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AUTHOR	Davis, Kathleen S.; Irwin, Chris
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ABSTRACT

Though there have been many efforts to reform science teaching at the K-12 level over the past decade so that all students can engage in meaningful science activity and become scientifically literate, colleges and universities are just beginning to redesign their science curriculum and instruction. This paper examines the structures, practices, and pedagogical approaches of a reform-based college science classroom and illuminates the pathways and roadblocks to the participation of females in this context. An investigation is made into how the instructional practices of inquiry, project, and technology-based college science courses facilitated the legitimate participation of females in science activity and discourse. The study focused on one science classroom in which students were provided with opportunities to engage in inquiry and project-based activities and use technology to collect data and communicate with others. Several methodological approaches were used in this study including classroom observation, interviews with participants in the course, and analysis of pertinent documents. (Contains 28 references.) (SAH)

Building a Bridge for Females to Equitable, Inclusive, and Participatory Science Activity

by
Kathleen S. Davis
University of Massachusetts, Amherst
&
Chris Irwin
University of Massachusetts, Amherst

Kathleen S. Davis
TECS Department, School of Education
University of Massachusetts, Amherst
Amherst, MA 01003
413-577-2317
kdavis@educ.umass.edu

Chris Irwin
TECS Department, School of Education
University of Massachusetts, Amherst
Amherst, MA 01003

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Introduction

Though reformers seek to facilitate the legitimate participation of all individuals in science (AAAS, 1989), research describes the disproportionately low participation rate of females and minorities (i.e., African Americans and Hispanics) in SMET courses, educational programs, and careers (NSF, 1999). For example, though women comprise 46% of the labor force, only 22% are scientists and engineers. People of color comprise 23% of the U.S. population, yet they constitute only 6% of those working in SMET.

Researchers have illuminated many factors that contribute to the construction of boundaries within the science community and the subsequent insider/participant status for some groups and peripheral/outsider status for others. Structures and practices have often inhibited and/or blocked females' and minorities' engagement in science practices instead of providing pathways (Harding, 1991; Oakes, 1990a, 1990b; Sadker, Sadker, & Klein, 1990; Seymour, 1995). Social structures, power relations, instructional practice, and requirements for legitimacy define what is possible for acquisition of knowledge and skills, identity development, and participation in science (Lave & Wenger, 1991).

Inclusive Pedagogy

Institutions and organizations, and the individuals who comprise them (i.e., teachers) can provide access to learning opportunities as well as jobs, and funding (Davis, 1999; Stanton-Salazar, Vasquez, & Mehan, 1995). Thus, the pedagogical approaches used by teachers can be key to providing inclusive/exclusive contexts. For example, pedagogy that portrays learning as "received and reproductive" rather than "authentic and constructed" (Hildebrand, 1998, p. 349) may lead individuals to see only the experiences, thoughts, and ideas of others as valued and fail to see a legitimate place for themselves within science.

Researchers working from a feminist perspective (Davis, 1999; Hildebrand, 1998; Rouchoudary, Tippins, & Nichols, 1995) have proposed inclusive pedagogical approaches where students use the knowledge, skills, and tools of science in relevant inquiry and engage in diverse ways of talking and thinking.

Inquiry is a concept that encompasses a broad field of meaning and methodology, and to think of it as a single pedagogical 'approach' is problematic at best. There are many dimensions to and interpretations of inquiry, but knowing that science is a continuing process of inquiry, and that the process of questioning is central to inquiry teaching and learning, will assist us in describing the features of inquiry-based learning.

The National Science Standards (NRC, 1996) describes inquiry as:

> ... the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. Inquiry is a multifaceted activity that involves making observations, posing questions, examining books and other information sources to see what is already known, planning investigations, reviewing what is already known in light of experimental evidence, using tools to gather, analyze and interpret data, proposing answers, explanations and predictions, and communicating results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p. 23)

Classroom inquiry builds on students' own curiosity; curriculum content is connected to and arises from student activity. Student ownership and responsibility for learning are other key ideas in inquiry (Magnusson & Palinscar, 1995). Patterns of classroom inquiry can shift from a more teacher-guided inquiry process through increasing levels of more student-directed inquiry, with the classroom teacher scaffolding the inquiry process, relinquishing more and more control to students as they become more experienced and efficient at directing their own inquiry activity. Following this technique, early stages of inquiry are heavily scaffolded, using teacher-posed situations and questions to provide modeling and support as students gain experience in the inquiry process, with students eventually conducting independent inquiry on questions of their own design (Metz, in press; White & Frederiksen, in press).

Inquiry teaching and learning incorporates experiences that allow for the development in the science process skills as described by Padilla (1991) as well as learning to organize and complete inquiry investigations. Students practice these skills of inquiry in small ways and then apply them in full recursive cycles of inquiry. Students learn how to pose and answer research questions, conjecture hypotheses, collect and analyze data, construct models and apply or test them in related situations, and generate new questions for further investigations. Students engaged in inquiry-based learning come to appreciate the nature of science methodology, become actively engaged in scientific inquiry, and gain confidence in their ability to become independent learners (Skolnik, 1995).

A feminist epistemology suggests that, as students engage in inquiry, they do so within open-ended projects where science learning is situated in their lived experiences, projects are long enough to allow a sense of bonding and connection with learning experiences, and a cooperative and supportive environment is provided. Classroom tasks associated with inquiry include hands-on laboratory work, making graphs and charts, writing descriptions, report writing, general discourse, cooperative small group work, procedures for facilitating the interaction of existing student knowledge, and tasks that encompass higher order thinking as outlined by Resnick (1987 in Flick 1995) that requires nonalgorithmic, complex, multiple paths for solution, application of multiple criteria, uncertainty, self regulation of thinking processes, negotiating and imposing meaning, and effortful activity.

As educators seek inclusive pedagogical approaches, they must consider what elements are key to their students' full and legitimate science activity and participation. In previous work, the first author (Davis, 1999, Davis, in press) has used legitimate participation in a community of practice as a theoretical model to explore student learning, identity development, inclusive practice and equitable social structures. Such a model suggests that through "engagement in social practice" and activity with experts and novices within a community of practice, such as science, individuals are provided with an open door to sources of knowledge and understanding (Lave & Wenger, 1991).

Full and legitimate participation in practice involves "*becoming* part of the community" and an "increasing sense of identity as a master practitioner" (Lave & Wenger, 1991, p. 111). (Italics are in the original.) A master or mature practitioner in the science community includes: (a) being skilled and knowledgeable about activities, tasks, tools, and understandings valued within science; (b) interacting and contributing within the profession and being seen as a valued member and participant in the change and construction of new and evolving capital, values, structures, practices, and membership of the science community; and (c) knowing what constitutes the structures and everyday practices of science including the tacit, implicit, indescribable competencies and unexamined ways of being a member (i. e.,; how novices become masters; how, when, and about what long-time members of the science community collaborate and disagree and what they enjoy, value, admire, reject, and ignore; where are the valuable contexts in which to do, present, and publish one's work) (Delamont, 1989; Lave & Wenger, 1991; Tonso, 1997).

Thus, a developed sense of community, an atmosphere of mutual respect and trust, shared leadership, cooperative structures, and integration of cognitive and affective learning, and action are key to equitable participation (Davis, 1996; Schniedewind, 1983). Educators must provide a context that is equitable, participatory, and autonomous so that the voices of all groups are acknowledged and valued. As mentors, educators must make explicit the ways and practices of science, including the bias, sexism, and racism there, and listen to, support, and provide pathways for students as they express their goals and needs (Davis, 1999; Davis, in press).

Purpose

Though there have been many efforts to reform science teaching at the K-12 levels over the last decade so that all students engage in meaningful science activity and become scientifically literate (AAAS, 1989; NRC, 1996), colleges and universities are just beginning to redesign their science curriculum and instruction. In this paper, we critically examine the structures, practices, and pedagogical approaches of a reform-based college science classroom, and we illuminate the pathways and roadblocks to the participation of females in this context. We investigate how the instructional practices of an inquiry-, project, and technology-based college science course facilitated the legitimate participation of females in science activity and discourse.

Methods

The study focused on one science classroom where students were provided with opportunities to engage in inquiry- and project-based activities and use technology to collect data and communicate with others. Several methodological approaches were used in this study: classroom observation, interviews of the educators and students participating in the course, and analysis of pertinent documents.

Study Site—New England College[1]

The site of this study was a college, freshman-level Marine and Fresh Water Ecology and Conservation course taught during the Fall 1999 semester at a small, New England College (NEC), a private college in the northeastern United States. NEC and the Marine Ecology course were chosen for several reasons. First of all, faculty in the Natural Sciences at this institution believed that science is best learned though student-initiated and student-designed projects that are interdisciplinary and carried out in the laboratory and/or the field. Five goals guided the development of Natural Science Division I (first year) courses. They are to:

1. Engage students in active and individualized scientific inquiry—students will ask their own questions about the natural world and attempt to answer them individually or in groups. Students engage with the material to a depth where they have a sense of ownership.
2. Help students gain a clear sense of the scientific process—science is not merely about learning facts. Instead, science is an active process involving repeated cycles of making observations, defining hypotheses, collecting and analyzing data, revising ideas, and developing better hypotheses.
3. Help students see their projects in broader contexts—students are expected to consider the ecological, sociocultural, historical, political-economic, and policy contexts in which science takes place.
4. Develop students' ability to use quantitative information—students should reach a level of increased understanding of why and how quantitative analyses play key roles in scientific investigations.
5. Develop students' oral and written communication skills—students should be able to a) identify and locate literature and relevant source

materials, b) critically evaluate primary research articles and synthesize information, c) organize their observations and ideas into clear and coherent presentations, d) through revision, sharpen oral and written presentations.

These goals provided the frame for the student activities of the Marine Ecology course. Course handouts made these goals explicit

Secondly, NEC faculty viewed their college science program as a successful context for females. They reported that females regularly made up approximately half of the institution's science graduates.[2] In addition, for more than 20 years, faculty at this college have developed project-based outreach programs that provide pre-college females with opportunities to engage in science activity.

Study Site—Marine and Fresh Water Ecology and Conservation Course

The Marine and Fresh Water Ecology and Conservation course was chosen for its emphasis on student inquiry through project-based instruction. The first author of this paper had listened to lectures given by the instructor of the course and had conversed with her regarding the project-based approaches she used in the course as well as in summer workshops with science teachers and middle school students. The instructor related the involvement of her students in meaningful, inquiry-, and project-based science activity and their use of relevant technologies—computers and other science tools.

Students in the course met for a total of seven hours each week for twelve weeks. On Tuesday and Thursday mornings, students met for a one and a half-hour lecture/discussion. On Thursday afternoons, they met for a four-hour lab.

The course included the following major components: 1) the salt marsh study; 2) the coastal eutrophication problem study; and 3) the urban aquaculture project. The first and third projects are discussed in detail in the findings section of this paper. Briefly, the salt marsh study included an introduction of students to the salt marsh through readings of the primary literature and discussion in

[1] Pseudonyms are substituted for the names of persons, places, and institutions throughout the manuscript to protect the anonymity of the informants.

class, a weekend fieldtrip to Cape Cod to collect data, and a written paper in which students analyzed that data. The coastal eutrophication problem study engaged students in a review of the literature regarding some aspect of coastal eutrophication. The course required each student to write a paper and present to the class a critical analysis of his/her chosen problem based on primary literature. In the urban aquaculture project, students, working in teams, designed and implemented a study to answer a question or solve a problem relative to a particular issue of urban aquaculture. They collected data and provided a written analysis of their findings.

Profile of the Course Instructor

Linda DiStefano, the instructor of the course, was a NEC faculty member in the Natural Sciences for over 20 years. She taught biology, marine biology, and ecology courses and guided students in their research. Her research has focused on marine life and effective science teaching, including project-based instruction. Linda published articles and made presentations at workshops and conferences regarding her use of project-based instruction in college science classrooms.

Profile of Student Informants

Six, white female students from various SES backgrounds who were enrolled in the course consented to participate in this study. Nancy, reported having both traditional and inquiry-based school experiences prior to taking the course. (See Table 1.) She had taken biology, chemistry, physics, anatomy and oceanography in high school, and had experienced field work associated with the study of ecology as part of her high school biology class. Nancy indicated a preferential interest in natural sciences over physical sciences, mostly because of an aversion to mathematics. She was interested in studying ecology and in pursuing environmental law as a career. Nancy described the processes of science as "tedious, yet interesting".

Mary, also reported having both traditional and inquiry-based school experiences prior to taking the course. She reported having "a pretty good

[2] Attempts were made to confirm the faculty's report, however, institutional data regarding graduating seniors' major discipline was not available due to the interdisciplinary nature of senior projects and the limited record keeping of NEC.

science background through grade school and in high school". Mary had taken Advanced Placement (AP) physics, biology and chemistry courses in high school, and indicated that she had experience in project-based science activities throughout her public school science classes. Mary reported having confidence in her ability to design, implement and draw conclusions from experiments. Mary describes the process of doing science as being "experimental... and impacting on society".

Esther, reported having traditional, text- and lecture-based school science experiences prior to taking this course, and reported taking physics, chemistry and advanced biology in high school. She indicated having rich personal and familial experiences in science, primarily centering on visiting science museums and sailing and discussing marine life and weather and related science topics with family members. She had participated in authentic science activity in the form of an independent study of a conservation area through 'Project Serve', which resulted in her compiling a portfolio on the history of local forests for a local town library. Esther stated that she had an interest in combining writing, environmental science and cultural studies in some way as a potential career. Esther described the process of doing science as "interesting, revolutionary... and occasionally tedious".

Barbara reported having both traditional and inquiry-based school science experiences prior to taking this course. She indicated a strong connection to school science and a solid background in the sciences, having attended a magnet high school to study environmental science. Barbara reported participating in authentic school science activity, which included field trips through the auspices of the Chesapeake Bay Foundation to study environmental factors impacting the Chesapeake Bay. Barbara saw herself as being knowledgeable in science, and interested in pursuing science in some way as a career. She described the process of science as coming up with an idea, designing an experiment, finding out what you need to test, researching what others have done, collaborating with colleagues and "fiddling with it until you get something that works."

Shelia reported having traditional school experiences prior to taking this course. She reported disliking taking science in school, taking the traditional college preparatory classes in high school only because they were required.

Shelia did participate in authentic personal science activity in the context of working at the Smithsonian Natural Science Museum, working with a staff member organizing and categorizing a seashell collection for the museum. She reported a change in her attitude towards science since attending college; she enjoyed science more now in her college science coursework experiences and described science as "fun, exciting, and self-gratifying."

Starr, having attended a Coalition[3] high school, reported having inquiry-based school science experiences prior to taking this course. She indicated having a number of school science experiences similar to the kinds of science activity in the freshwater and marine ecology class. She engaged in authentic school science activity in the context of studying river ecosystems and conservation lands in the form of observing and cataloguing plant and animal life and conducting testing and experiments. Starr was also engaged in personal authentic science activity through a Girl Scout program studying the Great Lakes in Michigan. Starr indicated an interest in scuba diving, marine biology and maritime studies, and archeology. She viewed science as "mainly a research field... probably more research than there is actually laboratory work."

One important point of interest in describing the profiles of these students is that their prior science experiences--in and out of school—was helpful in determining their familiarity and experience with the processes of 'doing' science and their exposure to science content prior to the course. The following chart provides an overview of each informant's science experiences prior to enrollment in the marine ecology course. (See Table 1.)

Three of the six student informants revealed that they had experienced both traditional and inquiry based school science experiences prior to enrollment in the marine ecology class. Two reported having only traditional school science experiences and one indicated having inquiry based school experiences. Both of the students reporting to have had inquiry based science learning experiences prior to enrollment in the marine ecology class also reported participating in authentic school science activity. Only one student informant reported feeling connected to school science. Three of the six student informants reported

[3] Coalition of Essential Schools founded and chaired by Theodore Sizer.

participation in authentic personal science activity and two reported engaging in recreational personal science activity. Three student informants reported a strong connection to personal science experiences. Only one student informant indicated that she felt knowledgeable in science. Of the six student informants, two had had experience in participating in science reform programs; one having attended a magnet high school, the other having attended a coalition school.

Methods

Observations

Observations were made of all class meetings and field trips. All observations were recorded in the form of field notes. Some activities were recorded via audiotape and photography.

Interviews

Formal and informal interviews were used. Students and the instructor were interviewed to enlist their perceptions of the activities, talk, and learning within the class. Formal student interviews were voluntary, approximately 30 minutes in length, tape-recorded, and later transcribed. Pseudonyms are used throughout the analysis to maintain anonymity of the informants.

Documents

Curriculum materials including the course syllabus, student readings and handouts were collected. Copies were made of all student work completed throughout the course. Pertinent documents (i.e., college catalog) were also collected.

Analysis of Site Data

The results of this study will be developed from interview transcripts, documents, and field notes of the activities of the classes. Ethnographic analysis will be used to determine prominent themes about the classrooms studied (Spradley, 1979).

Two charts were designed to analyze teacher and student behaviors and attitudes in order to characterize the learning environment and describe the teacher's role and student's role in inquiry. These charts were compiled from descriptions of elements of inquiry from a number of sources (NRC, 1996; Padilla, 1991; White & Frederiksen, 1995). A third table was constructed to examine the setting for elements of inclusive pedagogy. Fieldnotes and student interviews were coded and analyzed for evidence of inquiry and other emerging themes. Charts were examined to describe teacher and student activity and evaluated to determine patterns of teacher and student behaviors and attitudes as well as patterns of change as the course progressed.

We drew on several sources as we analyzed the kinds of teacher questions in the course. The first source was the data collected in the form of fieldnotes from this research project; several categories emerged from the classroom discourse. The second source used was *Primary Science Taking The Plunge (Harlen, 1985)*--specifically the chapters entitled *The Right Question at the Right Time* by Joe Elstgeest, and *Helping Children Raise Questions- And Answering Them* by Sheila Jelly. The third source of question types was a workshop offered by the Science Discovery Museum in Acton, MA, to provide educational staff with types of questions to use with the general public as they engaged in the hands-on exhibits.

The analysis includes particular description in the form of vignettes, field notes, and direct quotes, general description in the form of taxonomies and charts, and interpretive commentary to provide explanation and connections within the analysis (Erickson, 1986).

Findings

Data from this study points to several elements in this science education setting that were key to students' meaningful, legitimate science activity and their learning of critical inquiry skills and marine ecology principles. These elements included: 1) the teacher's ability to effectively scaffold students' inquiry activity; 2) the teacher's encouragement of discussion and questioning; 3) the interaction and communication between students, often in the context of structured, small group work; 4) the presence of contextualized, relevant science activity that incorporated the use of primary data and research resources including in- and out-of-classroom fieldwork data and the authentic use of science tools; and 5) the predominance of student-directed activity and ownership of their research—"finding things out for yourself." (See Table 2.) In this section, we describe the activities of the class that were instrumental in providing students with meaningful, authentic, and constructed science activity.

Building a Bridge: An Introduction to the Elements of Inquiry

Linda opened the Marine Ecology class during the fall semester with several class meetings devoted to introducing the class to critical inquiry and, thus, preparing them for the data collection and analysis they would do mid-semester at Cape Cod and the experimentation they would design and carry out later with the aquaculture project. Linda was clear about the necessity to bridge the gap between what skills students brought to the class and the skills they would need to fully engage in the scientific activity planned. She stated:

> My experience [is] that these guys have never written a scientific research paper so if you expect them to come up with the question, do the experimental design, and then the rest of it, it is just really overwhelming.

As we analyzed the student and teacher activity of the course, we came to see that in the early weeks of the class, Linda provided this scaffolding by primarily involving the students in the following aspects of inquiry: applying science content knowledge to problem solving; using skills of inquiry in context (observing, inferring, classifying, predicting, and interpreting data); making connections and applying new information; formulating predictions, hypothesis, and questions; constructing reasonable explanations; supporting and refuting models; recognizing alternative explanations; drawing reasonable conclusions from evidence; verbally communicating their ideas; and working in cooperative teams.

Observation and Interpretation

Beginning with the first class, Linda introduced her students to what she called doing a "page one" and "page two." Doing a "page one" meant to critically observe and to explain "what is being presented…and what the pattern is. These are the aspects [of a graph, figure, or setting] that everyone would agree with." Doing a "Page 2" meant coming up with one's "own interpretation of the data." During the first four weeks of the semester, students developed these skills as they explored primary research resources—slides of the Cape Cod area they would visit, research literature that included graphs and tables about salt marsh settings and coastal bays—and primary data resources—a local freshwater marsh where they did a page 1 and 2 of the landscape and talked about zonation.

Asking Questions

Through her continuous questioning, Linda guided and challenged her students as they engaged in observation and interpretation. Linda asked several types of questions including: directed, open-ended, clarifying, confirmation, assessment, evaluative, prompting attention, focusing, comparison, elaboration, summarizing, sustaining/extending, initiating/encouraging, problem posing, and reflective toss questions. The high frequency and pattern of directed questions illustrates the guidance and facilitation of student learning as the first and final projects were introduced to the class. The high frequency of assessment and sustaining/extending questions demonstrates the responsive nature of the teaching strategies of the instructor, who often capitalized on student ideas to guide classroom discourse.

Students were comfortable with Linda's questioning and viewed the context as one where they could also ask questions. For example, Shelia noted:

> Charlene is really, really neat about questions in class. I think she's a really great teacher and she encourages you to speak up.... [E]very other sentence she says is like, "So does anybody have any questions?"

Critical Analysis

In addition, at the beginning of the semester, Linda engaged her students in critical examination and reflection about scientists' research methodology, presentation of findings, and data interpretation. Students read the work of one author who critiqued the research and claims of ecologists and marine scientists. Linda invited her students to talk about the elements of good science and strong scientific writing through a critical analysis of this author's critique. "In a critical analysis," she tells them,

> you do not simply describe what the article is about and who said what. This is a description, not an analysis. In an analysis you: start with an overview of the article [and then] give you own opinion—say whether or not you agree...and why or which part of his arguments you agree with and which you don't and why....When a reader is finished...he/she should understand what

> [the] writing is about...plus your opinion of what [the author] says and why.

Students felt comfortable putting forth their ideas and opinions in the class and recognized the value of critical thinking in their learning. For example, Barbara pointed out:

> [Linda] really taught us to go over scientific papers. Like at the beginning of the year the language is big, and I didn't know what they're talking about here, there and stuff. But she really helped us in the beginning go over the scientific papers and figure out what to look for in the paper as to methods and things that might be going wrong in the paper or how to know whether it's trustworthy or not and that really helped. If I'm going to be doing research in the future I really need to know how to figure out whether a paper is going to be good for me. Are they really doing their methods right? Are they trustworthy or are they just skewing their thoughts?

Mary noted how this approach made for a comfortable learning setting. She stated:

> In the beginning of the [Marine Ecology] class, we did a little bit of discussion and a lot of reading... so I think she prepared us well in reading and feeling comfortable in reading from a lot of different sources and accumulating ideas in our heads that we can use later....I think those kinds of things also influence the way we feel more comfortable about speaking up. I do feel really comfortable speaking and putting forth ideas and things.

When comparing the Marine Ecology course to other classes she had taken, Mary noted that Linda's expectation that they think for themselves was important for their learning. Much like a biology professor Mary had had, Linda

> would encourage or prompt the students to answer the questions themselves or drawing conclusions themselves instead of saying this is why it happened. I think that's pretty good. The idea of hearing the answer, memorizing it and spitting it back out later in a different time is, like I don't think the thought doesn't really form,

or doesn't really connect to other experiences, unless you actually figure it out for yourself. It helps down the line in figuring other things out in other situations all around. That's the main thing.

Building a Bridge through Guided Inquiry--The Cape Cod Project

The course introduction to observation, questioning, interpretation, and critical analysis came together for students one weekend, several weeks into the semester, as they applied the inquiry skills to better understand the flora and fauna of the Sage Lot Pond marsh and the Childs River on Cape Cod. New skills that the students employed for this project and continued throughout the remainder of the class included identifying 'testable' questions; investigating and analyzing science questions; recording observations, analyses, and explanations of primary resource data; and use the tools of science (computers and scientific instrumentation).

Linda posed this question: "Why is the vegetation and animal life that is here here and why is it where it is?" which led the students to collect data on the vegetation and animal life at the two sites and then analyze the ecological context as a whole. When they returned to NEC, they would write two research papers—one reporting their findings and interpretations of the salt marsh setting and another exploring the issue of eutrophication of coastal bay areas.

On Cape Cod

The sun is shining on the bay in the background as Linda talks to her students about Waquoit Bay and the Waquoit Estuarial Research Center. Linda tells the class that she has done a lot of work here over the years. It is a good research site for many marine biologists. They can easily get their boats into the water here, and there is a library where they can review their data, read the work of other researchers, and write. It is also a place where they can leave their materials while out on the water. The Center used to be a private estate and, later, was given over to the federal government. There is now a visitor's center with exhibits that inform the public about the marine ecology of the area.

In one van, we make our way down a muddy road to the salt marsh. The clear blue sky over the marsh is occasionally dotted with birds winging their way across the bay. The birds' calls add a melody to the steady rhythm made by the lapping water of the bay.

Linda introduces the class to the marsh--pointing out the spartina, marsh aster, distichlis. She tells the class that they need to look, to observe. They are going to write a paper based on their observations. She talks about zonation, spartina, observation, and questioning.

"Why is the vegetation and animal life that is here here and why is it where it is?" she asks. "For example, crabs and fish swim in here from high tide." She talks about spartina and spike grass and the fact that HS2 exists in a large part of ocean. "Rack, where do you see rack?" she asks. "It is neap tide—quarter moon; how is that related? Be observant; this all goes into your paper." She points out dead man's fringe—introduced seaweed that competes with other plants. "That would be a cool thing to study," she says, "Oysters hang on to it and float away."

Linda tells the students that they are going to make a trisect—they will run three lines. For each line, every two meters, student teams will lay a quadrant and note the percent cover of the vegetation, whether it is 0-1%, 10%-25%, 50%, & 75-100%. Each group will have some identification directories to help identify the various plants and a clipboard with data sheets to record their observations. Teams will also put a flag in the middle of each quadrant and check for the elevation. "Are you OK on that?" she asks, "Let's do one."

Linda places a quadrant on the ground. She leaves the students to look at the plant matter contained within its bounds and talk among themselves about what they see. After a working out some details with Marcia, the teaching assistant (TA), she returns to the group. Linda asks, "So what did you come up with and were there any issues?" A student asks about some of the identifying features of patens. Linda asks, "What do you think? Does that look like the other one?"

"It's like spike grass," a student responds.

"Yea, but it doesn't look just the same," says another.

"OK," Linda says, "take out the spike grass…It… looks different to me."

"Yea and this is the spike grass," states the TA.

"Yea it's really different," confirms Linda. "So that one's patens, but you have a handout, you can look at it. So one of the big issues is the confusion between patens and spike grass. So maybe you'll have to keep coming back to that and ask me to come over, or you get some here that you know are patens and keep it in your pocket, and you can look at them, or you can look at your handout. OK, how about the % coverage, were you pretty much in agreement on what those would be?"

A student asks if they can through it with her and see if she agrees. Linda responds, "No, is up to whether you guys agree. You agree with each other. The reason [for] those big categories is—it's generally a no-no—but you might not agree on 20 and 25% and so I make them big enough."

Linda continues, "We need at least 2 people in each of the 3 lines and then 2 people to do the elevation. Marcia will operate the transect and then another person will hold a stadia rod and then that person can switch off with somebody else....So each line gets...transect flags of a different color.... [The]transect code will be A and then it says quadrant number and you write A1, A2, A3, A4..."

The transect A group begins to squish its way across the marsh to its start spot at the bay's edge and quickly see a blue crab in the water:

S: Oh, my goodness!

S: Here's another one, oh, my god!

S: Oh, it's a blue crab, Oh, wow! Look at that!

S: Look at that claw!

They then focus on the ground cover:

S: The categories, what are they?

S: 1%, 10%, 25%

They proceed to make their way up the marsh and away from the water and to examine one quadrant after another:

S: How much spike grass would you say there is?

S: Spike?

S: Yea.

S: OK, ummmmmmm....15...and then...

S: Spike grass, how much spike grass is there?

S: Call it a 100; tell them it's full, OK? ummmm; and 1% of the unknown, did you get that? The unknown that we haven't labeled yet?

The students then move to the next spot.

K: Lots of chicken stuff here

S: OK I say 25% of the chicken stuff.

S: What is its real name? Cause I'm...

S: Salicornia

S: Salicornia?

S: We should be using it,

S: I know, get to know to those terms.

S: Salicornia; it's 25%

S: (Long sigh) Oh there's some bare spots.

S: Probably 10% there?

S: Could be 25%.

S: Agreed?

K: What we got there--a little bug?

S: Are these eggs or something? What do you think that is?

K: I don't know.

C: Look underneath that, look at some of the critters in that. (Laughter)

S: Owwww! There's spiders in there.

T: Yea there's a lot of neat animals in this detritus.

The students completed their data collection and ended this part of the field trip with a sack lunch along the bay.

The next morning, the class met at Phillips Marine off the Childs River to organize their next exploration. Several canoes had been hauled behind the van in order for the students to complete this part of the project.

Four groups of students were formed to collect data from five stations along the channel. Linda provided the students with maps and assigned groups to gather information at several stations. Before Linda sent off each group, she showed the students how to use the equipment she had brought along to measure salinity, dissolved oxygen, and temperature. She also had a grab—a mechanical device that would bring up all kinds of things from the bottom of the river. As the students used the equipment, they would then record the information on data sheets. Linda gave a walkie-talkie to each canoe team so that she could communicate with them while they were out on the water.

After two hours, the students wrapped up this segment of the field trip. In an aside, Linda told me that she thought that the day was somewhat chaotic. She indicated, though, that, over time, she had simplified this part of the field trip quite a bit. On earlier trips, each team would take all of the readings—dissolved oxygen, salinity, temperature.

When students returned to class on Tuesday, they logged all of their data from the salt marsh and the Childs River into Excel charts, which they then converted to graphs. (See Figure X.) The students used their data and the research of other scientists to explain the vegetation of the Sage Marsh setting in their papers.

Building a Bridge through Student-Directed Inquiry: The Aquaculture Project

In the aquaculture project, Linda engaged her students further in the process of inquiry. Students now began experimentation (identifying 'testable' questions; investigating and analyzing science questions; systematic, organized, logical planning of long-term investigations; recording observations, analyses, and explanations); using the tools of science (computers and scientific instrumentation); and directing their science activity and taking on more responsibility for their earning.

The following classroom vignette contains many key elements of inquiry learning present in the freshwater and marine ecology class during this project. This first passage gives evidence of authentic school science activity in the form of possibilities for real world application; teacher serving as science mentor making explicit the practices of science and facilitating the activities of student newcomers; students eliciting the experience of others and sharing information; cooperative group work; students directing science activity and having choices concerning the topics of their research, with the teacher encouraging learners to make choices from a range of ideas; and students formulating and analyzing science questions and designing investigations, using the skills of inquiry in context.

The Aquaculture Project

The laboratory session begins with students sitting in small groups at computer stations. A guest presenter who is a specialist on the topic of the final class project is providing some background information on aquaculture. As the visiting presenter and course instructor present some major concepts related to aquaculture and fish waste, diagrams and notes are put up on the board, and the students are taking notes.

The final research project is connected to a real world problem. The college has just acquired an old fish hatchery facility and is beginning an aquaculture center at this site. The problem for the final research project is presented: How to deal with huge amounts of fish waste. Solutions arrived at by the student research teams could have applications to a real world issue: sustainability in aquaculture, regarding the uses of/disposal of fish feces for the aquaculture center.

After an initial discussion, the students move to another part of the building, the greenhouse, to observe a large fish tank holding about 4,000 fish. This fish tank includes an elaborate water intake/outtake filtering system. The system is examined, and students have the opportunity to make observations and ask questions about how the system functions.

The class returns to the laboratory classroom and a whole group discussion ensues addressing the process of this research project and some issues surrounding fish waste.

Teacher: Now we are going to start brainstorming questions for this project. I want you to work in groups of 3 or 4 to talk about potential projects. This project will be more open-ended than the previous ones. You will have more responsibility in stating your research question and designing the experiment, a process in which you will be guided less than before. While in groups, think about what questions could be asked and projects relating those questions you could do surrounding this problem.

The students then break up into small groups to brainstorm questions and talk about potential projects. The teacher visits each group, listening in, encouraging participation and providing support through the means of comments and sharing of primary resources. As students work in groups, discussion is lively and students demonstrate real engagement in the process.

After a time, the teacher reconvenes the whole group, and as small groups present their early ideas for uses of/disposal of fish waste, the whole group critically reflects on and offers suggestions for research project ideas.

Teacher: Okay, let's come back and share the question ideas your groups came up with.

S1: We were thinking of fertilizing plants with fish waste to see what the effects are. We could measure plant growth using plant height and number of leaves and look at the levels of ammonium nitrates from the fish waste in the soil.

S2: We thought of growing plants and comparing for types of fertilizers, one of which would be fish waste.

S3: We were interested in looking at nitrogen concentration in composting food with fish feces, measuring ammonium nitrate from a water sample to determine composting activity.

S4: We were discussing examining the effects of using fish waste in a hydroponics system.

Teacher: These are all great ideas, and you only had a short time in groups today. We will spend time in the next lab session to think more about these questions.

After this whole group processing discussion, the instructor informs the students that the next lecture class will be on the topic of the nitrogen cycle, a topic relevant to their research projects, because of the nitrate levels present in fish waste. She informs them that during laboratory period next week the groups will have more time to refine their early question ideas and begin to work on experimental design, and encourages student groups to meet outside of class during the week to collaboratively think more about their research questions.

A few class sessions later:

Teacher: From now on, all class time will be devoted to your projects. It's important to do hands-on and minds-on scientific work. This may be the biggest thing you do this semester: and this is our goal; for you to do science with ownership of your research, not just me telling you what to do, putting yourselves in charge, getting involved in your research. Can each group report on their project, the progress you are making toward answering your questions, or problems you are having? Maybe the other groups will have some suggestions for you.

Agriculture group: We are growing fast plants, radishes, and beans in potting soil with miracle grow, fish waste, and just plain water to determine which groups have the most growth.

Teacher: Does anyone have any questions or ideas for this group?

S1: How are you measuring plant growth?

Agriculture group: Plant height, number of leaves, overall appearance and thickness of stems.

S2: How much 'treatment" (fertilizer, fish waste or water) will you add?

Agriculture group: We will dissolve the same amount of each in a gallon of water.

Teacher: You are equating 1 gram of Miracle Gro with 1 gram of fish waste, you may want to make a mixture so the concentration ends up being the same. What if you got better results with miracle grow than with fish waste. What would that tell you?

S3: That maybe something else is going on with the fish waste.

Teacher: Yes! And that is the reiterative part. How about the hydroponics group?

Hydroponics group: We'll use already grown water hyacinths and grow them in fish manure 'tea' and measure the uptake of nitrogen.

S4: Where will you put the electrode to measure the nitrogen?

Hydroponics group: In the water.

S4: So you will only be measuring nitrogen in the water?

Hydroponics group: We are measuring the water over time, hopefully nitrogen will be decreasing in the water, because of the plant.

Teacher: What can be your control? Your hypothesis is that the ammonium nitrate will decrease in the water because it is going into the plant.

Hydroponics group: We could have a container with no plant to see if the nitrogen decreases.

Teacher: Good, next, let's hear from the compost group.

Compost group: We are looking at how fish waste introduced into compost will affect it.

S5: What are you measuring?

Compost group: We'll look at the effects of mineralization by measuring nitrate concentration.

Teacher: Trying to get a sense of available nitrates in the compost?

Compost group: Trying to take advantage of the nitrates in the compost. An issue for us is how we're going to store it; also the nature of the compost, how mature it is, and how fish waste affects the composting process. A problem we are having is trying to figure out how to de-water the fish waste.

S6: You could filter it somehow.

Compost group: All the water from the tank goes through a filter.

S7: But not all the waste gets trapped there.

Compost group: It should go to a place with valves, so we could stop it, scoop it out, and centrifuge it.

S8: You could figure out how much fish waste is produced, gather some, measure the nitrogen, then figure out how this meets the needs of the compost.

Compost group: We want the ideal carbon:nitrogen ratio for the compost. How much nitrogen there is to give, and then how much we get, and how much is needed.

Teacher: I think all of you should be proud of yourselves. Look how far you've come in the past few weeks!

In this next vignette sequence, the cooperative groups have been working on their research projects over a period of a few weeks. An observation of one of the groups, the compost group, reveals how student interactions within the small groups are used to deepen science content and process knowledge. It also illustrates the ownership by the students of the project they have designed and are currently implementing, and genuine teacher/student collaboration.

S1: So, now we know what we're going for, how much fish waste makes a good fertilizer. Maybe we should test with different ratios of fish waste.

S2: I don't think we'll have enough time to test different ratios, maybe we should just test for one.

S3: (Looking at her notes) I remember the teacher saying 30:1, carbon to nitrogen is the best ratio for compost...

S1: So, if we measure what is in the compost today...

S3: How do we calculate the amount of fish waste?

S3: We find out how much they fed the fish, take 80%, because we know that 80% of the food turns to waste...

S2: What is the rate of fish waste produced? And how much nitrogen is there in fish waste?

Teacher: (Who joins the group at this time) I don't think you know how much nitrogen there is in fish waste yet. There is a formula and a calculation needed to figure that out. I have a book upstairs in my office that should give you the information. I'll get it for you...

The teacher returns a few minutes later with an aquaculture text. Together, the group and the teacher look at the text to find out the information needed to calculate the amount of nitrogen in fish waste. The group and the teacher move to the blackboard and together work through a calculation.

Teacher: So, according to our calculations, if you produce 1 kilogram of biomass of fish you get162 grams of organic matter, which contains 30 grams total of nitrogen. 27% of this is fish waste, which yields 8 grams total of nitrogen...

S1: So, every kilogram of fish will produce 8 grams of nitrogen in their feces.

Teacher: Right, good work. What will you do next?

S3: Maybe we should go collect some water from the fish tank and try to filter it.

Teacher: Sounds like a good idea. I heard you talking about using the centrifuge to separate out the fish waste. Would one or two of you like to learn how to use it now?

At this point, one student goes to get some water from the large fish tank, while the others go with the teacher to get instruction on how to use the centrifuge.

This final piece illustrates key indicators of student inquiry. Here, the students are using computer technology to demonstrate knowledge and improve their communication of science ideas, thinking logically and analyzing experimental results, drawing reasonable conclusions and constructing reasonable explanations from data, and reflecting on issues that would continue in future investigations.

At the final class the students meet in the lab to wrap up their research findings. The students are all working at computer stations using Microsoft

Excel to create spreadsheets and graphs to represent their data, and writing their reports. Each group had collected enough data to draw some partial conclusions from their research projects, or generate ideas for the next cycle of testing.
Discussion within the Agriculture group:

S1: Because there was not a significant difference between the miracle grow fertilized plants and the fish waste fertilized plants I guess our results are inconclusive.

S2: Yeah, you know, we really don't know how much nutrients came from the potting soil, and how the nutrients were used by each type of plant.

S3: If we did this again, we should plant only one type of plant, and plant it in vermiculite.

S2: I guess we could write up our report as a research proposal so we could make suggestions for further study... with more time and money...

In these projects, students engaged in multiple aspects of inquiry. Linda described the Cape Cod project as guided inquiry. While at the salt marsh she talked about why she designed the project the way she did.

> This is guided inquiry. I present the question; I set up the experimental design and pretty much tell them what to do. So what they're going to do on their own is put all the data together and then go through it. The next project, they're going to have quite more—they're going to come up with the question. And the reason I do that is that it was my experience, I've been doing this project for a long time...[the students] get reasonably good data. It's pretty out here...too and it's enough data so that they can do a good project...but it's not so much that it's completely overwhelming. ...So I kind of take care of that first part for them so that they can concentrate on the data analysis and writing the research paper which is a pretty big deal for them to do. So that's why I do it that way.

Lia thought that the Cape Cod study was helpful in learning how to conduct research. She stated:

> When we went to Cape Cod, [it was] like sort of learning…the method of collecting data and sort of just like [learning] through …mistakes and…successes ….I guess like the first the Cape Cod one, we didn't design the project, so we sort of kind of just saw how to collect data and how to be consistent….

As Lia reflects on the aquaculture project, she notes the increased ownership and responsibility she and the other students have with the project but how it is still a learning opportunity.

> But then the one we're doing now, I really like 'cause we could actually, we designed the project and, kind of working with Linda, could figure out like, this is the reason that slant of the project wouldn't work and through just sort of like trial and error. I guess the class allowed for that. Like she would say at the beginning that we were actually going to be scientists, so she let us like make mistakes and like see why a certain thing wouldn't work.

Lia compared the inquiry work she did with her dad, the ornithologist, and her inquiry work in the class.

> Ah, I guess, with my dad it would be like he would be doing the project and he would just tell me, like a certain part of the project to do. So like I would go take the birds out of the net or something, but I wouldn't really know… unless I asked specifically why, what the focus of the project was…. The marine class is more like, I know exactly, well especially with this aquaculture project, I know exactly why I was doing a certain aspect, you know. So it's more like I'm sort of running the project, whereas with my dad it was more just helping with a project that I didn't necessarily know about.

Lia started working with her dad when she was 7 or 8 and then all the way through high school. Even when she was in high school, her role was just basically whatever he told her to do. However, in the Marine Ecology class, Lia and her peers had say about the project, which meant responsibility to create the design, but also the opportunity to make a significant contribution. Lia said:

> The aquaculture project, I'm really liking now, but at first I wasn't liking it as much, but now…like we figured out exactly what we're doing and…we're finding out different things and stuff like that, so that's really fun. [We're] actually learning something that maybe hasn't been done before, you know stuff like that. That's really neat!

Mary's description of the Cape Cod project shows the importance of learning within context. She said:

> I definitely really liked the trip out to Cape Cod. Not just the fact that it was a trip and got off campus for a couple of days, but actually collecting data from real natural salt marsh or something that actually occurs in nature…I could go out to a salt marsh and tell somebody why such and such a pattern is why it is...It kind of feels more relevant to me the fact that it actually is something that occurs naturally and also taking it directly from the source. Seeing what I'm experimenting or what I'm looking at instead of just reading about it. I like the field work in that way.

Mary talked about the aspects of the course that interested her and her peers as she compared the aquaculture experiment to those she did in high school:

> From what I've seen this semester everybody's really interested and involved in it and that definitely makes a big difference. And especially in this last project that we're choosing what we want to do…and what we're interested in instead of being assigned to do such and such experiment.
>
> Most, probably all, the experiments I did in high school were printed out on a paper. You had to do this, you had to do that and then the professor would help us [see] why this happened. He or she already knew what was going to happen because this experiment has been done a thousand times from this piece of paper. So…forming the experiment from a problem…definitely adds some enthusiasm for me…. I've done a bunch of experiments

but I've never designed anything myself before. I've done a bunch of experiments but nothing I've chosen to do or thought up myself so that's pretty exciting.

Like the day that Ken came in and Linda said, "Okay, here's the problem now, find a way to design an experiment to help solve it." I've never been in that situation before, but it was interesting--the fumbling around it takes to actually design an experiment and that makes sense and can actually answer a question that will relate to the problem. So that adds a lot to having designed it yourself; you feel more involved in it and interested it in general, so that adds something to it.

....[I]t's also interesting that it actually applies to something that is actually happening. Like it's a real tank of fish. Like with other things in high school--like a lot of their labs that we did were taking chemicals out of this bottle and out of that bottle and I mean, we were working with the chemicals but we didn't know how that could apply to actual life on earth. Like nobody needs to mix these chemicals in every day life for this reaction....

[U]nderstanding how the aquaculture projects benefit the general life on campus and relating it to other projects around anywhere, like...the NEC graduates who started their own aquaculture are growing basil or something like that, it's interesting how it can relate so closely to that, something that I'm doing really early on in college. Other friends that are at different places who are in genetics 101 or something like that, I'm definitely glad I'm not . . . I'm feel like I'm actually doing something that will make a difference right now instead of just like taking chemistry again or something like that which a lot of people are doing.

The idea that I can actually do it. It's not just something that I read about but something that is actually there and can benefit in the long run like this sustainable NEC community or something like that. It's interesting to actually have a say in what's going on in that regard.

Barbara pointed out:

> I really did like the field trips where we went out and were actually doing the fieldwork. Like when we went to Cape Cod and did the transect studies. That was really interesting especially because I had never done anything scientific like real work like I was a real scientist. You know there's already an answer to something and the teacher gives you a problem and she knows what it's going to turn out to be but this was something like Linda had no idea why some plants were growing in other places. It was all up to us to find the answers. She was just giving us the resources and I really enjoyed actually going out there and doing the actual scientific work.
>
> It taught me skills in researching, analyzing how I'm doing things, making sure I'm covering all the different kinds of controls and stuff, and covering everything that might possibly influence this instead of just putting together this lab that already has this perfect. It taught me how to put together my own lab instead of what is already set out for you. What we're doing now, planning all our experiments and stuff, where we're thinking of everything, it's pretty much us, since she's not telling us whether we're doing it right or not. We have to figure it out for ourselves. It's beneficial to me because I know that if I continue pursuing science, I'm going to need to know for myself how to design my own labs and think of everything because people aren't going to be there telling me, you know, you're not doing this right until I've already published a paper or something.

Discussion

It seems that the nature of classroom discourse and student activity in the introductory college science course encompassed many strategies of inclusive pedagogy, including instructional practices that incorporated inquiry- and project-based activity, the integration of the tools of science and technology in science activity. Major course assignments were designed to engage students in cooperative, contextualized science investigation with real world relevance and applications; in more teacher-directed activity at first, and then progressing to more student-directed activity. Patterns of teacher questioning prompted students to higher levels of critical thinking and ownership. Shared leadership and decision-making occurred as project-based inquiry was modeled and scaffolded by the teacher and as students became more adept at managing their own inquiry. The final project was larger in scope, which facilitated student bonding with the content and learning experience. As students progressed through the semester, becoming more autonomous in directing their own learning, a sense of community and an atmosphere of trust became prevalent.

Legitimate Science Activity

This class provided students many opportunities to legitimately participate in science. Mary's words highlight key elements of the class and her science activity that serve these ends when she said:

> I can actually do it. It's not just something that I read about but something that is actually there and can benefit in the long run...It's interesting to actually have a say in what's going on in that regard.

First of all, students do science in contrast to traditional school science where students read about the science activity of others or, as Mary put it, completed "experiment[s] that [had] been done a thousand times [before] from this piece of paper" where the teacher know already "what was going to happen." Students in the Marine Ecology course used multiple inquiry skills to answer questions and solve problems that had no previously agreed upon answer, were relevant and applicable to the world around them. As first year college students, they were engaged in a relatively high level of student science activity and performance.

Students used the tools of science—scientific instrumentation such as probes, sensors, centrifuges, and other field and laboratory equipment, as well as computer technology—to collect, record, and analyze data and communicate their findings. Linda embedded tool activity within students' explorations in such a way that it did not stand out as something "special" but as "just a tool" that scientists use to complete a task thus, providing further entry to authentic science activity.

Importantly, students had "say" about their science. Importantly, from the beginning of the semester, students had an active and vital role in the class and their learning. From the first class meeting, students were engaged in careful observation, critical thinking, and interpretation. Students' opinions, views, interests, knowledge, and skills were acknowledged and valued, and students' questions and ideas were built upon in the process of setting goals, planning their investigations, collecting their data, and interpreting and communicating their results. Students were encouraged to make choices between a range of ideas (Shapiro, 1994), and their interactions were used to deepen their understanding of science concepts and ideas. As in previous studies (Davis, 1999, 2000, Davis & Falba, 1999), the learners in this course highlighted their autonomy as critical to their feelings of connection with their science activity.

Bridging the Gap: Providing a Scaffold to Legitimate Inquiry

Data from this study shows the changing roles of the teacher and students during the semester. Early in the course Linda introduced her students to inquiry through its basic elements—questioning and problem-posing, careful and thorough observation, and critical interpretation of primary sources of data. Linda believed that scaffolding the inquiry process for her students was vital. Requiring her students to take on the entire responsibility of scientific inquiry—from question to investigation design to analysis to critical writing—would have been, in the beginning, too "overwhelming." However, over the course of the semester, Linda provided her students with opportunities to explore each important aspect of inquiry. As the semester proceeded, Linda's role as director of activity and investigation designer decreased, and the students' role as questioner, collaborator, investigation designer, experimenter, and data interpreter increased.

It appears key that the teacher must relinquish the central role in inquiry in order for students to take it on. In the first author's previous research of a science education reform setting, she found that as the teachers and the printed curriculum continued to serve as questioners, problem-posers, investigation designers, and, thus, dictate students' science activity, they interrupted students' ability to take on those roles (Davis, 1995). The less students were engaged in all aspects of science inquiry, the less they claimed responsibility for their learning, and the more this responsibility continued to reside with their teachers.

In contrast, Linda provided the necessary space for students to take on more responsibility and guide their own science activity. She encouraged and expected students' participation and decision-making, and she provided support in the form of discussions with teams, laboratory materials, experts and resources, and time.

Linda also provided students with a partial window into science as a career. Students developed scientific research, writing, and critical analysis skills as they read the work of other researchers, presented ideas and explanations before their peers, and wrote scientific papers. All of which provided them with an understanding of what valued and expected scientific work was like.

Linda invited students, who were considering science teaching as a career, to talk to her about what that would entail. While at the Cape, she introduced students to the research center and shared her experience of doing research there, providing the message "you can do this, too." However, the many obstacles and impediments females and minorities face in their pursuit of science education and careers was not made explicit in the class.

Discourse

It is interesting that students found this context—steeped in questioning and critique—as a comfortable setting for communication. Previous research by the first author has shown that the discourse of science is often based in competition and aggression and questioning and critique are seen as discourse tools to establish hierarchies and exclude individuals and groups (Davis, in press).

However, in the Marine Ecology course, the classroom context and its discourse were not so much about Linda being the most knowledgeable and the transmitter of a body of knowledge or about students "being right" or being perceived as the "best student." In contrast it was clear that the focus of the classroom was about gleaning new knowledge, and the discourse was about securing information to better understand a context, phenomenon, question, or problem. Students were encouraged to question others for information, share information, make suggestions, give examples, elicit the experiences of others, raise questions, pose problems, and describe situations, and events from their daily experiences. In a previous study, women working in the science profession communicated in similar ways to construct new knowledge of their professional environments (Davis, in press). They viewed their ways of talking as a contrast to the competitive, aggressive talk of their surroundings and considered their methods of communication as a path to new information and the inclusion of diverse voices.

It also appears that an open context for critique and challenge of the scientific explanations of others and what is considered public science knowledge (Shapiro, 1994) is critical to creating a safe setting for students talk. Linda dispelled the notion of all scientific writing as "sacred" when she engaged her students in the process of critical analysis of scientific papers. Such an instructional approach provided students with voice within science dialogue.

What was held as sacred, however, was the style of scientific expression. No alternative ways of writing or speaking outside of the traditional were suggested or promoted. Hildebrand (1998) describes traditional scientific discourse as positivist, masculine, hegemonic. She points to the tacit assumption "that access to power in science will occur only if all students are taught to write as the scientific elite write" (p. 350). However, she contends that

> Only a limited access to power can be envisaged from this standpoint....[T]o uncritically perpetuate writing practices that are implicitly underpinned by an ideology that links science with power and masculinity is to choose to teach in ways that generate privilege for *some* students. (p. 351) (Italics in the original.)

Thus, it is important to make explicit the many ways that individuals are privileged and how multiple discourses have a place in science.

There were other factors that contributed to the supportive discourse environment. The non-graded assessment policy lessened the chance for a competitive environment. In addition, Linda's interaction with her students on a first name basis, the comfort they felt in talking with her outside of class, and the small class size aided the teacher and students in developing a collaborative and supportive atmosphere rather than a competitive one.

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Table 1 Comparison Table of Student Informants' Prior Science Experiences

Prior Science Experience/Informants	Nancy	Mary	Esther	Barbara	Shelia	Sta
Traditional prior school science experiences	X	X	X	X	X	
Inquiry-based prior school science experiences	X	X		X		X
Authentic school science activity				X		X
Connection to school science				X		
Traditional prior personal science experiences						
Inquiry-based prior personal science experiences						
Authentic personal science activity			X		X	X
Recreational personal science activity			X			X
Connection to personal science experiences			X	X		X
Seeing self as scientist						
Seeing self as knowledgeable in science				X		
Prior experiences with science education reform				X		X

Note. X indicates evidence of experience reflected in informant interview

Table 2. Emerging Themes from Student Interviews

Emerging Themes/Informants	Nancy	Mary	Esther	Barbara	Shelia	Starr
Out-of-classroom fieldwork	X	X	X	X	X	X
Contextualized lab work		X	X	X		
Student directed activity/ ownership of student designed research		X	X	X	X	X
Communicating with other students	X	X	X	X		
Small group work as a positive				X		X
Small group work as a negative	X			X		
Student autonomy "finding things out for yourself"	X	X	X	X		
Problem-based real world applications of science activity		X	X			
Using primary research resources			X	X	X	
Using primary data resources		X		X	X	
Teacher encourages discussion and questioning	X	X		X	X	
Small class size		X	X		X	
Hands-on vs. lecture		X	X	X	X	X
Visiting 'experts'		X	X			
Strong female teacher			X			
Presence of TA			X			

Note: X means element present in student interview.

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