenticeship abilities within larger task contexts" (p 19 -20).

7. *Making Thinking Overt* - "[A] significant mechanism in environments for learning is to design situations in which the thinking of the learner is made apparent and overt to the teacher and to students. In this way, student thinking and reasoning can be examined, questioned, and shaped as an active object of constructive learning" (p 20).

These principles require fundamental changes in the roles of teachers and students, alterations in the aims and contents of curriculums as well as modifications in assessment practices. One way of contributing to educational innovations such as alternative assessment frameworks is to include the cognitive and epistemic dimensions of assessment as an integral part of instruction and curriculum (Duschl & Gitomer, 1993). Since 1991, NSF funded Project SEPIA (Science Education through Portfolio Instruction and Assessment) has constructed and examined models of instructional activities in an effort to make assessment a component of instruction. In so doing, Project SEPIA has sought to elucidate the dynamics of portfolio processes and assessment practices, and how these can be used to evaluate students' conceptual understanding, scientific reasoning and representation of scientific knowledge.

Study

The purpose of the study then was to develop a profile of students' conceptual understanding within the subject-matter of flotation and buoyancy. The data source is student interviews conducted as part of research and development efforts of Project SEPIA. In particular, we were interested in exploring the correspondence of students' conceptual understanding with the instructional goals targeted towards such an understanding. Hence, we used concept maps (which are integral parts of curriculum and instruction) to code students' responses from the interviews. In a broader sense, we are interested in how portfolio instruction and assessment can assist students' conceptual understanding. Thus, a record of students' use of their portfolios during the interview was significant. Finally, we wished to learn about students' performance on an assessment task which encouraged the use of portfolios.

Methodology

Interviews were conducted around folders of student work at the completion of the Vessels Unit. The Vessels Unit, a month long curriculum unit developed by Project SEPIA, is based on an engaging and authentic inquiry activity that functions in a student-centered classroom. Throughout the unit, students complete activity assignments that contribute to the construction of an explanation of why vessels can float with a load. The underlying goal of the unit then, is to facilitate students' meaning making and reasoning in the domain of flotation.

In order to assist teachers and students with this goal, the conceptual framework of the unit is represented in concept maps which present and illustrate core concepts as well as the relationships or links between these concepts. The core concepts such as buoyancy, gravity and water pressure not only provide a scheme towards an explanation of flotation but also are related to the design features such as height of sides, volume and bottom surface area of the vessel.

Upon completion of the Vessels Unit, interviews were conducted with 29 sixth-grade students selected from the classes of 6 teachers in 5 schools in the same urban school district. Selection of students was stratified. That is, special attention was given to including students of both gender as well as racial and academic backgrounds. Teachers selected students whom they believed represented in their classes a diverse population with respect to these attributes.

All interviews were conducted one-on-one, audio-taped and transcribed. Established interview protocols were followed. The interview protocol consisted of 4 segments which lasted for about 45 minutes (Appendix A). The overall goals of the interview were as follows:

1. To investigate students' criteria and perceptions of the work which they think exemplifies key concepts and relationships;

2. To investigate students' criteria and ability to identify characteristics which represent implementation of SEPIA criteria; and
3. To investigate students' ability to use information from their portfolios.

In order to accomplish these goals, the interview was structured in several segments. In the first segment, the *Reconstruction Task,* which lasted for about 5 minutes, the interviewers aimed to establish a comfortable atmosphere for the students by engaging them in casual conversation. Thereafter, the students were given the opportunity to talk about their folders and perceptions about the purpose of the activities in their science class. The next segment, the *Selection Task,* lasted for about 20 minutes. Relying on the work that they produced in their portfolios, the students answered questions about the concept of buoyancy as well as specific design features of the vessels which they built on two occasions. They were shown pictorial representations, the Rising Ball Storyboards, drawn by other students and they were asked to rank these representations and explain their judgment criteria.

The next 10 minutes was devoted to the *Manometer Demonstration* where the interviewers explained what happened to water pressure when a funnel, coated at the mouth with a rubber membrane and connected to a U-tube containing food coloring, was immersed and raised in water. Students were then asked to relate this demonstration to what they have done in their science class. They were informed to select items from their folders that would indicate the same principles involved in this demonstration. The final 20-minute segment of the interview encompassed a comprehensive account of the unit and thereby provided a rich source of information about students' explanations for flotation. The task involved a talk-aloud on-demand performance for two floating conditions: one with a load and the other without a load. For each of the conditions, the directions were the same and were as follows:

> Sketch the vessel. Use arrows, science terms, and the names of forces to label the sketches. The labels should explain what keeps the vessel afloat.

This study has concentrated on this last segment of the interview. Students' conceptual understanding was assessed with respect to three domains as established within the conceptual framework of the Vessels Unit. These domains (A, B and C) are illustrated in the concept map in Figure 1.

Domain A displays the core concepts of floating, sinking and rising explained in terms of buoyant and gravitational forces. These core concepts are built into the portfolio activities which take place at the beginning of the Vessels Unit. Domain B integrates aspects of vessel design into the framework of reasoning towards an explanation of flotation. The concepts pertinent to this domain follow those in Domain A in the instructional sequence. Domain C relates water pressure to design of the vessel and it constitutes concepts which are built into the final activities in the portfolio.

Transcribed tapes were analyzed to investigate students' meanings of definitions, beliefs as well as theories about flotation. Students' responses were coded using the concept maps in Appendix B. SEPIA criteria such as clarity, accuracy, consistency with evidence and relationships (Duschl & Gitomer, 1993) were considered in coding responses. Both verbal and pictorial representations were considered in coding. Concepts and relationships (or links) were coded once irrespective of the frequency with which they were mentioned by the students. That is, we were not interested in tracing the number of occurrence of concepts within a particular interview. Rather, we sought to capture each student's overall conceptual framework

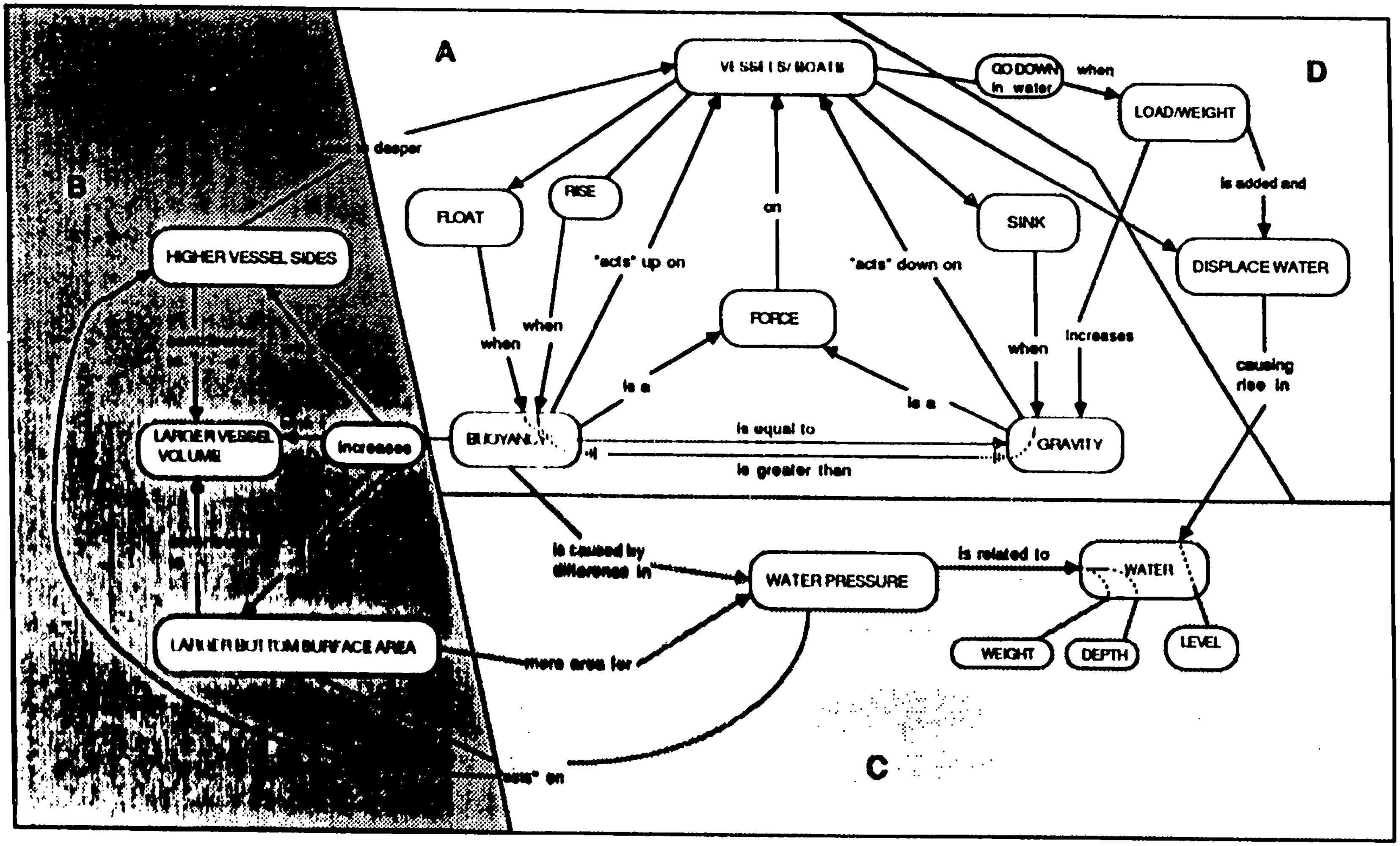

Figure 1. Concept Map of the Vessels Unit

which emerged during the interview. Particular attention was given to identify students' use of models, to causal reasoning patterns and complexity of thematic patterns.

Coding was verified across researchers. First, we separately coded responses from three students selected at random. Comparison of our coding revealed close agreement. We discussed our criteria for judging student responses and resolved the source of potential variation between our coding schemes as being related to the integration of verbal versus pictorial representations. We decided to place equal emphasis on students' pictorial and verbal representations. We then coded three more interviews selected at random. At this time, there was complete agreement between our coding patterns. The rest of the interviews was coded by one researcher and verified by the other.

Results

Some examples of student work from the last segment of the interview are given in Appendix C. Students responded to the questions in the interview by mentioning concepts from the three domains established as unit goals. All students mentioned another domain (part D in Figure 1) which concerns the vessel performance in water throughout the activities of the Vessels Unit. In other words, vessel performance concerns the sequence of actions that occur as weight is added to the vessel: vessel goes down in water and this in turn causes a rise in water level.

On average, students mentioned domain D concepts more than they mentioned concepts from other domains. The following table illustrates the average number of students referring to concepts from each domain:

Domain	Number of students
D	23
A	19
B	7
C	4

As illustrated by the following table, there were more number of pairs of concepts across domains A and D than across any other domains. A concept pair constitutes two concepts mentioned simultaneously by the same student. There were about the same number of domain B concepts paired with domain A and D concepts. Likewise, the number of domain A and D concepts that domain C concepts pair with was about the same. The least number of concept pairs occurred between domains B and C.

Correspondence	Number of pairs of concepts
AXD	726
AXB	228
BXD	219
AXC	80
CXD	72
BXC	22

Domain A (which constitutes core concepts and relationships) is introduced to the students via the Vessels Unit. Domain D concerns vessel performance in water and is a result of student interpretation. The simultaneous mention of concepts from domains A and D (Correspondence AXD) constitutes the largest number of concept pairs. This suggests that the students are not only employing the learned core concepts with about the same emphasis as their conceptions of vessel performance but also are using these two domains together the most. It is probable that the students' emphasis on vessel performance is reinforced during the last segment of the interview. The beginning question in this segment specifically demands that the student describes what he or she is drawing.

The results indicate that fewer students related core concepts to either the design features or the relation of this design aspect to water pressure. Figure 2 and Figure 3 illustrate the profile of mentioned concepts and relationships between these concepts. 97% of students made reference to vessel as an object in water and also to the concept of gravity. These concepts from domain A occurred with the highest number of students. Three percent (3%) of students mentioned rising of vessels in water as a concept: the lowest frequency with respect to domain A. The action of gravity down on an object was mentioned by 90% of the students, whereas only 3% of the students considered the action of rising of vessels, relation of this action to buoyancy and the case where buoyancy might be greater than gravity.

Highest and lowest percentage of students who mentioned concepts from each domain, and links across domains is illustrated in Figure 4.

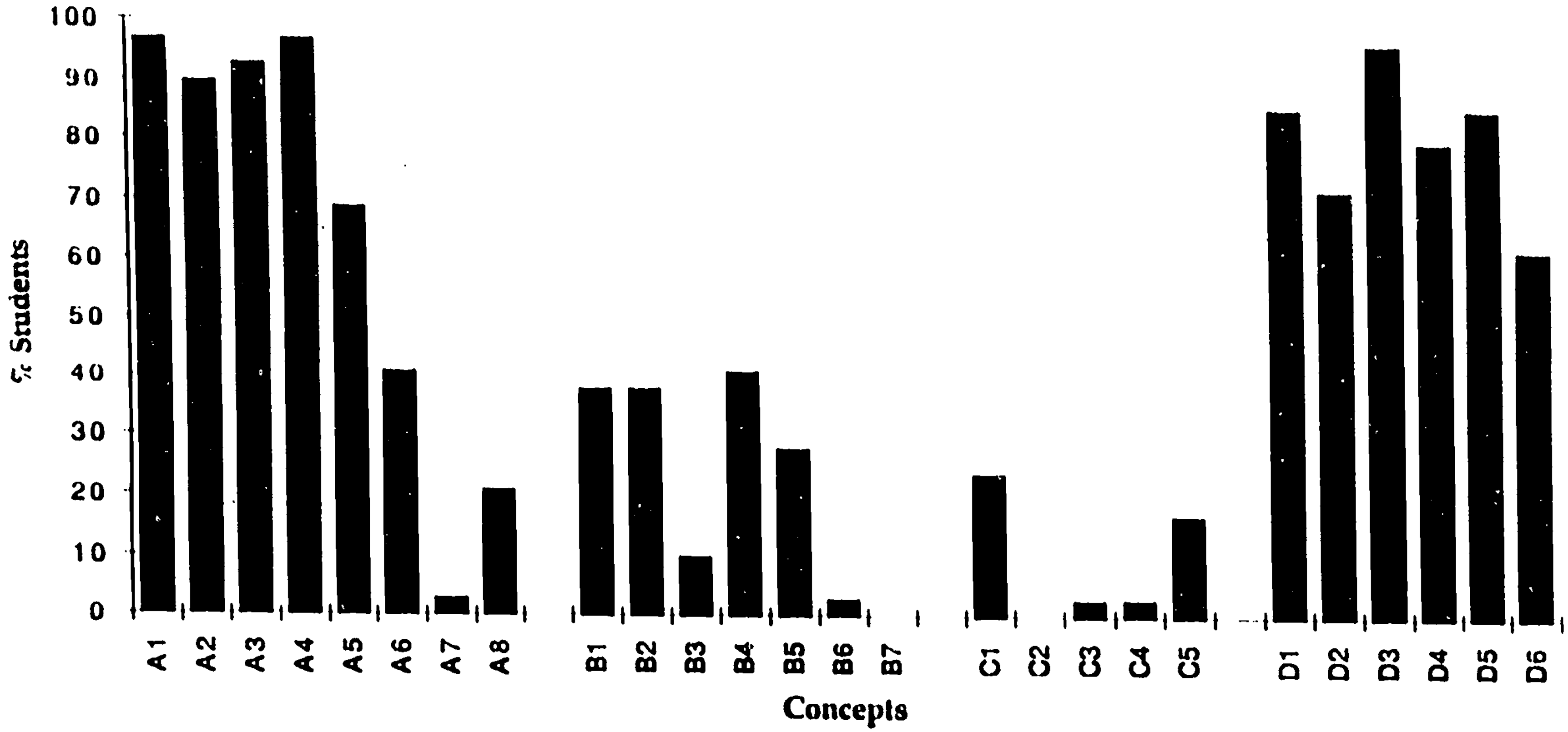

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Figure 2. **Profile of Mentioned Concepts**

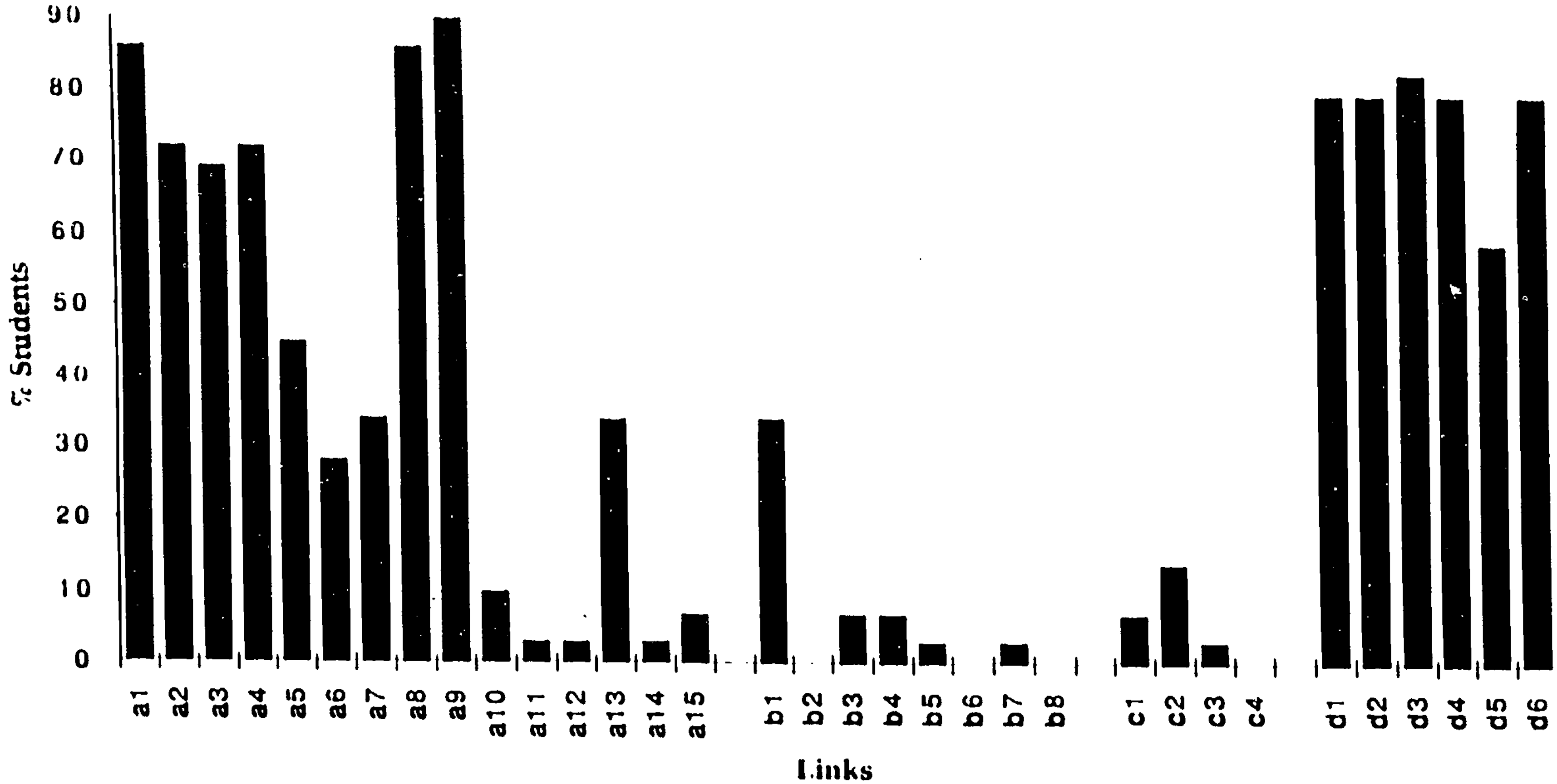

Figure 3. Profile of Mentioned Links

Concept or Link	% Students
Concept of load or weight *(Domain D concept-highest)*	97%
Relationship between addition of load and water displacement *(Domain D link-highest)*	83%
Gravity with respect to addition of load or weight to vessel *(Domain D concept-lowest)*	62%
Increase of gravity with load or weight *(Domain D link-lowest)*	59%
Bottom surface area of vessel *(Domain B concept-highest)*	41%
Concept of increase in buoyancy with no reference to any other concept *(Domain B link-highest)*	34%
Concept of water pressure *(Domain C concept-highest)*	24%
Relationship between water pressure and water depth *(Domain C link-highest)*	14%
Vessel and its position in water based on its design features *(Domain B concept-lowest)*	0%
Relationship between higher vessel sides and their influence on vessel performance in water *(Domain B link-lowest)*	0%
Bottom surface area of vessel in relation to water pressure *(Domain C concept-lowest)*	0%
Action of water pressure on bottom surface area of vessel *(Domain C link-lowest)*	0%

Figure 4. **Highest and lowest percentage of students mentioning concepts from each domain and links across domains.**

All seven students who demonstrated an understanding of a causal explanation with respect to design features and water pressure (links between domains B and C were established) also mentioned a particular portfolio item (Appendix D) during the interview. Two other students who didn't make connections across these domains also mentioned this item. We consider this portfolio item to be critical in developing students' understanding of water pressure increasing with depth in water. It involves an activity which focuses on changes in water pressure with depth when a cup is pressed down a body of water. Here, we refer to a *Forecast Portfolio Item* (Appendix D) which seems to predict students' conceptual understanding of the causal explanation associated with water pressure and flotation. In an earlier pilot interview around the same questions and 17 portfolio items (but different storyboards), 20% of all items selected by students was this Forecast Portfolio Item. In our view, this activity is an indicator of students' understanding of core unit concepts and relationships.

As a future investigation, we intend to carry out a qualitative study on students' explanations about flotation and buoyancy. However, some general trends are worth mentioning here. With respect to design features, students' explanations tend to emphasize the performance aspect of the vessel. That is, the sides of the vessel are high so as to keep the water from getting in:

> I learned about gravity force and buoyancy force, the surface area and sides, which help so that water doesn't rise up and go inside the boat.

In a similar fashion, the bottom surface area of the vessel is justified not in terms of its relation to the buoyant force acting on it or the volume of the vessel but in terms of the vessel as a carrier of materials:

> I was writing, uhh, the surface, I was writing why the surface area is big...cause the washers have to go in, to fit.

Finally, as a subsequent planned analysis based on this study, we intend to explore further the students' oral versus pictorial representations.

Conclusions and Implications

The investigation displays the use of portfolio assessment as an indicator of students' conceptual understanding. Results are mixed with respect to students' attainment of unit conceptual goals. Along with core unit concepts and relationships, students constructed and emphasized a domain which concerns vessel performance in water. This domain is not an integral part of the designed curriculum. Furthermore, particular aspects of the conceptual ecology, such as design features and the concepts related to water pressure, have been underemphasized. Students' construction of a causal explanation for flotation and buoyancy, a central goal of Project SEPIA, depends on articulation of these aspects of the conceptual ecology.

It is noteworthy to point out that students' use of their portfolios during the interview suggest the significance of certain portfolio items in bringing about effective instruction and assessment. Practical applications from the results of the study pertain to three aspects of the portfolio process. First, the study illustrates how assessment practices can be modified for more effective feedback to teachers, students as well as researchers. That is, reduced emphasis on certain concepts and relationships such as those related to design features, can be regarded as an indicator for modification of the performance assessment task. Second, curricular practices can be provided with specific information about what aspects of the conceptual ecology needs to be improved. For instance, the conception about rising of vessels in water, which is underemphasized by the students, could be explored by inclusion of an activity which questions the case where load is being removed from a floating vessel. Third, instructional practices can be informed by the results of this study, via more emphasis and elaboration, of the concepts which were least acknowledged by the students. For example, the study illustrates the necessity to stress, in the instructional activities as well as in curricular design, the relation of water pressure to water weight.

Design and revision of portfolio assessment processes can be considered in light of observations such as those reported here. The way with which we assessed students' conceptual understanding is consonant with the learning outcomes and goals that were set by Project SEPIA. That is, the set epistemic, cognitive and social goals were targeted in the assessment process. Portfolio assessment has been informative about the cognitive practices of learners. In particular, we received information that illustrates the ways in which individual children represent concepts and notation systems. This portfolio assessment process allows us to inquire about the strategies children use to solve problems and construct explanations. We have been informed about learners' conceptions of flotation separate from those intended with the designed curriculum. The model of portfolio assessment illustrated here enhances our abilities to improve educational practices and assist learners in the attainment of educational outcomes.

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APPENDIX A

SEPIA Student Interview and Storyboards

SEPIA Student Interview
Vessels Unit

Purposes:

1) To investigate students' criteria and perceptions of the work which they think exemplifies key concepts and relationships;
2) To investigate students' criteria and ability to identify characteristics which represent implementation of SEPIA criteria;
3) To investigate students' ability to use information from their portfolios.

Time constraint: 45 minutes maximum

A. Reconstruction Task (5 minutes)

[Start with a warm introduction]

"Hello my name is ______. I'd like to ask you some questions today about some things you have done in your science class. Do you remember using aluminium foil and learning about how to build the best vessel for carrying loads?"

Probe 1

[Interviewer hands the folder to the student and asks]

1.A "Let's take a look at the papers in your folder. I would like you to take a quick look through each of the papers in your folder. I'll check off the papers you completed on this sheet so I know what activities you did."
[Researcher checks off the activities on the sheet]

"Do you remember doing the vessels activities and completing these worksheets in class? Do you remember building more than one vessel? Please tell me more about what you did on [PI#2, PI#5, Blue Activity Sheet]**"**
[Interviewer states]
"Take a look at the letter that you got at the beginning of the vessels unit. I would like you to read aloud the last paragraph on page one and the first paragraph of page two."
[After the student finishes reading, the interviewer asks]

1.B "What do you think was the purpose of the vessel activity?"
[The correct response has two parts:

A. to design a hull that maximizes carrying capacity

B. to be able to explain why and how the design works.]

[If the student <u>states the correct purpose</u>, go on to **Selection Task.**
If the student <u>does not state the correct purpose</u>, point it out in the letter, read it aloud and then go on to the next step, **Selection Task.**]

<u>B. Selection Task</u> (20 minutes)

<u>Probe 2</u>

[Interviewer states]
2.A "Now I would like to know what you think about some of the work you have done in this folder. When you built your second vessel how was it different from your first vessel?"
[Ask the child to state as many differences as possible. e.g. "Any other way it was different?"]
2.B "What are the sheets of work that would show me why you built the second vessel the way you did?"
[Record the selected items by number on the data sheet]
[Interviewer asks]

2.C **"What do you think are the features of a vessel that carries the most load?"**
[If student gives only one response, ask] **"Anything else?"**
[Record student response (e.g. big bottom, high sides, strong sides, thick sides, etc.) and use it in the next two questions]
[Interviewer asks]
2.D **"Is there anything in the folder that made you think** [insert students' responses here] **was important?"**
[Repeat for each response in 2.C]
[Interviewer asks]
2.E **"Was there anything you did in class, but not in the folder, that made you think** [insert students' responses here] **was important?"**
[Repeat for each response in 2.C]

Probe 3 - Buoyancy

[Interviewer states]
3.A **"An important term in the Vessels Unit is buoyancy. What can you tell me about buoyancy?"**
"I'd like you to go through the papers in your folder and select the things you think shows you understand buoyancy or buoyant force."
[Record the selected items by number on the data sheet]
[Interviewer asks]
3.B **"Would you please explain why you selected each of these items?"**
[If student does not respond in terms of buoyancy, then ask]
3.C **"Can you tell me how these papers show you understand buoyancy or buoyant force?"**

Probe 4 - Improving a Task

[Interviewer places the three Rising Ball Storyboards in front of the student and states]

4.A "Let's look at these storyboards some students made. These students were asked to draw what would happen if you let go of a ball under water. Here are the directions they were given, would you please read them aloud. Look at the storyboards carefully and tell me what you see. What is happening in the drawings?"

[Interviewer takes notes that allow for compare/contrast follow-up questions]

4.B "Which of the three storyboards do you like the best? What do you notice in this storyboard [the child's best] **that makes it the better than the other storyboards?"**

4.C "I'd like you to put them in order from best to worst? Tell me why you put them in this order?"

4.D "Suppose you were in a group with this student [show lowest rank drawing]. **What advice would you give to help improve the story it tells? what questions would you ask? Is there anything he/she did that you do not understand?"**

[If the child says nothing then ask compare/contrast questions and repeat the question]

4.E "Suppose you were in a group with this student [show highest rank drawing]. **What advice would you give to help improve the story it tells? What questions would you ask them? Is there anything he/she did that you do not understand?"**

4.F "Okay, let's do something else. Suppose you were asked to explain floating and sinking to a 5th grader. How would you explain to a 5th grader who had never done the Vessels Unit why vessels float and sink?"

4.G "What work would you show them from your folder?"

[Record the selected items by number on the data sheet]

4.H "Is there anything you would change or add to [sheet student selects] **to help the 5th grader understand why vessels float and sink?"**

C. Manometer Demonstration Task (10 minutes)

Materials: Manometer, plastic container, water, paper towels, eyedropper vial, food coloring.

[Interviewer asks]

"Did your teacher do this demonstration?"

Option 1: If yes (teacher did do the manometer demonstration)

[Interviewer states]

"Could you please explain to me what is taking place?"

[Interviewer restates the correct idea if and when it is mentioned by the student]

"This is an instrument which shows that water pressure increases as you go deeper."

[Perform the demonstration, allowing the student to raise and lower the manometer. Let students push gently on the rubber membrane. Interviewer points to the water level change in the U-shaped tube as the funnel is immersed and raised in water]

Option 2: If no (teacher did not do the manometer demonstration)

[The interviewer performs the demonstration, allowing the student to raise and lower the manometer. The interviewer points to water level change in the U-shaped tube as the funnel is immersed in water. The interviewer explains what is taking place by pointing out how the level of colored water changes as the funnel is lowered and raised in water in the plastic container. The interviewer then states]

"This is an instrument which shows that water pressure increases as you go deeper."

Probe 5- Water Pressure

[Interviewer states]

5.A **"Can you point to things in your folder or things you did in the vessels unit that show the same ideas as this demonstration on water pressure, that water pressure increases as you go deeper in water?"**

5.B **"Can you describe how that particular** [portfolio item or activity] **shows the same idea found in the demonstration?"**

5.C **"How did learning about water pressure help you design your second vessel?"**

5.D **"How does knowing about water pressure help explain why a vessel can float with a load?"**

D. Use of Items in Portfolio Task (20 minutes)

Materials: Provide the student with pencils and crayons.

Probe 6 - Portfolio Item C
Option 1 - Portfolio Item C not completed

[Interviewer asks]

"Could you please take out Portfolio Item C?"

[If the student does not have the item, the interviewer gives a copy of Portfolio Item C]

[Interviewer states]

"The last thing I'd like you to do is complete this sheet of paper."

[The interviewer reads the directions from the paper aloud]

[The interviewer then adds]

"I'd like you to draw what these boats would look like and why they would look that way. Please explain what you're drawing."

"Do you have any questions?"

"Do not worry about the spelling of words as you write the labels."

[The interviewer points to the folder and spreads out the papers and stresses the following point]

"I want you to know that you may look at and use any of the sheets of paper in the folder to help you."

"If you use a paper, I'd like you to pick it up or point to it and then I'll write the number up here in the corner" [Interviewer points to upper left corner of Portfolio Item C]

[Once the student is done, the interviewer asks the following question]

"Based on this drawing can you tell me about the things you learned from doing the activities in the folder?"

Option 2 - Portfolio Item C is completed

[Interviewer states]

"I'd like you to do a drawing for me. Please draw a vessel in the water that is carrying a load and label it with arrows and terms that explain why it floats."

"I'd like you to draw what these boats would look like and why they would look that way. Please explain what you're drawing."

[The interviewer points to the folder and spreads out the papers, and stresses this point:]

"I want you to know that you may look at and use any of the sheets of paper in the folder to help you."

"If you use a paper, I'd like you to pick it up or point to it and then I'll write the number up here in the corner." [Interviewer points to upper left corner of Portfolio Item C]

Concluding Questions

"Please choose something in your folder that shows how well you understand the Vessels Unit."

[After child does selection task]

"Please explain why."

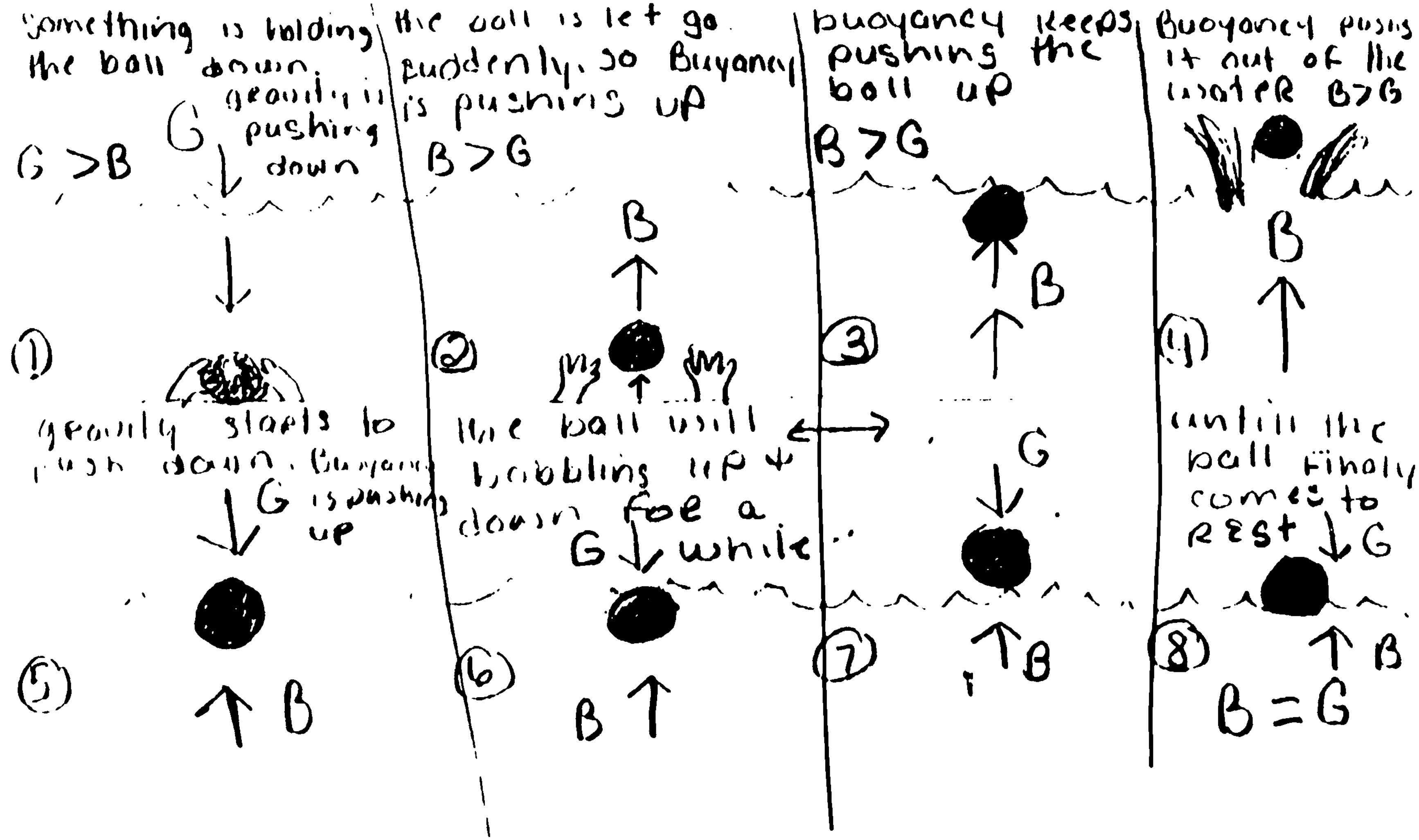
"Please choose any piece from your folder that shows something important about you as a learner."

[After child makes selection ask]

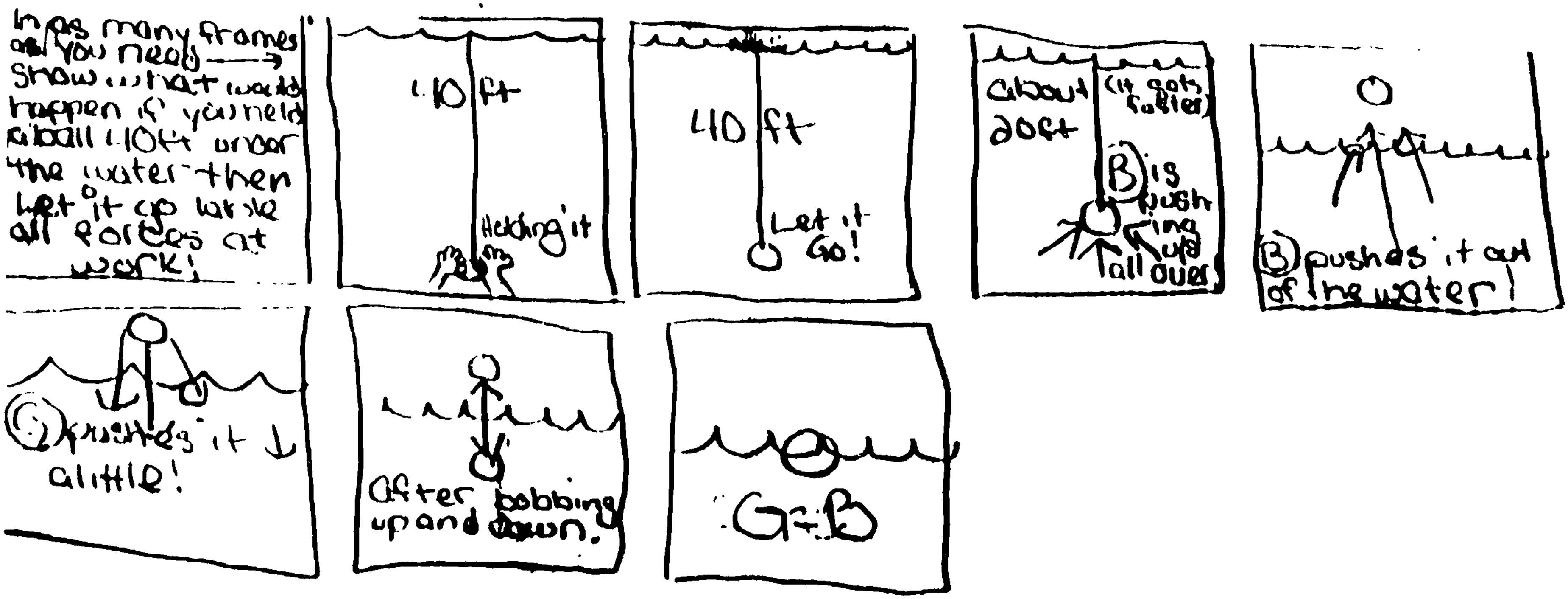
"What does it show?"

[Interviewer concludes warmly]

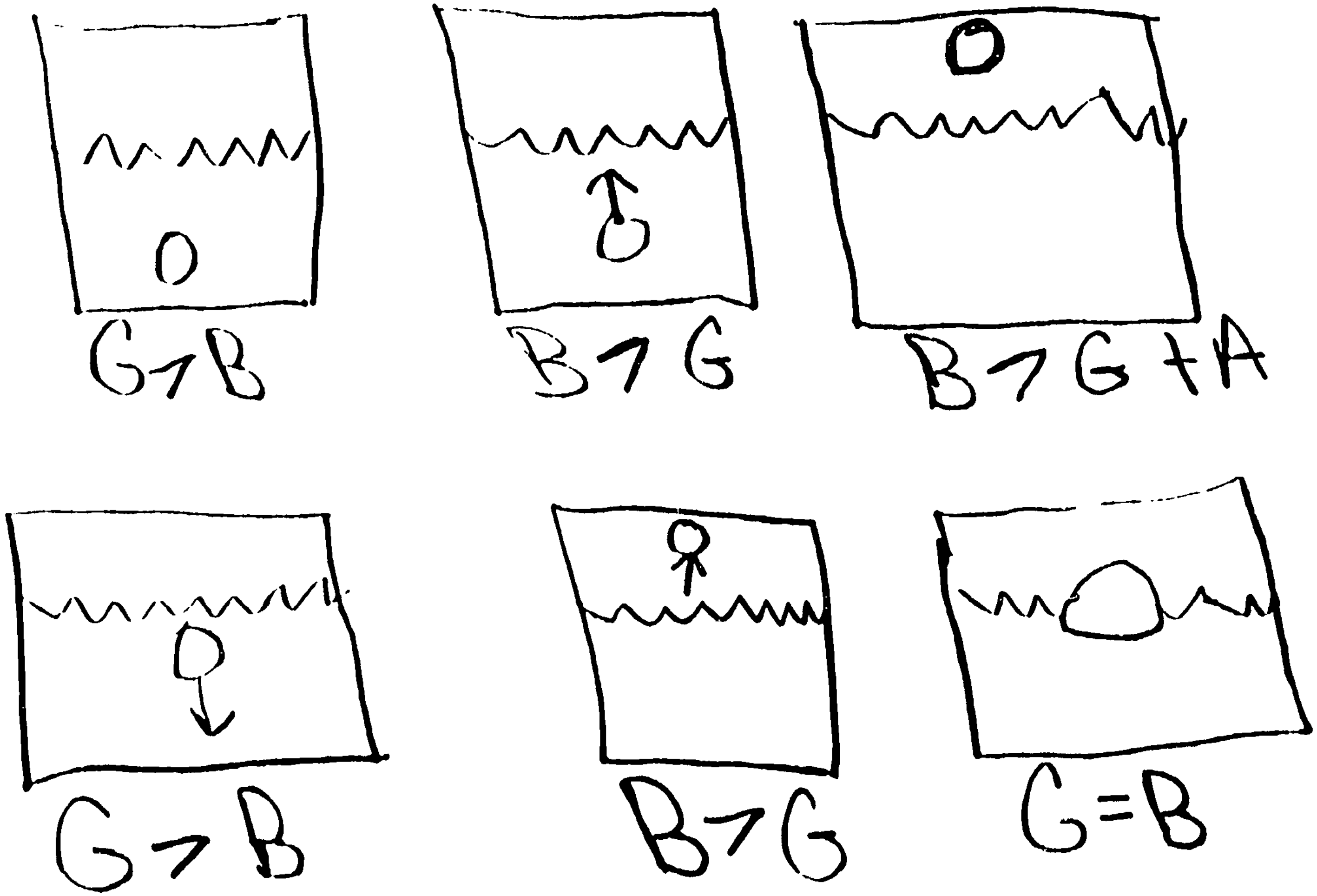
"Thank you for your help with this science education project. You have helped us to learn more about teaching and learning science."


Something is holding the ball down. gravity is pushing down
G > B
G
(1)
the ball is let go suddenly, so Buyancy is pushing up
B > G
B
(2)
buoyancy keeps pushing the ball up
B > G
B
(3)
Buoyancy pushs it out of the water B > G
B
(4)
gravity starts to push down. Buyancy G is pushing up
G
B
(5)
the ball will bobbling up & down for a while
G
B
(6)
G
B
(7)
until the ball finaly comes to rest
G
B
B = G
(8)

STORYBOARD B



BEST COPY AVAILABLE

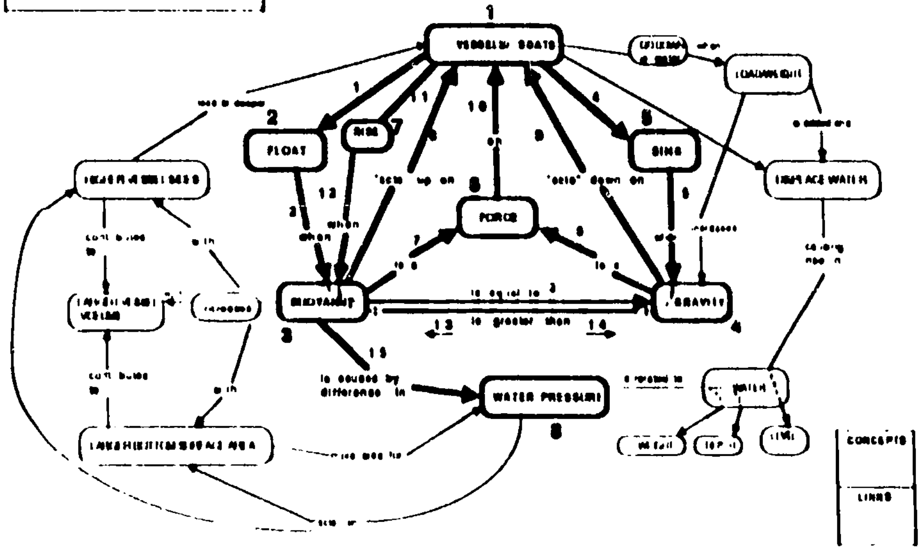

G>B
B>G
B>G+A
G>B
B>G
G=B

APPENDIX B

Concept Maps

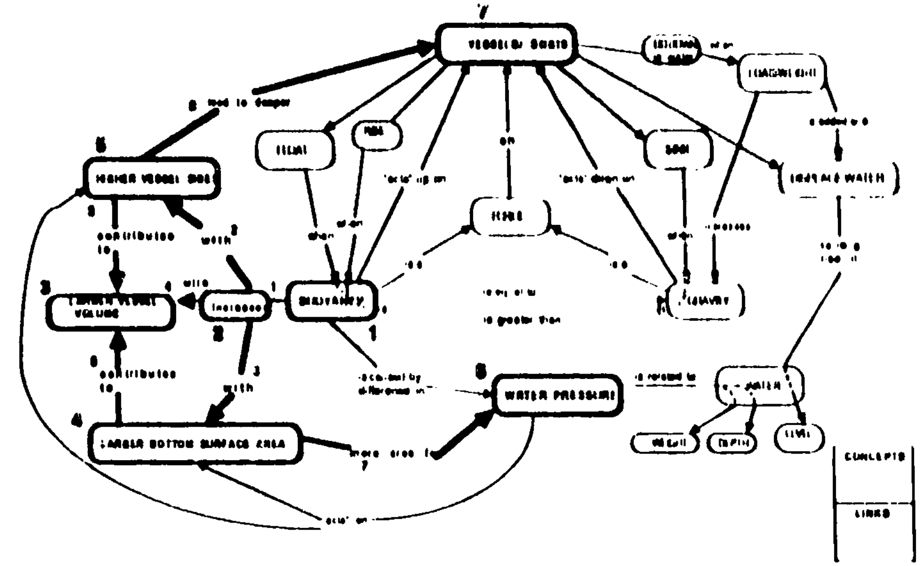
CORE CONCEPTS

A



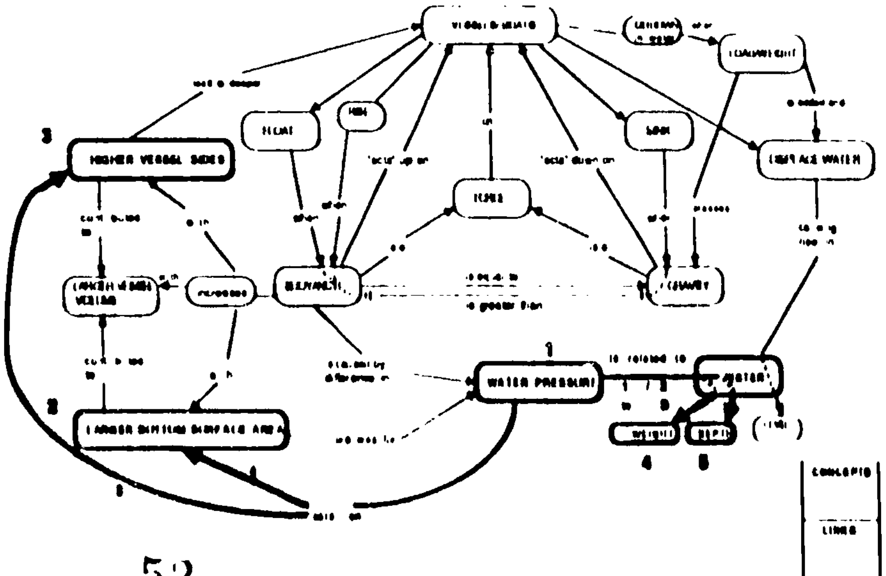
DESIGN

B



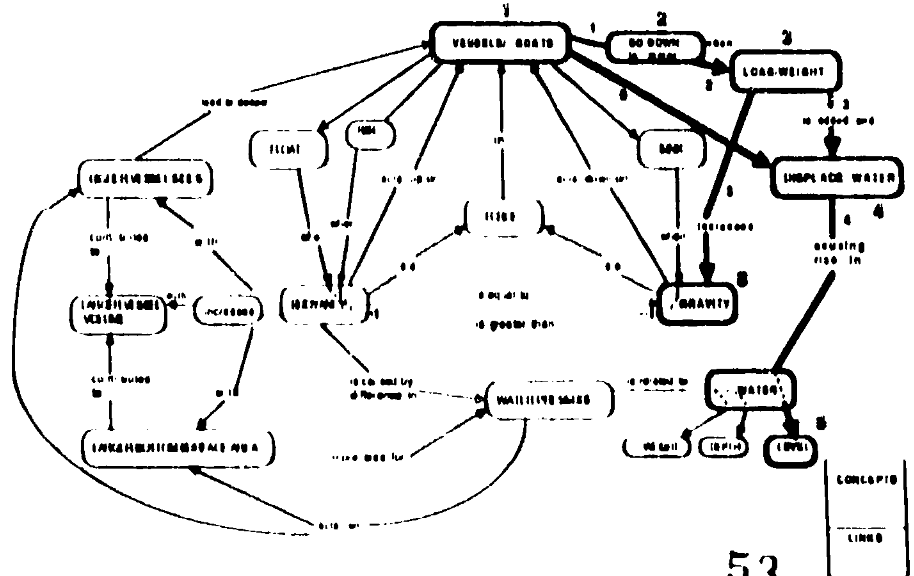
WATER PRESSURE

C



VESSEL PERFORMANCE

D



BEST COPY AVAILABLE

APPENDIX C

Student Work

Portfolio Item C
Design Packet - What keeps the vessel afloat?

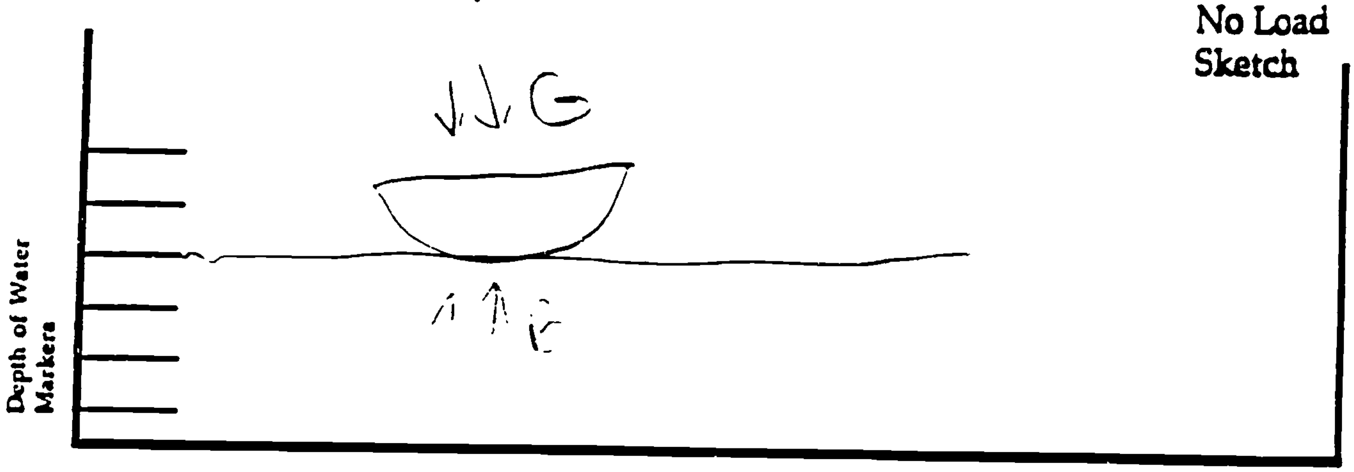
Name

Date

Teacher

Sketch the vessel. Use arrows, science terms, and the names of forces to label the sketches. The sketch and labels should explain what keeps the vessel afloat.

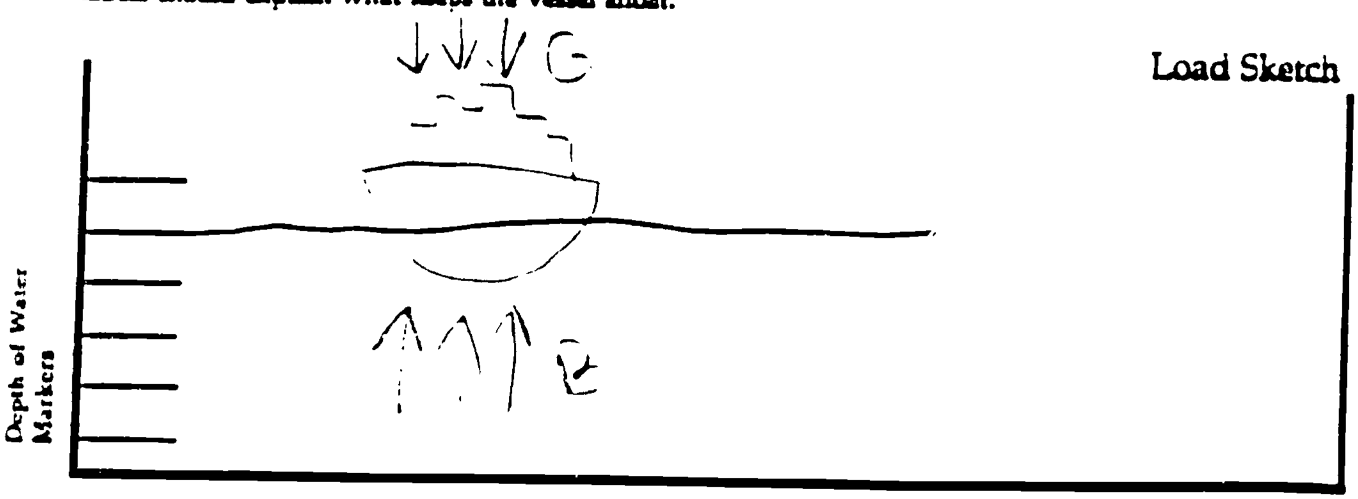
No Load Sketch



Vessel without a load
Mark the water line

Sketch the vessel. Use arrows, science terms, and the names of forces to label the sketches. The sketch and labels should explain what keeps the vessel afloat.

Load Sketch



Vessel with a load
Mark the water line

Criteria:
Accuracy
Clarity & Precision
Relationships

Portfolio Item C
Design Packet - What keeps the vessel afloat?

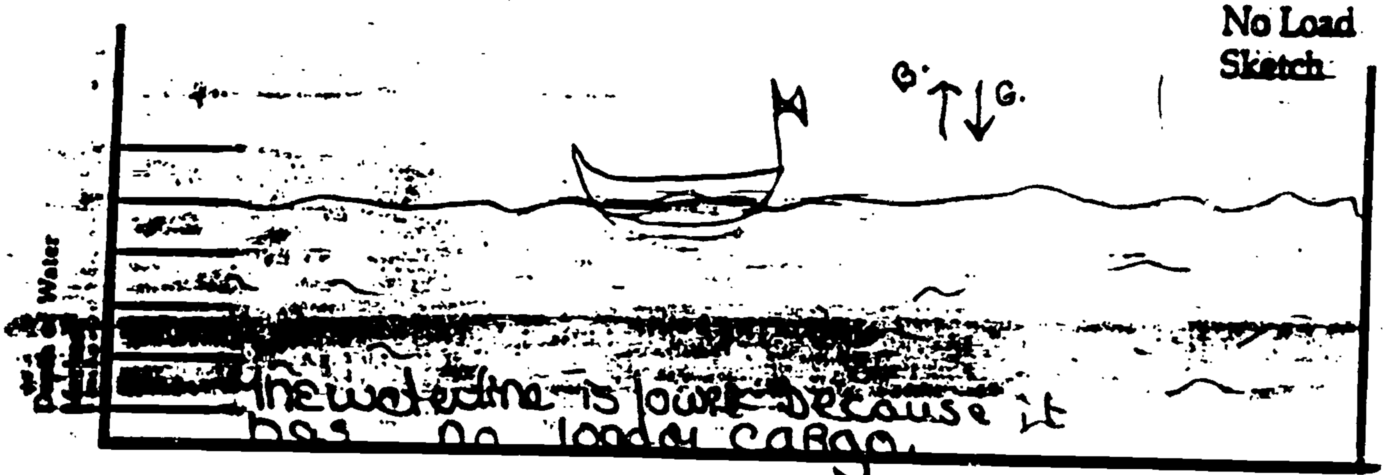
Name

Date

Teacher

Sketch the vessel. Use arrows, science terms, and the names of forces to label the sketches. The sketch and labels should explain what keeps the vessel afloat.

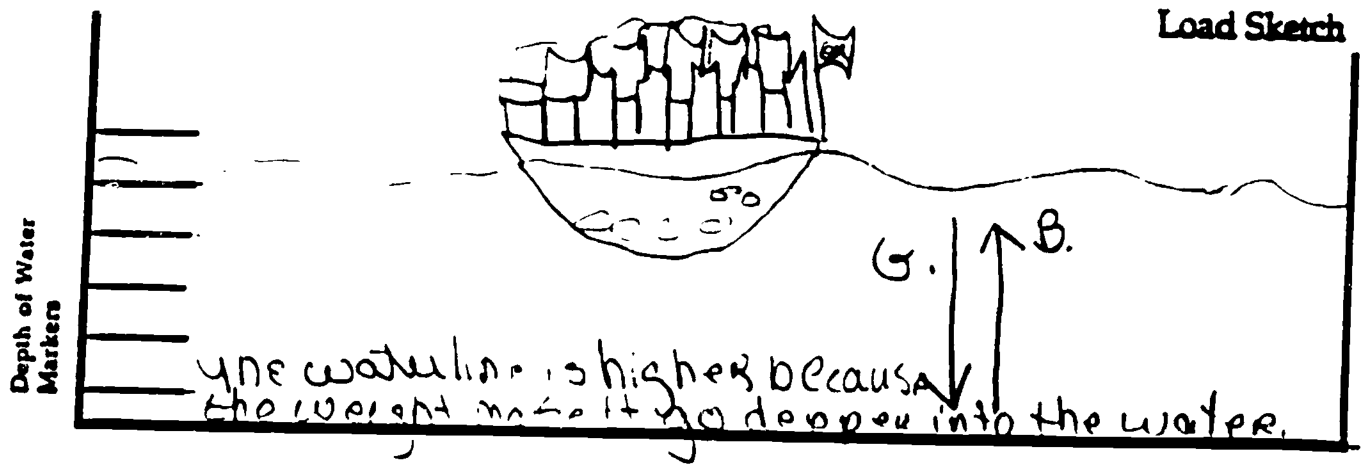
No Load Sketch



Vessel without a load
Mark the water line

Sketch the vessel. Use arrows, science terms, and the names of forces to label the sketches. The sketch and labels should explain what keeps the vessel afloat.

Load Sketch



Vessel with a load
Mark the water line

Criteria:
Accuracy
Clarity & Precision
Relationships

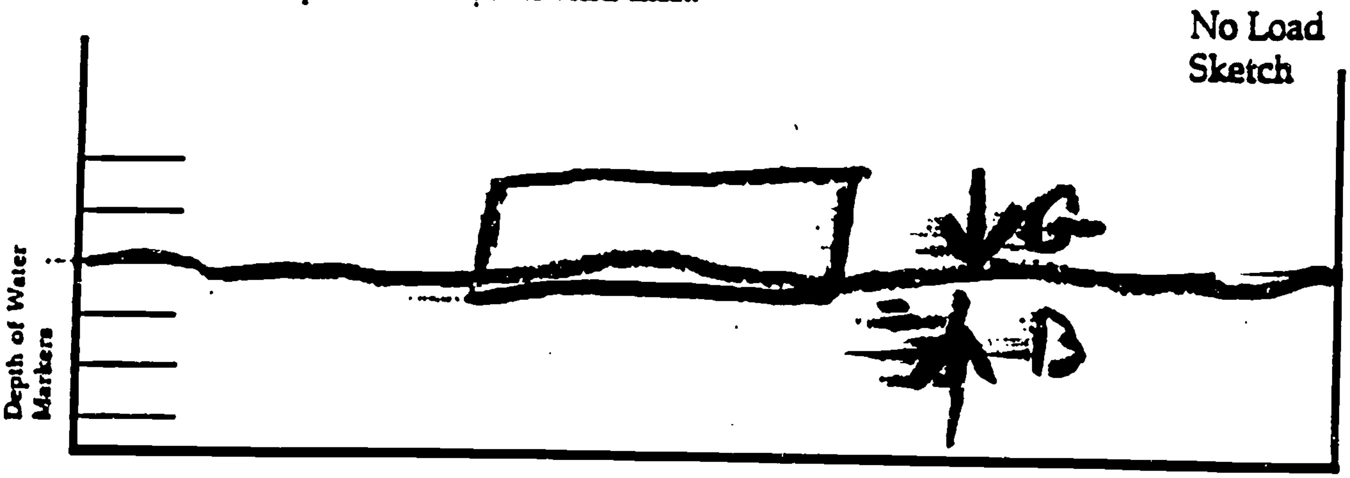
Portfolio Item C
Design Packet - What keeps the vessel afloat?

Name _

Date _

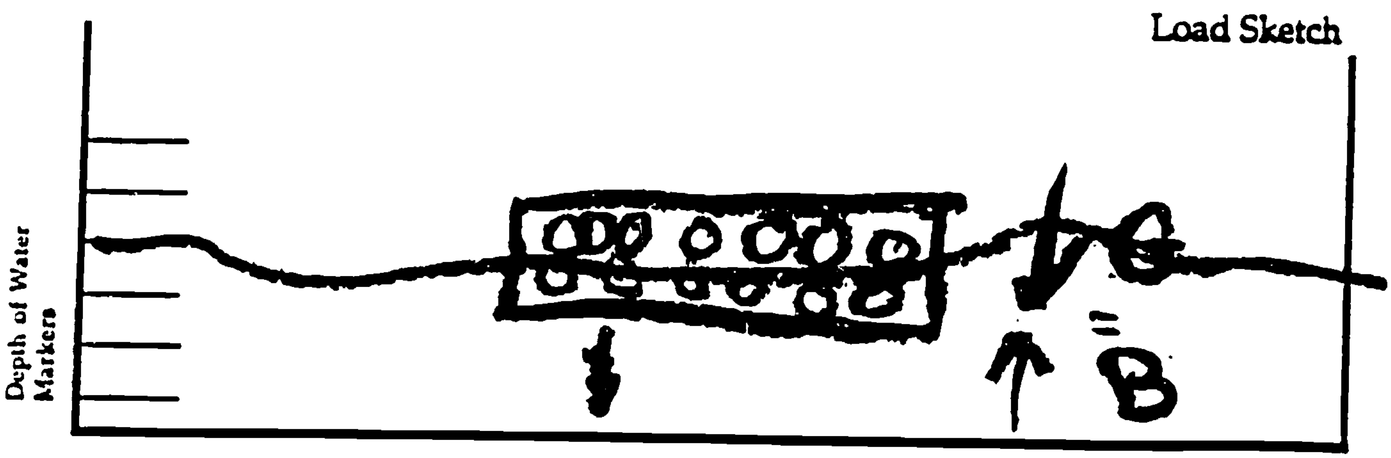
Teacher

Sketch the vessel. Use arrows, science terms, and the names of forces to label the sketches. The sketch and labels should explain what keeps the vessel afloat.



Vessel without a load
Mark the water line

Sketch the vessel. Use arrows, science terms, and the names of forces to label the sketches. The sketch and labels should explain what keeps the vessel afloat.



Vessel with a load
Mark the water line

Criteria:
Accuracy
Clarity & Precision
Relationships

APPENDIX D

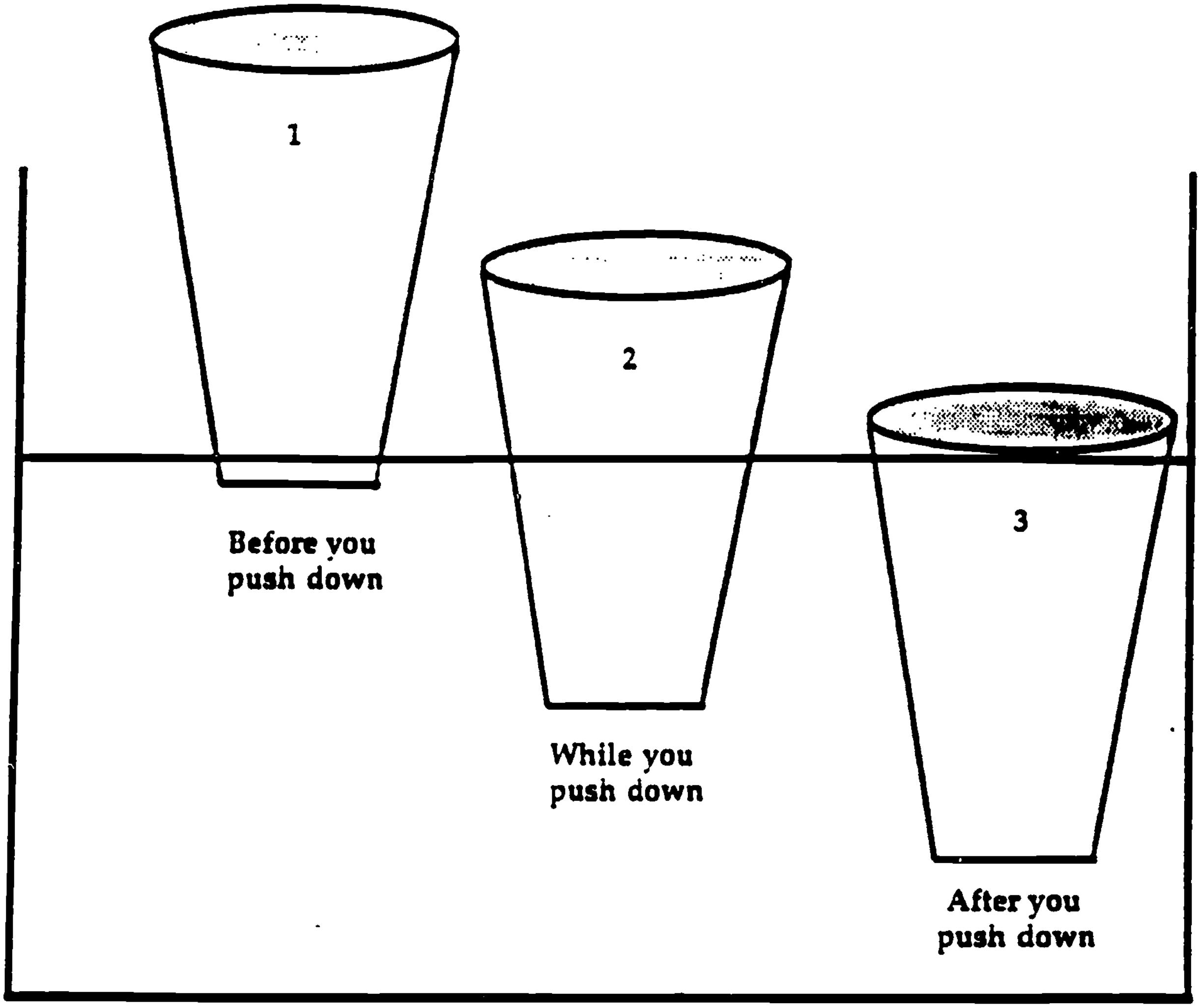
Forecast Portfolio Item

Portfolio Item 6

Name ______________________

Date ________________

Teacher ________________



1. Draw arrows on the drawing above to describe what you feel.
2. Now write in your own words what you felt while pushing the cup down into the water.

____

____

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