Gender Issues in the Construction of Scientific Knowledge: Inquiry into a 6th Grade Urban Classroom

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Preface

In this paper, we share with our readers preliminary data and analyses that point towards some themes that relate gender issues with the teaching and learning of science within our specific conceptual framework. We consider our work to be a form of teacher research in science education. One of us, Barbara, is an elementary school teacher and a school-based researcher and the rest of us are University-based researchers. Barbara and Maria have been working together for more than two years trying to bring in the science classroom a specific take on science education--one that views science as a socio-cultural activity that centers on the dialectic of theory and data, or the theory-data dance as we like to call it. Recently (this school year) Barbara and Maria became interested in exploring issues related to gender as they are played out in the science class as teacher and students attempt to develop scientific theories (stories), collect and analyze empirical data, and relate the two in order to construct scientific knowledge. Stacy and Jane joined us for this project which has been slowly getting off the ground due to many different reasons--reasons often discussed in relation to teacher research.

In this paper we focus on a 6th grade classroom that Barbara taught last year. We wanted to explore questions that would help us understand how girls and boys were participating in the lessons, how they were developing meaning around the topics that they were exploring, how teacher and students were interacting with each other even before the teacher has decided to make gender issues the object of her inquiry. We envision using the thinking that we have been doing in this research and the findings of this study to guide us in rethinking the science teaching that Barbara will be doing in the rest of this school year and in the next years. This project is part of a larger project that centers on teacher research which focuses on studying teacher change “not mandated by others but undertaken voluntarily” (Richardson, 1994, p. 6) as the teacher engages in systematic inquiry on issues that she considers critical to her role as a science teacher.

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Conceptual Framework and Context of the Study

Perspective on Science Education

Until quite recently, efforts in science education reform have been based on discovery learning approaches. Discovery learning, often based on Piagetian epistemology (e.g., Duckworth, 1987) or on misreading Dewey (Prawat, 1995), has two strands. One is that children develop their own scientific understandings through empirical inquiry as they interact with the physical world. The other is that children modify their conceptual understandings as a result of disequilibration when the views of others lead them to see the shortcoming of their own views.

Increasingly, the science education community is recognizing and elaborating socio-cultural constructivist approaches which stand in contrast to discovery learning approaches to science education. The socio-cultural viewpoint considers that both strands of discovery learning miss an essential aspect of education: the way the existing socio-cultural achievements influence the children's intellectual development. In a socio-cultural perspective, it is important for a teacher to bring to the students the organized and systematic understandings achieved by the culture, and to help students gain access to them (Driver, Asoko, Leach, Mortimer, & Scott, 1994). Driver and her colleagues present a theoretical perspective on teaching and learning science that "is informed by the view of scientific knowledge as socially constructed and by a perspective on the learning of science as knowledge construction involving both individual and social processes" (p. 5).

Their approach is similar to the conceptual framework of this study which one of us has elaborated in earlier writings (Becker & Varelas, 1995; Varelas, 1996; Varelas & Becker, in press). In this framework, which is based on Vygotsky's (1978, 1934/1987) theory of learning, learning involves the student's active construction of meaning, one that nobody else can do for the student. However, the student's meaning making is situated within the pre-existing socio-cultural activity of science, and the teacher helps the student construct meaning within this socio-cultural activity. Nevertheless, the student is also seen as gaining the abilities to push these traditions further, even in new directions, and to oppose them.

A central aspect of the socio-cultural practice of science is the dialectical relationship between two major elements: developing theories (theoretical element), and collecting and analyzing data (empirical element). We use the term "theory" to mean a network of concepts and ideas linked logically together that have explanatory power and not just formulation of isolated hypotheses or predictions (Varelas, 1996). A theory is a scientific "story" (Arnold & Millar, 1996), or a model of the behavior of some part of the physical world. In order to understand the natural world we need to use both elements which are not isolated from each other. Theories and data interact, influencing each other significantly (Dewey, 1929; Duschl, 1990; Holton 1988; Lythcott, 1991; Schwab, 1978), yet their differentiation and coordination are central to science.

Both Dewey and Vygotsky, two celebrated developers of socio-cultural approaches, have distinguished between more spontaneous and empirical knowing related to everyday living and situated cognition, and a more systematic organized form of knowing--for Dewey (1956) represented in his idea of the curriculum, and for Vygotsky (1934/1987) exemplified in his idea of scientific concepts defined primarily by their mutual relations. Both Vygotsky and Dewey saw this latter form of knowing as a cultural achievement into which teachers introduce children. In this approach, scientific activity is not seen as some skill that develops “naturally” or unproblematically, as a function of some kind of “normal” interaction with the world. Instead, both the theoretical and the empirical components of scientific activity, and their interplay, are all considered to be jointly created socio-cultural achievements. In enacting such an approach, an integration of hands-on experiences and discourse (Edwards & Mercer, 1987; Lemke, 1990; O’Loughlin, 1992) becomes the critical means for helping students experience the theory-data dialectic.

Furthermore, the approach puts a renewed emphasis on teacher’s own knowledge as it is supposed that all individuals, the teachers and the students, attain this knowledge largely through ways in which they gain access to existing organized knowledge in the culture and not through an “innocent” or independent construction. In this perspective, the teacher’s knowledge of the content and processes of science is important without detracting from the students’ need to construct that knowledge and not passively “receive” it. That is, this approach emphasizes teacher expertise but not in terms of the traditional transmission-oriented educational model.

Inducting Students Into Science: A Science Education Program

This conceptual framework has been the basis of a school-university partnership, a program called Inducting Students Into Science (ISIS), that Barbara, along with other elementary school teachers, and Maria have been building for more than two years. Teachers from Chicago Public Schools who wanted to rethink their science teaching have been meeting regularly (in 2-3 hour sessions every other week, and in a two-week summer session) with Maria and another University faculty member. Together we revisit content knowledge, plan science units where we explicitly incorporate the theory-data dialectic, analyze videotapes of the teachers’ classroom teaching of the units, explore their students’ ideas and questions, and in the light of all these experiences, rethink teaching practices and modify the units leading to a new cycle.

Teachers who have entered this collaboration have already experienced that neither simply telling students nor primarily engaging them in hands-on activities sufficiently help them achieve scientific understandings. In our on-going collaboration, the teachers are coming to use the socio-cultural framework to help them conceptualize and examine the need for balance between introducing students to existing understandings of the scientific community and encouraging them to explore and develop their own ideas. They use the socio-cultural framework as a means of integrating (a) an emphasis on hands-on experiences in which students acquire more empirical knowledge with (b) discussions in which they help the students relate these experiences and their own ideas to relevant theoretical achievements of the scientific community.

This school-university partnership is based on the notion that teachers develop their practice of teaching science through continuous movement between classroom activities with their students and reflective discussions with colleagues and university faculty on their successes and difficulties. It is this mixture of actual teaching and reflection shared with others who have the same concerns, that helps teachers and university faculty develop and implement new knowledge and skills in their classrooms.

This program is also built on the notion that dialogue and argumentation (taken together to define discourse) are central to the practice of science and essential elements in developing scientific understandings. By adopting a constructivist approach in the design and the implementation of their units, teachers encourage student discourse by allowing students to openly share and discuss their developing scientific concepts and how their data may or may not fit the theories they constructed. Furthermore, as teachers design and refine their units, they themselves extend their own understandings of specific scientific concepts through collaboration with their colleagues and university faculty.

Classroom Discourse

Participating teachers have determined that their role in teacher-student discourse is to guide yet not dominate classroom discourse. The teachers seek to engage students in more collaborative discourse structures, where teachers and students openly share and discuss their ideas. Such structures are different from the typical classroom experience, particularly the typical science classroom experience: a teacher-led discourse where the teacher's voice dominates.

The IRE (Initiation-Response-Evaluation) sequence has been identified as the discourse structure most commonly used by teachers and most commonly experienced by students (Cazden, 1988; Mehan, 1979). This structure has been critiqued as decreasing student participation in class discussion; reducing learning to knowledge of rote activities rather than principled understandings of concepts (Edwards & Mercer, 1987); and creating "[a] perception of curriculum as a set of facts to be transmitted under pressure of time" and "shaping of pupils' answers to questions toward predetermined and nonnegotiable semantic destinations" (Edwards & Westgate, 1987, cited in O'Connor & Michaels, 1996, p. 96).

Through the teacher-dominated discourse structures, such as IRE, students are cognitively and culturally socialized to view their knowledge and experiences as subordinate to the teacher's. Edwards and Mercer (1987) point out that it is traditionally through discourse dominated by a "teacher's own aims and expectations" that students' understandings are "shaped, interpreted, made salient or peripheral, [and] reinterpreted." (p 126). Thus, *which* experiences and ideas and *whose* experiences and ideas are valued is determined by the teacher.

A conversational participation framework in which teachers and students "alternate the roles as expert and novice" (Erickson, 1996) is one of the means by which teachers may support students' articulating, examining, and maintaining ownership and control of their ideas. Erickson describes Cazden's strategy of asking children "How did you figure that out?" as a way in which the teacher switches roles with the student. The teacher becomes the novice who asks the student, the "expert," to tell her how (s)he figured out the answer. In addition, in the conversational participation framework, not only the teacher but the other students participate in the "scaffolding, appropriating voicing, and revoicing" (p. 51) of their classmates' ideas.

O'Connor and Michaels (1996) conclude that a revoicing participant framework also expands participation in classroom discourse to more students. By repeating and also reformulating a student's comments, a teacher helps the student to clarify and more effectively communicate her or his reasoning. Revoicing is also a means by which teachers give validation and credit for ideas to students who may not have been recognized by their classmates. By aligning students with particular ideas, the revoicing framework also positions students as thinkers and hypothesizers.

Girls in the Science Classroom

In the last two decades much attention has been focused on the underrepresentation of women in science, mathematics, and engineering. Excluding the social sciences, women earn 14% of the science and engineering bachelor degrees (National Science Foundation, 1994). The roots of this underrepresentation are many and include girls' early experiences in school and at home. Our study focuses on girls' experiences within the science classroom shaped by a constructivist approach to science education that emphasizes the theory-data dance of scientific activity enacted through hands-on activities and classroom discourse.

Previous research highlights that girls in the sixth grade are on the brink of a period critical in terms of their learning experiences in science. While national testing finds girls performing at close to the same level of proficiency on average in science than boys at age nine, the gap widens significantly by age 13 and 17 with boys performing better (National Science Foundation, 1994; Vetter, 1995). Other studies find girls and boys sharing similar levels of interest in math and science until middle school (Kahle, 1995). Review of the literature finds that grades 4 to 8 are critical in considering the science participation of girls of color with a number of studies identifying grades 6 and 7 as the key period where the gender gap in science interest and self-beliefs occurs (Clewell & Ginorio, 1995).

Gendered interactions with Teachers and Peers

Differential teacher-student interaction in the classroom and sex role stereotypes held by children and adults have been identified as possible reasons for the less positive experience girls find in science. The subtle sexism within classroom interactions is not always easy to observe. In their decades of research Myra Sadker and David Sadker (1994) have pointed out the insidious kinds of unconscious gender bias that happen within seconds among the context of the fast paced K-12 classroom. Teachers interact less often and less actively with girls than boys. Boys are often seen as needing more discipline and more attention. Girls are ignored and neglected. "Neglect, even when benign, is withering; time and attention bear fruit" (Sadker & Sadker, 1994). Jane Butler Kahle (1995) reviews the research on girls' K-12 coeducational experiences in science and math. She concludes that there is partial support for the hypothesis that gender differences in achievement and attitude is related to differential treatment in the classroom.

Sex role stereotypes and gendered behaviors develop very early in children. These stereotypes include the stigma that girls do not do science, math, or engineering. Reinforcement of this stereotype is part of the US cultural landscape. The example of Thailand serves as a reminder of this cultural link to girls' science performance. While national surveys usually show boys achieving more than girls, science in Thailand serves as an exception. Girls in Thailand perform at least as well in chemistry and physics. In Thailand, science is compulsory; the teaching strategy is practical; tasks often have a "feminine" image, and girls are expected to do as well as boys in school. Women participate in all fields and levels of employment (Murphy, 1994).

The cultural construction of gender and science is further reinforced by research suggesting the importance of looking at how ethnicity as well as gender shape US students' experiences in science and math. For example, Kahle finds that the gender gap in attitude, confidence, and ability in doing science was greater for white boys and girls than for African American boys and girls. White girls have an image of themselves that is more strongly influenced by the stereotype that girls don't do science (Kahle & Damnjanovic, 1994, cited in Kahle, 1995). Beatriz Clewell and Angela Ginorio (1995) also stress the need to consider both gender and ethnicity in understanding student experience in science and math. Though they find gender differences within ethnic groups, they note ethnicity is more important than gender in issues related to science performance and participation. The complexity of understanding the influences on girls' experiences becomes even greater when one considers the usually underlooked statuses of socioeconomic status, disability, language minority status, and sexual preference.

Curriculum, Learning Strategies and Gender

Sue Rosser (1990) utilizes feminist scholarship on women's ways of approaching science in developing a model of how science education can better include more women and girls. She groups her recommendations for a gender inclusive science education environment into the categories of making observations, research methods, drawing conclusions, and the social practice of science. Her recommendations include:

- Incorporate and validate personal experiences women are likely to have had as a part of the class discussion or the laboratory exercise.
- Use a combination of qualitative and quantitative methods in data gathering.
- Use more interactive methods, thereby shortening the distance between observing and the object being studied.
- Use precise, gender neutral language in describing data and presenting theories.
- Use less competitive models to practice science.
- Discuss the role of scientist as only one facet which must be smoothly integrated with other aspects of students' lives.

Based on their readings of the work of Rosser (1990) and other feminist theorists, Anita Roychoudhury, Deborah Tippins, and Sharon Nichols (1995) consider implications for science teacher education. They propose that science education should (1) "provide opportunities for students to connect what is learned in the classroom with their real life experiences" (p. 899), (2) include longer projects so students can develop personal bonds with the learning experience, and (3) provide a cooperative and supportive environment. They embed their ideas of the feminist standpoint of science within a constructivist epistemology that recognizes the variegated interests of students of both genders.

Their descriptive and interpretive study explores the perceptions of students in a physical science course for science teachers. The course was constructed according to the authors' vision noted above. Many women in the class found the class exciting because of its connection with life and their freedom of choice in selecting the topics they explored. By including the component of student choice in how they structured their projects moves this work away from the trap of declaring a stereotypical view of what is "female-friendly." The study also finds women feeling capable in their abilities and enjoying the group work. The Roychoudhury et al. study addresses the college classroom for teachers. Its findings are intriguing but, as they note, not generalizable nor automatically applicable to the K-12 classroom.

Like Roychoudhury et al. (1995), Patricia Murphy proposes the need for active and open-ended projects in science. She suggests girls benefit if they can generate their own hypotheses. Clewell and Ginorio (1995) add their view that there is some evidence that hands-on and inquiry-oriented learning compared to traditional approaches in middle schools improves the learning experience for girls of color. Finally, Jane Roland Martin (1991) makes a case for teaching K-12 science in a way that presents the process as well as the products of science. Examining the ISIS program in the light of the recommendations of educators and researchers who have theorized about and explored empirically girls' experiences in science classes, we find that ISIS provides the potential of enacting such recommendations. The focus of our study was to explore this potential and to study girls' and boys' experiences in science lessons of the ISIS program as enacted by one participating teacher, Barbara, the school-based researcher in our team, in one of her classes.

Study Design

Participants and Setting

The study focused on science lessons Barbara taught at R. Nathaniel Dett Elementary School on Chicago's west side. This school is one of several schools in the city that has networking ties with the University of Illinois at Chicago. The school for pre-schoolers through eighth grade is located in a predominantly African-American neighborhood. Most students come from low- and middle-income homes. The site for this investigation was Barbara's sixth-grade, self-contained classroom with 25 students (11 boys, 14 girls) in the 1995-96 school year.

Science was taught usually on a daily basis for a period that could range from 40 minutes to 1 hour. The data for this study come from two science units that Barbara taught in the Fall of 1995. The first unit explored the phenomenon of evaporation and the second the phenomenon of sinking and floating. The "Evaporation" unit took 5 lessons, some of which lasted longer than an hour, and the "Sinking and Floating" unit took 8 lessons, some of which again lasted longer than an hour.

At that time Barbara had one year of experience teaching at the elementary level. She had taught the "Evaporation" unit once before and had been part of the design team of both units. The "Sinking and Floating" unit was a new undertaking for her. Although the curriculum outlines a series of specific objectives and activities, Barbara revised activities and / or developed new ones to address the specific needs of her class.

Barbara's philosophy about teaching and learning in general, and teaching and learning in science specifically, incorporates a structured but child-centered perspective. In the 6th grade class that we explore in this study, Barbara engaged her students in creating classroom norms, and in planning and structuring activities. An important aspect of her work became the building of a classroom community. She wanted students to work together, share ideas and understandings, and build on and elaborate each other's contributions. In that classroom, conversation and argumentation of students' reasonings were continuously emphasized and celebrated.

Research Questions

In the present study we explore the following sets of questions.

- Questions addressing the nature of teacher-student and student-student interactions: Who contributed to the science discourse and in what ways? Who asked questions? Who answered questions? How did the teacher respond to students' contributions? How are these issues played out along gender lines?

- Questions addressing the students' attempts and successes in developing meaning: What kind of questions were girls and boys asking? Were boys and girls offering signs of understanding or struggling for understanding? Were they trying to develop meaning in these science lessons? Were they linking their class discussions with everyday / out of school experiences in their attempt to make these lessons meaningful to themselves?

- Questions addressing the students' views of themselves as they were doing science: How did boys and girls see themselves in the science classroom? How did they view their classroom interactions with peers and teacher? Did they view themselves as scientists?

Data Sources and Analysis
The data for this study include (a) videotapes of the science lessons, (b) written transcripts of the audio portion of these videotapes, (c) students' written work, and (d) Barbara's reflections. These data were analyzed using a qualitative, interpretive design seeking to identify themes and patterns that would shed light on the research questions specified earlier. The written transcripts and the students' written work were studied and annotated by all four investigators. Our interpretations of these data were shared in regular meetings where tentative assertions were generated and discussed. These assertions were further revised and modified as each of us presented her way of understanding a specific event or a specific sample of students' work. As themes and patterns began to emerge, data from all science lessons were compared and contrasted to support, further elaborate, or suggest changes. Triangulation and constant-comparison techniques were used throughout the analysis (Lincoln & Guba, 1985). In keeping with the socio-cultural perspective on science and education, these techniques are seen not as generating a knowledge of "pure facts" and "truths," but as ensuring that the knowledge constructed is robust enough to serve communities of science educators.

Findings and Discussion
We present our findings organized around the questions we set out to explore in this study. However, some classroom episodes raise issues that fit in more than one of these sets of questions. This is because the issues included under each set of questions are not isolated from each other.

Teacher-Student and Student-Student Interactions
In both units, "Evaporation" and "Sinking and Floating," girls seemed to dominate the classroom discourse. Most of the time, girls were answering Barbara's questions and posing their own questions. But not all of the girls were participating. On the other hand, there were relatively more boys who were not participating in the class discussions. Only a few boys seemed to get involved.

Most of the "Evaporation" lessons and a good portion of the "Sinking and Floating" lessons were conducted as whole-class discussions. In these whole-class discussions, Barbara seemed to be the one who posed most of the questions directing the students to think about elements of the scientific story they were trying to develop, set-up their experiments and data collection activities, and discuss whether their data seemed to fit their story. Most of the time, Barbara (or a designated student) called on students who had indicated that they wanted to contribute to the discourse. There were only a couple of times that Barbara called on students who had not volunteered--mostly boys. Barbara did not spend a lot of time disciplining students. She focused on getting the students thinking science, developing ways of understanding the phenomena they were studying. She took seriously all their statements and questions--both girls' and boys' contributions. Most of the time, she revoiced their contributions and probed students (boys and girls) pushing them to think further about what they were sharing. She asked them why they had said something, or how they could use the scientific model they were trying to develop to explain an everyday experience they were sharing. In this way, she placed the students in the role of the "expert" who was trying to develop meaning. A lot of times she engaged in one-to-one interactions with the students. A few of them were extended interactions where she tried to first understand what a student was saying and then help her or him develop meaning.

Barbara's classroom discourse cannot be described by the IRE structure. Although Barbara mostly initiated questions and students answered them, she did not just evaluate their answers and move on. She sometimes asked other students what they thought. Other times, she pushed the student who answered to elaborate on her or his answer. In a couple of occasions, she encouraged the rest of the class to get involved in the discussion she was having with a specific student. In addition, students themselves raised questions attempting to understand the issues discussed in class or relate these issues to their everyday experiences.

As gender issues were the focus of our study, we decided to take a closer look at how students of different gender were participating in different situations: (a) when the teacher was raising issues, bringing in ideas, and asking questions, (b) when the teacher explicitly encouraged the rest of the class to get involved in the discussion she was having with a specific student, and (c) when a student asked a question. As mentioned earlier, the majority of the lessons were dominated with type (a) situations. As we explored this type of situations in terms of gender dynamics we noticed interaction between girls and boys. Given that there was a heavy female contribution to the class discourse, we did not identify any patterns that would point to potential segregation of girls' and boys' participation. The following episode illustrates and supports this conclusion. Just before this episode, the students had tried to push a balloon underneath water in a container so that they could feel the upward force, the water force or buoyancy. In this episode, girls and boys guided by Barbara came to develop meaningful links between the displacement of water that occurs when a solid object is submerged in water with the upward force (buoyancy) which results from the tendency of the water to come back to its original place.

Episode 1[1]

Tchr: We're going to talk about that. And this might help clear up that question as we go along. Listen up everyone. I have this balloon. Before I put it in the water, the water level is just sitting there, all calm. Not moving around and it's taking up every space. All the surface area in this container. Now, when I put the balloon in here, what happens? Is there any change or is everything exactly the same? What do you think is going on? Martin?
Martin: I think that the um (...) what was the um (...)
Tchr: I put the balloon in the water, what happened? What do you think?
Martin: You're submerging the balloon in the water.
Tchr: I'm submerging the balloon in the water. What's happening to the water?
Martin: It's moving.
Tchr: It's moving where?
Martin: Around the balloon.
Tchr: It's moving around the balloon. OK, Brook?
Brook: The balloon is pushing up the water from this side to that side.
Tchr: The balloon is moving up the water from this side to that side. Maria?
Maria: It takes you back to molecules...
Tchr: Can I get everybody attention? Pay attention to what's going on up here. I'm sorry, Maria.
Maria: It's (???) molecules, and, uh, when certain molecules want to move and (???) the balloon and try to go under it and they'll move
Tchr: OK. All right. Bobby, don't ask a question unless it's related.
Bobby: I think it has something to do with the air in the balloon.
Tchr: It has something to do with the air in the balloon. Now, Anatosha, you're going to have to stay still. [irrelevant comments].

[1] All students' names are pseudonyms. (...) signifies a pause. (???) signifies inaudible speech.

And for those of you who cannon see and may not have something in front of them (...) I have this on tape. Here's my water. Everyone see my water leave right here? I got this balloon. [Tchr. draws diagram of oval balloon floating in container of water.]
And I'm going to move it down and put it here where it ends up right here. Now Brook it split up the water. Where does the water go?

Boy Oh, it's on the sides of it.
Tchr: It's on the sides. Over here, the water's moved out.
Boy: Oh, yeah! Ms. Luster, that's what I be saying. I stick my finger in the water and the water don't come back. How water going to come in the middle?
Tchr: Say that again.
Boy: Like I stick my finger in the water, right? And it moved the water out of the way and I didn't know that.
Tchr: It moved the water away.
Boy: [aside addressed to another child] We learned that in third grade. I moved my finger in the water (...)
Tchr: OK, Brook is saying it's what we call displacement. The water has been displaced by the balloon.
Boy: You get a cup or something and put it down in there and the water is going to be in the middle.
Bobby: That's not right! [Commenting on Tchr's drawing of balloon floating in container of water]
Tchr: What's not right?
Bobby: That. Well you see for one thing the balloon is not half (...) [Gets up to walk over to board]
Tchr: My balloon should be sitting up on top.
Bobby: Yes.
Tchr: This is my balloon. My balloon is more like this. [Alters drawing.] Is this okay?
Girl: Yeah.
Boy: Yes.
Girl: Can I ask you something. Why is your balloon two (???)
Tchr: Let me get rid of it. [Tchr erases extraneous balloon drawing above the drawing which is being discussed.]
Tchr: OK? It is in the water. Is it not in the water? Is it totally (...)?
Bobby: But only a little of it is [still dissatisfied with the drawing]
Tchr: You still think that's too much [erases bottom of balloon below water line]
Girl: Why do you have to make it hard?
Tchr: He's nit-picking. [Redraws bottom of balloon so it's almost even with water line]
OK? [Bobby nods yes.] Thank you.
Tchr: OK. This is the water, this is my balloon and it's only displaced a little bit of the water. Now, if you are displaced and your natural thought is to be where you were where you normally are, what would you try to do?
Brook: I would try to push it back up.
Tchr: You would try to push it back up. And that's what the water force is doing. It's trying to push this thing back up so it can do what?
Brook: Get it's place back.
Tchr: Go back to its place. And that's what were talking about when we talk about displacement. So, we have buoyancy, we have gravity and we have

displacement. There's one more thing I want to add on to sinking and floating for today that has something to do with why objects sink and why objects float. We're all doing this. 6th, 7th and 8th grade are doing it. Questions, people? Everybody understand that?

Class: Yes.

Tchr: Maria?

Maria: That's just like with the water force, with the buoyancy and gravity, it's pulling - both of them are trying to pull together, but it's like the balloon is so light that the gravity can't really (???) Like it's just not (???) to the gravity. So, the water force, that [the balloon] being so light and stuff, it's not always weight. But that being so light, the water force has more effect on it.

Tchr: OK. Well said (???) your explanation. Bobby?

We noticed similar interactions between boys and girls when the teacher explicitly invited the rest of the students to get involved in a conversation she had with a particular student. There were only two such situations during the lessons we analyzed. Episode 2 (presented below) involved a girl, Anatosha. Barbara and Anatosha were talking about the mass of water that was inside a graduated cylinder. The class had weighted the cylinder with and without the water and found that it was 80 grams without the water and 176 grams with the water. So the teacher said that the mass of the water was 96 grams. However, Anatosha had been focusing on another difference 96-80=16 grams but she was not clear what this 16 grams was. In her attempt to help Anatosha clear up whatever confusion was in her mind, the teacher encouraged other students to help Anatosha.

Episode 2

Tchr: I'm not happy with this class this morning. If you don't want to be involved in a conversation by raising your hand, then just sit there and listen. Now can someone help Anatosha understand what it is that she is not clear about? I don't have to be the only one. Try to help her out.

Brook: She's saying with the graduated cylinder with water it equals up to 176 grams and without water, it's equal to 80. So you subtract and you get 96.

Anatosha: No, but I'm saying - but what I'm saying is when you weigh the cylinder with the water, but afterwards, the blank container weighs 80, right? So when you add in the water, the water just (...)

Although Brook was chosen to help Anatosha, two boys and another girl were also raising their hands volunteering to contribute to the classroom discourse.

In Episode 3, at the teacher's request for a volunteer to "help Bobby out" Brook offered her understanding of how the scientific story that the class had been developing could be used in the case they were discussing.

Episode 3

Tchr: So, Bobby. Let me ask you a question. Based on what we said so far. That rock, that big rock that sits down in the middle of the ocean, that's just sitting down there, how can you relate that to our story? What's going on with that rock?

Bobby: Well, first of all, you should think about nature.

Tchr: No, I need you to think about our story. Stay with our story.
Tchr: No, I need you to think about our story. Stay with our story.
Bobby: Well, I think it's just sitting there.
Tchr: Why is it just sitting there? What's going on? Can anybody help Bobby out?
Brook: The gravity has more pull on the rock.
Tchr: The rock is sitting on the top, more like. Part of it is up, not all of it's down. It's a big rock sitting out in the middle of the ocean.
Brook: The gravity and the water force met the ideal level.
Tchr: Met the ideal level. And which one is has greater pull right now?
Brook: Neither one.

Let us turn, now, to the situations that involved students initiating questions. In about half of these situations, Barbara addressed the student's question either by directly answering it or engaging in a conversation with this student. In the other half of the situations, Barbara did not directly answer the student's question and somehow other students got involved in the discussion. All these situations involved questions initiated by girls. Furthermore, in most of these cases girls, and not boys, got involved in the class discourse. The following episodes illustrate this point.

Episode 4

Brook: Ms. Luster, why when we put it in a ball form it sank. When we put it in a boat form, why did it float?
Tchr: I don't know. Somebody? Wait a minute, Brook, think of our story. What happened? What happened in our story?
[Sylvia raises her hand.]
Brook: You said we ain't lose no weight.
Tchr: We lost no weight.
Brook: But then (???) [referring to an object] how come that didn't sink like the ball sank?
Sylvia: Because the boat, if it floats, it didn't sink because it took up more water than the ball.
Tchr: It displaced more water?
Maria: I think, I want to answer Brook's question. I think it is because, like, when it was a ball, all the weight was together. Now that it is a boat, it is like it's thin. And then that's how it sinked and floated.
Darlene: It have more room and more air circulates through it
Tchr: It's taking up more space. Remember, Brook, go back to your drawing. This one takes up the most amount of space. Remember, everybody, in drawing A. You're looking at drawing A with the circle, the ball. It only displaces a certain amount of water. Buoyancy depends on displacement in order to help an object float. So, Brook, the boat has a lot more displacement than the ball does. So which of the two forces are winning in here? Right here when it sank?
Stdt: Gravity.

In this episode Brook raised a question. Apparently it was not clear to her why a piece of clay shaped as a ball sank but the same piece shaped as a boat floated. Barbara engaged Brook in a discussion so she can help her understand. Three other girls engaged in the discussion addressing Brook's question.

Episode 5

Tchr: Could you repeat that? I got confused somewhere. That's okay, I'll listen to it again later. Does anybody have something different? Other than a different prediction. So far we said it was going to float. Did anybody have anything different?
Class: No.
Tchr: Brandy?
Brandy: If the boat, you know, it's heavy and it's still floating, but how come if there's a little hole and water gets in there it sinks?
Tchr: Can you tell me why you think it sinks then? It gets a hole in it. So, if you observed what was going on, what would you see?
Brandy: I mean, it's a little hole in the boat and the water is coming in.
Tchr: And the water is coming in. So (...)
Anatosha: It gets heavier than the boat.
Tchr: Now the water is making it heavier. So, now we're back to heavy.
Anatosha: I think because the pressure of water coming in will ride it down.
Tchr: The pressure of the water coming in pulls it down.
Anatosha: It's like pressure, and it comes down.
Tchr: And it starts to pull it down? Okay.

Again, in this episode, a girl, Brandy raised a question. She could not understand how a heavy object, such as a boat, that floats, sinks when a little hole lets water get in. Anatosha, another girl, got in the discussion to address Brandy's question.

Episode 6

Maria: . . . When a boat, it's floating, right? On water. How come when a storm comes, it will sink?
Tchr: When a storm comes, it will sink?
Brandy: Yeah, when it starts raining it will sink.
Tchr: It just automatically sinks? Nothing happens to the boat?
[Anatosha--the student responsible for allotting the turns to speak--indicates that Darlene and then Julie are to speak next.]
Tchr: Ah, can I hear Julie?
[Barb mistakenly calls on Julie first.]

Darlene: She said I could (...) [Darlene objects, saying that it's her turn to speak]
Tchr: [consulting Anatosha] Who'd you call right now? Darlene?
Anatosha: Darlene and then Julie.
Tchr: OK
Darlene: The rainwater is getting in and is making it heavier.
Tchr: Okay, if a lot more rain water get in there (...) what's going on now? Is it buoyancy or gravity?

Maria: Gravity.
Tchr: Okay, now we've got gravity. It's the same amount of volume, displacement, but now we're starting to get more mass. [Waits for Julie to take her turn.]
Julie: I forgot what I was going to say.

This episode took place during the last lesson on "Sinking and Floating." Maria asked a question that was similar to the question Brandy asked in the previous episode (Episode 5) during the first lesson on "Sinking and Floating." Darlene addressed Maria's question and although Julie had something to say she eventually forgot it.

These data, of course, are not enough to allow us to think of and talk about a pattern. However, they point towards a interesting issue that we would like to explore further. We wonder whether the tendency towards the absence of boys' participation in the class discourse when girls initiated questions is an indication of boys' attitudes and beliefs towards girls' questions. It may be instead a mere function of the fact that, in general, girls dominated the classroom discourse in all these science lessons, and student-initiated questions were usually answered either directly by the teacher or in an one-to-one conversation between teacher and student.

Students' Attempts and Successes in Developing Meaning
The analysis of the lessons on the two science units reveal many instances where girls attempted to make sense of the science ideas that were discussed. The following episodes illustrate girls' attempts (and successes in some of the cases) to reconstruct ideas that were developed both in the data level and the theory level so that they were meaningful to them.

<u>Episode 7</u>

Tchr: Okay. What can you tell me, just from looking at this graph, with the one exception and we'll talk about that in a minute. Maria, what's your question?

Maria: I just wondered how come you said they'll float.
Tchr: Which one's above water?
Maria: The one that sank.
Girl 1: Because they're 2!
Brandy: Their density is lower than water.
Girl 2: Their density is higher than water.
Brandy: I wasn't talking about (...)
Tchr: Well, Maria asked (...) What's your question again? Let's make sure we understand your question.
Maria: It looks like (...) 'Cause ain't that the water line? [pointing to drawing on board]
Tchr: That's the water line.
Maria: The cork looks like under the water. [adding softly] It still floats.
Tchr: It is under water!
Girl 1: 'Cause it's under one!
[Maria looks puzzled]
Tchr: It's less than 1.
Maria: Oh!
Brandy: And she [the Tchr] got it under "Floats" so that means it float but it's under water.

Maria: [sounding still puzzled and slightly frustrated] And the rock float (...) and the rock (...) I'm talking about the rock. The rock looks like it (...)
Tchr: The rock is 2. The density is 2.
Brandy: I know what she's talking about. She's talking about the stuff that floats, uh, looks like the stuff that comes down (...)
Tchr: The stuff that floats, it looks like it's sinking because it's underneath water. I got you. Thank you for clearing that up. Because I didn't get that until you did.

In this episode, Barbara was trying to get the students to notice the pattern in the graph that they had produced. The graph showed on the horizontal axis the different objects they worked with (and water) labeled whether they sink or float in water and on the vertical axis their density. They were talking about different objects referring to their densities and whether they sank or floated. In this way Barbara was trying to help the students see that objects with densities lower than the density of water (which was about 1 gm/cc) floated in water and objects with densities higher than the density of water sank in water. (There was an exception--wax that floated but its density was higher than the density of water.) Maria, though, raised a question. She tried to say that all the objects with densities lower than the density of water were shown on the graph "under the water line." This implied to her that these objects sank in water. Maria was trying to make sense. On one hand, she had in her mind the physical phenomenon--objects below the surface of the water sank and objects that at least partially were above the surface of the water floated. On the other hand, she had a representation of the phenomenon in the form of a symbolic tool that scientists use--a graph that linked the densities of the objects to their behavior. She tried to coordinate these two entities in her mind which resulted to her confusion and question. It seems like Brandy was able to see and maybe share Maria's confusion ("I know what she's talking about. She's talking about the stuff that floats, uh, looks like the stuff that comes down (...)"). By revoicing Maria's problem, Brandy helped the teacher understand Maria's point.

Episode 8

Tchr: What would happen if I let this thing go? If I let the wooden sphere go and it didn't move?
Anatosha: The water force, the buoyancy forces and the gravity forces both working at the same time on that one thing because gravity, it's pushing up and (...) no, the gravity is pushing down and the buoyancy is pushing up, so it's making it stay in one place.
Tchr: They're fighting, but what's happening?
Girls: Both of them win. It's a tie.
Tchr: Both of them are tied. What do my arrows look like? Is one arrow longer than the other?
Anatosha: No, they're even.

Before this episode, Barbara and the students had been talking about the two forces, gravity and buoyancy, that act on an object that is submerged in water. They had been associating sinking with gravity winning over buoyancy, and floating with buoyancy winning over gravity. In this episode, Barbara raised the hypothetical situation that an object did not move when submerged in water. Anatosha and other girls showed clear signs of being able to use the scientific story of the two forces that the class had been developing to explain and reason about the new situation.

Episode 9

Maria: Rain evaporates too.
Tchr: Tell me about rain evaporating. Class I need everybody to listen up and pay attention.
Maria: Like when it rains and it becomes sunny and then it goes up.
Tchr: Try to explain it in terms of our model, Maria. Go back to the model.
Maria: When it falls it's like a solid, because it's like real cold -
Tchr: Rain?
Maria: Hail. Then when it gets on the ground and then the sun come out, it's like a liquid and then it evaporates and becomes a gas.
Tchr: But can someone tell me what's going on that you can go back to our model (...)? Could you say that again?

Maria: When the hail falls and then melts and then like a liquid and then it just evaporates, like on a hot day, it evaporates to gas. It goes back up as gas.
Tchr: Julie?
Julie: I'm talking about rain. When there's rain, the rain hits the ground. If it stay there when the sun comes out, it dries up and the heat from the rain goes back up into the air. It dries up in the ground and come up back to the sky.
Tchr: Brook?
Brook: Okay, like she was saying, hail (???) and then when the sun hit it, it turns to, like, liquid, then it evaporates into the air, that's gas.
Tchr: Yeah, it becomes a gas. But what is going on in the molecules? What's going on with the molecules?
Girl: They move around, they just go around.
Tchr: But why? We have hail, wait a minute, Brook. Let your class get prepared.
Brook: Hail to rain. Rain to gas.
Tchr: Hail is a solid, you said. So, how does the solid, based on our model, let's go back to our model, how does a solid change from hail to that liquid you talked about, rain?
Brook: It get loose.
Tchr: The molecules get freer because the heat and the bonds get weaker. They go from the strong bonds to the weaker bonds.
Brook: When it evaporated into the air (???)
Tchr: The bonds are practically none at all. They're very, very, if we have a very weak bond, now we're going to very, very, very weak bonds.
Girl: Bonds are like a lock. Once it's locked you can't pull it. Until you unlock it, then it gets loose, then you can pull it up.
Tchr: Okay, good analogy. Maria?
Maria: So, when we come back to rain, I mean hail (...) like, ain't, when the hail fall, it's like a solid, and then when it go all the way down it just sit there for awhile, it turns to a liquid, then the sun heats, the heat from the sun change it to a gas.
Tchr: Change it to a vapor, a gas. Does the heat from the sun change it to the liquid?
Maria: And then it change to the gas.
Tchr: So, the molecules are freer because the heat is making them more active and they're moving around more and their bonds are becoming more weaker.

This is a rich excerpt of science discourse for several reasons. Maria brought in an everyday experience, rain, and related it with the changes of matter that the class had been talking about. "Rain evaporates, too" said Maria and Barbara encouraged her to talk more about this. As Maria attempted to do so, we witness the lack of common framework between the teacher and the students, Maria and later Brook. The girls did not quite know what the teacher meant by asking them to "go back to the model." The girls had been responding to the teacher's requests to use the model with describing the phenomenon--hail turns to rain which turns to gas as it gets warmer. Barbara wanted the students to use the model, meaning she wanted them to explain what happens in terms of the movement and bonding of the molecules that explains how hail changes to rain which changes to gas. As soon as Barbara helped the students know what she meant by going back to the model, when she asked "what is going on in the molecules," the girls showed clear signs of their ability to use the model to explain the phenomenon they were discussing. One girl went further to think of an analogy ("bonds are practically like a lock . . .") in her attempt to develop meaning of the theory level.

The question is, now, how boys did in terms of showing signs of understanding or attempts to make meaning. We have fewer incidents that involved boys rather than girls engaged in meaning making. We also have a couple of incidents where boys clearly indicate either their lack of interest in what was going on or their lack of making meaning in the science class.

<u>Episode 10</u>

Tchr: Buoyancy. Now, granted, we got two forces, everybody. We got gravity and water force or buoyancy. This is what we have. There are two things we need to decide whether an object will sink or float. Things sink or float because of either gravity or buoyancy. Brook is talking about right here, they both weigh the same. Why is it one sinks and the other one floats? Something has to be winning here and something has to be winning over here. The other thing that they need are mass and volume. And displacement. We need all of these things going on in order for an object to either sink or float. If the object has more mass and gravity, then what's going to happen to it?

Girl: It's going to sink.

Tchr: Somebody other (...) Ah, Bruce? If an object has more gravity and mass what's going to happen to the object, Bruce?

Bruce: I don't care.

Tchr: I know you don't. That's right. Wilhemina? If an object has more mass which means it has more gravity, what will it do? Sink or float?

Wilhemina: It will sink.

Tchr: It will sink. But if it has more volume, taking up more space, occupies more space, it's going to have more buoyancy.

Brook: I get it. You're talking about when you spaced it out, it got circular or round (...)

Tchr: It's no longer circular.

Brook: Okay, it was all bunched up and now you got a lot more space when you shaped it into a boat.

In this episode Bruce publicly announced that he did not care. In contrast, in this excerpt of classroom discourse, Brook showed signs of making meaning and publicly shared "I get t." Brook realized that when the piece of clay was in a ball shape "it was all bunched up" and when they made it into a boat it "got a lot more space."

Episode 11

Tchr: More moisture will be able to leave because there are a lot more molecules at the surface level. [Draws on board] See in this container, how many I got? Like four, for example. In a skinnier container there might only be two at the surface level. This is my surface level. I can only get two molecules. Only two are going up where, as like Anatosha said, four are going up in this one. Twice as many. Okay? So we're going to make the scientific vocabulary. We're going to make a hypothesis that this one will evaporate. The water in this one will evaporate. The same level of water will evaporate faster based on surface area. What other things can we looked at, look at, that will help, that will increase the rate of evaporation or decrease the rate of evaporation. We talked about some them, now let's discuss a little bit. Tommy?
Tommy: The moisture.
Tchr: The moisture, what do you mean by the moisture?
Tommy: Like it helps, helps it to evaporate.
Tchr: What moisture?
Tommy: The moisture in the water.
Tchr: Okay, where is the moisture coming from?
Tommy: I don't know I was just saying something. [Smiles looking a little embarrassed. A classmate laughs.]

In this episode, Tommy picked up a word out of the teacher's lengthy talk without understanding what they were discussing. He admitted his lack of meaning making ("I don't know I was just saying something") as the teacher pushed him to elaborate his answer.

However, there were instances where the boys indicated attempts to develop meaning both in the theory level and in the data level. In two occasions, Bobby attempted to coordinate theory and data.

Episode 12

Bobby: I only got two short questions for you. I want to ask if this is illogical because how in the world (...)? Now, if, if water force, um, you know, gravity is equal then it's like the object is in the middle of nowhere.
Tchr: It's in the middle of water. It's in water to begin with.
Bobby: How can it be in the middle of the water? I never seen nothing in the middle of water.

In this episode, Bobby showed his attempt to coordinate theory and data. He objected to the possibility of the case where gravity is equal to buoyancy because in such a case "the object is in the middle of nowhere," or " in the middle of the water" as he came to say after the teacher's intervention, and he had "never seen nothing in the middle of water."

Episode 13

Bobby: Like Collin said, now one of the animals I can think of that that basically is like, as large as the blue whale. What I wanted to say is that if the blue whale is so large, like if it could be the rock or something, how in the world can it float?
Tchr: How does it end up floating? And other times it actually sinks. I don't know.
Stdt: When it's dead, it sinks.
Tchr: What about when it's down underneath the water?
Bobby: Well wait, but the only time it sinks is because it's swimming down.
Brandy: [in background shakes head no in disagreement] Uh un.
Tchr: It's swimming down.
Bobby: But we want to know without swimming, we want to know how it floats.
Tchr: (...) how it floats
Bobby: without it moving in the water.
Tchr: OK, so is it denser than the water?
Brandy: The water force!
Tchr: Well, again, we got buoyancy and gravity going on.
Maria: Because a big old wave pushing it. [Sweeps arm back and forth in wave motion]
Tchr: If it's floating, which force is winning?
Maria: Buoyancy.
Stdt: Neither one
Tchr: One of them has got to win.
Maria: Buoyancy.
Tchr: Buoyancy is winning if it's floating.
Bobby: Yeah, but ah (...) but so you're telling me that the water force or the gravitational pull can take control of animals, us, and (...)
Tchr: No, I'm not saying that they take control.
Bobby: Right!
Tchr: Gravity acts on everything that's made up of matter. And we are all made up of matter.
Bobby: Including the blue whale.
Tchr: Including the blue whale. And the pink whale, just kidding.
Bobby: So, you're telling me that the water force pulls up on the blue whale but I don't understand how could the water force control the blue whale, but the blue whale can only control itself in order to go down or up.
Tchr: But we've got two forces working. Gravity is pulling it down. Water force, remember now, let's go back to this. We talked about this other thing called displacement. When the blue whale sits on top of the water, it displaces a certain amount of water. The water wants to go back. It wants to stay with all its other little water molecules. So it pushes it up to try to get back into that space.
Bobby: OK, now, in deep water. For instance, I take swimming class, when I be at the deep and when I go down, sometimes it's like the water force pushes me back up.
Tchr: Right. You displaced it.
Bobby: But I see movies with animals and water animals, they don't seem like the water force is pushing it up. It seems like they're pushing themselves up.

In this episode, Bobby had a difficult time accepting that the scientific model, the theory, that the teacher was trying to help the students understand, and that explained the phenomenon of sinking and floating, could be applied to living beings, to blue whales and to humans. Bobby was using his own experiences when swimming as empirical evidence that living beings push themselves up and forces do not play a role in these cases.

Classroom dialogue seemed to indicate that girls more than boys attempted to develop meaning and understand the phenomena that were discussed. The students' written work on the final project of the "Sinking and Floating" unit supports this result. At the end of the "Sinking and Floating" unit, Barbara asked the students to tell her why things sink or float in an essay form, or a play, or a rap song. Eleven girls turned in their work and only 3 boys. Six girls wrote plays, three wrote rap songs, and two wrote essays. From the boys, one wrote a rap song and the other two wrote plays. Sylvester who wrote the rap song managed to bring lots of important ideas in his writing and link them together. The other two boys' plays do not show signs of understanding--they include references to the two forces, gravity and buoyancy, but there is no reference to how these forces are related to sinking and floating. We found more variation in the girls' written products. Sylvia's and Charlotte's plays brought out most of the important ideas and the links among them. Brook's essay and Brandy's rap song come close missing some elements. Anatosha's, Darlene's, and Liza's plays all indicate the race (tug-of-war) between gravity and buoyancy that makes things either sink or float. The work of four of the girls does not show clear signs of understanding especially of the interrelationships between ideas. However, two of them were in the rap song form and we now question how easy it was to express fully understandings in this form.

Let us, now, switch back to classroom discourse. As we were studying the transcripts of the science classroom discourse that took place in the day before the last one spent on "Sinking and Floating," we came across a few students' statements that included "you said," referring to Barbara, the teacher, something we have not noticed in earlier lessons. Looking more closely at what the children were discussing at the moment, we found that Barbara started off that lesson asking the students to "review or tell us about what we learned from yesterday and any other day." We isolate here the students' answers to the teacher's request.

Maria: Yesterday we made boats to see if they sink or float like a sunken ship and what we did was we made balls to see if they float and they floated. And then we made boats to see if they float, and some boats floated and some of them sank. And you said some reason why they sank is because the water got in the inside of the boat.

Brandy: We had learned yesterday, when water force and gravity is equal, they, I mean, we call that the ideal level.

Brook: We made our story about why things sink and float and some people said that if they sink, the gravity pulls on it and if it floats, the water force is reacting on it more than gravity.

Anatosha: Yesterday we learned that if a hole get in your boat, it's going to sink because more and more water is coming in. And when we made our boat, the clay had a crack in it and more and more water was coming in and as more and more water came in it would sink and get heavy.

Charlotte: We learned that if the it's putting more pressure on the boat and and (...)

looking at Anatosha] you already just said that!

Brook: I was just about to say that. You said that water force is created by the displacement of water.

Anatosha: Ms. Luster, the other day you said sometimes the molecules, the water is a liquid, so they be real loose, and you said sometimes it would be enough room for the object to sink down through. But if it's like a solid, if it's like a solid, then they're real tight, it's not going to let the object sink. Like if you take some of clay and put it on ice, it would just roll around on the ice.

Brandy: You had told us that water force is created by displacement.

This part of the lesson was heavily dominated by girls sharing with the teacher what they had learned. In fact, there was no contribution from the boys. Let us examine closely the girls' contributions. Maria talked about making boats and when it came to explain the behavior of their boats she used "you said some reason why . . ." Brandy referred to some impersonal "they" that she quickly changed to "we call that . . ." Brook said "we made our story about why . . . and some people said . . ." Anatosha and Charlotte said "we learned that . . ." Brook added "you said that water force is created . . ." Anatosha came back to say "the other day you said sometimes the molecules, the water . . ." Brandy added "You had told us that water force is . . ."

What sense should we make of these data? The students' (girls') ways of talking raised several concerns for us. Should we take the phrase "you said" as an indication of students' not owning the knowledge they were sharing? Did these girls see the science lessons, and especially the parts spent on developing explanations of the behavior of different solid objects in water, as a set of ideas and explanations that the teacher presented to them and they accepted? Did this knowledge make sense to them? Did they use the phrase "you said" to indicate something new they learned that made sense to them? Do we have a better indication that students own some knowledge if they use phrases such as "we learned . . ." or "we made our story . . . and some people said . . .?" Do such phrases come out of students' feeling that learning was a process of developing understandings in a community of people? We do not have answers to these questions right now but we believe that these are crucial questions for a teacher to ask herself or himself as (s)he tries to engage all children, girls and boys, in the development of scientific knowledge. We also want to point out that the girls who, in that lesson, used phrases like "you said" to explain parts of the phenomenon of sinking and floating had been quite vocal throughout both units, contributing to the science discourse and showing signs of attempting to and succeeding in (at least in that specific moment) developing meaningful understandings. We have clear indication that some of these girls used the elements of the scientific story that Barbara brought to them to make sense of their own data and everyday experiences. The question that remains is whether these girls still saw these elements as knowledge not yet internalized and owned by them.

Finally, we explored whether and how boys and girls linked their class discussions with everyday / out of school experiences in their attempt to make these lessons meaningful to themselves. Examination of classroom discourse reveals that both boys and girls pulled in their outside experiences during their science class. For example, in the "Evaporation" unit, girls talked about boulders, juice, water in a pot, and frying hamburgers; boys talked about thawing frozen foods, milk, air pollution, and rain. As they learned about sinking and floating, boys brought up outside ideas and experiences of rocks in the ocean, seaweed, blue whales, and swimming class. Girls brought up storms sinking boats, pebbles, boulders in the ocean. These ideas emerged without specific encouragement from Barbara to pull in outside events.

As we took a closer look at the discussions that took place as students brought in everyday experiences to make meaning of their developing scientific knowledge we identified two issues that we believe are worth thinking about. First, everyday experiences may not be easily explained and understood with the scientific concepts that the students are developing in a specific unit. To explain everyday experiences may sometimes require more complex understandings than the ones the teacher and students aim to develop. Critical questions then arise. How does the teacher handle these conversations? To what extent do students get a satisfying feeling that what they are learning in science is useful in explaining some everyday experiences? Second, students bringing in everyday experiences could lead class discourse to focus on just one student to the neglect of all the others. Again, what does this mean for the teacher?

Students' Views of Themselves as They were Doing Science
At the end of the unit on evaporation, Barbara asked the students to think about and write in their science journals whether or not they felt like scientists as they were exploring evaporation and to present their reasons for their answers. The students later shared publicly in class how they felt. We had responses from 8 girls and only 3 boys. The number of girls and boys who felt and / or did not feel like scientists are shown in Table 1.

Table 1
Girls' and boys' answers to the question "Did you feel like a scientist?"

Answers	Girls (n=8)	Boys (n=3)
YES	4	1
YES and NO	3	1
NO	1	1

First, we were disappointed that only 3 boys spent some time on this question. Second, we were pleased that 7 out of the 8 girls who responded and 2 out of the 3 boys felt as scientists (at least partly). Examining, though, the reasons that girls and boys brought up to explain their answers, a pattern seems to arise (even with the small numbers we have). Boys tended to associate having disagreements among themselves with being scientists thinking that disagreements and problems take place in the community of scientists. However, girls tended to associate disagreement and arguing with not being scientists. This raises an important issue for us to explore in the classroom. What kind of images boys and girls have formed in their minds about the scientific community? And how do these images influence the type of activities that boys and girls engage in as they do science in the classroom? Because we wanted to get a sense of the students' conceptions of the nature of science and the scientists' work we asked these students to think about and share in class their responses to the following three questions: What is science? What do scientists do and why? When you do science in school, are you like a scientist and why or why not? The students' responses to these questions were interesting and will be the focus of our later analysis. Their responses, though, to these questions did not address the issue of disagreement in the process of collaborating with other scientists.

Another interesting finding in these data is that the majority of the students (boys and girls) who discussed this issue tended to associate elements of data collection and presentation to the scientist's work. For example, students stated that they felt like scientists because they were checking how much water evaporated, they were looking for results, they were checking the readings in the graduated cylinders, and they were charting down results. Only two girls associated to the scientists' work elements that could be linked to the theory level of scientific activity. The girls said that they felt like scientists because they were "thinking" and "using my imagination."

As mentioned earlier, in the final projects in the "Sinking and Floating" unit, some students chose to express their understandings of the phenomenon of sinking and floating through plays. These plays also highlight their views of the classroom interactions with peers and the teacher.

In her play Anatosha includes the following dialogue. After the teacher announces the experiment on sinking and floating, the conversation continues.

> Anatosha: It's going to be fun. Let's get the show on the road.
> Tommy: Anatosha, I hate you. I don't want to learn anything.
> Anatosha: Well, you should. (Whispers) Boger Nose Butt.

Later in her play the boys are scolded for not paying attention to the lesson and the girls are thanked for their work. The girls in Anatosha's play call the teacher Sister Luster.

In Charlotte's play, as the girls and boys discuss sinking and floating, the following interruption occurs.

> Bruce: Anatosha, you better get out my face before I hurt you.
> Mrs. Luster: Boy! Come here. Stop threatening girls.

Later the teacher sends Tommy out into the hallway to discipline bad behavior. The students stage a tug of war to better understand how gravity and buoyancy oppose each other.

> Mrs. Luster: Now, write what you felt.
> Charlotte: I felt strong.
> Martin: You know you are weak.
> Class: Laughs (ha, ha, ha)

In Charlotte's play the teacher asks questions and give directives (take notes, make boats), but there is also interaction among students.

In Sylvia's play only girls contribute to the science discourse. Bobby, a boy asks a question about the purpose of the experiment. The teacher asks a question that gets answered by a student. Then she asks another question and get answers from three different students. Next a student asks a question that gets answered by another student.
Erica's play is a dialogue between two boys with fictitious names, Joe and Mike. Joe does not know

anything and Mike tells him some things.

Will's play is also a dialogue between two boys who both contribute to science ideas. In Bobby's play, Bobby and Maria contribute to the science discourse and Brandy asks a procedural question "are we using clay boats?"

The students' plays provide us a window to their views of themselves during the science lessons. The girls felt positively about science. They also felt that girls were contributing to the science discourse (with one exception-- Erica), but that boys were not paying much attention. They also reported some tensions with boys. The two boys are split in their interpretations: one of them portrays boys as contributing to the classroom dialogue, whereas the other indicates girls' and boys' involvement.

Beyond categories

As we were exploring classroom discourse, one episode drew our attention. We noticed there a quite isolated incident--a boy, J.R., publicly making the point that he was smart and that "he got it all up here" (pointing at this head) because his prediction was validated by the teacher. Let us listen in.

<u>Episode 14</u>

Tchr: All right. Excuse me everyone. Brook.
Brook: This, the wider one evaporates first because [pointing to the skinnier one as shown in Figure 1] it'll be at 500 milliliters and it'll take a while for it to get to the top and evaporate.
Tchr: It will take a while for the gas that's formed. The little gas molecules to come up to the top?
J.R.: You mean they gotta wait till it get out of it?
Tchr: We'll see (...) Anatosha.
Anatosha: I know I can. I think it's gonna be the thin one because this one is longer than this one. This one is longer than this one, and this one right here, it's, you could be more air in it (???) a little more faster because it's more wider and it's more short. That's more long. If it has 500 ml, it's gonna take all day just to go up, just one little line to go up.
Tchr: Anatosha's, she kind of hitting on it. Okay? All right. One little line, yeah.
J.R.: Now, Anatosha, explain that what you just said again. No, no, I'm for real. No, I got a question though. Explain what you just said.
Tchr: She said it's gonna take a while for each layer, she called it a line, of molecules to go up. To come up from down here all the way up to the top and outside the cylinder.
J.R.: I think, I could tell that that fat one is gonna go up before the big one cause the 500 ml is closer to top.
Tchr: Okay. All right, the 500 ml is closer to the top. All right, now, where is evaporation happening?
Anatosha: At the surface level.
Tchr: Surface level. Now do I have more surface level in this one or in this one?
J.R.: In that one.
Tchr: I have more surface level in this one. Which means I have more molecules at the surface level. So more of them get to go up out of the container faster.

And that's why you're going to have evaporation quicker in this one.
J.R.: See, I told you all, I'm smart.
Tchr: Anatosha.
J.R.: I got it all up here.
Anatosha: I know how you can get the answer. It's more thin. It'll be less and that one's wider (...)
Tchr: Ah, can I hear Anatosha everyone? Thank you.
Anatosha: It'd be less, and that one's wider. It gonna be a lot, it gonna be probably twice as more (...)
Tchr: OK.
Anatosha: at the at the surface then is gonna be in them because that one is thinner than this one.
Tchr: Right. I couldn't explain it better. Brook. Okay, please sit down in that chair. Okay, so we're going to expect evaporation to happen quicker in this one than this one or the other little skinny one over there that we're going to use.

As we studied further this episode, we found several points we would like to discuss that cross over the sets of questions that we aimed to explore. But first let us retell the story. The students were asked to predict (make a hypothesis) in which of the two containers, shown in Figure 1, the water would evaporate faster. Both containers had 500 ml of water.

First, Brook predicted that the "wider one evaporates first because [pointing to the skinnier one] it'll be at 500 milliliters and it'll take a while for it to get to the top and evaporate." Brook was then joined by Anatosha who struggled a bit to express her understandings. She also chose the fat container as the one that would evaporate faster because "it's more

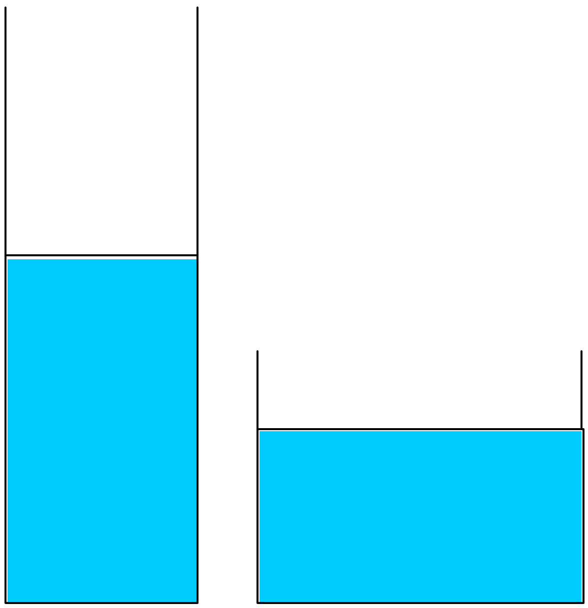

Figure 1. The containers used in the evaporation experiment.

wider and it's more short" For her the water in the taller thinner container would not evaporate as fast because "it's gonna take all day just to go up, just one little line to go up"--an idea similar to Brook's. Barbara validated Anatosha's point. Then J.R. wanted Anatosha to repeat what she said because he had a question to ask. Barbara, though, chose to intervene and repeat Anatosha's statement herself paraphrasing Anatosha's "line" of molecules to a "layer" of molecules (the more scientifically appropriate term). Then J.R. said that "the fat one is gonna go up before the big one cause the 500 ml is closer to the top' --which is the same as what the two girls have said before him. Barbara acknowledges part of his statement ("all right, the 500 ml is closer to the top") and proceeded making sure that students knew that evaporation happened at the surface level and one of the two containers had a bigger surface area. Barbara then spelled out for the students an explanation about why evaporation would happen faster in the wider container ("I have more surface level in this one. Which means I have more molecules at the surface level. So more of them get to go up out of the container faster. And that's why you're going to have evaporation quicker in this one."). It was then that J.R. shared with the rest of his class that he was smart. As we continue listening in the class discussion, we witness one more time Anatosha trying to understand and verbalize her understandings, but now she had picked up the teacher's way of thinking about this issue. Anatosha was now comparing the amount of molecules on the top surface in each container rather than talking about the time it will take for molecules to reach the opening of each container. Once again, Barbara validated Anatosha's contribution and moved along.

We see at least three issues worth exploring in this excerpt of class dialogue that did not last longer than 3 minutes. First, why did Barbara choose to repeat Anatosha's statement as a response to the boy's explicit invitation to Anatosha to do so? Why did not Barbara let Anatosha repeat her point to the boy herself? Does it matter? Barbara views her "jumping in" to repeat Anatosha's statement as part of her "dominating" the classroom discourse. But also Barbara is caught in a difficult and complex situation. Barbara knew that Anatosha was often expressing her understandings in convoluted ways--ways difficult to understand. Revoicing Anatosha's contribution, paraphrasing Anatosha's statement instead of letting her struggle with it again could have cleared things up for J.R. and could have even made clearer to the rest of the students what Anatosha was saying, and the lesson could have moved on. An important dilemma for a teacher--how do we as teachers honor the children's individual voices and ways of making sense and at the same time help all children understand and move on? This dilemma becomes more critical, we believe, when gender lines are crossed. By repeating Anatosha's statement rather than letting her speak, did the teacher give an unconscious signal that a girl was not able to deal with a boy's challenge, question? Of course, Barbara did not intend that, but she worries when such a thing happens. Barbara sees clearer and clearer the need to step aside, even a little bit, letting students develop their own competencies in discussing and talking science with each other.

Another issue is the boy's pompous behavior (exhibiting his cleverness and putting it out in the class) vs. the girls' "quiet" meaning making. Again, this was an isolated incidence, at least during the two units that we made the focus of our study, but it is so consistent with the differences between boys' and girls' behavior in school and in life in general. The question for us becomes, do such cases send hidden messages to girls (especially those who were not participating in the class discussions) that science is not for them? The girls who dominated the class dialogue during both science units did not seem affected by J.R.'s comment. But we do not know about the rest. On another level, we started thinking about how we should address such incidents. Of course, it is not clear at all whether Barbara heard J.R. The fact that the video-camera picked that up does not mean that the teacher who was in the midst of many kids talking realized then what J.R. said. That aside, we see two issues that we need to explore. First, what we do in a classroom to address the attitude that lies behind such statements, and, second, how we address the statements themselves. We need to ask ourselves why J.R. did that. There are many, many ways to interpret J.R.'s behavior. We would like to discuss one of them. Perhaps, J.R. felt good about contributing to the class discussion, he also felt good that the teacher validated his prediction and gave himself "a pat on the shoulder" reaffirming that he could do science, he was smart, and he had a lot of stuff in his head. What is wrong about this?

We all believe that children, independent from their gender, need to see themselves as smart individuals who try to make sense and can make sense of the world around them. But, that is again a place where a teacher's difficult dilemmas come to light--help an individual student feel good, become more confident, develop self-esteem and, at the same time, keep in mind and strive for success in these areas of the class as a whole.

The third issue is the lack of building on, acknowledging, and differentiating each other's ideas. All three students (two girls and one boy) brought up the same idea. But, there was not public mentioning of this similarity. Furthermore, Barbara's explanation was different from the students' explanation. The students were thinking in terms of the distance between the surface of the water and the opening of the container, whereas Barbara put forth an explanation that was based on the number of molecules on the surface of the water. When we try to develop a classroom community that emphasizes collaboration (both among students and between teacher and students) as a means of meaning making, of developing meaningful understandings of the world around us, this issue becomes a critical one. If students are not helped to realize the similarities and differences between arguments, ways of reasoning, ideas, they remain locked in their own way of looking at the world or they just accept the teacher's way of looking at it without much understanding. The class discussions become a collection of one-to-one exchanges between a student and the teacher without building a sense of community of learners who debate and develop scientific knowledge. Maybe, if explicit links were made among the children's ideas, if the children were encouraged to examine how their thinking was similar or different from their classmates', maybe J.R. could have seen how his contributions were the same as Anatosha's and Brook's and he may have come to share publicly that all of them were smart! And, all children might have realized the problematics of these three children's original reasoning that the distance between the water surface and the opening of the container determines the rate of evaporation--a conception that could imply that evaporation happens only when the water molecules escape from the container rather than the surface of liquid water.

Conclusions

We view our findings as a celebration of girls participating in the classroom and making sense of science. In the classroom interactions we analyzed, girls were actively involved in collecting data, making predictions, developing explanations, and working to understand scientific models in terms of their own experiences. The girls, more than the boys, were verbalizing and writing about science in a way that exhibited their movement past memorization toward a deeper understanding. We are actually concerned by the limited progress that all but a couple of the boys made.

Why did the girls in Barbara's class succeed more than the boys in engaging in classroom discourse and in understanding science? Previous research finds gender differences in test scores and sex role stereotypes that would suggest that girls would not be doing as well. What explains the active involvement of the girls in Barbara's class?

One answer may be the approach to science education that Barbara enacted in her classroom. This approach includes a number of elements that other scholars suggest are beneficial for making science more "female-friendly." For example, students in Barbara's class spent a great deal of time talking about their data and scientific stories / models. They were trying to develop explanations of phenomena they had experienced in their everyday life, such as, evaporation and sinking and floating. They were trying to make sense of science by coordinating empirical experiences with ways of understanding them. The teacher was guiding them in this endeavor, offering them, and helping them make meaning of, concepts essential to their attempts for understanding. Students in Barbara's class could bring up and discuss personal experiences as a way of making sense.

Another explanation of girls' strong performance is clear when we reexamine past scholarship on African American girls. Previous studies find less pronounced or different gender differences within communities of color compared to the experiences of white students. The African American girls in Barbara's class experience school differently than their boy classmates, but evidently in a way that helps support their participation in their science class. Gender dynamics would perhaps differ if the students in Barbara's class were Latino, Asian American, Native American, or white. The culture of science, ethnicity, and gender are all involved in a given classroom.

A further explanation for the girls' participation rests in Barbara's interaction with them. She creates in her classroom a place where it is safe for them to speak and be heard. The signs of sexism seen in many classrooms--girls neglected by the teacher, boys demanding excessive attention through misbehavior--are at a minimal level in Barbara's class. However, sexist tensions are not absent from the class, only suppressed. Charlotte's and Anatosha's dramas about the classroom interactions show clearly that some boys in the class show hostility to the girls. The potential for the girls being distracted from learning science by boys is clear. Barbara's role in controlling the classroom climate to make it conducive to girls learning is also clear in these dramas written by students. Barbara tells the boys to stop bothering the girls. In one play the girls call her by a name that expresses their feelings of community with her--Sister Luster.

Yet, while Barbara's role in the interactions with the students is beneficial in making the class a safe place for girls to talk, Barbara worries that she needs to remove herself more often from the discussion. At times the classroom dialogue centers on her as the provider of answers and knowledge. The students need to engage more in dialogue among themselves. Their meaning making should extend beyond one-to-one interactions with the teacher. Barbara notices this in the videos and wants to take herself out of the center of attention and let the classmates interact. Perhaps by stepping out of the conversation she can encourage other students to participate. A question that Barbara keeps asking herself is what is the optimum level of her interaction with students from both a gender lens and a socio-cultural perspective to science education.

We wonder, too, about the many students who were silent throughout the classroom discussion. The 25 members of the class participated at very different levels. While a number of girls and a few boys spoke often during class, some of the girls and many of the boys did not. What were they thinking? How do we hear from these students without forcing them to speak? We want to know if these students developed meaningful understandings of the phenomena explored in class.

Our study raises many more questions than it answers. It provides important food for thought for Barbara as she continues to teach science at the Dett school this year and in the future. Among the questions raised that we hope to address in future teacher research, and we urge others to consider, are the following:

- What is the optimum level of interaction between teacher and students and among students themselves that can ensure that both girls and boys in the classroom participate in classroom dialogue and develop meaningful knowledge?

- Why did the children who did not talk in class stay silent? Why were boys silent? Why were girls silent?

- If the teacher removes herself from the discussion, does peer sexism increase?

- Do girls participate more in discussions where the question is raised by another girl? What are the implications of that?

- Do the students make connections between what they do in the science class and the work scientists do in their jobs? What kind of arguments, question generation, collaboration, and so forth, do they think scientists participate in? Would it help them to work as scientists but also to discuss the world of science from an outside perspective?
- Considering the students we focused on in this study, what are their science classrooms like now that they are in 7th grade?

- How does an approach to science education that focuses on the data-theory dance work for girls in other settings? With other women and men teachers? Students of other ages, other ethnicities, other socioeconomic statuses?

- What other scholarship on discourse, power, and gender can inform this inquiry?

In conclusion, we recognize the exploratory but important nature of this study. Our findings do not provide any generalizable knowledge about how best to teach sixth grade girls and boys science.

However, we learned many things. Most importantly, Barbara gained the opportunity to critically consider the interactions in her classroom in order to shape her future teaching. In addition, we share with the reader an in-depth look at girls learning science. We move past test scores and into the mechanisms of learning in a real classroom: a classroom full of 25 energetic children and one teacher. We see the challenging, complicated teaching choices and dilemmas that Barbara must face, diagnose, and make in split seconds. From our analysis of the complexities of these classroom dynamics, we contribute to a greater understanding of the need for careful balance between (and more research on) science classroom discourse--its structure and its content, students' learning in relation to their understandings, feelings, and attitudes, and a girl-friendly science classroom environment.

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