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AUTHOR	Bianchini, Julie A.; Whitney, David J.; Breton, Therese D.; Hilton-Brown, Bryan A.
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ABSTRACT

This paper investigates the perceptions of scientists and their awareness of issues, goals, and beliefs related to gender and ethnicity in science and questions the curriculum, classroom management, and teaching strategies of instructors. The study examined 18 science faculty members' perceptions in a professional development seminar series and focused on these issues: (1) perceptions of students; (2) use of inclusive curriculum and instruction; and (3) views of the nature of science. Results indicate that family, cultural, and social expectations have effects on the academic achievement of students at the elementary and secondary education levels. Using scientists' experience-based ideas on equity issues to provide more equitable science education for all is recommended. (Contains 76 references.) (YDS)

Inclusive Science Education:

Scientistsí Views and Instructional Practices

Julie A. Bianchini, David J. Whitney, Therese D. Breton, and Bryan A. Hilton-Brown

Paper presented at the annual meeting of the National Association for Research in Science Teaching in Boston, MA, March 1999. Correspondence concerning this article should be addressed to Julie A. Bianchini, University of California, Department of Education, Santa Barbara, CA 93106-9490. Electronic mail may be sent to jbianchi@education.ucsb.edu.

> All students [must] have access to supportive, excellent undergraduate education in science, mathematics, engineering, and technology, and all students [must] learn these subjects by direct experience with the methods and processes of inquiry. Americaís undergraduates--all of them--must attain a higher level of competence in science, mathematics, engineering, and technology. Americaís institutions of higher education must expect all students to learn more SME&T, must no longer see study in these fields solely as narrow preparation for one specialized career, but must accept them as important to every student. Americaís SME&T faculty must actively engage those students preparing to become K-12 teachers; technicians; professional scientists, mathematicians, or engineers; business or public leaders; and other types of "knowledge workers" and knowledgeable citizens. (National Science Foundation [NSF], 1996a, p. ii)

In recent years, scientists, science educators, and scholars of science have called for the development of a more inclusive undergraduate science education, one that makes science interesting, understandable, and relevant to all students, particularly to those traditionally positioned on the periphery of college science. The mandate put forth in the NSF report, Shaping the Future (1996a), reproduced above, is just one of many examples (see also Ginorio, 1995; Malcom, 1993; National Research Council, 1996; Rosser, 1991, 1995, 1997; Tobias, 1990, 1992; Traweek, 1988; Vetter, 1996). In response to such calls, science and womenís studies faculty at a comprehensive university in California have embarked on a curriculum and faculty development initiative designed to transform undergraduate science courses. Their project, Promoting Women and Scientific Literacy, was begun in 1997 and is expected to last a minimum of three years.

This study investigated the first year of this professional and curricular transformation process; it examined the perceptions and practices of 18 scientists who participated in a yearlong seminar series designed both to heighten their awareness of issues related to gender, ethnicity, and science, and to change their patterns of instructional practice accordingly. In this paper, we discuss three aspects of scientistsí conceptions of inclusive science education: (a) their rationales for differential student success in science education; (b) the ways they structure, teach, and assess their courses to promote inclusion; and (c) their views of the gendered and/or raced nature of science. Our purpose is to provide a sense of the range of scientistsí goals, beliefs, and practices regarding issues of gender and ethnicity in science, as well as to locate points of agreement and areas of conflict across their views--to better ascertain how scientists and science educators can assist each other in building more just and equitable undergraduate science education programs.

Conceptual Framework

As stated above, the purpose of this paper is to explore scientistsí beliefs and experiences related to issues of gender and ethnicity in science, to provide a foundation for ways to help move scientists first to awareness of and then to action to address such issues. At present, there are few studies that explore professional development opportunities for university scientists around issues of inclusion. Muller and Pavone (1998) briefly sketched faculty development activities included in their Women in Science Project at Dartmouth, while Sanders, Campbell, and Steinbrueck (1997) presented findings from a gender equity project for methods professors of mathematics, science, and technology education. Studies at the K-12 preservice and inservice levels are more plentiful (Haggerty, 1995; McGinnis, & Pearsall, 1998; Rennie, Parker, & Kahle, 1996; Richmond, Howes, Kurth, & Hazelwood, 1998; Rodriguez, 1998). McGinnis and Pearsall (1998) and Rodriguez (1998), for example, documented preservice teachersí resistance to recognizing inequities in science education and/or implementing inclusive pedagogical practices. Richmond, Howes, Kurth, and Hazelwood (1998) not only explored student teachersí resistance to inclusive theory and pedagogy, they examined how their studentsí ideas about and reactions to feminist theory could inform future professional development opportunities. We follow their lead in this paper: We too attempt to learn from our participants about ways to better address issues of inclusion.

Because the professional development of science educators around issues of inclusion is a relatively recent phenomenon, then, the authors of this study thought it important to step back and examine research strands with longer histories in framing and attempting to resolve the "problem" of women and ethnic minorities in science education. As such, our study is informed by three areas of science education and science studies scholarship: research on female and ethnic minority studentsí experiences in science education, proposed models of inclusive science instruction, and descriptions by feminist scholars of scienceís raced and gendered nature.

The "Problem" of Underrepresented Groups in Science Education: Why Donít All Students Succeed?

In recent years, there have been myriad studies documenting the numbers and experiences of underrepresented groups in science education (for examples specific to undergraduate science education, see Ginorio, 1995; Malcom, 1993; NSF, 1996b; Vetter, 1996). The message from these reports is simple: Women and people of color are far from having the same opportunities in science education as are White men. Although women have earned a majority of bachelorís degrees since 1982, for example, they do not constitute the majority of any natural science graduates except in the biosciences. Engineering continues to be one of the least popular fields for women: In 1993, they earned only 16% of engineering bachelorís degrees (NSF, 1996b; Vetter, 1996). It is important to note, however, that women of color, particularly African American women, earn a higher percentage of engineering degrees awarded to their ethnic group than do White women (Vetter, 1996). In judging the desirability of a major and future career, many women and ethnic minorities express greater concern about making their professional priorities cohere with myriad personal ones than do White men; they worry their professional lives as scientists will conflict with their personal goals and responsibilities (Seymour & Hewitt, 1997). Women and minorities labor under stereotype threat, apprehension about being negatively judged because of group membership, and disidentification, dropping out of and/or refusing to internalize academic subjects that they expect to fail. As a result, women often do not persist in advanced quantitative fields and African American students underperform in school in general (Steele, 1997). Even in the face of continued academic success, women undergraduates experience a diminished sense of competency (Brainard, 1994; Seymour & Hewitt, 1997) and are more likely than their male counterparts to switch from their original science major to a different major in science (Ginorio et al., 1994). Minority students who switch out of science, mathematics, or engineering differ from majority students in their reasons for doing so: Students of color tend to blame themselves for switching, whereas White students often point to institutional failures (NSF, 1996b).

These and other descriptions of underrepresented groupsí experiences in undergraduate science education make it "hard to deny that the climate--or culture--of science has been chilly to women, ethnic minorities, and people with disabilities" (Giniorio, 1995, p. vi). Ginorio, a womenís studies scholars, used such findings to frame a series of recommendations for warming the climate; she linked her recommendations to how the problem of differential student success in science is framed. She began with an allegory, that of university as plant conservatory, to present various ways undergraduates are viewed and treated by scientists and institutions. Like plant conservatories, she explained, universities attempt to secure the very best students from as diverse locals as possible. Once students arrive on campus, instructors have three choices in how to treat them: They can treat all students the same, they can attend to only those who are thriving, or they can try to provide what each student needs. Decisions about student treatment, she argued, translate into student success and retention in science: Like plants, unless provided with what each needs, some will flourish while others will not survive.

From this allegory, Ginorio continued, insight into recent changes in and possible directions for undergraduate science education can be gained. At one level, the story can be understood to raise questions about who belongs in science. In years past, Ginorio argued, women, ethnic minorities, and students with disabilities--anyone but White men--would have been seen as specimens not fit for life in the conservatory. Instructors would have asked, Why do not all students flourish?, and answered simply that some do not belong. Today, because instructors begin with a different question, Is the problem something we are doing?, they can develop solutions that target instructors and institutions rather than students themselves. At a second level, the allegory can inform discussion of desired outcomes of undergraduate science education. Read this way, in years past, most science instructors and institutions were not concerned with helping all students to succeed; they focused their attention only on students who were thriving. In contrast, todayís students are not only more diverse in terms of race, ethnicity, gender, age, sexual orientation, class and disabilities than in decades past, there is a new emphasis on helping all students excel in science. Given the current student population and science education goals, Ginorio concluded, instructors should be encouraged to attend to all students and to adopt the "what each student needs" approach.

Willis (1996) offered another framework to use in understanding the "problem" of underrepresented student groups in science and identifying means to its solution. She identified four perspectives math educators use to make sense of and act upon notions of disadvantage, curriculum, and social justice; we use them here in our discussion of science education. One perspective, the remedial or disadvantaged learner perspective, views some students, because of their gender, ethnicity, class, and/or ability, as unprepared to understand and excel in science. For educators who view the problem of underrepresentation in this way, the solution becomes to "fix" those students who are deficit, to provide them with the missing attitudes, knowledge, skills, or experiences needed to succeed. A second perspective, Willisí nondiscriminatory perspective, understands the problem of underrepresented groups to reside not with students but with the enacted curriculum. Differential student outcomes in science are seen to result from differential treatment by teachers, for example, using analogies of greater relevance to middle than working class students. Given this framing of the problem, educators see the solution as ensuring all students have equal opportunity to succeed. They think it vital to consider studentsí background and experiences, to eliminate inequitable curriculum materials and instructional strategies, and to incorporate nonsexist (or nonracist and nonclassist) content and practices. The third perspective, the inclusive perspective, views the intended science curriculum as problematic. Science content and sequence are seen to reflect the dominant cultureís values, views, and practices; students from the margins are expected to learn content which fails to resonate with their interests, experiences, and future needs. According to proponents of this perspective, curriculum materials must be changed to acknowledge and respect student diversity: "to rethink who school [science] is for, what school [science] is, what should be learned, by whom and when" (p. 46). Willisí fourth perspective, the socially critical perspective, sees the science curriculum as "actively implicated in producing and reproducing social inequity" (p. 47). The curriculum is understood to work inside and outside of schools to systematically position, classify, and select students so that only those from the dominant group succeed. When viewed in this way, the solution becomes to empower all students to see how they are positioned in school science, to decide what they want to do about it, and to help them reshape science in ways that make it more personally relevant and socially just.

Models of Inclusive Science Education

As implied above, women and ethnic minorities do not enjoy equal access to and adequate representation in science and engineering professions. In education circles, a growing number of researchers have called for changes in both how teachers teach science and what science curricula students are expected to learn, in other words, for instructional and curricular innovations that will make science courses more attractive and inviting to all students, particularly to members of underrepresented groups (Banks, 1995, 1999; Barton, 1998; Mayberry, 1998; McCormick, 1994; Nieto, 1996; Rodriguez, 1998; Rosser, 1991, 1995, 1997). Coherent curricular and pedagogical models designed to promote inclusion of all students in science range from those identified specifically as female-friendly or culturally inclusive, to those that encompass both gender and culture. In this paper, the female-friendly model of Rosser (1991, 1995, 1997) and the multicultural model of Banks (1995, 1999) provide readers a sense of this range.

Rosserís (1991, 1995, 1997) female-friendly model of pedagogical and curricular transformation, for example, is specific to science and mathematics at the undergraduate level. Her model was derived from and serves as a complement to those of feminist scholars in other disciplines (McIntosh, 1984, Schuster & Van Dyne, 1985, Tetreault, 1985). Rosserís six-phase model outlines the phases individual faculty members, departments, and/or institutions follow as they become aware of and attempt to eliminate androcentric and ethnocentric biases in science curriculum and pedagogy. In phase I of her model, the absence of women in science is not recognized. In phase II, faculty recognize that most scientists are men and that science may reflect a masculine perspective. During phase III, there is identification and discussion of barriers that prevent women from pursuing and succeeding in science. In phase IV, faculty initiate research into women scientists and their unique contributions. In phase V, scientists are presented as feminists and women. Finally, in phase VI, science is redefined and reconstructed to include all. The ultimate goal of Rosserís six phase model is "the production of curriculum and pedagogy that includes women and people of color and therefore attracts individuals from those groups to become scientists" (1995, p.17).

In Rosserís edited volume, Teaching the Majority (1995), professors in the physical sciences, mathematics, and engineering provided concrete examples of how the above model could be used to enhance science education courses. To better reach the majority of students in their geosciences classes, Richardson, Sutton, and Cercone (1995) developed and implemented eight pedagogical and curricular innovations. These inclusive strategies ranged from using nonsexist language during lectures, to integrating reading materials other than textbooks, to incorporating field trips as an integral part of each geoscience course, to clearly demonstrating the relevance of science to studentsí lives, to designing diverse assessment methods that underscored how and in what contexts science is practiced. By radically revising the goals, content, and instruction of their courses, the three geoscientists claimed that they were able to make the geosciences more friendly to all students, particularly women; to better connect students to the geosciences; and to establish stronger bonds between themselves and their students.

Banks (1999) provided a second model, a multicultural model, of inclusive instruction. In contrast to Rosser, his model examined issues of multiculturalism more prominently than those of gender, encompassed the whole of K-16 education, and was applied to all disciplines. Banks identified four approaches to the integration of multicultural content into K-12 and university curriculum. The first and most rudimentary approach, the contributions approach, includes examination of ethnic and cultural groups in the context of holidays and celebrations, for example, Cinco de Mayo, Asian/Pacific Heritage Week, African American History Month, and Womenís History Week. A second approach, termed by Banks the additive approach, integrates cultural content, concepts, and themes into the curriculum, without changing its basic structure, purposes, and characteristics. The addition of a book, unit, or special course are examples of this second approach to curriculum development. These first two approaches, Banks continued, fail to challenge the basic structure and canon of the curriculum: When these approaches are used, people, events, and interpretations related to ethnic groups and women often reflect the norms and values of the dominant culture rather than those of cultural communities. In contrast, the third, or transformation, approach changes the assumptions, values, and content of the curriculum, enabling students to consider concepts, events, and people from diverse perspectives, to understand knowledge as a social construction, and to develop skills to analyze, formulate, and/or justify conclusions and generalizations. Finally, the decision-making and social action approach extends the transformative curriculum by allowing students to pursue projects and activities in which they take personal, social, and civic actions related to the ideas and issues they have studied. In other words, through this fourth approach, students learn "to know, to care, and to act in ways that will develop and foster a democratic and just society" (p. 33). A revised curriculum, Banks (1995) concluded, must be coupled with a transformed pedagogy. Teachers must use cooperative learning and other pedagogical techniques that cater to the learning and cultural styles of diverse student groups.

Banks (1995) suggested teachers use a transformative model to teach students about the origin and evolution of scientific conceptions of race by studying key events in American history. Students, Banks explained, could begin by reading Columbusí description of the Taino Indians when he arrived in the Caribbean. They could discuss how on Columbusí initial encounter with these Indians, he began to conceptualize them as the Other, as a different and inferior race from Western Europeans. Students could then examine the ways in which ideas and concepts about Indians have both changed and remained constant over time: The ideas that Columbus constructed about the Tainos could be successively compared with those that Cortes and the Spanish conquistadors invented about the Aztecs, those held by pioneers during the Westward movement in the 1800s, and the images of American Indians in contemporary films. Through this study of race, students would grow to understand the extent to which the idea of human races and knowledge about race are social constructions that reflect both objective reality and the subjectivity of knowers. Students would also learn to interrogate the assumptions of knowers, to avoid being victimized by knowledge that protects hegemony and inequality, and to produce knowledge that is less partial and destructive.

Feminist Scholarsí Descriptions of the Gendered and Raced Nature of Science

Ginorio (1995) and Willis (1996) offered two ways to frame student success (or failure) in the sciences. Educators like Rosser (1991, 1995, 1997) and Banks (1995, 1999) described ways to transform science curriculum and pedagogy to better promote an equitable and excellent education for all. A third group of scholars, feminist scholars of science, implicate the nature of science in the marginalization of women and ethnic minorities: They examine how gender, at times in combination with race, culture, and/or class, is inscribed in science--how the constructs of gender and science influence one another. Like feminists in other disciplines, feminist science scholars start from a commitment to feminism:

> Feminism as a movement to end sexist oppression directs our attention to systems of domination and the inter-relatedness of sex, race, and class oppression. . . . [I]t compels us to centralize the experiences and the social predicaments of women who bear the brunt of sexist oppression as a way to understand the collective social status of women. (hooks, 1984, p. 31)

Most feminist scholars of science situate themselves within the post-Kuhnian stream of science studies, following Thomas Kuhn (1970) and other scholarsí lead in viewing the modern sciences as historical, sociological, cultural, and political constructs (Harding, 1998). A few also draw from postcolonialism, a political movement which "organizes its concerns and conceptual frameworks from outside the familiar eurocentric ones" (Harding, 1998, p. 8).

Although feminist scholars of science share common goals and intellectual traditions, they do not speak with a singular, unified voice. Some feminist scholars attempt to explain science as a gendered and raced enterprise created and controlled by White men: From scienceís inception to the present day, they argue, White men have determined access to the profession, standards for methods used, and criteria for successful performance (Eisenhart, 1994; Eisenhart & Finkel, 1998; Kass-Simon & Farnes, 1990; Keller, 1977, 1983; 1985; Rossiter, 1982, 1995; Sands, 1993; Wertheim, 1995). Others provide important evidence for the "invention" rather than "discovery" of nature, pointing to the myriad examples of gender and racial bias in past and present scientific research questions, methodological practices, and theoretical constructs. They explain how the products of scientific research have often been used to benefit those in power and oppress or exclude those already on the margins (Ginzberg, 1989; Gould, 1993, 1996; Haraway, 1989; Harding, 1998; Lewontin, Rose, & Kamin, 1993; Merchant, 1980; Mies & Shiva, 1993; Schiebinger, 1989; Stepan, 1996; The Biology and Gender Study Group, 1989). Still others render problematic conventional definitions of what counts as science and how science works; they question scienceís claims of objectivity, value neutrality, universality, and epistemic privilege (Barad, 1996; Harding, 1991, 1994, 1998; Hartsock, 1983; Hess, 1995; Keller, 1985; Longino, 1990; Narayan, 1989; Tuana, 1995). Although critical of science, most feminist scholars call not for scienceís elimination but for its transformation (Rosser, 1997).

In her now classic biography of Barbara McClintock, for example, Evelyn Fox Keller (1983, 1985) claimed the Nobel prize-winning plant geneticist enjoyed success and endured marginality throughout her career because both her research methodology and gender differed from the norm. McClintockís respect for difference and complexity, her "feeling for the organism," her ability to become conscious of the self, Keller explained, were views of science not shared by most of her colleagues. To complicate matters, Keller continued, McClintock was a women in a field dominated by men and ruled by masculine assumptions: Her identity as a woman scientist clashed both with the reality that most other geneticists were men and with the view that scientific practice was best described as a marriage between masculine mind and female nature. In other words,

> although McClintock [was] not a total outsider to science, she [was] equally clearly not an insider. And however atypical she [was] as a woman, what she [was] <u>not</u> is a man. Between these two facts lies a crucial connection--a connection signaled by the recognition that, as McClintock herself admit[ted], the matter of gender [in science] never does drop away. (1985, p. 174)

At the other end of the feminist scholarship of science spectrum, Sandra Harding (1994) challenged the very definition of what counts as science. Drawing from postcolonial studies, she argued that modern sciences should be viewed not as transcending culture but rather as having multicultural roots and embodying distinctively Western values and beliefs. The modern sciences, Harding noted, have non-Western origins; the borrowing from other culturesí knowledge systems, such as Egyptian mysticism and pre-Columbian agriculture, has been far more extensive and important than conventional histories of science have allowed. Indeed, she countered, given that other knowledge traditions have generated insights often incorporated into or later replicated by the modern sciences, it is useful to consider all knowledge-seeking systems as culturally distinctive sciences. Not only can the modern sciences be considered some of many sciences, Harding continued, they can be seen to bear the distinctive fingerprints of Western culture. In particular, modern sciences can be understood as tightly tied to European imperialism: European expansion into Africa, Asia, and the Americas advanced modern sciences; the modern sciences, in turn, crafted scientific theories and technological tools vital for further European conquest. Rejection of the modern sciences as acultural and recognition of their multicultural and Western imprints, Harding concluded, "can lead to far more accurate and valuable understandings, not only of other culturesí scientific legacies, but also of rich possibilities in the legacy of European culture and practice" (p. 330). (See Harding, 1998, for a more extensive argument.)

Research Questions

To investigate scientistsí views of inclusive undergraduate science education within a professional development seminar series, to see what insights scientists could shed on issues of inclusion, we crafted three sets of research questions. At the outset, we decided the research questions should place less emphasis on tracing change within or across participants and give greater weight to identifying the range and prevalence of ideas expressed; we started from the knowledge that those participating in our study were already committed to and, to varying degrees, expert in issues of inclusion. Questions were fashioned to reflect both our studyís purpose--to consider how ideas voiced and concerns raised by scientists could inform science educatorsí conceptions of inclusive practice and their creation of professional development opportunities--and the ideas put forth in our conceptual framework. They were expanded and refined after data were collected and data analysis, partially completed.

Our first set of research questions was informed by studies of women and ethnic minoritiesí experiences in science and reflection on how challenges faced by these underrepresented groups can be effectively framed: How do the scientists in our study explain differential student success in their undergraduate science courses? What responsibilities do they see students as shouldering for their own academic progress? What role does or should instructors play? What factors external to student and instructor influence student retention and achievement in science as well? From our review of inclusive instructional models, we created a second set of questions: How do participants attempt to address issues of inclusion through their course content, instruction, and assessments? What reasons do scientists give for their acceptance or rejection of new ideas and/or instructional innovations? What factors do they identify as potential or real constraints to their implementation of particular female-friendly or culturally inclusive strategies? And from our examination of feminist science scholarship, we thought it important to ascertain scientistsí conceptions of the nature of science, to what extent and in what ways scientists saw aspects of the scientific enterprise as gendered and/or raced. We thus fashioned a third set of questions: How do scientists understand the nature of science? How do their descriptions of inequities within the scientific enterprise resonate or conflict with those proposed by feminist science scholars? What descriptions by feminist scholars do scientists view as appropriate and insightful? What concerns or criticisms do they raise in response to feminist claims and recommendations?

Setting, Sample, and Method

As stated in the Introduction, our study investigated the views of 18 scientists employed at a large urban university and involved in a project to transform undergraduate science education. Using questionnaires and interviews coupled with statistical and qualitative analyses, we attempted to provide critical insight into the three sets of research questions posed above. Below we describe in greater detail the goals and structure of the Promoting Women and Scientific Literacy project, its project participants, and the methods used to study this professional development process.

Promoting Women and Scientific Literacy: A Project Overview

The participants and professional development seminar series studied here are part of a Promoting Women and Scientific Literacy project sponsored by the Universityís College of Natural Sciences and Mathematics. The project is expected to last a minimum of three years and has three primary goals: one, to increase faculty awareness, sensitivity, and knowledge related to issues of gender, ethnicity, and the nature of science; two, to design and share pedagogical strategies to make science education more inclusive; and three, to promote the revision of courses to incorporate more inclusive science content and pedagogy. The projectís purpose is to make undergraduate science education at this University more inclusive, to better meet the needs of the many women and students of color enrolled in both major and general education science courses.

To help achieve these stated goals, beginning in August of 1997, the first of three years of faculty workshop sessions were developed and implemented. (Other aspects of this multi-year project are not discussed here.) The sessions were expected to inform scientists about issues related to gender and ethnicity in science education and science, as well as to assist them in their efforts to make targeted undergraduate courses more friendly to women and ethnic minorities. Participants were expected to attend all sessions and, beginning spring semester, strengthen and expand the kinds and number of inclusive strategies they used in science courses. Workshop sessions were organized by this articleís first author, a science educator at a nearby university, in consultation with a womenís studies professor and, to a lesser extent, with faculty participants; during the second semester, responsibility for selecting session topics shifted from the science educator to scientists involved in the project. Guest speakers from the sciences, science education, and womenís studies led the vast majority of these seminar sessions. Speakers were drawn both from within the project and from nearby universities. Most sessions were supplemented by scholarly readings pertaining to the topic at hand. Readings included journal articles from The Science Teacher, Journal of Research on Science Teaching, and Science Education; selected passages from books such as Women of Science: Righting the Record (Kass-Simon & Farnes, 1990), Teaching the Majority (Rosser, 1995), Theyíre Not Dumb: Theyíre Different (Tobias, 1990), and Warming the Climate for Women in Academic Science (Ginorio, 1995); and University pamphlets and brochures. For many of faculty participants, these readings served as introductions to the fields of science education and feminist science scholarship.

At the beginning of the professional development seminar series, participants attended two full-day sessions covering a variety of topics: the experiences of local women science students and scientists, common ethnic and gender stereotypes related to science and science education, the definition and use of inclusive language in classroom settings, past and present contributions of women to science and resources for locating them, science education research on student learning, inclusive instructional strategies, mentoring of students from underrepresented groups, and alternative assessment procedures. Three additional half-day sessions were held during the first semester to examine the nature of science, inclusive instructional strategies, and gender bias in textbooks. A third full day session conducted during the break between Fall and Spring semesters revisited issues of gender and ethnic discrimination in society at large, as well as considered specific instances of gender bias in scientific research. At this mid-year session, participants were encouraged to discuss their personal understandings of the importance of inclusiveness in science and asked to share plans for changes in their course content and pedagogy. As explained above, faculty were expected to better articulate project goals and/or to use workshop materials in targeted science courses during the second semester of this project.

During the second semester, then, professional development sessions continued with brown bag lunch meetings offered approximately every other week. Some brown bag sessions were led by science educators or womenís studies professors; they examined topics ranging from the contributions of women of color in science, to effective classroom questioning strategies, to ways to evaluate oneís own teaching. Most brown bag lunches, however, allowed faculty participants to discuss their personal progress in implementing changes intended to promote greater inclusiveness in the classroom. The final professional development session for this first academic year was held in May. The half-day session included additional discussion of inclusive instructional strategies maintained or initiated as a result of participantsí involvement in the Promoting Women and Scientific Literacy project; debate around Evelyn Fox Kellerís description of the gendered nature of science; and reflection on possible directions for the second year of this project.

Sample

As stated above, 18 science faculty members at a large, urban university located in California served as participants. Ten of the participants have careers in the biological sciences, four in chemistry or biochemistry, two in geology, and one each in physics and science education. Nine women self-identified as White; one woman, as Asian American; four men, as White; one man, as Asian American; two men, as mixed; and one man, simply as *Homo sapien* . At the time of this study, all but two were employed full-time as faculty by the university. Tenure in their position ranged from one to over 30 years.

The sample of 18 scientists was not random. Five of the science faculty participants are part of a ten-person interdisciplinary team who solicited grant monies for, organized, and helped implement the Women and Scientific Literacy project. These five had attended two national conferences on feminist science scholarship in an effort to better tackle issues of gender and ethnicity in science. Several had also previously served on University committees established to address issues of educational improvement, gender equity, and/or multiculturalism. The remaining 13 participants were science faculty recruited for involvement in the project. Approximately 20 scientists who both taught introductory science courses and were considered open to issues of inclusion and instructional innovation were informed of the professional development seminar and invited to participate. Several faculty declined due to time constraints, and several others did not feel the goals of the project were necessary. As with the team members, most of these faculty participants held a long-time commitment to improving undergraduate education in general, and issues of women and people of color in science in particular. The 18 scientists varied in their familiarity with science education research and feminist science scholarship.

Tangible benefits to scientists participating in this project were minimal: They were paid $600 for the yearlong workshop series and recognized by the College of Natural Sciences and Mathematics for their commitment to undergraduate education. In return, project participants agreed to attend seminar sessions; read selected articles on gender, ethnicity, science, and science education; submit a summary of expected changes to an introductory science course; implement course revisions in the spring; keep a journal of these attempted innovations; and support teaching assistants in their implementation of similar instructional strategies. They were also encouraged, although not required, to continue their participation in the project during its second year of implementation.

Present Study

The present study examined faculty perceptions of issues of gender and ethnicity in science expressed prior to and after completion of this first year of professional development activities. We were particularly interested in the degree to which faculty achieved consensus on their views, the conceptual and instructional dilemmas they resolved over the course of the year, and the questions that persisted. As stated above, involvement in this faculty development seminar series exposed many faculty participants to literature in science education and/or feminist scholarship for the first time. Further, these sessions fostered previously rare discussions among colleagues, who shared their concerns regarding the need for inclusive pedagogy. Given their strong commitment to their own disciplines and their previous consideration of issues related to educational innovation, we hoped to capture scientistsí impressions of effective ways undergraduate science education could be made more inclusive--to learn from, rather than criticize, our informants. As explained in our Research Questions above, we focused our efforts on three areas: their understanding of differential student success, their views of inclusive instruction and content, and their perceptions of the nature of science.

Data for this study were collected at two times during the 1997-1998 academic year using both Likert-type surveys and semi-structured interviews. These measures were administered prior to participation in the professional development seminar (i.e., pre-test) and again following the last workshop session of the year (i.e., post-test). The pre- and post-test questionnaires were used to broadly assess scientistsí perceptions related to science studentsí interests and abilities, inclusive science education practice, and the nature of science. The questionnaire included 29 items. Items were developed to reflect the projectís three primary goals. Many were also fashioned after those found in other surveys used to examine studentsí attitudes toward science, their experiences in science classrooms, and their perceptions of scienceís nature (see Aikenhead et al., 1987; Fraser, 1978; Jones, Mullis, Raizen, Weiss, & Weston, 1992; Lapointe, Meed, & Phillips, 1989). Pre-test and post-test questionnaires were virtually identical: The post-test survey included additional items assessing the self-reported level of attendance at workshop sessions and the approximate percentage of the assigned readings completed. Respondents indicated their level of agreement with each item using a five point, Likert-type rating scale. Surveys were completed in approximately 10 minutes. Table 1 presents each of the survey items.

Questionnaire pre and post data were analyzed using statistical methods. Item means and standard deviations were examined to determine the level of endorsement of each of the items, and the degree of variability in endorsement. Additionally, repeated measures analysis of variance (MANOVA) was used to examine each of the 29 repeated items on the pre-test and post-test surveys. Participant sex was used as a between subjects factor and time served as a within subjects factor. Analysis allowed determination of whether (a) sex differences between participants influenced responding, (b) differences in attitudes were evident across time, or (c) responses indicated a participant sex by time interaction. Findings from these questionnaires were then compared to patterns discerned during interview analysis--to ensure greater depth and accuracy of claims made.

Like the questionnaires, semi-structured faculty interviews were conducted before and after the yearlong professional development seminar series. The same interviewer, the second author of this article, met individually with each faculty member. Interview questions were developed to assess beliefs and knowledge regarding issues of gender and ethnicity in science education, as well as to learn the structure, content, and pedagogical strategies employed in courses. A copy of the pre-test interview protocol is presented in Figure 1. The pre-test and post-test interview questions were very similar, although the post-test interview included questions which focused on changes implemented in the targeted introductory science course. Changes may have included classroom environment, instructional strategies, assessment of learning, or course content. Questions regarding insights into how students learn science, contributions of women and ethnic minority scientists, and the relationship between science and society were unchanged for the second administration of the interview. Demographic information was also collected: sex, ethnicity, university employment status (full-time or part-time), and tenure in the university. The length of each interview varied depending upon the participantsí responses, but interviews were generally completed in 45 to 50 minutes for the pre-test, and 35 to 40 minutes for the post-test. All interviews were recorded on audiotape, transcribed by a professional, and the transcripts checked for accuracy by the research team.

Resulting transcripts were then analyzed qualitatively. The process was iterative (see Strauss, 1987); every attempt was made to identify those patterns that held currency within and across scientists studied. Our coding schema first grew to eight analytic domains (see Spradley, 1980) and then collapsed into three: student success (or lack thereof) in science courses, inclusive course content and instruction, and views of the nature of science. The first, third, and fourth authors each took primary responsibility for coding interview data in one of these three domains. To help ensure reliability of the coding process, researchers individually coded two sets of pre/post interviews per domain and then met collectively to reach consensus on what counted as data for each. The final schema included three analytic domains, each with several categories and subcategories. To answer our research question, How do scientists understand differential student success in science courses?, for example, we grouped participantsí views into three categories under the domain student success: student choice, instructorsí roles and responsibilities, and external constraints and pressures. Within each of these categories, subcategories were then created. Finally, we looked for patterns that addressed issues of gender and ethnicity in science.

Before turning to our results, we offer one final methodological note. We understand our survey and interview data to be jointly produced by researchers and informants, to be the products of social events (Briggs, 1986; Mishler, 1986). The questions asked and responses given are constrained by our own and our participantsí socially constituted perceptions of science education research, issues of gender and ethnicity in science, and identities as academics. Similarly, we share Roth and Lucasí (1997) view that informantsí talk about attitudes and beliefs are dependent on context and are highly variable within a given individual. Rather than reflecting individual beliefs, informantsí "talk reflects the communities and language games in which they participate, for there are no private languages" (p. 147). Thus, we make no claims that the data presented here represent informantsí permanent and deep-seated views; rather, we read them as socially constituted in the moment.

Results

From our analyses of closed-ended questionnaires and semi-structured interviews, we present scientistsí perspectives on three aspects of inclusion: science students, science curriculum and instruction, and the nature of science. We begin with an overview of scientistsí opinions and practices as represented in their questionnaires. Once situated, we then turn to the interview data. Because there is insufficient room in this paper to describe the full range of scientistsí views across the three areas of interest, we focus here on issues raised and understandings gleaned that inform movement toward an excellent and equitable science education for all. In other words, we treat these scientists as "critical friends" (see Richmond et al., 1998), outsiders able to provide science educators with critical insights into conceptions of inclusion and professional development projects.

<u>Analysis of Questionnaires: An Overview of Scientistsí Views</u>

As stated above, scientistsí survey data were used to provide a foundation for their interviews. Scientistsí pre and post questionnaires were examined for (a) perceptions of students, (b) use of inclusive curriculum and instruction, and (c) views of the nature of science. Pre and post mean responses to survey items are presented in Table 1. As is evident from the Table, participantsí views did not shift noticeably from pre to post surveys. (Responses for those few items that changed significantly over time are discussed in detail at the end of this section.)

Participantsí responses to questions about students, science instruction, and the nature of science reflected at least partial alignment with the goals and objectives of the Promoting Women and Scientific Literacy project. Three items on the survey, for example, examined faculty perceptions of students (items 10, 13, and 14). Across pre and post surveys, science faculty weakly endorsed the idea that anyone can learn science if he or she studied sufficiently. They thought that the presence of more men than women in science was much more likely explained by a failure of schools to encourage women, than by gender differences in scientific ability. Fifteen survey items assessed faculty instructional strategies (items 1ñ3, and 18-29). On the pre and post surveys, faculty indicated a fairly high level of awareness of the need for inclusive pedagogy. Participants reported implementation of a wide variety of inclusive instructional strategies, including use of inclusive language, awareness of the need to develop a classroom environment supportive of all students, and equal interaction with and mentoring of all students. Participants, however, did note that the content of their courses rarely included even a single lectureís worth of material discussing the sciences of other cultures or the contributions of women and ethnic minorities to science. Finally, eleven of the survey items can be said to assess faculty views of the nature of science (items 4ñ9, 11, 12, and 15-17). Low levels of endorsement were found in the pre and post questionnaires for the notion of a scientist as an older, White man and a neutral opinion was registered regarding whether science is intimidating. Participants moderately endorsed the ideas that scientific research is influenced by the personal biases of scientists and that science and society influence each other. As project leaders had expected, scientists thought feminism and multiculturalism offered important perspectives for science and science education; their level of endorsement for this item increased over time (see below). Not surprisingly, the nature of science items most strongly endorsed by science faculty reflected perceptions of science as beneficial and creative.

Additional statistical analysis of survey data was performed using repeated measures multiple analysis of variance (MANOVA) to detect significant differences in responses across participantsí sex, time of administration, or an interaction of these two variables. No significant sex by time interactions were found for any of the 29 survey items. This indicates that the professional development series did not have a differential influence on female and male participants over time. Several of the questionnaire items, however, did exhibit significant main effects by sex or time.

Two of the 29 survey items revealed differences in responses by sex; both items assessed perceptions of the nature of science. Specifically, in comparison to female faculty participants, male faculty participants more strongly endorsed the item, "Scientists are always open-minded, logical, unbiased, and objective in their work," across the pre-test and post-test time periods combined, $F(1,15) = 4.56$, $p=.05$. The combined mean for male faculty was 2.26 ($SD = .78$) while the combined mean for female faculty was 1.56 ($SD = .77$). In contrast, female participants more strongly endorsed the item, "Scientific research is often influenced by the experiences, interests, and values of the scientist" than their male counterparts, again collapsing across time, $F(1,15) = 7.23$, $p<.05$. The combined mean for female faculty was 4.56 ($SD = .46$) while the combined mean for male faculty was 4.19 ($SD = .41$). No sex differences in responses were found across the remaining 27 items.

A significant main effect across time was also found for four of the 29 items (see Table 1 for means and standard deviations of pre and post test items). The fact that faculty responses to survey items remained remarkably consistent over time was noted above. Two of participantsí changes in responses related to their views of the nature of science. The direction of these changes reflected the goals and ideas of the project. Over time, respondents increased their endorsement of the item, "Feminism and multiculturalism offer important perspectives for science and science education," $F(1,16) = 7.27$, $p<.05$, while they decreased their level of endorsement for the statement, "Scientists are always open-minded, logical, unbiased, and objective in their work," $F(1,15) = 10.41$, $p<.05$. The other two changes related to participantsí implementation of inclusive instructional strategies. In the post questionnaire, as was expected, scientists more strongly endorsed the statement, "The content of my course incorporates approximately one lectureís worth (or more) of material detailing the contributions of women and ethnic minorities," $F(1,14) = 7.12$, $p<.05$. Their intentions to discuss "instructional and/or assessment strategies" with their teaching assistants decreased, $F(1,9) = 8.44$, $p<.05$. Since not all instructors were assigned teaching assistants, the sample size for this last item was very limited ($N = 11$). The fact that there were few significant differences in participantsí responses over time or by sex was supported by our analysis of the interview data as well.

Analysis of Interviews: Which Way toward an Inclusive Science Education?

With an overview of participantsí attitudes and practices in hand, we turned to examination of pre and post interviews; we hoped to garner data to inform the design and implementation of future professional development opportunities around issues of inclusion. Given participating scientistsí commitment to improving undergraduate science courses and their varying degrees of expertise in issues of equity and diversity, we looked to them for insights gleaned and obstacles encountered in their work toward an inclusive undergraduate science program. Below, we discuss questions raised and answers fashioned by these scientists along three dimensions of science education; these dimensions were introduced in our conceptual framework and targeted in our research questions. They are: scientistsí views of student success and failure, their implementation of inclusive curricular and pedagogical strategies, and their understanding of the gender/less and a/cultural nature of science.

Can All Students Succeed in Science?

We began by investigating scientistsí perceptions of undergraduate studentsí experiences in science education. Through careful examination of interview data and reflection on research in the Why Donít All Students Succeed? section of our Conceptual Framework, we decided to narrow our focus to views of student success and failure. We were persuaded to pursue this line of investigation by Ginorio (1995) and Willis (1996): They argued that how educators frame the problem of differential student success influences the identification and enactment of solutions. The university professors in our study discussed three factors that serve to either promote or constrain student success in science: student choice, instructorsí actions, and external-to-the-university pressures. The ways instructors wove issues of gender and ethnicity into their discussions of student success became more noticeable as we moved through these factors; for this reason, we devoted the most space to professorsí perceptions of external forces.

<u>Student choice.</u> In their discussion of how studentsí actions or choices help or hinder their achievement in science, university professors collectively stressed the need for all students--regardless of gender, ethnicity, or socioeconomic standing--to take on greater academic responsibility. In pre and post interviews, they called for all students to make academic achievement a priority in their lives and to be more active participants in the learning process. Natalie, for example, saw hard work and dedication as keys to academic success.

> [B]y the end of the first day in lab, you can pretty much look around the lab and you can tell who's going to do well and who's not going to do well. And it has nothing to do with ethnic[ity], sex, or anything else. It's commitment. It's their willingness to work hard at it and take it seriously. . . . I find that that prevails more so than any other factor . . .

Robert concurred: He thought older students "far superior" to those who come to college directly after high school, because they "want to" be in school and thus are willing to work hard.

Besides and/or in combination with hard work, most instructors thought it imperative for students to take an active role in the learning process if they intended to succeed in science. Joe, for example, saw learning as first and foremost "an individual [student] effort." Instructors can certainly motivate, encourage, and guide students, he explained, but they "canít learn it [the science] for them." Tim noted that most students in his general education Human Physiology course do not do well because they "tend to rely too much on just memorizing facts and spending as little time as they possibly can to pass an exam. The better students," he continued, "incorporate the concepts before they come to class and deal with the lecture as a way of discussing those [concepts]." Justine also explained that, for students to do well in science courses, they "need to actually think about it [the subject matter]." "[G]ood students, . . . the students who do well, actually quiz themselves and test themselves and they draw out the figures themselves." Good students, she continued, "come to class, are interested, and then put a lot of effort in." They work "really hard to understand science."

<u>Instructorsí influence on student success: Perceptions of students and pedagogical practices.</u> Participants not only discussed how students can contribute to their own success or failure, they described the role that they as instructors can play as well. Unlike their discussion of student choice, however, scientistsí reflections on their own roles and responsibilities were more often tied to perceived inequities in women and ethnic minoritiesí experiences in science. Scientists in our study identified two ways instructors can shape student success or failure: their perceptions of students and their pedagogical practices.

A small number of university professors, for example, thought a thorough understanding by scientists of studentsí background, needs, and interests critical for promoting student success. In her post interview, Theresa described how she had adopted a more informed perception of who her students were as a result of participation in the Women and Scientific Literary project. Before the project, she explained, she had seen students as either "good" or "bad," attributed studentsí success or failure to their individual effort, and thus taken few extraordinary steps to help those struggling in her courses.

> I used to have the attitude that if I did my part by being . . . well prepared for class and being well

> organized and trying to give an enthusiastic, well organized lecture [and] that if they [students] didnít do their part, if they didnít put out the extra . . . effort that they needed to do to really learn the material and be comfortable with the material and seek me out if they needed clarification, . . . I just thought, "OK thatís your problem, it's not mine." . . . And so the good students, of course, were the ones, didnít matter what nationality they were or what age or sex they were. It was just, if they came to class on a regular basis and they took notes and they did the assignments and they studied, then they would do well on exams. If they didnít, it was because they werenít doing their part.

As a result of working on the project, Theresa continued, her views of students had changed: "Instead of just seeing them all as just across the board science students, good science students and bad science students, I began looking more at the gray areas." When she now saw a student in trouble, she no longer thought, "Thatís not my problem, thatís your problem," and elected to do nothing. Rather, her new view of students prompted her to take on greater responsibility for their success; she had become "more willing to intervene."

Cynthia agreed with Theresa that her views of students and thus, her understanding of appropriate strategies to ensure student success had changed over the academic year. She expressed concern that many faculty continued to contribute to differential student success by failing to recognize the different needs, interests, and experiences that exist among students. When faculty see all learners as "the same," she explained, they then think treating students all the same is treating them equally. In fact, Cynthia argued, such so-called equitable treatment is an injustice to female students: "Faculty members think they're treating everybody the same, but in actuality, they're not. . . . [W]omen do learn a little differently than do men."

Participating scientists also emphasized how their actions within the classroom--irrespective of their perceptions of students--help determine student academic achievement. Tim, for example, described how scientistsí adherence to traditional criteria, instruction, and assessment make the climate in many introductory science courses hostile to students from underrepresented groups, particularly to women. By designing entry level courses as proving grounds for students, he explained, scientists unnecessarily limit the kinds and numbers of students who pursue science majors.

> [O]ur science curriculum . . . [is] failing miserably to present an image [of science] which is attractive to students of all backgrounds. I think our beginning science classes here, we've tried to introduce more rigor into them and what we've done actually is select for students who are more tenacious, not necessarily more creative. In that first cut, weíre trying to make it a proving ground for people and so weíre really just getting students who do well in that environment. . . . I think thatís one of the things that selects against women, for instance. I donít think they enjoy that sort of learning environment.

Other scientists in our study shared inclusive instructional practices they used to promote rather than constrain student success, strategies that included increasing wait time, avoiding the use of rhetorical questions, administering quizzes on a frequent basis, beginning instruction by learning what misconceptions students hold, and being consistent in their use of inclusive language. Chris made the observation that "women tend to respond more than men perhaps to a holistic approach to teaching and to putting the course material into a context, into perspective in terms of their lives"; he asked students to explain in writing how some aspect of his course connected to their personal experiences. Additional examples of inclusive instructional strategies employed by participating scientists are presented in the Promoting Inclusivity through Curriculum and Instruction section below.

<u>Outside forces: Academic preparation, family and cultural pressures, and societal expectations.</u> In their discussions of studentsí experiences in science, instructors also addressed how outside forces promote and constrain student academic achievement; they described how student success in science is shaped by K-12 academic preparation, family and cultural pressures, and societal expectations. As stated in the introduction to this section, it is within these descriptions of external forces that issues of gender and ethnicity as tied to student success were most often raised. It is here, too, that the costs and benefits of framing the problem of women and ethnic minoritiesí experiences in particular ways become evident, that identifying what needs to be fixed is often less clear and more costly than initially conceived.

University professors, for example, saw studentsí K-12 preparation in and background knowledge of science as influencing their success. Some scientists expressed concern that many students arrive in their introductory science courses never having received the types of experiences and opportunities needed to achieve success. Kevin explained that students who entered his Human Anatomy course with little science background usually faired poorly. "There's a huge range in preparation of students coming into our university," Kevin observed. Some students "come in with very little science exposure. They hit this kind of anatomy course without taking any introductory biology [and] don't do very well. . . . I've seen that for twenty, twenty-five years now."

Justine agreed with Kevin: Many students do not have the science background needed to do well in science courses. She, however, framed the problem as one primarily faced by students from underrepresented ethnic groups. When describing one of her most successful students, Justine explained that as a Black student, this womanís achievements were unusual. This student had excelled in science despite the poor academic training most people in her community receive.

> I know different people have really different academic backgrounds. . . . My first semester I taught, the smartest student in my class was this Black woman. She's incredible and she's down at graduate school [now]. . . . She's successful, and she's wonderful, and she came from this poor Baptist family. . . .[B]ut I know a lot of the Black students that come [to this university] are really not prepared. They're totally not prepared. . . . They don't have the study skills, they don't have the reading skills [needed to do well] . . .

While some scientists framed studentsí lack of prior knowledge and skills as a problem to be addressed in the push toward equity, a few warned against assuming too much about studentsí prior knowledge or current academic potential based solely on their gender or ethnicity. Rather than seeing awareness of inadequate K-12 preparation as a first step toward promoting greater inclusivity, they worried that students were carelessly and unnecessarily placed into academic bins based on generalizations about prior preparation, innate intelligence, and/or work ethic. Theresa, for example, thought ethnic minority students encounter bias in courses because instructors assume they lack the appropriate dedication and academic background.

> Thereís still this bias that somehow they [ethnic minorities] don't have what it takes. [This bias exists] either because of some stereotyped notion that they [minority students] are not willing to work as hard, or because of some stereotyped notion that they aren't as intelligent, whether it's because they lack the innate intelligence or because they just don't have the family motivating factors, encouragement, or opportunities . . . to get the kind of schooling that they want.

Joe echoed Theresaís concerns. He worried that professors made incorrect, unconscious judgments about studentsí academic potential based solely on gender or skin color. He likened university personnelís unconscious bias against female and ethnic minority students to the publicís assumption that most people on welfare are African Americans.

> I don't think it's necessarily that people [within the university] say, "Well, women just aren't as good and therefore I'm going to do this in a conscious effort." I think the same thing may occur with ethnic minorities. We live in a society that portrays. For example, any time you see a story on welfare, it's an African American even though there are more Whites on welfare than there are African Americans on welfare. And so consequently, you get bombarded by this and bombarded this and so people sort of just absorb the fact that if you're on welfare, you're African American and, therefore, whatever the consequences which flow from that depending upon how you feel about welfare. And so, I think that we, a large number of our faculty have those unconscious biases [toward female and ethnic minority students] . . .

A second external factor was seen by scientists as instrumental in shaping student participation and achievement in science: studentsí families and cultural heritage. Some scientists discussed how family expectations and/or responsibilities influenced womenís decisions to pursue or avoid science majors. Chris, for example, thought women are discouraged by those close to them from considering science as a major. "[F]emales are not encouraged to go into science at early ages. [They] are, in fact, discouraged from it by parents, by teachers, [and by] peers." Robert believed some women opted out of geology as a career because research requirements conflicted with responsibilities as wives and/or mothers. "[I]n a department like ours, geology, weíre getting a lot of real field experiences [as major and career requirements]. . . . Those requirements have much more severe impact on women that have children, if theyíre the primary caregiver. [They] have to deal with that in one way or another."

Family and culture were seen to be particularly powerful actors in the school lives and majorís decisions of female minority students. These womenís ethnic identity as well as their identities as daughters, wives, and/or mothers were seen to deter some from pursuing majors in science and to pressure others towards science careers for which they lack genuine interest and/or ability. Women of Hispanic or Indian heritage, Lorraine explained, are often discouraged by their families from pursuing education in science and mathematics.

> [I]n Hispanic groups, there's a real difference between how women from Hispanic families are treated versus men. They're [women are] more protected. They're not supposed to go to college. I've had Indian students, . . . [Indian women] students [treated] the same way. Families just think it's a waste of time for education, especially in science and math.

In contrast, Lorraine continued, Vietnamese women often feel pressure from their families to pursue careers in medicine irrespective of their own talents or interests.

> I would say some of the Vietnamese women that we have, I think they're being pressured to fill certain [medical technology] careers because it's perceived . . . that's a good job area. . . . And some of these students, really, some of them are excellent, but some don't [have the skills or interest]. . . . [T]hey haven't screened themselves out based on what their real interests are instead of being pressured by family.

Although some professors identified family and culture as negatively influencing women and ethnic minoritiesí participation in the sciences, none could satisfactorily resolve the conflicts they saw among family responsibilities and cultural roles, studentsí own interests and talents, and science course requirements. Justine, for example, discussed how Hispanic women drop from science majors in large numbers and how their exodus from science can be attributed to substantial family responsibilities. She wondered aloud what scientists could or should do to reverse this trend. After all, scientists could not insist students ignore their family responsibilities or deny their cultural heritage.

> [I]n general, [in our departmental study, we found]. . . Hispanic women really dropped out more [then other groups from biology]. . . . [I]t just really comes from what's expected in your family. And if it's expected that you're supposed to be cooking dinner and taking care of the kids and doing a million things, you're not going to have time to study. And if it's expected that you're to just go home and study and we'll take care of you, [then itís a different story]. . . . But I do think those things [family responsibilities] exist and I don't really know how you do that [intervene]. . . . [Y]ou can't really knock somebody's family . . . or the[ir] culture.

Kevin also discussed conflicts that arise for students who are both science majors and members of particular cultural groups, conflicts between science and cultural heritage that can impinge upon studentsí success in science. He noted the mismatch between studentsí Asian American or Hispanic culture and human anatomy laboratory requirements. Over the years, Kevin explained, he has found some students reluctant to participate in certain aspects of human dissection because they conflict with their cultural values and norms.

> I know, for instance, that Oriental students are much more reticent to look at the reproductive system parts on a cadaver. I mean, there's a cultural thing here that may be true even in Hispanics. . . . [T]here is more of a resistance to, or mere prudishness about the human body and that is very definitely true of Orientals . . . and Hispanic students compared to Caucasians. They come in with a different . . . mind set.

As an instructor charged with preparing students for careers in medicine and physical therapy, however, Kevin did not know how to both honor studentsí cultural heritage and teach them the necessary knowledge and skills to succeed in scientific careers. Was there any way to resolve this cultural mismatch?

> And yet all those students, somewhere along the line, have got to change their point of view. Because when they get into the hospital setting as nurses, for instance, or physical . . . therapists, they're not going to have the choice of saying, "Well, I can only work on this ward. I don't really want any patients, because I might have to change a bedpan. . . ." [T]hey're going to have to accept all of that eventually when they get into their careers. So we don't, I don't try to shield or ameliorate the conditions for them. . .

Scientists identified societal pressures and expectations as a third and final external actor in creating and constraining opportunities for student success. Again, while some scientists saw differential socialization as a way to frame the problem of women and minorities underrepresentation in science, other participants questioned what workable solutions could arise from viewing the issue as such. On the one hand, then, several participating scientists identified a mismatch between the way women are socialized in present day society and the skills deemed necessary to become a successful scientist. In her post interview, for example, Marianne noted that "as you drift toward the physical sciences and engineering, [the] numbers [of women] go away." As girls grow up, Marianne clarified, they learn that they must do something practical with their lives: Early on, girls realize that they will "be juggling a lot of different things and that may include the family and this and that and the other thing. Doing something [as a career] just for the sake of yourself, . . . isn't something . . . that a lot of girls get socialized to do." "People don't go into the physical sciences, " Marianne continued, "to save the world or cure cancer. They don't go into those things for practical reasons"; rather, they pursue chemistry or math "because it's fun and it's pretty and it makes a lot of sense." That is part of the reason why women avoid physical science fields, Marianne concluded. Women simply are not socialized to do impractical work.

While Marianne underscored how socialization affects womenís career choices, Joe discussed how girls are socialized away from skills commonly used in science. Joe described how boys are socialized to develop the very skills and attitudes necessary to achieve in science, skills and attitudes like competition, aggression, and objectivity, while girls are not.

> So that's acculturation. Well, I think that females, for example, are acculturated not to get dirty, not to play with trucks, not to play with tinker toys, to play with dolls and [be] in more nurturing roles, and not to be as competitive, to be pleasers. I believe that that's the way we acculturate females. Males, on the contrary, I believe are acculturated to be competitive, to play with tinker toys, to take things apart, get dirty, and be more aggressive and wilder as it were. I think those are put in by the culture. . . . So from that point of view, it seems to be that the kinds of skills that science generally values at this particular time are those which boys are acculturated to and not girls. . . . Boys are supposedly more objective and girls are more feeling and science is supposedly objective and you should divorce your feelings from it.

On the other hand, a few scientists recognized the danger in trying to encourage members of underrepresented groups to pursue science disciplines whose cultures are foreign to them. In his reflection on the ways girls and students of color are socialized, for example, Joe identified this contradiction. For those traditionally excluded from science to succeed in it, he explained, they must balance their own gender and/or ethnic identities with those expected and valued in science. At present, Joe noted, students from underrepresented group have to change to fit into science. Was gaining entrance into and acceptance in science really worth such effort?

> I just finished reading Eric [David] Shiplerís book on race in America. . . . [H]e talks about a[n] . . . outstanding student who was going to a white school. . . . [T]he school had an exchange program with Morehouse College and this student went down to Morehouse and spent a year there and decided to transfer there instead of coming back. . . . And the issue was that he felt that at this white school, he had to be a different person than he would and he had to relate differently than he did at Morehouse. He didnít have to play a game. . . . [H]e could be his own self at Morehouse. . . . I think that the fact that there arenít many minorities or women in science, in the physical sciences [in particular], would tend to inhibit other people who were coming in. [T]hey would have to say, "Well, Iím going to do that kind of thing. Iím going to go in and learn that

culture, which is something in addition to the science they have to learn, but learn that culture in order to survive in that culture." [A]nd itís not something that I'm not necessarily comfortable with. And so I think that can be intimidating for ethnic minorities and females to get into physical sciences.

Building Inclusive Science Curriculum and Instruction

As the second part of our qualitative analysis, we looked for patterns of inclusivity across scientistsí reports of pedagogical strategies employed, course content delivered, and roles and responsibilities adopted. We attempted to highlight perceived individual, disciplinary, and institutional constraints to inclusive practice, constraints instructors reported as limiting their ability to promote an environment inclusive of all students. We also checked for distinct patterns in views by sex or discipline, but found none. For clarity and interest, we begin with a brief description of female-friendly and/or culturally inclusive strategies used by instructors; we then move quickly to examination of perceived constraints to innovation.

Promoting inclusivity through curriculum and instruction. We began by identifying the methods used by scientists to promote student involvement, understanding and personal relevance, to provide a forum for discussing the contributions of women scientists, scientists of color, and cultural groups, and to interpret their studentsí knowledge of and skills in science. Scientists in our study implemented a broad range of pedagogical and curricular innovations to promote inclusion. Because we think it more useful to focus on perceived constraints to innovation, however, we discuss here only a small sample of what was employed: We describe instructional strategies identified by instructors as promoting greater student participation.

Across the five disciplines of biology, chemistry, geology, astronomy, and science education, the majority of instructorsí techniques centered around building a community of learning for all students. To increase and even out student participation, many instructors reported expanding and refining their questioning strategies. There was a general awareness, for example, that a large classroom can make students feel "a bit shut out and excluded," especially when there are a few students who are "unusually willing to speak up" or "jump in" before anyone else has had an opportunity. Some instructors reported that they had modified their classroom management techniques to confront this issue head-on. Marianne reported taking "the time to lay those sorts things on the table and say, ëNow, I like questions. Iím not going to be offended by questions and I encourage you to ask.í " A few talked in private to those students who consistently raise their hands or who answer questions during lecture, asking them to wait a few minutes before they respond. Increased wait time was another strategy instructors used to encourage all students to participate. Those instructors who waited longer before calling on students were surprised to see many more hands raised and better answers provided. In addition, several instructors reported making themselves more accessible to students and enabling a broader selection of students to participate by walking around their large lecture halls. Chris, in particular, explained he had a "tendency to walk around the class" and to "talk from various parts of the room . . . so that [he] can call on people [students] back there which doními necessarily do [raise their hands] as readily from the front" of the classroom. Like many of his colleagues, Chris also made a conscious effort to call on "women, as well as men, . . . non-Whites, as well as Whites, and so on."

There were other strategies, outside of questioning techniques, that instructors used to positively impact student participation during lecture. Techniques included deliberate eye-contact with individual students; humor; energetic mannerisms while telling the personal or fantastic; accounts of the lives and work of research scientists; and current events from news channels, newspapers, or scientific organizations. Tim, for example, "encourage[d] people [students] to bring things into the classroom. Frequently," he explained, students "will bring newspaper clippings for me." Tim thought such discussions of current events served "to get people involved" in his large general education science course. Other strategies implemented to enhance opportunities for teacher-student and student-student interaction were the use of in-class activities, like individual presentations, quick writing assignments, and group tasks. Professors who used in-class activities indicated that they provided a safe forum for practicing the shared language of the classroom community, fostering friendships, promoting better communication, and developing a deeper understanding of the course content and curriculum; in other words, in-class assignments were perceived as helping students to become more actively involved in their own learning process.

Constraints to innovation: A matter of time. Although all participants in this project began or continued to implement inclusive pedagogical and curricular strategies, there were course changes some wished to make, but were unable to do so. We thus thought it important to examine the kinds of constraints encountered by scientists as they considered and/or attempted to build more inclusive classroom environments--so as to learn how professional developers can better aid scientists in reaching the goal of science for all. Below, we discuss two clusters of constraints: those that limited implementation of innovative pedagogical strategies and those that prevented integration of inclusive science content. Where possible, we also provide examples of exceptions to the rule: Scientists who seemed to ignore or push through obstacles to implement innovations they perceived as necessary and vital for student success.

The enacted curriculum is constrained by multiple factors associated with the culture in which teaching and learning occurs. In the constraints clustered around pedagogical strategies, scientists identified (a) large class size and (b) lack of time as impediments toward innovation. Some scientists, for example, described large class size as restricting them to teacher-talk, or lecture mode, in their presentation of course material. Because they taught such large classes, these scientists saw few opportunities to promote individual or group involvement, utilize more in-class activities, or monitor student learning through innovative assessment strategies. In her interview, Natalie thought it "really difficult in [a] lecture hall with 200 students to give any individual attention." She tried "to answer questions in the lecture that are pertinent to whatever needs to be solved." Rather than devising new strategies to increase student participation in her lecture course, however, Natalie focused on student engagement in her laboratory sections. She kept "the labs as small as possible because . . . [they are] where you can get more individual contact with the students. . . . [T]he lab is really the place where you get more of a one-to-one, teacher-student relationship."

In his interview, Daniel also discussed large class size as hindering his ability to engage and interact with students during lecture: "[T]hereís not much of an aspect of [student] participation in the lecture." Like Natalie, he too contrasted opportunities for student participation in his lectures to those in labs; he too saw the labs as a more appropriate place for instructors to interact with students.

> In the laboratory, I see an enormous improvement in what students are doing and how they feel about doing experiments and how theyíre feeling a lot more in control and a lot more able to do the laboratory work. But in the lecture itself, I donít have much of a situation where I can allow students to give me much feedback other than asking me specific questions.

There were some instructors who saw large class size as a constraint on inclusive instruction, but implemented a number of female-friendly and/or culturally inclusive strategies anyway. These instructors created a standard for what can be accomplished in large undergraduate science classes, but offered little hope of finding easy solutions to overcome class size difficulties. Instead of his large introductory astronomy course, for example, Joe would have "much prefer[red] . . . a small class" of about 20 students "where it would be a discussion as opposed to a lecture." In a student-centered seminar, he explained, students could raise questions and direct the content covered: "I feel itís more important for the instructor to deal with what the students are concerned about than what the instructorís concerned about, but the lecture format mode doesnít lend itself readily to that." Given the current size of his general education science course, Joe continued, he "seem[ed] to be unable to stimulate . . . many [student] questions." He did, however, require all students to participate by presenting "two talks." Each student gave one oral presentation on a scientist (Joe encouraged students to investigate scientists of their own gender and/or ethnicity) and a second, on a current event related to a topic covered in the course. He also "include[ed] one essay question on each exam" to promote greater student reflection and dialogue with the instructor.

Elaine had also worked hard over the years to make her general education geology course more interesting and understandable to non-science majors. Despite the courseís profile--"an introductory science lecture class that tends to have numbers of people in excess of 100"--and course setting--"a standard auditorium," each week, Elaine "had an in-class writing assignment that often involved interactions with people in adjacent seats or forming of small teams of people to address questions." She had students complete a "five page paper, which actually for a large 100 level class, turned out to be very distinctively different grading opportunity than those people had had." To cater to the needs of women, Elaine used exams of "70% essay and short answer with only 30% multiple choice."

> [T]he exams . . . [were] something I had done before the Women in Science program, but I

expanded due mostly to Julieís presentations on active learning . . . [and] also my work with the General Ed Institute. . . . As an instructional strategy, testing strategy, it was much harder for the students. . . . But in terms of demonstrating learning and allowing them to tie concepts together and integrate them, it was much more effective. . . . [R]esearch shows that many women in particular like to see the big picture, how things interconnect.

Besides changing the format of her exams, Elaine also decreased the percentage of studentsí grades which were based on them; to be more inclusive and fair in her grading, her practices had "metamorphosed" over the years to include a range of assessment techniques, such as research papers, in- and out-of-class writing assignments, and class participation, as well as exams.

More so than Joe, however, Elaine underscored that all these innovative assignments and assessments were not without personal cost: "It increased my workload way too much and that caused . . . problems in terms of me being able to do all of the other things I had to do for work and home life. It was too much work." This problem, Elaine concluded, would only "be mitigated in the future by . . . being very adamant, saying, ëI want no more than 45 students in this class.í. . . [I]n fact," when planning the course, she thought she "would have about 60 students, but it went up to 125. . . . [T]hat was way too much."

A second constraint on instructional innovation was lack of time: Some scientists were reluctant to incorporate particular strategies because of pressing course loads and research responsibilities. In other words, many instructors reported that time for them was a scarce commodity and, when accompanied by large class size, served to limit their choice of instructional innovations, particularly the kinds of assessment strategies they employed. Often reluctantly, these scientists selected less time-consuming multiple choice exams over loose-portfolios, rubrics, term papers, and/or personalized research projects to assess their students. Tim, for example, did not think "the multiple choice [exam]. . . a perfect assessment of their [studentsí] abilities in the lecture." Because his introductory science course was large, however, he felt "stuck with multiple choice questions. . . . [W]ith that many students," he explained, he really didnít "have a choice. It would just take too much time [to include essays]." Marlene agreed with Tim: She did not have enough time to grade essays or end-of-semester reports. Because her human anatomy course had "over a hundred plus students," she used "primarily multiple choice" exams. Indeed, the simple inclusion of fill-in-the-blank questions added significantly to the time needed to evaluate them. More importantly, she continued, students in her course had so much material to learn in preparation for their careers as nurses and physical therapists, they did not have time for such alternative assessments either. On exams, "[t]hey don't have time to do essays. They have 75 questions in 50 minutes to answer. There's no way [to] do a lot of other types." She also did not "have them do [research] papers. There's too much material as it is to have them go out and do other things."

Again, there were some scientists who seemed to recognize the inordinate amount of time needed to grade alternative forms of assessment and yet who chose to implement innovative assessments over traditional multiple choice exams. Elaine, discussed above, is a case in point. Chris, a biology professor, also moved toward exams with multiple question formats by the end of the professional development seminar. During his pre interview, Chris noted that multiple choice exams were not optimal for detecting student learning: "Some students like the multiple choice. Some of them crave a little bit of more essay; they do better on that kind of thing. And we're not, if we do all multiple choice, we're not really giving those students a chance to [show what they know]." Because of class size and time constraints, however, Chris had abandoned use of short answer questions and returned exclusively to multiple choice exams: "It's a big enough class that most of us are leaning more toward the multiple choice just because of . . . grading, . . . to ease the grading process." By the post interview, however, Chris had reinstituted "multiple . . . question formats on the exam." He "had learned from some of the readings . . . [for the project] that women tend to respond perhaps well to a variety of [types of] questions on exams. . . . Even though it was a lot more work and kind of a pain in the butt to grade," Chris used short answer essay questions because he thought them a much more effective way to solicit studentsí ideas and assess their learning.

Besides identifying constraints to inclusive instructional strategies, many scientists felt restricted in their ability to incorporate inclusive science content, to discuss the contributions of women scientists, ethnic minority scientists, or other cultures to the breadth and depth desired. Within this cluster of constraints, they discussed (a) lack of time to cover required material, (b) lack of time and resources to research underrepresented groupsí contributions, and (c) mismatches between the history of science and the goals of the Women and Scientific Literacy project. As with the presentation of constraints on instruction above, some scientists recognized the existence of content restrictions but still managed to implement course revisions, while other scientists did not. Again, no easy solutions were identified.

Time to cover required content was one curricular constraint identified by scientists. For many, the coverage of prescribed content took precedence over discussing scientistsí or other culturesí contributions; there was simply not enough time in their 16-week courses to do both. Adherence to a variety of parameters placed instructors in a position of disempowerment, with an inability to make changes, to provide their students with a more creative and inclusive curriculum. Daniel, for example, expressed interest in including the work of scientists from underrepresented groups, as well as the contributions of other cultures in his introductory chemistry course: "I think it's really important to point out at some point that a large number of great discoveries and ideas have come from women and minorities and people that you wouldn't suspect." "[U]nfortunately," he noted, "we donít have a lot of time in the course, so we donít really get too much into the background of scientists and where they come from and what theyíve done." Daniel saw his inability to cover individual and group contributions as a function of scientific progress. The history of science shrinks "each year as the volume of technical material increases in the class," he explained. "Because of the growth of the field," discussion of the history of science "just doesn't happen in a freshman [introductory chemistry] book and maybe we ought to rewrite something to consider that."

Other scientists were also unable or unwilling to change course content because of university requirements and/or national norms. Donna, for example, explained that as the instructor of an introductory chemistry course she was expected to follow an informal set of national content standards: "The content is pretty standard across the country. There is a good deal of agreement across the country that there is too much content; there is not a good deal of agreement on what we're covering that we could leave out." Because there all already "too many topics, because there are arguments against leaving [any of] them out," she did not see a great deal of room in her already overcrowded chemistry syllabus to discuss the contributions of underrepresented groups. Like Donna, Anand and Tim felt too constrained by the Universityís general education requirements to include a great deal of discussion on contributions. Tim noted: "It's a GE approved class which means weíre pretty structured in what we can do. It has to be approved for a GE credit." Anand, who taught the same general education course, agreed.

> [He did] talk a little bit about . . . medicine which comes from India and . . . a little bit about how some people have learned [to] control their autonomic nervous system. . . . [T]he course content is so much, [however,] we can hardly cover that. We really need to cover the bases first and in 16 weeks, it's just kind of hard.

There were a few scientists who chose to sacrifice traditional content in hopes of making their courses more meaningful and relevant to the majority of their students. Cynthia, for example, instituted "Fun Fridays" in her interdisciplinary human immunology course. Each Friday, students worked in groups to discuss a scientific research article that "brought in more of the ethical kinds of considerations or some of the really current things that are happening" in science. Cynthia noted that she had to "give up some of your [her] lecture time" to make room for these discussions, but thought it worth the student participation and interest generated. Similarly, Robert decided to throw out some of the content usually covered in a general education geology course. He focused on only those chapters of relevance to his studentsí lives.

> [W]hat I teach . . . was different than a lot of my colleagues. I think [I was] influenced by trying to reach the students and that is that thereís far too much material in the textbook to cover in a semester. You canít do all the chapters. . . . I was only able to do about maybe 65% of the material in the textbook. . . . [I] really focus[ed] on the stuff I thought people had a chance of having daily experience with either already in their lives or in their future lives. . . . I specifically chose . . . to exclude the stuff that theyíre the least likely to impact their lives here in California.

A second curricular constraint identified by scientists was lack of time in interaction with lack of resources: Many of the scientists themselves did not have the time and resources needed to research inclusive content and incorporate it into their courses. As above, lack of time and resources constrained some scientistsí ability to build a personal knowledge base or to take time in class to discuss the contributions of women, ethnic minorities, or those of other cultures; time and resources did not appear to act as constraints for others. As explained under content time restraints above, for example, Daniel was interested in incorporating information about the contributions of other cultures to science, but had yet to do so by the end of the professional development seminar. One reason for this oversight was the amount of content required in an introductory chemistry course. A second was the lack of support from the textbook he used. In his pre interview, Daniel noted that the textbook he used did a poor job of discussing the contributions of other cultures; his sonís middle school social studies book did a much better job.

> [M]ost of the books we've employed have a section on the history of chemistry. Most of it is Eurocentric, European and Middle Eastern. That's where most of chemistry came from that we teach. . . . You use some references, for other sources. I just don't really have too much. My son actually gets a lot more on chemistry and things about China and the Middle East and India than I have, to be frank. I guess his classes are getting more inclusive than ours are here.

A third reasons Daniel did not include more discussions of contributions was his own lack of time. Because he had been asked to switch chemistry courses mid-year, he had yet to find the time to learn about and to introduce historical aspects into his instruction.

> I was planning on introducing some historical parts. I have not done that, I have to be frank about that. Iíve been wanting to introduce the historical parts in freshman chemistry and then when I got stuck teaching this [other course], I didnít really have a chance to do that.

Like Daniel, Marlene thought it important to discuss the contributions of women and ethnic minority scientists, but did not have the time needed to research such things. She thought discussion of scientistsí contributions "could really benefit students," could draw more members of underrepresnted groups into science.

> [W]hen a female has accomplished something or when somebody of some ethnic minority has accomplished something, to state that we've learned this . . . because of their own experiences from where they lived, to add that to what the fact is that we're teaching would be really good. I don't know a lot of the history, but I think that would be a really good thing to do.

She agreed with Daniel that she did not know a great deal about the contributions of women and ethnic minority scientists and did not have time to research them.

> [R]eading some of those books and some of those references [as part of the professional development workshop,] that's about the limit of my knowledge. I honestly don't know, because I don't take the time. I'm in class [teaching] 9 to 12 hours a day and I don't go home and learn those kinds of things afterwards.

While Marlene did not know or teach a great deal about underrepresented groupsí contributions to science, she did take the time to research and discuss differences in human anatomy by gender and ethnicity. She thought textbooks had improved over the years, that they now provided instructors adequate information about female anatomy: "We are now getting to the point where we have female authors of our textbooks and we have equity within the academic material that's being presented. . . .We're getting better about presenting in the published references the female perspectives." However, she thought textbooks provided little support for discussion of ethnic differences, that they still lagged behind in their inclusion of information about ethnic minorities: Textbooks say "[v]ery little, again in parenthesis, if there's an ethnic difference. . . . When we talk about the differences between the skin, the pigmentation of black, white, Asian, whatever, yellow skin, red skin, why is it there? It's not really discussed, . . . not in the textbooks anyway." To find such material, she had had to turn to anthropology textbooks. "Not all the instructors around here," she noted, "are going to take the time to go to a different book to find out why. Even if a question's asked, many of my colleagues would not go to a different book to find out why."

Natalie was one scientist who recognized the limitations of time and textbook and yet, over the course of the professional development seminar, worked to change the content of her course to better reflect the interests and lives of her students. In her pre interview, Natalie noted that the work of scientists from underrepresented groups and the contributions of other cultures to science were not covered in her textbook.

> [T]here's very little on history of science, history of chemistry, people involved in it. How the concepts came into being, could be history of the periodic table, it's just not covered.
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> I think youíll find that in 90% of your chemistry books, maybe even a 100%. I don't think I've seen a chemistry book that has an introductory [history of chemistry section].

Given the textbook used and the heavy emphasis on acquiring mathematical skills, Natalie talked little of past and present contributions in her course lectures.

By her post interview, however, Natalie had made changes in both the textbook she used and the kinds of information she taught. She had switched to a textbook that discussed chemistry in everyday contexts, a textbook she thought would appeal to female and ethnic minority students.

> I felt that I was not getting a full understanding of the topic [from the old textbook] because I had no idea how chemistry related to everyday science. . . . I love this [new] book of how chemistry is used in your house, even with cleaning products in the kitchen, outside, glues, . . .
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> [The textbook discusses] things that they can kind of relate to and understand to make them want to learn more. . . . [It makes students] realize that, hey, chemistry is [not] just for males. It's for females too. And that females use it everyday just as much as males, as well as the people from the ghetto are going to use it the same amount as people from Beverly Hills.

She had also spent some time perusing newspapers and science magazines for stories of women scientists and ethnic minority scientists, for past and current contributions from members of underrepresented groups. She "subscribe[d] to Discover and Journal of Chem Ed, and C&E News" and had started to "do a lot of reading to try and bring some of this stuff to the classroom." She had "started looking for stuff this spring," "collected [articles], and stuck [them] away in my [her] folder to bring out for next semester."

A third curricular constraint identified by scientists in our study related to the nature and history of science: Besides discussing the contributions of members of underrepresented groups, many scientists wondered how else to make the content of their courses more inclusive. Elaine, for example, understood how discussion of contributions could make geology more appealing to women and ethnic minorities; she did not know, however, how to infuse issues of gender and ethnicity into other aspects of her science content. After all, she explained, the discipline of geology deals primarily with processes and objects that are inanimate: A rock has neither sex nor culture. "Unless you're talking history of science and you're saying, ëWell what we really need to do is highlight the achievements of women and quote, unquote, minority groups.í It's really hard when you're talking about a rock to say well, this is a European rock." Because Elaine was one of many scientists in our study who raised this concern, rather than continue this discussion within the context of curricular constraints, we thought it best to devote our third and final section of qualitative data analysis to scientistsí views of the gender/less and a/cultural nature of science. It is to this extended discussion of the nature and history of science that we now turn.

How Inclusive Can the Nature of Science Be?

As stated above, almost all scientists in our study agreed that discussion of the contributions of women scientists, ethnic minority scientists, and the sciences of other cultures was an effective and realistic way to reach female and minority students. Justine, for example, thought "talking about scientists as people . . . really brought in students." The rest of "molecular biology," she explained, "just is not by nature going to be real inclusive." There was less consensus among these scientists, however, on what additional steps should be taken to broaden the nature of science, to make conceptions of science more inclusive. We examine four of these alternative approaches below. As might be expected, scientistsí responses to the inclusive nature of science question sometimes split along disciplinary lines.

Scientists who taught courses related to humans--courses like human anatomy, physiology, and immunology--offered one additional way the nature of science could be reinvisioned to promote greater access to and recognition of traditionally underrepresented groups: They recommended the incorporation of scientific research on sex, racial, and/or ethnic difference. In his human physiology course, for example, Michael included research of particular interest to women--research on bone homeostasis, the reproductive system, and genetics. To emphasize the true range of variation in the human species, to encourage students to recognize and appreciate diversity, Michael also presented research related to skin color, the types and frequency of diseases across ethnic groups, and alleged differences in brain activity between the sexes. In particular, he spent "a great deal of time talking about skin color, how it is that the skin color develops, what's the mechanism, once again just because our society is so obsessed with skin color." Scientists who taught courses in geology and chemistry thought themselves at a distinct disadvantage in this respect. As Daniel remarked, "[M]ost of the chemistry course is about things that really are inanimate. The subject matter and the core content of the course donít have any [of] the human or psychological aspects as far as that goes."

The socially situated nature of knowledge was a second aspect of science seen by participants as useful in reaching out to those uninterested in or intimidated by science. Robert, for example, saw the linking of geologic research to larger social issues as a way to address issues of ethnic and cultural diversity in his class. Although he did not spend a great deal of time, he did try to drive home to students the impact of scientistsí actions on the larger world.

> For instance, as a geologist, I may be involved in developing a mine, okay? An open pit mine, thereís all sorts of economic ramifications. Well, you donít generally do open pit mines in Bel Air. You donít do open pit mines in Laguna Beach. You do your open pit mines in the Appalachians or in poorer areas where the wealth is not enough for people to have the choice. . . . [D]irty industries tend to be in poorer neighborhoods and poorer neighborhoods tend to be more minorities. . . . [T]heyíre related to resources and geology and skills that people are learning and I usually try to point those issues out [to students in my class] in saying, "You know, at some point in your career, youíre going to have to make a decision. Do I use my skills and my knowledge to help these people or do I choose not to use those because I think that itís causing a greater damage to the earth?"

As a result of her involvement in the Promoting Women and Scientific Literacy project, Lorraine also saw presenting science in context as more crucial for drawing women and ethnic minorities to science. In recent years, she had "tried to pull a lot of things in[to] virology . . . from the molecular biology, . . . medical stuff, and health issues." She had "talked a little bit about, for example, with AIDS, all the social aspects and all the health aspects, and things like communities and insurance." Next time she taught her classes, she insisted, she would address many "other diseases [in the same manner as AIDS], to try and sort of look at things in a bigger picture."

A few participants in this study grew to see not just the products of science as socially situated, but the production of scientific knowledge as well. Lorraine, presented above, was one such participant. Her colleague, Cynthia, was another. At the beginning of the study, Cynthia "didn't know epistemology from an episiotomy." Her subsequent examination of feminist scholarship, however, had changed the way she viewed the construction of scientific questions and findings. She now saw the interpretation of data as influenced by the scientistís gender.

> [Feminist epistemology] was totally new to me and this is where all this stuff about context comes in. This is where in the interpretation of data, you can't get away from the cultural differences between men and women. . . . They see the same thing, but they're going to describe it differently because . . . [theyíre] looking at it from a male viewpoint versus a female viewpoint.

A third colleague, Theresa, agreed. She also explained that the kinds of questions scientists ask and the data they find are influenced by their gender and ethnicity.

> I'm sure that because of the differences in our cultural background, they [women and minorities] must be bringing to the science that they do a different perspective.
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> I'm sure that the kinds of problems one might choose to work on can depend upon one's own cultural experiences. So the questions that one might ask, I can't imagine that those wouldnít vary.

Recognition of the situated nature of knowledge production flowed into discussions of a third way to broaden descriptions of scienceís nature: Recognition and discussion of gender and/or ethnic bias in past and present research questions, methods, and findings. Like scientific research along sex and ethnic lines described above, examination of bias in research was limited primarily to the biological sciences. Unlike the first two aspects of the nature of science discussed here, however, not all scientists agreed on the existence or extent of bias in science. Several scientists, for example, noted that the medical sciences had a long history of excluding women from clinical trials, devoting little research to womenís diseases, and ignoring signs of illness in women patients. In Natalieís case, she argued for increased research on womenís health issues and increased use of women as test subjects: "[What] I'd like to see is a lot more research in science that has to do with women. And when they test subjects, I'd like to see women as test subjects, not just men as test subjects." Research into and treatment of women, Cynthia noted, had been skewed toward male concerns for years because most scientists had been men.

> [In my course,] I made it a point to make sure the students realized that for many years, they didn't have a definition of AIDS that applied to women. . . . [I]tís only been in the last 5 years or something like that that they've included vaginal yeast infections, chronic vaginal yeast infections, as a marker for an AIDS infected female. And so here and there I would try to point out a few things about how medical sciences have been skewed
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> by male influences or just the male point of view.

In contrast to the views voiced by Natalie and Cynthia, Michael did not see discussion of gender and ethnic bias as particularly relevant to present day science; he thought racism and sexism integral to the scienceís history, but not to its present. The 19th century science of craniology, Michael explained, is an example of a racist and sexist science: "I talk about the craniologists in the last century who were going around measuring brains. And they always had Europeans as the largest brains and consequently most intelligent. . . .[T]he Eskimos, I guess, were ignored cause they had bigger brains than anybody else." Biology, Michael continued, has become less racist and sexist over the years; sexism and racism are really issues best addressed in "something like the history of science." Michael criticized feminist scholarship for treating sciences of the past as if they remained in the present, for singling out practices and perceptions that were no longer part of biology. "[Feminist] literature on stuff in biology . . . [is] all really out of date. I was thinking, have these people seen a recent [biology text]book?" He also expressed annoyance over the common practice of lumping all the sciences together in their critiques: Feminist scholars "donít seem to realize that there's a different way of doing things in biology." The method and philosophy of physics, he cautioned, are not representative of all sciences.

Still other scientists did not see issues of gender or ethnic bias as permeating the fabric of scientific research. Daniel, for example, thought bias was introduced into science by the scientists who teach it; chemistry itself did not have a bias against women or ethnic minorities. "In my area [of chemistry], I donít see that the subject matter and the way of teaching have any strong bias. Itís always the personal bias of the teacher, not so much the content of the course." Donna, a chemist as well, thought issues of gender and ethnicity relevant to discussions of science instruction, but not to scientific research: "I think most scientists take the attitude that issues of gender or ethnicity are absolutely irrelevant to what we do. And I think that's true for what we do. For the socialization of the students in the world that we live in, it's not." Like Michael, Donna also expressed concern that feminist scholars had gone too far in trying to show the influence of gender on scientific research. Yes, she agreed with feminist scholars that women have been discriminated against pursuing science careers and that womenís concerns are different from men. She rejected the notion, however, that a female science could or should exist.

> The idea that there is a female science, that there is a female mathematics, that there is a separate world, is one that I reject at the gut level because I've spent my life rejecting the idea that there is a male science, a male world. I've spent my life fighting for a place of equality, and not for a place of separation. . . . [T]he idea that there are ways in which women have been discriminated against, of course. The idea that women have concerns that might be different from those of men, and that these are important and valid concerns, sure.

Scientists also disagreed on a fourth and final proposed revision to the nature of science: To what extent, they pondered, could the modern sciences be considered multicultural? Many of the scientists interviewed thought science a European construct to which other cultures have and continue to contribute. Joe, for example, thought it important for his students to recognize and appreciate other cultures and their contributions to science: "[T]he world is diverse and the only way that weíre going to get along is if people recognize that others have made contributions and othersí value systems have just as much legitimacy as [the] value systems of people who are sitting in the room." He explained to students that the history of astronomy, as currently written, reflects a European perspective: "I try to indicate that . . . when we look at the history, and that's generally where you start out in astronomy, that this is a history which reflects the European perspective." Where possible, however, he shared with students the contributions of other cultures to astronomy.

> I do point out that the Chinese astronomy was way ahead of European astronomy several thousand years ago, cause I'm aware of that. And I indicate that the Mayan astronomy was also relatively well sophisticated, although, again, I'm not as conversant with that as I should be. . . . And I also indicate that that doesn't mean that there weren't other societies that we now don't know enough about that didn't also do very good work, but that just has not survived. I try and point those out, especially in the history of discoveries that are put in a [text]book.

Elaine agreed with Joe that other cultures had contributed to the natural sciences and that such recognition was important to share with students. "Geology is a culture." she explained, "that began in the British Isles. And so all the textbooks focus on a very narrowly defined group of people, about 1% of the population that resides in the British Isles." In recent decades, however, geology has begun to pay greater attention to the contributions made by other cultures.

> There is a lot more attention now to creation myths, to observational patterns of natural phenomenon in other cultures. And geology is related to creation myths because geology provides history, the solar system. . . . We want to see well, where's the background for science principles that we hold true today? Were there roots in other cultures and was there cross-fertilization to this magical group of people in the British Isles that did a lot of early geology? Can we find those ties?

Since the 1960s, Elaine continued, geologists have also begun to revise history to give proper credit to those from other cultures who have made contributions: "[S]cientists in Asian cultures, have been given, if you will, retroactive credit for accomplishments that formerly were credited to European scientists in geology." Elaine applauded both these trends and recognized that "[t]here's still some work that probably needs to be done."

Other scientists in our study, however, cautioned against equating the contributions of other cultures to science with the existence of different kinds of sciences in different cultures. Robert, for example, thought one got a cultural flavor for geology through the "works of colleagues . . . from different parts of the world" or through "examples [of] fantastic glacial valleys in Switzerland and Italy." He did not, however, mean to imply that "science is different in different cultures." He saw "science formed by people from different cultures, but not different sciences." Like Robert, Tim did not think the science performed in other parts of the world fundamentally different from that conducted in the United States. He had spent time in several European cities and knew scientists from all over the world: "I was married in Budapest to a Hungarian scientist. . . . And I spent some time there in [Hungary] and in England. . . . I never found the differences between those European cultures and ours particularly significant." Rather than see science as influenced by national boundaries, he saw "science [itself] as a culture."

> [S]cience carries its own beliefs, its own value structures. That doesn't say that we're not constantly fighting the problem of people not adhering to the norms in our culture, but it is in a sense a culture that tries to stress honesty, integrity, and equality. . . . I think scientists generally like to think of themselves as non-racist, non-sexist, and judging people upon their intellectual accomplishments. . . . I agree, we don't always accomplish that, but . . . all of us seem to share a common interest, a common place in science . . .

Finally, a few scientists expressed concern that too great a push toward multicultural science would lead to further marginalization of underrepresented groups down the road. In Donnaís case, she worried that too heavy an emphasis on multicultural issues would only divide people further by their cultural heritage. She was "strongly in favor of multiculturalism in the sense that we shouldn't be trying to homogenize everybody, that we shouldn't be trying to make everybody into a single image." Too much attention to cultural difference, however, forced students to view each other as members of particular ethnic groups rather than as individuals.

> The idea that you have to make sure you go out of your way to get an example of every little group in every single activity, I think youíre still insisting on separation that I don't think to see. Inclusive, yes, but I think my problem with it [multiculturalism] comes in with letting, forcing people to be representatives of their group and not individuals.

In Lindaís case, she wondered what good could come from placing indigenous knowledge systems on an equal footing with traditional science content. Should American Indian myths about corn singing be taught in a science course? By making everything science, would not other culturesí knowledge systems be marginalized?

> I have no problems with multiculturalism. I think . . . there's so much to be gained by the diversity of people. . . . In trying not to marginalize a culture, [however,] you end up marginalizing everything.
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> //
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> [T]here's an example I know of, I forget which Indian tribe it is, but they hear the corn singing and thatís when they know it's time to harvest. Well, thatís fine but thatís not science in my understanding of what science [is]. . . . I think that you almost, you get to a point where you can't communicate with each other because we have different definitions of what science is. So, when people say in science education that we should have multicultural science and accept all these other culturesí ways of knowing as being science, I have a hard time with that because I doního consider them sciences.

Rather than push to have science content become multicultural, Linda continued, she thought it better to address culture through instructional strategies: She viewed taking "into account the various, diverse cultures and what experiences students have had in their culture . . . [as] a very powerful learning tool."

Implications

Data revealed a long list of obstacles encountered and tensions experienced along the road toward a more equitable and excellent science education for all undergraduates. From our findings, we argue that issues of inclusion in science education are more complex and that answers to equity questions, less clear than initially conceived. We structure the following discussion of challenges faced by scientists and professional developers interested in inclusion around the three major dimensions of our Conceptual Framework: student success, the implementation of inclusive curriculum and instruction, and feminist scholarship of science.

Walking a Fine Line or Crossing Boundaries?

Scientists in our study identified three sets of actors that promote or constrain student success in undergraduate science courses: the students themselves, their instructors, and external-to-the-university pressures (specifically, academic preparation, family and cultural expectations, and socialization practices). As stated in our data section, scientists provided clear directives to all students--regardless of gender or ethnicity--on how to better ensure personal academic success. Scientists also described the importance of rethinking their own perceptions of the causes and consequences of student success, as well as the need to address all studentsí interests and experiences in their patterns of instructional practice. In regards to student and instructor recommendations, then, there were few objections voiced or concerns raised.

Somewhat ironically, it was in the realm beyond student and teacher control that scientists both described the most barriers to women and minority studentsí success in science education and highlighted the costs as well as benefits of framing the problem of underrepresented groups in particular ways. Justine, for example, noted many underrepresented ethnic minorities enter college without the knowledge and skills needed to succeed as science majors. Such awareness, she thought, was a first step toward better addressing this knowledge gap. In contrast, Theresa and Joe expressed concern that members of underrepresented ethnic groups were automatically labeled as academically impoverished; they worried that scientistsí judgments of studentsí academic ability rested too heavily on their ethnicity. Tensions between countering family expectations and honoring studentsí cultural heritage, as well as those between disrupting social stereotypes and encouraging entry into scienceís foreign culture were also identified. What lessons can be learned from consideration of such tensions?

We offer two ways professional developers and scientists can begin to understand and negotiate through external pressures to studentsí success identified here. One, in professional development activities around issues of inclusions, scientists must be made aware that tensions exist between the goals, norms, and practices of science education and the external forces that constrain studentsí aspirations, attitudes, and actions. What are the costs and benefits of framing differential student success as influenced by prior academic oversights? Of what use is the recognition that studentsí family roles and responsibilities are often in conflict with the requirements and workload of science courses? What can be gained or lost by thinking about the ways women and ethnic minorities are socialized to hold values and skills in opposition to those of science? Discussion of these topics can at least help scientists understand and appreciate the full range and complexity of factors influencing underrepresented studentsí decisions and actions in undergraduate science courses.

Two, university scientists must recognize that they and their students do not exist in a vacuum; undergraduate science education programs can only achieve inclusion if supported by the larger social structures in which they are embedded. Scientists should be encouraged to develop outreach programs to their surrounding communities, to inform, engage in dialogue with, and learn from their studentsí families and community leaders. Unless and until communities have a better understanding of the roles and responsibilities of science undergraduate majors, and scientists, a better sense of community needs and practices, many studentsí lives in academia and in the real world will continue to clash.

The Need for Institutional Support

As explained in the introduction to our Conceptual Framework above, most studies on the professional development of science educators around issues of inclusion examine the kinds and layers of teachersí resistance to awareness of equity issues and to implementation of curricular and pedagogical innovations. This study differs from the norm in that it examines a group of scientists already committed to issues of inclusion; rather than resisting identification of the equity "problem," many participants in this study had already spent years attempting to promote student success in their introductory science courses. Data presented in the Constraints to Innovation section, however, make clear that an instructorís commitment and initiative are not always sufficient to implement inclusive curriculum and instruction. As such, this study serves as yet another reminder that instructors cannot easily and consistently implement innovations on their own.

From our data, we argue for increased institutional support for educators interested in promoting an excellent and equitable science education for all. Within the university, department and college administrators must give serious consideration to the reduction of undergraduate class sizes and instructorsí course loads. As requested by Joe and Elaine, scientists need smaller classes to employ instruction and assessment strategies considered more in tune with the needs and interests of those traditionally positioned on the periphery of science. As reminded by Daniel, Marlene, and Natalie, scientists also require adequate release time to research and/or develop materials that are more interesting and accessible to students. Departments and colleges of science must also make a concerted effort to change their norms and values, to make their climates less hostile and more nurturing to members of underrepresented groups.

Changes outside the university are needed as well. Textbook companies, for example, must continue their movement toward inclusive science content: They must integrate women and ethnic minoritiesí contributions more thoroughly into the story of science and more closely tie the applications of science to everyday life. National science organizations should also be encouraged to rethink the nature and purpose of their introductory science courses. For courses designed for non-majors, what content can be cut so that innovative pedagogical strategies are used and the goal of scientific literacy for all is attained? Robert and Cynthia, for example, went against the current tides in their disciplines by cutting course content in favor of promoting greater student interest and understanding. For science major courses, what content is truly necessary for progression toward a science career? At present, Donna noted, introductory chemistry courses attempt to cover too many concepts, too superficially, and in too little time. In truth, then, the professional development of scientists is only one of many interrelated steps toward building a truly inclusive undergraduate science program for all; work at the department, college, university, and national levels is needed as well.

Building a Two-Way Street between Feminist Science Scholars and Scientists

Like perceptions of students and use of innovative strategies above, our data revealed differences across scientistsí descriptions of what science is; how issues of gender and ethnicity shape scientific norms, ideas, and practices; and to what depth such issues permeate the scientific enterprise. Some of the scientists interviewed expressed traditional views of what science is and how science works: Daniel and Marlene, for example, did not know a great deal about the contributions of women and ethnic minorities to the science; Daniel and Donna viewed scientific practice as unbiased; and Tim and Robert, saw science as practiced in all cultures in identical ways. From our perspective, then, it appears feminist science scholars could provide insight and information to many of our participants; we suggest that feminist literature could offer these scientists a different perspective from which to view their own and othersí experiences in science. As explained in our Methods section, although participants in our study were introduced to a small sampling of feminist scholarship, few examined feminist constructs or claims in great depth. More tightly integrating feminist scholarship into professional development opportunities--first exposing scientists to the literature and then providing them time to discuss, assimilate and incorporate such views--should help shed light on issues of inclusion in science and provide insight into ways to address inequities in the science classroom.

While we call for more serious consideration of feminist scholarship by scientists interested in issues of inclusion, we are not advocating the out-of-hand dismissal of any and all opinions by scientists that contradict those of feminist science scholars. We realize that there are many scientists, like Michael, who have read widely and yet choose to disagree with feminist scholarsí methodology and claims. Instead, we argue that scientists, like Michael, Linda, and Donna, can raise important questions about the currency, accuracy, and generalizability of feminist perspectives across science disciplines and recommend that feminist scholars more seriously consider how differences within the scientific enterprise can be addressed in feminist claims and theories. Are feminist accounts of gender and racial bias in questions and findings more germane to the life than physical sciences? to the past than the present? Do feminists equate norms and methods specific to physics as representative of all science disciplines? How does culture influence descriptions of objects and concepts in such "inanimate" fields as geology? We also contend that more can be learned from the experiences of real women and ethnic minority scientists, that feminist scholars should continue to use diverse experiences of scientists as points from which to theorize about the biased nature of science. How do women and minoritiesí experiences in physics differ from those in biology or geology? Why have more women decided to enter the life sciences in recent years than the physical sciences? Why do some members of underrepresented groups excel in science while others drop out? In short, we encourage feminist scholars of science to engage in open and extended dialogue with scientists. (We recognize such conversations have already been initiated in certain circles. Interested readers are encouraged to examine special volumes of the Journal of Women and Minorities in Science and Engineering [Kahle, 1998] and Osiris [Kohlstedt &

Longino, 1997].)

Given both sides of this feminism in science education issue, we struggled to create an internally consistent recommendation for professional developers and science education reformers. We asked ourselves: How important is it to encourage scientists to consider feminist views? And once they do, how does one manage the conflicts that inevitably arise when a scientistís conception of or experience with science differs from a feministís description? Whose conception do we privilege? Whose version of the story is more useful and for what purposes? To promote agency rather than alienation of scientists, professional developers must raise awareness of gender and racial bias in science while simultaneously respecting multiple, dissenting voices and experiences--a difficult task indeed. Recommending scientists look more closely at the intersection of views of students, classroom practice, and the nature of science is a potentially fruitful first step. Providing space for scientists to develop their own response to equity issues from their experiences-in-interaction-with-feminist-research will help create a more just and equitable science education for all.

References

Aikenhead, G. S., et al. (1987). High-school graduates' beliefs about science-technology-society. I. Methods and issues in monitoring student views. Science Education, 71(2), 145-161.

Banks, J. A. (1995). The historical reconstruction of knowledge about race: Implications for transformative teaching. Educational Researcher, 24(2), 15-25.

Banks, J. A. (1999). An introduction to multicultural education (2nd ed.). Boston, MA: Allyn and Bacon.

Barad, K. (1996). Meeting the universe halfway: Realism and social constructivism without contradiction. In L. H. Nelson & J. Nelson (Eds.), Feminism, science, and the philosophy of science (pp. 161-194). The Netherlands: Kluwer Academic Press.

Barton, A. C. (1998). Feminist science education. New York: Teachers College Press.

Brainard, S. G. (1994). The freshman intervention program. Final report to the Alfred P. Sloan Foundation. Seattle, WA: University of Washington.

Briggs, C. L. (1986). Learning how to ask: A sociolinguistic appraisal of the role of the interview in social science research. Cambridge, England: Cambridge University Press.

Eisenhart, M. (1994). Women scientists and the norm of gender neutrality at work. Journal of Women and Minorities in Science and Engineering, 1, 193-207.

Eisenhart, M. A., & Finkel, E. (1998). Womenís science: Learning and succeeding from the margins. Chicago: University of Chicago Press.

Fraser, B. J. (1978). Development of a Test of Science-Related Attitudes. Science Education, 62(4), 509-515.

Ginorio, A. B. (1995). Warming the climate for women in academic science. Washington, DC: Association of American Colleges and Universities.

Ginorio, A. B. et al. (1994, July). Patterns of persistence: Switching and attrition among science and engineering majors for women and men students at the University of Washington, 1985-1991. Final report to the Alfred P. Sloan Foundation. Seattle, WA: University of Washington.

Ginzberg, R. (1989). Uncovering gynocentric science. In N. Tuana (Ed.), Feminism and science (pp. 69 - 84). Bloomington, IN: Indiana University Press.

Gould, S. J. (1993). American polygeny and craniometry before Darwin. In S. Harding (Ed.), The racial economy of science (pp. 84-115). Bloomington, IN: Indiana University Press.

Gould, S. J. (1996). The mismeasure of man (2nd ed.). New York: Norton.

Haggerty, S. M. (1995). Gender and teacher development: Issues of power and culture. International Journal of Science Education, 17, 1-15.

Haraway, D. J. (1989). Primate visions: Gender, race, and nature in the world of modern science. New York: Routledge.

Harding, S. (1991). Whose science? Whose knowledge? Thinking from womenís lives. Ithaca, NY: Cornell University Press.

Harding, S. (1994). Is science multicultural? Configurations, 2, 301-330.

Harding, S. (1998). Is science multicultural? Bloomington, IN: Indiana University Press.

Hartsock, N. (1983). Money, sex, and power: Toward a feminist historical materialism. New York: Longman.

Hess, D. (1995). Science and technology in a multicultural world. New York: Columbia.

hooks, b. (1984). Feminist theory: From margin to center. Boston: South End Press.

Jones, L. R., Mullis, I. V.S., Raizen, S. A., Weiss, I. R., & Weston, E. A. (1992). The 1990 science report card: NAEPís assessment of fourth, eighth, and twelfth graders. Washington, DC: National Center for Education Statistics, Office of Educational Research and Improvement, U.S. Department of Education.

Kahle, J. B. (Ed.). (1998). [Special double issue]. Journal of Women and Minorities in Science and Engineering, 4 (2&3).

Kass-Simon, G., & Farnes, P. (Eds.). (1990). Women of science: Righting the record. Bloomington, IN: Indiana University Press.

Keller, E. F. (1977). The anomaly of a woman in physics. In S. Ruddick & P. Daniels (Eds.), Working it out (pp. 77-91). New York: Pantheon Books.

Keller, E. F. (1983). A feeling for the organism: The life and work of Barbara McClintock. New York: Freeman.

Keller, E. F. (1985). Reflections on gender and science. New Haven, RI: Yale University Press.

Kohlstedt, S. G. & Longino, H. (Eds.). (1997). Women, gender, and science: New directions [Special issue]. Osiris, 12.

Kuhn, T. (1970). The structure of scientific revolutions (2nd ed.). Chicago: University of Chicago Press.

Lapointe, A. E., Mead, N. A., & Phillips, G. W. (1989). A world of differences: An international assessment of mathematics and science. Princeton, NJ: Center for the Assessment of Educational Progress, Educational Testing Service.

Lewontin, R. C., Rose, S., & Kamin, L. J. (1993). IQ: the rank ordering of the world. In S. Harding (Ed.), The racial economy of science (pp. 142-160). Bloomington, IN: Indiana University.

Longino, H. (1990). Science as social knowledge: Values and objectivity in scientific inquiry. Princeton, NJ: Princeton University Press.

Malcom, S. M. (1993). Undergraduate and beyond: Letting nurture take its course. In D. C. Fort (Ed.), A hand up: Women mentoring women in science (pp. 181-193). Washington, DC: The Association for Women in Science.

Mayberry, M. (1998). Reproductive and resistant pedagogies: The comparative roles of collaborative learning and feminist pedagogy in science education. Journal of Research in Science Teaching, 35(4), 443-459.

McCormick, T. (1994). Creating the non-sexist classroom. New York: Teachers College Press.

McGinnis, J. R., & Pearsall, M. (1998). Teaching elementary science methods to women: A male professorís experience from two perspectives. Journal of Research in Science Teaching, 35(8), 919-949.

McIntosh, P. (1984). The study of women: Processes of personal and curricular revision. The Forum for Liberal Education, 6(5), 2-4.

Merchant, C. (1980). The death of nature. San Francisco: Harper & Row.

Mies, M., & Shiva, V. (1993). Ecofeminism. London: Zed Books.

Mishler, E. G. (1986). Research interviewing: Context and narrative. Cambridge, MA: Harvard University Press.

Muller, C. B., & Pavone, M. L. (1998). The women and science project at Dartmouth: One campus model for support and systemic change. In A. M. Pattatucci (Ed.), Women in science: Meeting career challenges (pp. 247-265). Thousand Oaks, CA: Sage Publications.

Narayan, U. (1989). The project of feminist epistemology: perspectives from a Nonwestern feminist. In A. Jagger and S. Bordo (Eds.), Gender/body/knowledge: Feminist reconstructions of being and knowing (pp. 255-269). New Brunswick, NJ: Rutgers University Press.

National Research Council. (1996). From analysis to action: Undergraduate education in science, mathematics, engineering, and technology: Report of a convocation. Washington, DC: National Academy Press.

National Science Foundation. (1996a). Shaping the future: New expectations for undergraduate education in science, mathematics, engineering, and technology. (A report on its Review of Undergraduate Education by the Advisory Committee to the Directorate for Education and Human Resources, NSF Publication No. 96-139). Arlington, VA: Author.

National Science Foundation. (1996b). Women, minorities, and persons with disabilities in science and engineering: 1996 [On-line]. Available Internet: http://www.nsf.gov/sbe/srs/nsf96311/.

Nieto, S. (1996). Affirming diversity: The sociopolitical context of multicultural education (2nd ed.). White Plains, NY: Longman Publishers.

Rennie, L. J., Parker, L. H., & Kahle, J. B. (1996). Informing teaching and research in science education through gender equity initiatives. In L. H. Parker, L. J. Rennie, & B. J. Fraser (Eds.), Gender, science, and mathematics: Shortening the shadow (pp. 203-222). Dordrecht, the Netherlands: Kluwer Academic Publishers.

Richardson, D. S., Sutton, C. J., & Cercone, K. R. (1995). Female-friendly geoscience: Eight techniques for reaching the majority. In S. V. Rosser (Ed.), Teaching the majority: Breaking the gender barrier in science, mathematics and engineering (pp. 183-192). New York: Teachers College Press.

Richmond, G., Howes, E., Kurth, L, & Hazelwood, C. (1998). Connections and critique: Feminist pedagogy and science teacher education. Journal of Research in Science Teaching, 35(8), 897-918.

Rodriguez, A. J. (1998). Strategies for counterresistance: Toward sociotransformative constructivism and learning to teach science for diversity and understanding. Journal of Research in Science Teaching, 35(6), 589-622.

Rosser, S. V. (1991). Female friendly science: Applying womenís studies methods and theories to attract students. New York: Teachers College Press.

Rosser, S. V. (1995). Teaching the majority: Breaking the gender barrier in science, mathematics and engineering. New York: Teachers College Press.

Rosser, S. V. (1997). Re-engineering female friendly science. New York: Teachers College Press.

Rossiter, M. W. (1982). Women scientists in America: Struggles and strategies to 1940. Baltimore, MD: Johns Hopkins University Press.

Rossiter, M. W. (1995). Women scientists in America: Before affirmative action, 1940-1972. Baltimore, MD: Johns Hopkins University Press.

Roth, W. M., & Lucas, K. B. (1997). From "truth" to "invented reality": A discourse analysis of high school physics studentsí talk about scientific knowledge. Journal of Research in Science Teaching, 34(2), 145-180.

Sanders, J., Campbell, P. B., & Steinbrueck, K. (1997). One project, many strategies: Making preservice teacher education more equitable. Journal of Women and Minorities in Science and Engineering, 3, 225-243.

Sands, A. (1993). Never meant to survive: A black womanís journey--an interview with Evelynn Hammonds. In S. Harding (Ed.), The racial economy of science (pp. 239-248). Bloomington, IN: Indiana University Press.

Schiebinger, L. L. (1989). The mind has no sex? Cambridge, MA: Harvard University Press.

Schuster, M., & Van Dyne, S. (1985). Womenís place in the academy: Transforming the liberal arts curriculum. Totowa, NJ: Rowman & Allanheld.

Seymour, E., & Hewitt, N. M. (1997). Talking about leaving: Why undergraduates leave the sciences. Boulder, CO: Westview Press.

Spradley, J. P. (1980). Participant observation. New York: Holt, Rinehart, & Winston.

Steele, C. M. (1997). A threat in the air. American Psychologist, 52(6), 613-629.

Stepan, N. L. (1996). Race and gender: The role of analogy in science. In E. F. Keller and H. E. Longino (Eds.), Feminism and science (pp. 121-136). Oxford: Oxford University Press.

Strauss, A. L. (1987). Qualitative analysis for social scientists. Cambridge: Cambridge University Press.

Tetreault, M. K. (1985). Stages of thinking about women: An experience-derived evaluation model. Journal of Higher Education, 5(4), 368-384.

The Biology and Gender Study Group. (1989). The importance of feminist critique for contemporary cell biology. In N. Tuana (Ed.), Feminism and science (pp. 172-187). Bloomington, IN: Indiana University Press.

Tobias, S. (1990). Theyíre not dumb, theyíre different. Tucson, AZ: Research Corporation.

Tobias, S. (1992). Revitalizing undergraduate science: Why some things work and most donít. Tucson, AZ: Research Corporation.

Traweek, S. (1988). Beamtimes and lifetimes: the world of high energy physics. Cambridge, MA: Harvard University Press.

Tuana, N. (1995). The values of science: Empiricism from a feminist perspective. Synthese, 104(3) 441-461.

Vetter, B. M. (1996). Myths and realities of women's progress in the sciences, mathematics, and engineering. In C. Davis, A. B. Ginorio, C. S. Hollenshead, B. B. Lazarus, P. M. Rayman, & Associates (Eds.), The equity equation: Fostering the advancement of women in the sciences, mathematics, and engineering (pp. 29-56). San Francisco: Jossey-Bass Publishers.

Wertheim, M. (1995). Pythagorasí trousers. New York: W. W. Norton.

Willis, S. (1996). Gender justice and the mathematics curriculum: Four perspectives. In L. H. Parker, L. J. Rennie, & B. J. Fraser (Eds.), Gender, science, and mathematics: Shortening the shadow (pp. 41-52). Dordrecht, the Netherlands: Kluwer Academic Publishers.

Table 1

Survey Items, Means, and Standard Deviations

	Pre-test	Post-test
Survey Item	Mean SD	Mean SD
1. I doubt that my own classroom behaviors alienate people of certain genders and/or ethnicities	3.81 .88	3.50 1.00
2. I would like to make changes in the content and instructional strategies of my course to better reach students of both genders and all ethnicities.	4.11 .89	4.10 .79
3. I feel that there is very little that can be done to improve the performance of female and/or ethnic minority students in my class, beyond what I have already implemented.	2.33 .92	2.05 1.00
4. Feminism and multiculturalism offer important perspectives for science and science education.	3.70 .95	4.35 .67
5. Science is beneficial.	4.81 .40	4.65 .59
6. Science is competitive.	4.04 .94	4.15 .93
7. Science is intimidating.	3.04 1.06	2.80 1.11
8. Science is creative.	4.44 .64	4.60 .82
9. Science is Euro-centric.	3.36 1.04	3.65 .93
10. Almost anyone can understand science if she/he studies it enough.	3.85 .82	3.50 1.10
11. My image of a scientist is that of an older, white man.	2.19 1.04	2.05 1.05

12. I am well informed about the contributions of women and ethnic minority scientists.	2.74 .98	2.75 .91
13. There are many more male scientists than female scientists because men seem to have more scientific ability than women.	1.33 .48	1.17 .38
14. There are many more male scientists than female scientists because schools have not done enough to encourage women to take science courses and excel in them.	3.74 1.06	3.83 .92
15. Scientists are always open-minded, logical, unbiased, and objective in their work.	2.11 .97	1.44 .62
16. Scientific research is often influenced by the experiences, interests, and values of the scientist.	4.19 .56	4.56 .51
17. Science and society influence each other; science shapes and reflects the current cultural and political context.	3.93 .68	4.28 .57
18. I promote an environment which is supportive of male and female students, ethnic minority and white students equally.	4.26 .53	4.22 .55
19. I consistently use inclusive language in lectures, handouts, & exams.	3.81 .62	3.82 .73
20. I ask and field questions from male and female students, ethnic minority and white students equally.	4.41 .69	4.06 .66
21. When referring to an individual in an example, I use a female pronoun or ethnically diverse name roughly half the time.	3.58 .90	3.94 1.52
22. I interact equally with female and male students, white and ethnic minority students during class and office hours.	4.33 .78	4.18 .64
23. I make a point of providing equal mentoring to all students, female or male, ethnic minority or white.	4.37 .74	4.24 .83
24. I plan on incorporating a wider array of instructional strategies in my courses.	4.00 .68	4.29 .85
25. I plan on incorporating a wider array of assessment strategies to determine student learning.	3.56 .64	3.65 .86
26. The content of my course incorporates approximately one lectureís worth (or more) of material detailing the contributions of women and ethnic minorities.	2.56 1.15	2.65 .86

27. The content of my course incorporates approximately one lectureís worth (or more) of material discussing sciences in other cultures.	2.12 .82	2.12 .70
28. I plan on discussing the contributions of women and ethnic minorities in science with my teaching assistant(s).	3.45 .83	3.42 .79
29. I plan on discussing instructional and/or assessment strategies presented in the Women and Science project with my teaching assistant(s).	4.05 .89	3.77 .44

Figure Captions

Figure 1. Pre-test interview questions.

PROMOTING WOMEN AND SCIENTIFIC LITERACY

PRE-TEST FACULTY INTERVIEW

1. What courses do you regularly teach? What courses might you teach in the future?

2. Describe the organization and content of your syllabus.

3. Describe each of the instructional strategies you currently use in the classroom and/or lab. How do you think each influences student participation and learning?

4. Describe some of the assessment strategies that you currently use. How do you think each of these strategies influences student achievement?

5. In what ways have you tried to provide an inclusive environment in the classroom?

ï Do you employ the use of inclusive language?

ï Do you use examples with female and ethnic minority referents?

ï Do you specifically lecture about the contributions of women & ethnic minorities? How much?

6. How do you incorporate information about the sciences of other cultures into your courses? Why do you (or do you not) do so?

7. In what ways might the behaviors of an instructor create or perpetuate inequities in the science classroom?

8. What are some of the common gender and ethnic stereotypes related to science and/or science education?

9. In what ways do males and females differ in terms of their science-related attitudes, experiences and achievement prior to college? ...during college? ...in a science-related

career?

10. What are some of the ways in which science curricula have failed to adequately address issues related to women and minorities in the classroom?

11. What are some of the ways that women and ethnic minorities have contributed to science?

12. What are your thoughts about feminism? multiculturalism?

13. What do you see as the relationship between science and society?

14. Briefly describe how students learn science.

15. Do you have any questions for us?

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Author(s): Bianchini, Julie A.; Whitney, David J.; Breton, Therese D.; and Hilton-Brown, Bryan A.

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Signature: Julie A. Bianchini

Printed Name/Position/Title: Julie A. Bianchini, Assistant professor of science education

Organization/Address: University of California, Santa Barbara

Telephone: 805.893.4110

Fax: 805.893.7264

E-mail Address: jbianchi@education.ucsb.edu

Date: 8.18.00

Address: University of California Dept of Education Santa Barbara, CA 9310

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