Third Misconceptions Seminar Proceedings (1993)

Paper Title: **Diagnosing Students' Conceptions Using Portfolio Teaching Strategies: The Case of Flotation and Buoyancy**

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Keywords: Concept Formation,Teaching for Conceptual Change,Thinking Skills,Empowering Students,Feedback,Informal Assessment,,,
General School Subject: Physics
Specific School Subject: Fluid Mechanics
Students: Middle School (6,7,8,)

Macintosh File Name: Duschl - Flotation & Bouyancy
Release Date: 7-6-94 H, 11-10-1994 I

Publisher: Misconceptions Trust
Publisher Location: Ithaca, NY
Volume Name: The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics
Publication Year: 1993
Conference Date: August 1-4, 1993
Contact Information (correct as of 12-23-2010):
Web: www.mlrg.org
Email: info@mlrg.org

A Correct Reference Format: Author, Paper Title in The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Misconceptions Trust: Ithaca, NY (1993).

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Diagnosing Students' Conceptions Using Portfolio Teaching Strategies: The Case of Flotation and Buoyancy[1]

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Technical Editor's Note: Tables and Figures have been left as supplied by the author, and can be found at the end of this article.

Introduction

The adoption of performance-based or portfolio assessment strategies is a commitment to the reform of education that, by intent, will hopefully extend into the schools and the classroom. By changing the standards of performance expected of children we are indirectly changing the standards of performance expected of curriculum writers, supervisors and teachers. Consequently, changing the procedures and the standards for determining students' success in science will require that these assessment changes be supported by and be evident in changes in the learning environment of classrooms. Most would agree that if the performance assessment is the first instance where a student encounters new expectations and standards of learning, then the system of education for that child is inadequate. It isn't surprising, then, that educational standards initiatives like the New Standards Project are seeking school delivery standards or social contracts with school districts. The basic and compelling issue is what good is raising standards if the curriculum and instructional practices in schools do not contribute to the preparation of students to achieve the new standards.

In science classrooms, a compelling and persistent problem is that of conceptual change. Raising educational standards in science programs to embrace conceptual change cognition or thinking demands that changes also occur with how science is taught. Our position is that an effective conceptual change science classroom will be one that provides teachers and students with information about the construction of knowledge in three different arenas of classroom dynamics. The three dynamics are scientific knowledge or epistemic dynamics, thinking,

[1] Funding for this project is provided by a grant from the National Science Foundation (MDR-90055574). The opinions expressed do not necessarily reflect the positions or policies of NSF and no official endorsement should be inferred.

meaning making and reasoning or cognitive dynamics, and representing and communcating information or social dynamics. Having access to and learning to employ information from each of these three arenas is, we feel, critical to empowering teachers and students to take control of their learning. It follows, then, that conceptual change science teaching should involve the use of those instructional activities and tasks that make available information about the epistemic, cognitive and social dynamics of individual students and groups of students doing science.

Questions and recommendations about school reform and restructuring must reach into the classrooms and must involve teachers in monitoring the construction of knowledge by their students. We must ask of all educational innovations, what does this mean at the level of the classroom? We must ask of conceptual change learning environments, then, how do teachers acquire the necessary information to monitor, assessment, and give feedback on students' meaning making, thinking, and communication of knowledge. In our work with the reform of science instruction at the middle school grades, we are examining ways to create a classroom learning environment that can provide this information for assessments. Evidence from our investigations and our work with teachers suggests that assessment information from each of the three dynamic domains mentioned above should be made available and used to facilitate learning science and how scientists learn.

There are,then, three assessment domains:

(1)*scientific knowledge* - the epistemic domain,

(2) *thinking skills* - the cognitive domain, and

(3) *communication skills* - the social domain.

Respectively, each domain seeks answers from teachers and students to the following questions:

What knowledge evidence or data do we choose to use and toward what goal?

What reasoning and meaning making strategies do we choose to monitor and to use?

What classroom actions support acquiring information to address the first two questions?

The domains and questions are presented in Table 1. The process of obtaining, recognizing, analyzing and deploying information to get at the answers to these questions is what shapes the instruction that fosters a learning environment guided by assessment information and decisions.

Taken together these three domains when executed as co-construction activities begin to develop a portfolio culture learning environment.

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Insert Table 1 About Here

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Project SEPIA - Science Education through Portfolio Instruction and Assessment - seeks to make assessment in classrooms an integral component of instruction. A goal is to provide the teacher, and we hope eventually the students as well, with instructional strategies and curriculum approaches that generate information about the cognitive procedures students are using to solve authentic problems, to reason, and to apply what they know. In brief, we seek to provide teachers with new kinds of information they can use to make informed decisions about the instruction and activities that support student learning. What is sought is a radical and comprehensive change in the character and the dynamics of the feedback students receive.

Given this orientation toward effective feedback, we must by necessity be concerned with the three classroom level dynamics outlined in Table 1. In turn, we must also be concerned about the criteria that set the standards for guiding and assessing students' performance in these three domains. In general this means creating and then applying criteria that focus on

- what counts as scientific knowledge and evidence in the epistemic domain,

- the reasoning and meaning making of students in the cognitive domain, and

- the characteristics of the classroom learning community that support dialogue and conversations about personal and scientific ideas and information in the social domain.

It is fundamentally important for us is to create a classroom that provides for and supports the communication and representation of ideas from students, from texts, and from teachers. Recall that a goal of assessment-driven instruction is to gain access to information that can be used to give students feedback. But this information is more often than not a kind of information that has not previously been made available to or recognized by middle-school science teachers as relevant to science teaching. Moreover, the management of students' ideas and information represent a very different challenge to teachers who are more adept at the management of activities, materials, and students' behaviors.

To date, we have had some success with teachers to employ activities that get students to tell us what they know in a variety of ways(e.g., letter writing, journals, drawings, oral presentations, etc.). But there are still many unanswered questions about how to interpret this information and then use it to inform instructional decision making that raises the standards of performance in science classrooms. What does meaning making and reasoning look like in these student products? What are the best sources of assessment information? Are there different kinds of assessment information? Where do we look and listen for assessment information while teaching? If we find the information, what are the types of actions teachers and students should take to use this information? How do we feed the assessment information back into instructional activities? How do we structure the learning environment such that assessment in the service of meaningful learning and higher standards is possible?

STATEMENT OF PURPOSE

The purpose of this paper is to report on the results of a portfolio assessment curriculum and instructional intervention in middle school science classrooms that provided information about students meaning making and reasoning in the construction of a causal explanation. It signals to us that information about students conceptions and the impact these have on the growth of knowledge can be obtained by teachers.

Conducting interviews with students around a body of work produced by the students during a specially designed curriculum revealed that the 6th and 7th grade students' hold an alternative theory students' for explaining why vessels float when carrying a load. Specifically, our research data indicate students have a conception about flotation and buoyancy that inhibits the development of a causal explanation for flotation. The interviews conducted with students on the work they produced suggest that these student interviews can be used as a source of information for identify student misconceptions about scientific explanations.

The first section of the paper describes our prototype curriculum approach which is organized around the implementation of assessment conversations. The science subject matter context is flotation and buoyancy. The instructional context is a design problem task that challenges students to construct an aluminum vessel that maximizes load carrying capacity. The second section examines and discusses the character of the student work generated by the Vessels Unit and how this work can be used to provide assessment information. In the last section, implications for classroom teachers and recommendations and challenges for teachers and researchers working in the reform of classrooms and schools are discussed.

VESSELS UNIT CURRICULUM

When we think of instructional tasks and the classroom social organizations being designed in the service of providing assessment information, we get a very different image of classroom management and of what counts as important learning activities. In our Project SEPIA classrooms, we try to organize instruction such that we gain information about the development of learners' reasoning and meaning making, and their use of skills like communication, explanation and argumentation. Obtaining information about each of these cognitive activities in order to make an assessment and then give feedback requires, however , that there exists a classroom learning environment in which students get the chance to practice these tasks. We refer to this specialized learning environment as a portfolio culture and have written a special curriculum unit - The Vessels Unit.

One approach to reform science classroom learning environments is to adopt alternative assessment strategies like portfolios that serve to inform both teachers and learners about what ought to be the next step of instruction. The ultimate goal is the creation of portfolio culture science classrooms. The term culture is purposely used to reflect the complex nature of the enterprise since the use of portfolio assessment techniques requires that both subtle and fundamental changes occur in teachers, students, and curriculum. Hence, a portfolio is not just a collection of work that documents the sequence of instructional activities performed by students. Nor, is a portfolio a collection of work judged or graded only by the teacher. Rather, a portfolio is a **select sample** of a student's work that serves to demonstrate how that student understands, communicates, reasons with , and constructs scientific knowledge. The sample is selected by teachers and by students according to publicly shared and negotiated criteria. In this sense, a portfolio culture and the assessments that take place in this culture are said to be criteria-driven.

The application of the criteria to instructional activities and tasks, and thus to the construction of a folder of work, is an endpoint of a long and involved set of activities. It is vitally important that the day-to-day actions of teachers and students and the structure of the curriculum reflect a strong commitment to the criteria or standards of a portfolio culture science classroom. Thus, the criteria are an integral component of instruction; components that should under gird everything that takes place in the classroom. The criteria must become the standards of the classroom, the currency of exchange, and the commodity that is most valued.

The criteria themselves, and the vision of how we see the criteria being used, even at this early stage of development, reflect a dual commitment. The dual commitment is a distinction and a balance between science as exploration and science as argument. It is that dual relationship between conceptual development and the skills and logic of reasoning that we want. On the one hand, we need to monitor, assess, and develop forms of reasoning, i.e., making connections. On the other hand, we need to monitor, assess, and develop the precise ways in which scientific knowledge is explored, represented, modified and justified - the target cluster of science concepts and the goals of investigation if you will. In Project SEPIA we are focusing on getting students to use and understand the use of explanations, experimentation, and models in science.

At present our working criteria reflect a commitment to these two important elements: (1) criteria that emphasize the development of reasoning skills, and (2) criteria that stress meaning making and sense making of scientific knowledge claims. It is working list because the criteria should change over time as the students develop the capacity to engage in higher and higher levels of cognitive processes or as the class decides examine other contexts of science that then require other criteria (i.e., statistical significance). Our present list of working list of criteria is provided in Table 2 and a schematic that places the individual categories of criteria on a 'Meaning Making - Reasoning' continuum is given in Figure 1.

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Insert Table 2 and Figure 1 about here

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The title of the unit is Vessels and an outline of the unit is presented in Appendix A. The unit involves students in a problem solving task, namely, the design of a vessel hull out of aluminum foil that maximizes load carrying capacity. The task is introduced through a letter from a fictitious mayor of Pittsburgh but the task is authentic. The letter outlines the problem as well as the expectations of student work. In brief, the purpose of the investigation and the goals of the investigation are given to the students. Here is how the letter finishes:

After completing your investigation, the packet of information you submit to the City should contain the information and materials in the items listed below. Only complete packets will be considered. We want to hire the firm that can design the best hull. But the City must have confidence that the designers understand and can explain why a vessel will float and carry a load. Without this explanation, the City can't be certain the design model you submit will work.

Design Packet Items

1. A sketch of the vessel hull.

The sketch should be neat and have the height, length and width of the vessel labeled.

2. A scale model of the vessel.

The scale model should be made of aluminum foil. It will represent the hull of the vessel. It should be made as best as you can to look like the sketch you submit.

3. Sketches of the vessel hull in water with and without a load

These two sketches should be side by side on the same piece of paper. Using arrows, science terms and the names of forces, label the sketches to explain the forces that keep the vessel afloat. Please mark the water line.

These sketches are a very important part of the design packet. We want to hire the firm that understands and can best explain why vessels float.

4. A report of tests and results.

Please list the tests, experiments, and investigations you performed. Then provide the a report of results. For example, what is the mass in grams (g) that it took to sink your vessel. Include in your packet any tables, graphs, or test design sketches you think will demonstrate you have thought through the problem carefully.

The conceptual ecology of the unit is buoyancy and flotation - See Appendix B. Inasmuch as we are interested in helping students construct a *causal explanation* for flotation the curriculum plan is designed around the differential pressures model. That is, the difference in water pressures at two depths produces a total net upward force called the buoyant force. It is the balance between the upward buoyant force and downward gravitational force that causes an object to float. It is an imbalance in favor of the gravitational force that causes an object to sink and an imbalance in favor of the buoyancy force that causes an object to rise. For example, if you take a small block of wood and place it at the bottom of a tub of water, when you release it the difference in water pressure between the top of the block (low) and the bottom of the block(high) will push the block up. It continues upward until the buoyant force up equals the gravitational force down. Now if we perform the same activity but this time substitute a helium balloon for the block of wood, the balloon will rise to the top of the water and then continue rising into the atmosphere since the buoyant force is now large enough to lift the balloon and push it out of the water and continue pushing it up into the air. The 'pressure below/pressure above' principle applies to all fluids and air is a fluid.

Now the problem in the design of the vessel, then, can, and should, be understood in terms of increasing the buoyant force. If you increase the buoyant force, then you increase the carrying capacity (i.e., weight the vessel can hold and still remain afloat). There are two ways to increase the buoyant force. You can increase the bottom surface area of the vessel or you can increase the height of the sides of the vessel. But in either case - bottom or height of sides - there is a limit to which the increase is beneficial when your problem is restricted by the amount of material with which you have to work - one sheet of aluminum foil. Thus, another and an important characteristic of the vessels unit is that it involves students in a trade-off problem. How much foil should one invest in the height of the sides? How much foil should one invest in the bottom?

The Vessels Unit allows students the opportunity to **do** science in the full sense of what it means to **do** science. And, this full sense means (1) the construction of explanations and models based on experiments and experiences - the epistemic dynamics of the domain; (2) reasoning about the relation of evidence to explanation - the cognitive dynamics; (3) communicating and discussing knowledge claims and evidence with members of the class - the social dynamics. In the Vessels Unit students individually construct a vessel , test its carrying capacity, compare and contrast the diversity of designs against performance by all students, identify via conversations design features associated with performance, explore via demonstrations and conversations what occurs with changes in depth of water, design and conduct experiments that test the specific design features, report via conversations the results of the experiments and then be given the opportunity to construct a second and third vessel. And, all along the way be encouraged to think about and communicate their thoughts about why things float, and why it is that one design can hold more weight than another design.

Traditionally, our assessment and evaluation of student learning has emphasized measuring students acquisitions of declarative knowledge. The research shows though that the development of strategic or procedural knowledge frameworks is what seems to distinguish superior knowers from novices knowers. Thus, one desired outcome of alternative assessment tasks is to get information on how learners use strategic knowledge. Such information can then be used to provide feedback on reasoning and on the development of procedural knowledge frameworks.

Consider the following example that involves a procedure for reading information off of a graph. In a special curriculum unit that we've design to help promote assessment opportunities in classrooms, students were asked to make and then test the carrying capacity of aluminum vessels. The class set of vessels was then plotted on a bulletin board graph and a discussion then followed that gets students to think about what features of the vessels seems to correlate with performance. Students will naturally focus on the extreme vessels in the graph - the best and worst - and will quickly conclude "Make it bigger!"

A different procedure for obtaining information from the graph, however, is to get students to focus on the vessels in the same column of the graph - say all those that held between 300 and 400 grams. This graph reading strategy reveals that different designs can produce the same performance and it shows that the features of the vessels which need to be bigger are the height of the sides and the bottom surface area. The use of the graph reading procedure 'look within a category' can be modeled and taught. A performance assessment task might then probe a student's ability to use this is important scientific way of knowing.

Research on learning has also made it quite apparent that the acquisition of knowledge - declarative and procedural - is a social activity. So much of what any individual comes to know takes place in social learning environments. In particular, it is out of social situations that the criteria and standards for performance are learned. The research shows that when the opportunities for conversation and argumentation increase so too does the ability of learners to comprehend and understand the topics under investigation and the reasoning procedures. In short, it is the public display and reporting of information and strategies and the opportunity to act on this information and strategies that contributes to the growth of knowledge.

For an example of how social situations effect learning, consider the graphing of the vessels once again. From this public display of information it is possible for students to quickly see some of the ways to redesign their vessel so as to improve the load carrying capacity. The conversation about what design features of vessels seem to effect performance is also made public and social. Posing the question "How do we know which of these design features is most important in determining carrying capacity?" invites the opportunity for conversation and argumentation about competing explanations and designs for how and why vessels float, rise and sink.

By shifting the aim of instruction from activities and tasks that ask learners to merely display what they know (declarative knowledge) on individual reports or exams to activities and tasks that require students to use apply, and publicly report what they know (procedural knowledge) , we contend, windows are opened into students' reasoning. We are working to create a classroom learning environment that supplies teachers and students with information about students' reasoning and meaning making. The core features of our instructional approach are:

- engaging in an authentic task
- employing criteria-driven assessment conversations
- publicly communicating and displaying ideas, explanations, and information
- involving students in portfolio tasks around the work they produce.

CONCEPTIONS ABOUT BUOYANCY

An analysis of student drawings, labels of drawings, interview statements, and presentation statements indicates that students are constructing an incomplete explanation for flotation with and without a load. Through the practices arranged by teachers (e.g., assessment conversations, demonstrations, questions and answer) and those given to students (e.g., drawings, warm-ups, presentations, writings) information about how students are relating concepts and how they are reasoning is made available. In particular, steps have been taken to provide a sequence of activities, such that, sources of assessment information to teachers about students' learning and reasoning can emerge. Such activities involve students in doing drawings, writing explanatory statements, labeling models and sketches, participating in conversations, and giving oral presentations.

The conceptual ecology of the unit is summarized and presented in the concept maps found in Appendix B. Although the unit begins with the concepts of gravity and buoyancy, the core concept is water pressure for it is the causal link that explains why a vessel with higher sides or a larger bottom is able to carry more load. The label used by the students to explain floating is buoyancy or buoyant force but the causal link that explains why a vessel remains afloat when weight is added has do to with the fact that water pressure increases with depth. The subject matter objectives for the unit as written in the teacher background materials are:

1) Floating is a state of balance; gravity = buoyancy. Objects that float do so because the force of gravity pulling the object down is equal to the buoyant force pushing the object up.

2) Sinking is a state of imbalance; gravity > buoyancy. Objects that sink do so because the force of gravity pulling the object down is greater than the buoyant force pushing the object up.

3) Buoyancy is a force caused by water pressure. The pressure in the water at a given point is caused by the weight of the water above that point and acts in all directions equally around that point. The lower the vessel can go without sinking the greater the water pressure which causes the buoyant force.

4) The buoyant force (upward) is caused by differences in water pressure at the top (lesser pressure) and bottom (greater pressure) on the object. Floating is a special case where the top pressure, being above water, is equal to zero. The larger the buoyancy the more weight the vessels can hold.

5) Buoyancy is a force affected by surface area. The larger the surface for the buoyant force to act on, the greater the force at a given depth.

6) Water displacement is the amount of water pushed aside when an object is placed in water. When an object floats, the weight of the displaced water is equal to both the force of gravity pulling down and the buoyant force pushing up. The more water a vessel can displace, the more load it will be able to carry.

The information from the portfolio interviews indicates that students can tell you why something floats and typically do so in terms of gravity being equal to buoyancy. Students can also tell you why something sinks and typically do so in terms of gravity being greater than buoyancy. The student drawing in Figure 2 is representative of that produced by most students.

When students are asked though to explain floating without a load and compare it to floating with a load a misconception emerges. Again, the drawing in Figure 3 is representative. The problem that emerges is that students interpret floating lower and lower in the water as a 'kind of sinking' process. Thus, rather than preserving the notion of gravity equal to buoyancy as the vessels float lower and lower in the water, the students use the notion of gravity getting greater and buoyancy getting less as the vessel floats lower and lower in the water. In their minds, the process appears to be a zero sum game. The problem that exists here is that the students conception of floating with buoyancy getting less blocks the need to develop a sense of water pressure changing with depth. If the equal and opposite forces of gravity and buoyancy idea is preserved, then we must ask what it is that is causing the buoyant force to increase as we add weight to the floating vessel. With the students present conception of the buoyant force getting less or weaker, there is no compelling reason to investigation changes in water pressure with depth and, consequently, no compelling reason to think about the importance of the height of the sides in the design of the vessel.

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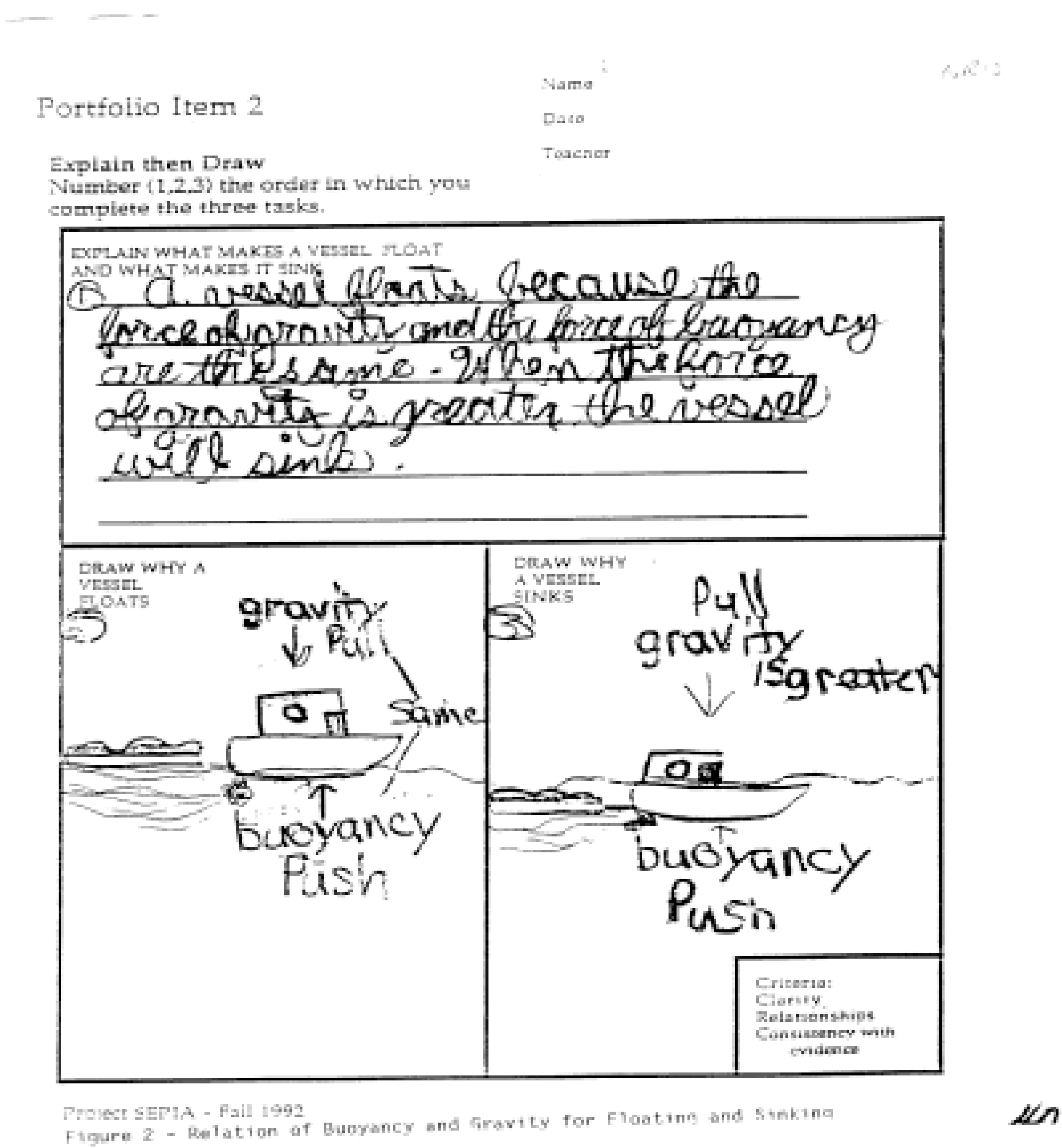

Figure 2. Relation of Bouyancy and Gravity for Floating and Sinking
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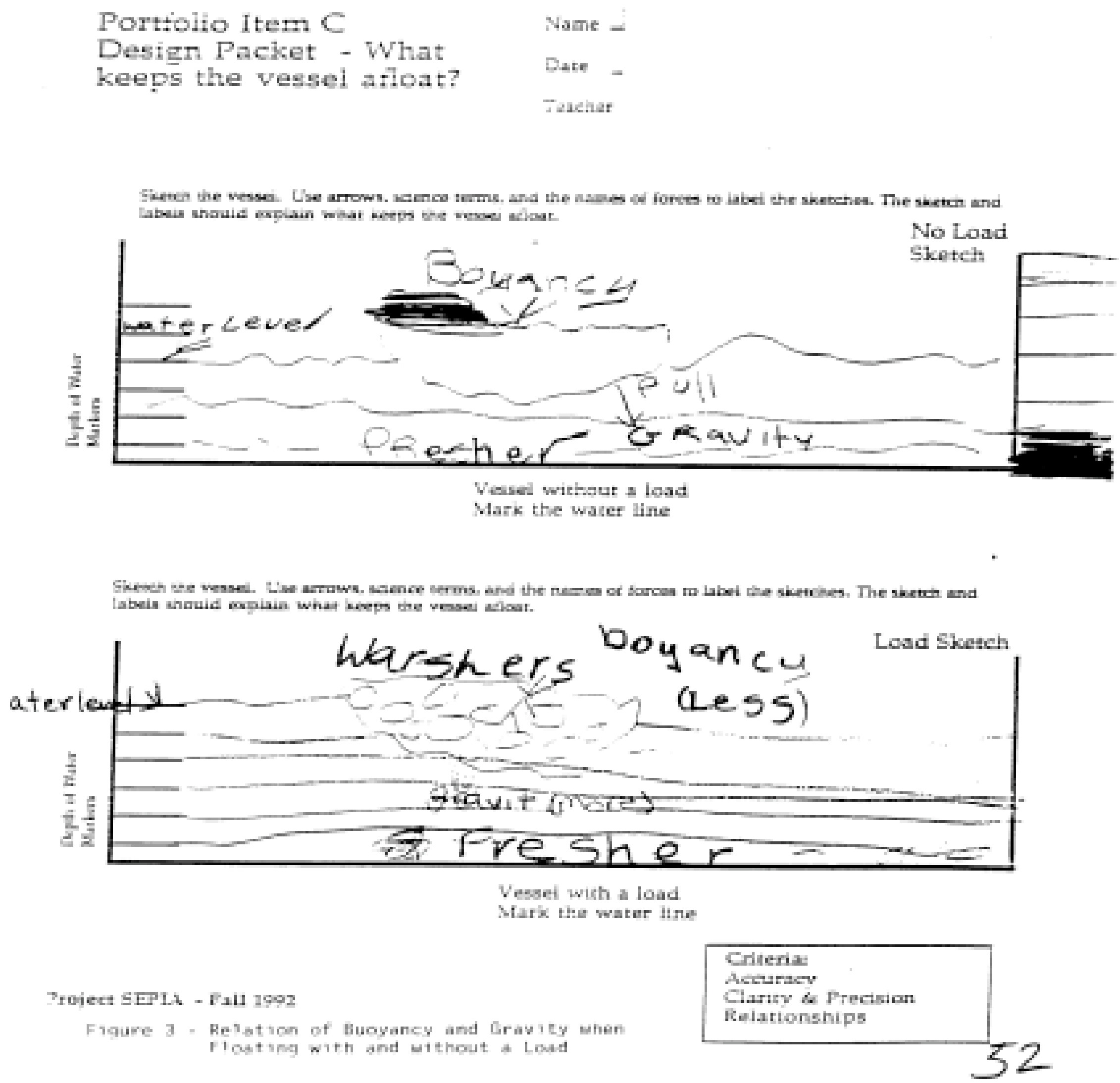

Figure 3. Relation of Bouyancy and Gravity when Floating with and without a Load.

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Now we want to emphasize that this is a wonderful problem for us to discover. For one it tells us that our portfolio culture instructional process and materials are making it possible to locate and use assessment information that can be used as feedback. Let's look at the two arguments for floating - the curriculum argument and the students' argument - in more detail. The two instructional arguments are as follows:

<u>*Instructional Argument in Curriculum:*</u>

1a. Flotation is a state in which the gravitation force (G) is equal to the buoyant force (B).
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1b. Sinking is a state in which the gravitation force (G) is greater than the buoyant force (B).

2. An aluminum vessel with no load will float on or near the surface of the water. G=B.

3. When a load is added to the vessel is floats lower in the water. G=B

4. The additional mass increases the gravitational force acting on that mass pulling the vessel down into the water.

5. Since the vessel is still floating then G=B, therefore B must increase as G increases.

6. The increase in B is caused by the increase in water pressure as the vessel floats lower in the water.

<u>*Instructional Argument among some Learners*</u>

1a. Flotation is a state in which the gravitation force (G) is equal to the buoyant force (B).

1b. Sinking is a state in which the gravitation force (G) is greater than the buoyant force (B).

2. An aluminum vessel with no load will float on or near the surface of the water. G=B.

3. When a load is added to the vessel it sinks lower in the water. G>B

4. The additional mass increases the gravitational force acting on that mass pulling the vessel down into the water.

5. Since the vessel is sinking then G>B, therefore B must decrease or remain the same as G increases.

The curriculum argument requires that an appeal be made to what causes the buoyant force to increase (i.e., water pressure) in order to preserve the equality needed between G and B when the vessel continues to float. In contrast, the student argument need not invoke an appeal to water pressure since their model of flotation employs a 'partial sinking' mechanism for floating lower in the water when weight is added. Applying the sinking rule G>B to this partial situation, it makes sense to think and talk about getting lower in the water being an increase in gravity and a decrease in buoyancy, relative or otherwise.

The dilemma is that students do not need to think about the evidence related to things changing with the depth of water. As stated above, the explanation given by students is one that ignores water pressure changing with depth. Getting students to recognize that B=G when ever an object floats and to then adopt the correct explanation that buoyancy increases when the gravity increases as a load is added opens up the instructional opportunity to ask what is causing the buoyancy force to increase. The epistemic dynamics of the class and of our instructional approach were found to be inadequate.

The opposite of sinking is not floating. It is rising. We do not talk about nor do we give students experiences with things that rise. We could, for example, ask students to monitor what happens to a vessel floating with a load when you take weights out of the vessel. We can ask then what is pushing it up? There also is a semantic concern. We hear students talking about the vessel sinking lower as you add a load. A clearer distinction between floating and sinking needs to be made in our classrooms and a conscious effort to use say floating lower in the water with a load should be made. The semantic understanding by students and used by teachers of floating, sinking, rising, and balance would seem to be an important issue. Thus, the data from the student interviews has provided us with information about how to assess students meaning making and it has given us a window into how to change our curriculum design and implementation strategies to make it more epistemically sound.

CONCLUSION

Properly construed instructional activities and classroom practices can be designed and implemented to provide access to student meaning making and reasoning. It requires a curriculum balance between the epistemic, cognitive and social dynamics of the classroom. Key to the process is giving students the opportunity to communicate and discuss what they know. The portfolio interview is one such opportunity. When students are given access to the work they produce and then asked to interpret and use the information we get insights into students meaning making and reasoning.

Engaging students in individual interviews that take them through a reflective conversation about the work they do, however, while certainly a rich source of information is nonetheless an 'after-the-fact' source of information for classroom teachers. A challenge we face in our research program is how to bring this kind of assessment information on-line. That is, how do we begin to make it part of the social dynamics of the classroom that teachers and students do as part of the culture of the classroom. When we look at classroom transcripts we discover that the assessment information is subtle, very subtle. It often occurs in comments, gestures, and in notations not presently consider relevant to instructional goals. It is an arrow in this drawing, a word in that drawing, a comment in response to this or that question. Locating the information requires:

1) the employment of astute listening. observing and reading skills,

2) constant attention be given to the target conceptual ecology; e.g., concept maps in Appendix B,

3) attention to the representation and capture of information **learners** can use to reason to or construct the appropriate conceptual framework.

All of this must take place along with all the other decision making events in the classroom like who's on task or off task, who is behaving and misbehaving, when do you begin closure on the lesson, or make a transition from the warm-up to the lab activity.

We know, for example, how powerful it is to have students examine the diversity of responses or products from their own efforts. We also know that the examination of student work to arrive at relevant information to make assessments occurs best when it is carried out with that group. For example, when we graph the vessels and have a conversation with students this single act enables students to see the features of the vessels that contribute to its ability to carry a load. While the initial information emerges more often than not from individuals, the complex information like explanations must become part of the community dialog to enable conceptual change to occur. This appeal to the community is also needed to motivate the learners to deal with science understanding and representation at this deep level of knowledge, knowing, meaning making, and reasoning. These are complex changes and require teachers to listen and look for new forms of information. The problem, then, is to develop effective and manageable strategies teachers and students can use for looking, listening, and assessing.

Our interview data indicate that instructional tasks and activities can be designed and implemented to support the assessment of students' meaning making and reasoning. The results also indicate that portfolio assessment information can be used to evaluate curriculum scope and sequence and instructional strategies. Information about the learned curriculum can be used as a window to guide in the modification of the designed and implemented curriculum. The portfolio interviews provided a window into the kinds of changes needed to support alternative assessment in science classrooms. We discovered that in addition to talking about floating and sinking we must also talk about rising. We now know that we need to pay careful attention to the way in which we speak about flotation with students. In addition to having demonstrations and activities that focus on the lowering of the vessel when a load is added we need to also have demonstrations and activities that focus on the rising of the vessel when a load is removed. Employing portfolio assessment instructional practices makes it possible to monitor the epistemic, cognitive and social dynamics of science classrooms.

Table 1

Co-Construction Domains in an Assessment Driven Learning Environment:

Central Questions

Domain	Central Question
Epistemic/Scientific Knowledge	What knowledge, evidence, or data do we choose to use and to what goal do we use it?
Cognitive/Thinking Skills	What reasoning and meaning making strategies do we monitor and use?
Social/Communication Skills	What actions support getting information about scientific knowledge, thinking skills, and communication skills?

Table 2
SEPIA Criteria for Guiding Design and Assessment of Student Work
<u>Criteria</u> and Sample Questions Posed to Students

<u>Relationships</u>

What goes together?
How do they go together?
Is there a name we can give to the relationship?
Is there anything that does not belong?
How are things alike?

<u>Clarity</u>

Is it clear?
Does it tell what you want it to tell?
Will it be clear to someone else?

<u>Consistency with Evidence</u>

Is the statement supported by observations? If so, what?
Is it supported by the observations of others? If so, what?
Is the statement consistent with lab data? If so, what data?
Can you identify evidence from nature that supports the statement?
Does your statement reflect the data?

<u>Use of Examples</u>

Can you give an example?
Is it a good example for this purpose?
Is there a better example for this purpose?
Can you think of an original example?

<u>Making Sense</u>

Is this what you expected?
Are there any surprises here?
Is there anything that does not fit?
Does your hypothesis make sense with what you know?
Can you predict what will be the outcome?

Table 2 - cont.
SEPIA Criteria for Guiding Design and Assessment of Student Work
Criteria and Sample Questions Posed to Students

Acknowledging Alternative Explanations

Is there another way to explain this?
Is your explanation or hypothesis plausible - can it happen?
What does this explanation say that the other doesn't?

Elaboration of a Theme

Is this term related to something we did before?
Is it familiar? If so, how?
Is it related to anything you did in another class?

Accuracy

Is the statement consistent with other information on the same topic?
How does the model compare with other models?
How does it compare with other representations?

	Sense Making
Making Sense	
	What is Known
Relationships	
Elaborating a Theme	
Acknowledging Alternative Explanations	
Accuracy	
Use of Examples	
Clarity	
	Reasoning
Consistency with Evidence	
	How it is Known

Figure 1. SEPIA Criteria Continuum

Appendix A
Vessels Unit Outline

<u>1. Engaging Authentic Problem/Question</u>

<u>Letter/Reading the Letter</u>

Emphasize the goals - to build a model that helps in the design of a vessel; to explain why and how the design works - the packet

Emphasize the function of the model - to maximize how much a vessel can carry

Emphasize the performance variable - interactions with water, what matters in the letter - what doesn't matter in the letter

Capture Prior Knowledge about Vessels
- Diversity of Vessels
- Design of Uses

Why do things float?
Why do things stay afloat when a load is added?
Why do things sink?

****

The development of lists of important concepts from the discussion of the letter should be captured and displayed publicly as word banks, concept map, cards.

****

<u>2. Assessment Conversation related to 1</u>

Models

Student Work (Portfolio item)
- Sketch of a vessel
- Label or otherwise explain:
  - Why a vessel floats?
  - Why a vessel sinks?

Teacher Led SEPIA Criteria Discussion of Student Work
- Performance Criteria; i.e., clarity & precision
- Subject Matter Content Focus;

<u>3. Perform the Task - 1st Effort</u>

<u>Individually students sketch-plan-do</u>

Ss build 1st vessel
Sketch vessel (Portfolio Item) - relate to goals in letter

<u>4. Assessment Conversation related to 3</u>

SEPIA Criteria Discussion gives rise to
Performance Predictions (Which vessels will work best? Why?)
Initial conversation about contrast features
Need to capture details about vessel design - acquire bottom surface area and height of sides

****

Do all the boats weigh the same?

Teachers can pursue this question as either a warm-up activity or as a demonstration. Take one S's vessel. Ask if anyone thinks their vessel will weigh a significantly different amount ($\pm$ 2 g). If a Ss volunteers, then take that vessel and place it on a double pan balance with the first vessel. Compare and point out they weigh the same. Continue this procedure until you have convinced the students that all of the vessels regardless of shape are in the same narrow weight range.

****

5. Test/Solve

Students reminded to "keep an eye on things" - boat down water up why my boat sinks, how my boat sinks

Students reminded to "keep a record"; surface area value, weight it took to sink the vessel, design features of the vessel

****

Group students so that there is a distribution of vessels according to size. This will facilitate completion of the vessel testing within one class period. It will also facilitate the acquisition of evidence for the ensuing assessment conversation.

****

6. Look-for-Contrasts/Patterns Assessment Conversation related to 3,4,5

Review performance predictions and explanations during warm-up

Graph Display of Vessels
Student work (Portfolio Item)
Visual representation of graph

Locate examples of contrasts and patterns
Same performance different design (within same category)
Different performance same design (bottom area)
Different performance different design (extreme categories)

Summarize contrasts and patterns
Return to Subject Matter Focus - why things float and sink?
Apply SEPIA criteria to:

review and critique of performance/strategy/plan
Student Work (Portfolio Item)
Provide sketch and explanation of performance/strategy/plan
Capture diversity of ideas and knowledge claims
Acquire evidence that support ideas and knowledge claims
interaction with water
Name the forces buoyant force - gravity force
pressure increases with depth

****

Demonstrations can be used to assist in establishing and/or reviewing the concepts and evidence involved in flotation and buoyancy.

1) level of water
2) pressing cups/tubs into a trough/sink/aquarium of water
3) coffee can with holes (the taller the object the better)
4) manometer (thistle tube with rubber diaphragm attached to glass u-tube.

****

<u>Student work</u>

Compare and relate cup pressing in water with adding weight to vessel.
Sketch, draw or other wise explain how the demonstration with the cup is related to the performance of the vessel. (Portfolio Item)

<u>7. Nested Unit on Models, Experimentation, or Explanation</u>

a. Class discussion of criteria for plan and a fair test
b. Groups of Ss design individual plans
c. Class discussion of exemplary plans; i.e., those that address SEPIA and Fair Test criteria
d. Implement the Plan
e. Report the results
f. Post the results

Experiments on contrasts to include but not be limited to:
- shape of vessel
- bottom size of vessel
- height of sides of vessel
- distribution of weight in the vessel
- measurement of change in depth of water

<u>8. Assessment Conversation related to 7; particularly e and f</u>

Return to contrasts and patterns; what counts and what doesn't count
Apply SEPIA Criteria to guide this dialog
Relationships

Alternative Explanations
Evidence for Explanations

****

The purpose of this assessment conversation is to highlight the elements of vessel design that help to meet the goal of the project - design a model that maximizes the load a vessel can carry and provide an explanation of why it works

****

9. Perform the Task - 2nd Effort

Review goals and SEPIA Criteria
Plan of Action by Groups of Ss
Sketch of Vessel Design with Performance Explanation (Portfolio Item)
Construct vessel - each student makes a vessel (Portfolio Item)
Performance Packet (Portfolio Item)

****

The test of the vessels can be done as a large group activity with each vessel being tested at the front of the class. The vessel that has the best results will be the one submitted to the 7th grade competition. Stress that the effort was a group effort - whole class effort.

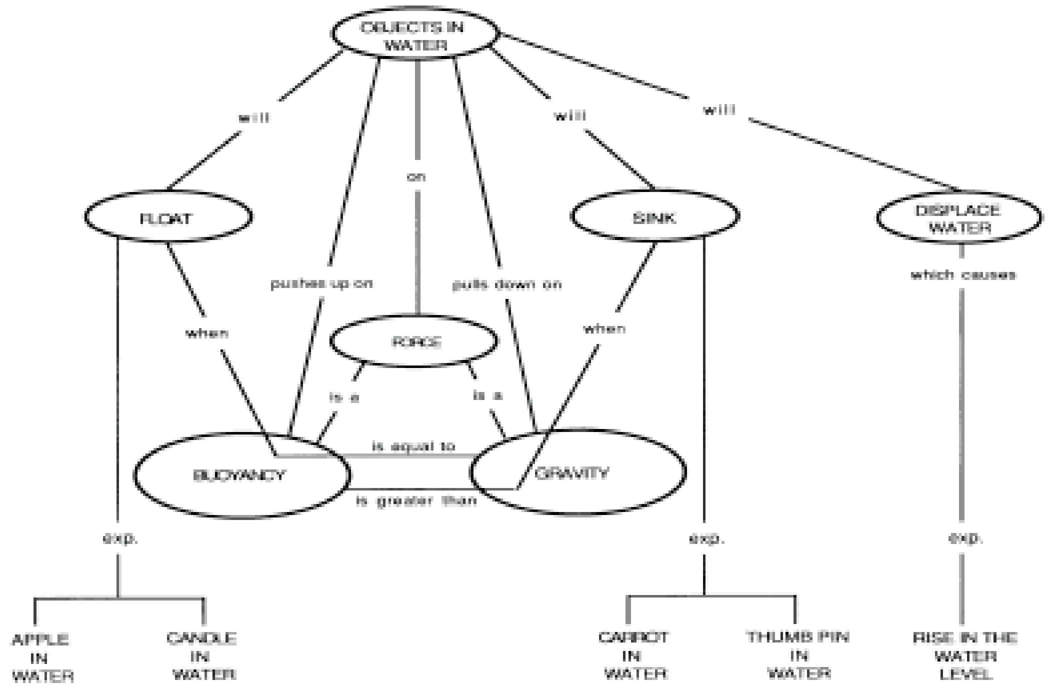
****

10. Assessment Conversation related to 9

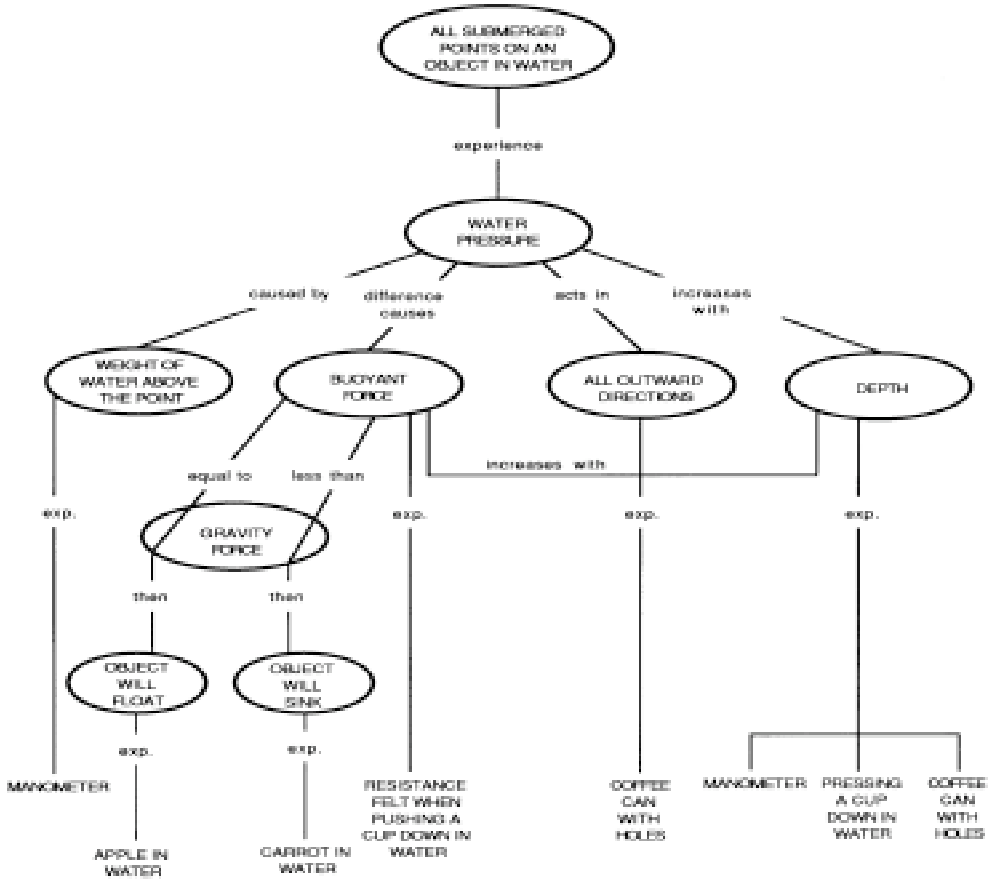
Submission of Final Plans and Packet
Assemble portfolio of work

Appendix B

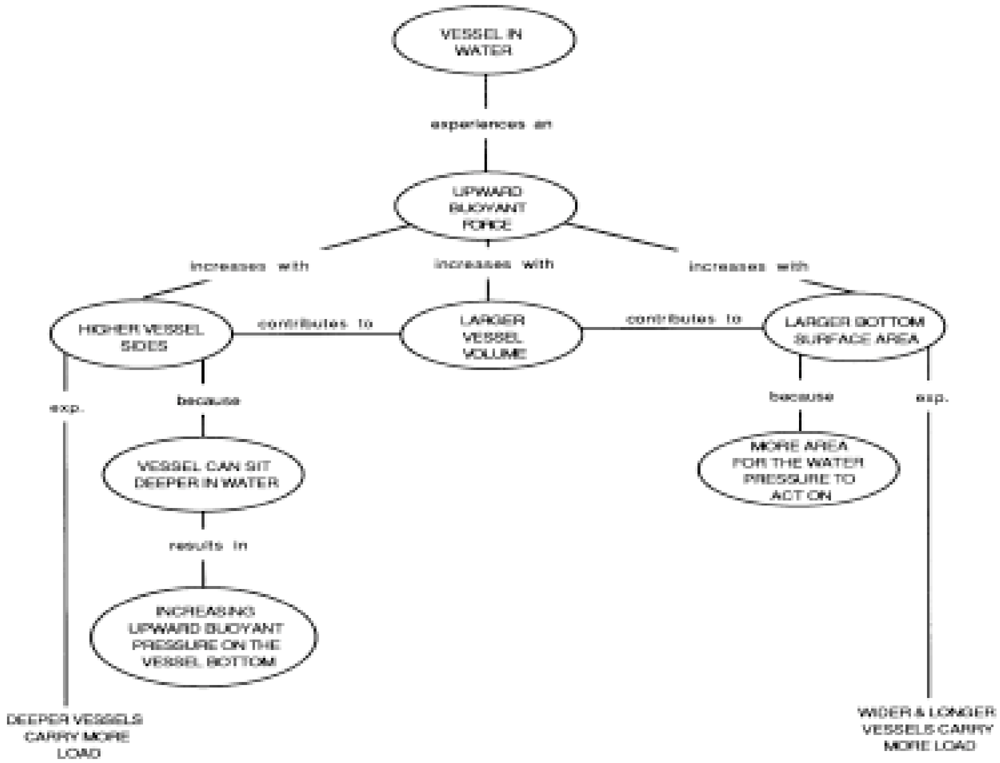
Conceptual Ecology of the Vessels Unit
in
Three Parts



CONCEPT MAP
PARTS 1 & 2



CONCEPT MAP
PART 3



CONCEPT MAP
PART 4

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