Toward Inclusive Science Education: University Scientists' Views of Students, Instructional Practices, and the Nature of Science

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ABSTRACT: This study examined the perceptions and self-reported practices of 18 scientists participating in a yearlong seminar series designed to explore issues of gender and ethnicity in science. Scientists and seminar were part of the Promoting Women and Scientific Literacy project, a curriculum transformation and professional development initiative undertaken by science, science education, and women's studies faculty at their university. Researchers treated participating scientists as critical friends able to bring clarity to and raise questions about conceptions of inclusion in science education. Through questionnaires and semistructured interviews, we explored their (a) rationales for differential student success in undergraduate science education; (b) self-reports of ways they structure, teach, and assess courses to promote inclusion; and (c) views of androcentric and ethnocentric bias in science. Statistical analysis of questionnaires yielded few differences in scientists' views and reported practices by sex or across time. Qualitative analysis of interviews offered insight into how scientists can help address the problem of women and ethnic minorities in science education; constraints encountered in attempts to implement pedagogical and curricular innovations; and areas of consensus and debate across scientists and science studies scholars' descriptions of science. From our findings, we provided recommendations for other professional developers working with scientists to promote excellence and equity in undergraduate science education. *Sci Ed* **86:**42–78, 2001.

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INTRODUCTION

> *All students [must] have access to supportive, excellent undergraduate education in science, mathematics, engineering, and technology . . . America's 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.*
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> National Science Foundation [NSF], 1996, 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 above mandate put forth by NSF (1996) is just one of many examples (see also Ginorio, 1995; Malcom, 1993; National Research Council [NRC], 1996a; Rosser, 1991, 1995, 1997; Tobias, 1990, 1992; Vetter, 1996). In response to such calls, faculty at a comprehensive university in California embarked on a curriculum and professional development initiative designed to transform their undergraduate science courses. Begun in 1997, their Promoting Women and Scientific Literacy project was part of a national, 3-year effort to facilitate communication among women's studies and science faculty, and to infuse recent feminist science studies scholarship into undergraduate courses toward the goal of increasing scientific literacy for all students. The larger national project, Women and Scientific Literacy: Building Two-Way Streets, included 10 institutions of higher education, was coordinated by the Association of American Colleges and Universities, and received funding from NSF (see AAC&U, 1999b, for more information about this larger project).

This study investigated the perceptions and self-reported practices of 18 scientists participating in the first year of the Promoting Women and Scientific Literacy curricular transformation and professional development process. These scientists attended a yearlong seminar series designed both to heighten their awareness of issues related to gender and ethnicity in science, and to change their course content and patterns of instruction accordingly. Researchers administered questionnaires and conducted semistructured interviews both prior to and following the professional development seminar sessions. Using statistical and qualitative methods, we explored scientists' (a) rationales for differential student success in science education; (b) self-reports of ways they structure, teach, and assess their courses to promote inclusion; and (c) views of the nature of science as a gendered and/or raced enterprise. Statistical analysis of questionnaires yielded few differences in scientists' views and reported practices by sex of participant or across time of project. Qualitative analysis of interviews offered insight into the range of scientists' goals, beliefs, and practices regarding inclusive science education, as well as identified points of agreement and areas of conflict across their views: Scientists described steps they and their students could take to help address the "problem" of women and ethnic minorities in science; discussed institutional and disciplinary constraints to pedagogical and curricular innovations; and voiced both support for and disagreement with science studies scholars' descriptions of science. From our findings, we provided recommendations for professional developers working with scientists around issues of inclusion; we drew from the views and practices of the scientists in our study to inform future professional development endeavors.

CONCEPTUAL FRAMEWORK

As stated earlier, the purpose of this paper was to examine scientists' beliefs and experiences related to issues of gender and ethnicity in science, to provide a foundation for ways scientists and science educators can assist each other in building more just and equitable undergraduate science education programs. At present, there are few studies that explore professional development opportunities for university scientists around issues of inclusion (see for exceptions, Muller & Pavone, 1998; Rosser, 1997; Sanders, Campbell, & Steinbrueck, 1997). Studies at the K-12 preservice and inservice levels also have a short history, but are more abundant (Haggerty, 1995; McGinnis & Pearsall, 1998; Rennie, Parker, & Kahle, 1996; Richmond, Howes, Kurth, & Hazelwood, 1998; Rodriguez, 1998; Southerland & Gess-Newsome, 1999). In particular, Richmond et al. (1998) explored prospective and practicing teachers' resistance to recognizing inequities in science classrooms and/or implementing inclusive pedagogical strategies taught in science methods courses. They also examined how these teachers' ideas about and reactions to feminist theory could inform their own and other teacher educators' practices. We followed their lead in this paper: We too attempted to learn from our participants about ways to better address issues of inclusion through professional development opportunities.

Because the professional development of science educators around issues of inclusion is an emerging area of research, the authors of this study thought it important to 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 was informed by three areas of science education and science studies scholarship: research on female and ethnic minority students' experiences in science education, proposed models of inclusive science instruction, and descriptions of androcentric and ethnocentric bias in science. Here, we examine each of these areas in turn.

The Problem of Underrepresented Groups in Science Education: Why Don't All Students Succeed?

Myriad studies document the numbers and experiences of underrepresented groups in science education (for examples specific to undergraduate science education, see Ginorio, 1995; Malcom, 1993; NSF, 1998; Seymour & Hewitt, 1997; Vetter, 1996). The message from these reports is simple: In the United States, women and ethnic minority students do not have the same opportunities to succeed in science as European American men. Although women have earned a majority of bachelor's degrees since 1982, for example, they do not constitute the majority of any natural science graduates except in the biosciences (NSF, 1998; Vetter, 1996). Women and ethnic 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 (Arnold, 1995; 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). Ethnic minority students who switch out of science, mathematics, or engineering differ from European American 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, 1998).

These and other descriptions of underrepresented groups' 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" (Ginorio, 1995, p. vi).

Ginorio, a women's studies scholar, crafted a series of recommendations for warming the science education climate from her examination of the problem of differential student success; she argued that the way instructors frame this problem influences their identification of possible solutions. 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 many diverse places as possible. Once students arrive on campus, instructors can treat them as all the same, attend to only those who are thriving, or provide what each student needs. Decisions about how to view and treat students, she argued, translate into student success and retention in science. At one level, Ginorio continued, this allegory can be understood to address questions about who belongs in science. In the past, women, ethnic minorities, and students with disabilities were seen as specimens not fit for life in the conservatory. Instructors asked, "Why do not all students flourish?" and answered that some simply do not belong. Today, because instructors are encouraged to begin with a different question, "Is the problem something we are doing?" they can develop solutions that involve themselves and their institutions rather than students. At a second level, the allegory can inform discussion of desired outcomes of undergraduate science education. Read this way, in the past, most scientists and universities focused their attention on students who were thriving. In contrast, because today's students are more diverse and because there is a new emphasis on helping all students excel in science, instructors should be encouraged to view all students as academically able and to help each succeed. Indeed, this "what each student needs" (p. 1) approach was championed in the Promoting Women and Scientific Literacy Project under investigation.

Willis (1996) agreed that how instructors frame the problem of underrepresented student groups influences their identification of means to its solution. One perspective on underrepresentation, that of the disadvantaged learner, views some students as unprepared to excel in science because of their gender, ethnicity, class, and/or ability. For educators who view the problem of underrepresentation in this way, Willis explained, the solution becomes to provide those students who are "deficit" with the missing attitudes, knowledge, skills, or experiences needed to succeed. A second perspective, the nondiscriminatory perspective, understands the problem of underrepresented groups to reside with the enacted curriculum and instruction. Given this framing of the problem, educators describe the solution as ensuring all students have equal opportunity to succeed: They think it vital to consider students' background and experiences; to eliminate inequitable curriculum materials and instructional strategies; and to incorporate nonsexist, nonracist, and/or nonclassist content and practices. The third perspective, Willis continued, is the inclusive perspective. From this perspective, the intended science curriculum is viewed as problematic; science content and sequence are seen to reflect the dominant culture's values, views, and practices and to exclude the interests, experiences, and needs of students from the margins. 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). Willis' 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 understand 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 stated earlier, the ways instructors frame the problem of underrepresentation in science education shapes identification and enactment of possible solutions. 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 (Banks, 1995, 1999; Barton, 1998; Mayberry, 1998; Mayberry & Rose, 1999; McCormick, 1994; Nieto, 1996, 1999; Rodriguez, 1998; Rosser, 1991, 1995, 1997). Coherent curricular and pedagogical models designed to promote the 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; these models reflect both the ideas examined in our professional development seminar series and our second set of research questions posed later.

Rosser's female-friendly model of pedagogical and curricular transformation (Rosser, 1991, 1995, 1997) 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). Rosser's model outlines six 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 the Promoting Women and Scientific Literacy Project, participants were encouraged to move through as many of Rosser's phases as able. In phase I of her model, the absence both of women in the scientific enterprise and of women's issues in the science curriculum is not recognized. In phase II, faculty become aware that most scientists are men, that science may reflect a masculine perspective, and that traditional science teaching rarely reflects the perspectives and experiences of underrepresented groups. During phase III, Rosser continued, there is identification of barriers that prevent women from pursuing science and discussion of strategies found successful in eliminating them. Faculty initiate research of women scientists and their long history of unique contributions in phase IV. In phase V, the work of women and men scientists is compared, and differences in articulation of theories and approaches to subjects are examined. Finally, in phase VI, science is transformed to interest and retain all students. The ultimate goal of Rosser's 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" (Rosser, 1995, p.17).

In contrast to Rosser, Banks (1999) outlined a model of instruction that examines issues of multiculturalism more prominently than those of gender, encompasses the whole of K-16 education, and applies to all disciplines. Banks identified four approaches to the integration of multicultural content into K-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. A second approach, termed by Banks the additive approach, integrates cultural content, concepts, and themes into the curriculum by adding a book, unit, or special course; the curriculum's basic structure remains intact. These first two approaches, Banks continued, fail to challenge the perspective and organization of the curriculum: When these approaches are used, people, events, and interpretations related to ethnic groups and women continue to reflect the norms and values of the dominant culture rather than those of cultural communities. In contrast, the third, or transformative, approach enables students to consider concepts, events, and people from diverse perspectives; to understand knowledge as socially constructed; 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. Difficulties Promoting Women and Scientific Literacy participants experienced in attempting to transform both content and pedagogy are discussed in our Results and Implications sections later.

Science Studies Scholars' Descriptions of Androcentric and Ethnocentric Bias in 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, science studies scholars, implicate the nature of science in the marginalization of women and ethnic minorities: They examine how the constructs of gender, race, culture, and/or class are inscribed in science. Some feminist scholars attempt to explain science as an enterprise created and controlled by White men. From science's inception, they argue, European and European American 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; Traweek, 1988; Wertheim, 1995). This first cluster of feminist science studies work was most heavily emphasized in the Promoting Women and Scientific Literacy project. In her now classic biography of Barbara McClintock, for example, Keller (1983, 1985) claimed the Nobel prize-winning plant geneticist enjoyed success and endured marginality because both her research methodology and gender differed from the norm. McClintock's 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.

Other science scholars provide important evidence for the "invention" rather than "discovery" of nature. They describe science as a human activity embedded in the larger society; point to the myriad examples of androcentric and ethnocentric bias in past and present scientific research questions, methodological practices, and theoretical constructs; and 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, 1996; Haraway, 1989; Haraway & Goodeve, 2000; Harding, 1998; Lewontin, Rose, & Kamin, 1993; Martin, 1999; Merchant, 1980; Mies & Shiva, 1993; Schiebinger, 1999; Spanier, 1995; Stepan, 1996; The Biology and Gender Study Group, 1989). Stepan (1996), for example, described how racism and sexism permeated the biosocial study of human variation in the nineteenth and early twentieth centuries: Phrenologists, Stepan explained, used differences in the shape and size of human skulls to argue that Black men could represent themselves and their Black sisters, Black men could be compared to White women, and these two groups could then be contrasted with the superior White man. (See Gould, 1996, for additional discussion of gender, class, and racial bias in craniometry, as well as in intelligence testing.) Starting from the politics and theories of feminism and antiracism, Haraway (1989) traced changes in the initial androcentric assumptions, language, and theories of primatology; she examined how the infusion of women into the primatology field helped reshape stories constructed by scientists to explain primate behavior and social organization.

Still other science studies scholars render problematic conventional definitions of science, raising epistemological questions about the nature of scientific knowledge, its research methods, and whose knowledge and practices should count as science (Barad, 1996; Harding, 1991, 1994, 1998; Hart, 1999; Hartsock, 1983; Hess, 1995; Keller, 1985; Longino, 1990; Narayan, 1989; Tuana, 1995; Weatherford, 1993). Drawing from postcolonial studies, for example, Harding (1994) argued that the modern sciences should be viewed not as transcending culture but rather as having multicultural roots and embodying distinctively Western values and beliefs. Rejection of the modern sciences as acultural and universal, Harding explained, "can lead to far more accurate and valuable understandings, not only of other cultures' scientific legacies, but also of rich possibilities in the legacy of European culture and practice" (p. 330). Weatherford (1993) provided one example of early non-Western science: He argued that the Andean Indians' work to domesticate the potato be viewed as agricultural experimentation. Hart (1999) agreed that claims of science as uniquely Western ignore the substantial evidence that many forms of knowledge and practices called science existed in other cultures, particularly China. To begin to understand the existence of science across cultures, Hart continued, scholars must question their assumption that China and the West have been and remain fundamentally different; "it is through the narration of stories about radical differences that the antithetical communities of 'China' and the 'West' are imagined" (p. 197).

RESEARCH QUESTIONS

To investigate scientists' conceptions of inclusive science education within a professional development seminar series, we crafted three sets of research questions. At the outset, we decided that the questions should place less emphasis on tracing changes across participants' views as a result of the seminar and give greater weight to identifying the range and prevalence of ideas scientists expressed. We started from the knowledge that those participating in our study held varied expertise related to inclusive science education, that we had much to learn from our participants about issues of underrepresentation in the sciences. Questions were fashioned to reflect both our study's purpose—to consider how ideas voiced and concerns raised by scientists could inform science educators' conceptions of inclusive practice and their creation of professional development opportunities—and the ideas put forth in our Conceptual Framework—recommendations for eliminating differential student success in science, models of inclusive science education, and recent science studies scholarship on the nature of science. Research questions 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 minorities' experiences in science and through reflection on how challenges faced by these underrepresented groups can be effectively framed: How did the scientists in our study explain differential student success in their undergraduate science courses? What responsibilities did they see students as shouldering for their own academic progress? What role did they think instructors played? What factors external to student and instructor did they identify as influencing student retention and achievement in science as well? From our review of inclusive instructional models, we created a second set of questions: How did participants attempt to address issues of inclusion through their course content, instruction, and assessments? What reasons did they give for their acceptance or rejection of new ideas and/or instructional innovations? What factors did scientists identify as constraints to their implementation of particular female-friendly or culturally inclusive strategies? And from our examination of science studies scholarship, we thought it important to ascertain scientists' conceptions of the nature of science, to determine in what ways and to what extent scientists saw aspects of the scientific enterprise as gendered and/or raced. We thus fashioned a third set of questions: How did scientists understand the nature of science? How did their descriptions of inequities within the scientific enterprise resonate or conflict with those proposed by recent science studies scholarship? What concerns or criticisms did they raise in response to science studies' claims and recommendations?

SETTING, SAMPLE, AND METHODOLOGY

As stated in the Introduction, our study investigated the views of 18 scientists employed at a public, urban university and involved in a project to transform undergraduate science education. Using questionnaires and interviews coupled with statistical and qualitative methodologies, we attempted to provide critical insight into the three sets of research questions posed earlier. Here we describe in greater detail the goals and structure of the Promoting Women and Scientific Literacy project, its project participants and research team, and the methods used to study scientists' views during the first year of its implementation.

Promoting Women and Scientific Literacy: A Project Overview

The participants studied here were part of a Promoting Women and Scientific Literacy project sponsored by the University's College of Natural Sciences and Mathematics. They were also members of a national initiative, Women and Scientific Literacy: Building Two-Way Streets, coordinated by the Association of American Colleges and Universities and funded by NSF. The local project's purpose was to make the university's undergraduate science education program more inclusive, to better meet the needs of the many women and ethnic minority students enrolled in both major and general education science courses. It had three primary goals: one, to increase science faculty's 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 encourage movement of the undergraduate science program toward the goal of scientific literacy for all students.

To help achieve these stated goals, during the 1997–98 academic year, monthly professional development seminar sessions were held to inform scientists about issues related to gender and ethnicity in science and science education, as well as to assist them in their efforts to make targeted undergraduate courses more interesting and understandable to women and ethnic minorities. Sessions ranged in length from brown bag seminars to all-day workshops. 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 initially organized by the first author, a science educator at a nearby university, in consultation with a women's studies professor and, to a lesser extent, with faculty participants. During the second semester, greater responsibility for selecting session topics and making presentations shifted from the science educator to the scientists involved in the project. Guest speakers from the sciences, science education, and women's studies regularly led seminar sessions; they 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, selected passages from books, and university pamphlets and brochures. For many faculty participants, these readings served as introductions to both the fields of science education and science studies scholarship. (For more information about the professional development seminar sessions, please see Bianchini, Hilton-Brown, and Breton, 2000.)

Participating Scientists and Science Education Researchers

Participants in the Promoting Women and Scientific Literacy project taught at a comprehensive university in California with a large and diverse student body. Approximately 30,000 students were enrolled: 63% female and 37% male; 36% White, 21% Latino/a, 19% Asian American, 7% African American, and 8% other. Of the 18 participating scientists, 10 had careers in the biological sciences, 4 in chemistry or biochemistry, 2 in geology, and 1 each in physics and science education. Nine women self-identified as European American; one woman, as Asian American; four men, as European American; 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. Tenure in their position ranged from 1 to over 30 years.

It is important to note the sample of 18 scientists was not random. Five participants were part of a 10-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 studies scholarship sponsored by AAC&U in an effort to better understand 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. Approximately 20 additional 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 series and invited to participate. Several faculty declined due to time constraints, and several others thought the initiative was unnecessary; in the end, 13 additional faculty agreed to join the project. As with the team members, most of these additional faculty participants held a long-time commitment to improving undergraduate education in general, and to addressing issues of women and ethnic minorities in science in particular. Project participants received a small stipend for their efforts: They were paid $600 for attending the yearlong workshop series and documenting revisions to their targeted science courses.

Four researchers also participated in this study; to promote reflexivity, we thought it imperative to situate the researchers as well as our participants within the research process (Bloor, 1976; Kelly, Chen, & Crawford, 1998; Rodriguez, 1998; Woolgar, 1988). The first author is a European American woman and an assistant professor of science education. Julie Bianchini served as a member of the 10-person Promoting Women and Scientific Literacy team, was responsible for implementing the yearlong professional development seminar series, and was codirector of the project's evaluation. Trained primarily in qualitative methodology, she took responsibility for analysis of scientists' interviews. The second author is a European American man and an associate professor of psychology. David Whitney also served as a member of the 10-person project team. He attended the professional development seminar series as a participant, served as coevaluator of the project, administered pre- and postfaculty questionnaires, and conducted all semistructured interviews. Trained in statistical methods, he analyzed the questionnaire data of this study. The third and fourth authors are graduate students in science education. Therese Breton is a European American woman; Bryan Hilton-Brown, an African American man. Both assisted in the qualitative analysis of interview data.

Research Methodology

The present study examined faculty perceptions of issues of gender and ethnicity in science prior to and after completion of 1 year of professional development activities. We were particularly interested in the extent to which faculty achieved consensus on their views, the conceptual and instructional dilemmas they resolved over time, and the questions that persisted. Given their strong commitment to their own disciplines and their previous consideration of issues related to educational innovation, we hoped to capture scientists' 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 earlier, we focused our efforts on three areas: their understanding of differential student success, their implementation of inclusive content and instruction, and their perceptions of the nature of science.

Data for this study were collected at two times during the 1997–98 academic year: Both closed-ended surveys and semistructured interviews were administered prior to participation in the professional development seminar and again following the last workshop session of the year. The pre- and postquestionnaires were used to broadly assess scientists' perceptions related to their students' interests and abilities, inclusive science education practices, and the nature of science. The 29-item questionnaire administered to participating scientists closely matched a questionnaire developed for undergraduates involved in this same project; we included the same items in the scientist and student questionnaires so as to be able to compare responses across groups (which we will do in a separate paper). Questionnaire items were developed to reflect the project's three primary goals. They were often fashioned after those found in other surveys used to examine students' attitudes toward science, their experiences in science classrooms, and their perceptions of science's nature (see Aikenhead et al., 1987; Fraser, 1978; Jones, Mullis, Raizen, Weiss, & Weston, 1992; Lapointe, Meed, & Phillips, 1989). The postquestionnaire was also virtually identical to the prequestionnaire: The postsurvey included additional items to ascertain the 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 5-point, Likert-type rating scale. Surveys were completed in approximately 10 min. Table 1 presents each of the survey items.

Pre- and postquestionnaire data were analyzed using statistical methods. Item means and standard deviations were examined to determine the level of endorsement for 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- and postsurveys. 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 responses, (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, semistructured faculty interviews were conducted before and after the yearlong professional development seminar series. The same interviewer (the second author of this paper) 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. The pre- and postinterview questions were similar, although the postinterview protocol included questions which focused on changes implemented in the targeted introductory science course. A copy of the preinterview protocol is presented in Figure 1.

TABLE 1
Questionnaire Items, Means, and Standard Deviations

Survey Item	Pre		Post	
	M	SD	*M*	SD
1. I doubt that my own classroom behaviors alienate people of certain genders and/or ethnicities.	3.81	0.88	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	0.89	4.10	0.79
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	0.92	2.05	1.00
4. Feminism and multiculturalism offer important perspectives for science and science education.	3.70	0.95	4.35	0.67
5. Science is beneficial.	4.81	0.40	4.65	0.59
6. Science is competitive.	4.04	0.94	4.15	0.93
7. Science is intimidating.	3.04	1.06	2.80	1.11
8. Science is creative.	4.44	0.64	4.60	0.82
9. Science is Euro-centric.	3.36	1.04	3.65	0.93
10. Almost anyone can understand science if she/he studies it enough.	3.85	0.82	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	0.98	2.75	0.91
13. There are many more male scientists than female scientists because men seem to have more scientific ability than women.	1.33	0.48	1.17	0.38
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	0.92
15. Scientists are always open-minded, logical, unbiased, and objective in their work.	2.11	0.97	1.44	0.62
16. Scientific research is often influenced by the experiences, interests, and values of the scientist.	4.19	0.56	4.56	0.51
17. Science and society influence each other; science shapes and reflects the current cultural and political context.	3.93	0.68	4.28	0.57
18. I promote an environment which is supportive of male and female students, ethnic minority and White students equally.	4.26	0.53	4.22	0.55
19. I consistently use inclusive language in lectures, handouts, and exams.	3.81	0.62	3.82	0.73
20. I ask and field questions from male and female students, ethnic minority and White students equally.	4.41	0.69	4.06	0.66
21. When referring to an individual in an example, I use a female pronoun or ethnically diverse name roughly half the time.	3.58	0.90	3.94	1.52

Continued

TABLE 1
Questionnaire Items, Means, and Standard Deviations *(Continued)*

Survey Item	Pre *M*	Pre SD	Post *M*	Post SD
22. I interact equally with female and male students, White and ethnic minority students during class and office hours.	4.33	0.78	4.18	0.64
23. I make a point of providing equal mentoring to all students, female or male, ethnic minority or White.	4.37	0.74	4.24	0.83
24. I plan on incorporating a wider array of instructional strategies in my courses.	4.00	0.68	4.29	0.85
25. I plan on incorporating a wider array of assessment strategies to determine student learning.	3.56	0.64	3.65	0.86
26. The content of my course incorporates approximately one lecture's worth (or more) of material detailing the contributions of women and ethnic minorities.	2.56	1.15	2.65	0.86
27. The content of my course incorporates approximately one lecture's worth (or more) of material discussing sciences in other cultures.	2.12	0.82	2.12	0.70
28. I plan on discussing the contributions of women and ethnic minorities in science with my teaching assistant(s).	3.45	0.83	3.42	0.79
29. I plan on discussing instructional and/or assessment strategies presented in the Women and Science project with my teaching assistant(s).	4.05	0.89	3.77	0.44

Demographic information was also collected: sex, ethnicity, university employment status (full-time or part-time), and tenure. The length of the interviews varied depending upon participants' responses; interviews were generally completed in 40–50 min. 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 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: reasons for student success (or lack thereof) in science courses, inclusive course content and instruction, and views of the nature of science. Although categories and subcategories were subsequently constructed, we decided not to divide interview data by sex of participant or by time of interview. (These decisions were supported by statistical analysis of questionnaire data; see Results section.) The first, third, and fourth authors each took primary responsibility for coding interview data in one of the 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. Each researcher also completed the coding and domain construction process twice for her or his assigned domain. The first author checked the three sets of codes for accuracy. To answer our research question, "How do scientists understand differential student success in science courses?" for example, we grouped participants' views into three categories under the domain student success: student choice, instructors' roles and responsibilities, and external constraints and pressures. We then created subcategories within each.

PROMOTING WOMEN AND SCIENTIFIC LITERACY
FACULTY PREINTERVIEW

1. What courses do you regularly teach? What courses might you teach in the future?
2. Describe the organization and content of your syllabus for your targeted course.
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?
   - Do you employ the use of inclusive language?
   - Do you use examples with female and ethnic minority referents?
   - Do you specifically lecture about the contributions of women and 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?

Figure 1. Preinterview questions.

RESULTS OF QUESTIONNAIRE AND INTERVIEW DATA

From our analyses of closed-ended questionnaires and semistructured interviews, we present scientists' perspectives on three aspects of inclusion: differential student success, science curriculum and instruction, and the nature of science. We begin with an overview of scientists' 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 scientists' 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.

Analysis of Questionnaires: An Overview of Scientists' Conceptions of Inclusion

As stated earlier, scientists' survey data provided a foundation for and guide to analysis of their interviews. To facilitate understanding of the questionnaire data, we rationally sorted survey items into three categories of interest: (a) perceptions of differential student success, (b) self-reports of inclusive curriculum and instruction, and (c) views of the nature of science. These categories were used during the item development phase, and are employed later to guide explanation of the results. Pre- and postmean responses to survey items are presented in Table 1. As is evident from the Table, participants' views did not shift noticeably from pre-to postsurveys. (Responses to those few items that changed significantly over time are discussed in detail at the end of this section.)

Participants' responses to questions about students' experiences in science, their educational practice, and their views of the nature of science reflected at least partial alignment with the goals of the Promoting Women and Scientific Literacy project and supported our decision to treat participants as critical friends. Three items on the survey, for example, were thought to represent faculty perceptions of students (items 10, 13, and 14). Across pre- and postsurveys, science faculty endorsed the idea that anyone can learn science if he or she studied sufficiently. They also thought that the presence of more men than women in science was better explained by a failure of schools to encourage women, than by gender differences in scientific ability. Fifteen survey items were developed to assess faculty instructional strategies (items 1–3 and 18–29). On the pre- and postsurveys, faculty indicated a fairly high level of awareness of the need for inclusive pedagogy. Participants reported implementation of a wide variety of innovative 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 lecture's worth of material discussing the sciences of other cultures or the contributions of women and ethnic minorities to science. Finally, 11 of the survey items were considered indicators of faculty views on the nature of science (items 4–9, 11, 12, and 15–17). Low levels of endorsement were found in the pre- and postquestionnaires 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 later). Not surprisingly, the nature of science items most strongly endorsed by science faculty reflected perceptions of science as a creative endeavor and as beneficial to humanity.

Additional statistical analysis of survey data was performed using repeated measures multiple analysis of variance (MANOVA) to check for significant differences in responses across participants' sex, time of administration, or an interaction of these two variables. (Because of small sample sizes, examination of participants' responses by ethnicity was not conducted.) No significant sex by time interactions were found for any of the 29 survey items. In other words, the professional development series did not have a differential influence on female and male participants over time. A few 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 were developed to assess perceptions of the nature of science. Specifically, in comparison to male faculty participants, female scientists did not as strongly endorse the item, "Scientists are always open-minded, logical, unbiased, and objective in their work," across the pre- and posttime periods combined, $F(1, 15) = 4.56$, $p = 0.05$. The combined mean for female faculty was 1.56 (SD = 0.77) while the combined mean for male faculty was 2.26 (SD = 0.78). In addition, 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, $F(1, 15) = 7.23$, $p < 0.05$. The combined mean for female faculty was 4.56 (SD = 0.46) while the combined mean for male faculty was 4.19 (SD = 0.41). No sex differences in responses were found across the remaining 27 items. The fact that there were few significant differences between male and female participants' responses was used to inform our analysis of the interview data: We did not deem it necessary to divide scientists' interview responses by their sex.

A significant main effect across time was also found for 4 of the 29 items (see Table 1 for means and standard deviations of pre- and postquestionnaire items). Two changes related to participants' implementation of inclusive instructional strategies. In their postquestionnaires, as was expected, scientists more strongly endorsed the statement, "The content of my course incorporates approximately one lecture's worth (or more) of material detailing the contributions of women and ethnic minorities," $F(1, 14) = 7.12$, $p < 0.05$. Their intentions to discuss "instructional and/or assessment strategies" with their teaching assistants, however, decreased, $F(1, 9) = 8.44$, $p < 0.05$. Since not all instructors were assigned teaching assistants, the sample size for this item was very limited ($N = 11$). Two additional changes in participants' 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," $F(1, 16) = 7.27$, $p < 0.05$, while they decreased their level of endorsement for the statement, "Scientists are always open-minded, logical, unbiased, and objective in their work," $F(1, 15) = 10.41$, $p < 0.05$. Because we found few significant differences in participants' responses over time in the questionnaire data, in our analysis of interviews, we decided to focus on what we could learn from scientists about inclusive science education rather than examine changes in scientists' views from pre to post.

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

With an overview of participants' attitudes and self-reported practices in hand, we turned to examination of pre- and postinterviews. Our intent was to marshal data to inform the design and implementation of future professional development opportunities around issues of inclusion: Given participating scientists' 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 during a curriculum transformation and professional development project. Here, we discuss questions raised and answers fashioned by these scientists along three dimensions introduced in our Conceptual Framework and targeted in our research questions: (a) scientists' views of differential student success; (b) their self-reported implementation of inclusive curricular and pedagogical strategies; and (c) their understanding of the gender/less and a/cultural nature of science.

Can All Students Succeed in Science? We began by investigating scientists' reasons for and possible solutions to students' success or failure in science. We were persuaded to pursue this line of investigation by Ginorio (1995) and Willis (1996), who argued that the way the problem of differential student success is framed influences the identification and enactment of solutions (see under Why Don't All Students Succeed?). Participants in our study identified three sets of actors who promote or constrain student success in science: the students themselves; their university instructors; and forces beyond the university (more specifically, K-12 education, family expectations, and sociocultural norms).

Students as Active Participants in the Learning Process. In discussions of how students' attitudes and actions help or hinder their own achievement in science, university scientists collectively stressed the need for all students—irrespective of gender or ethnicity—to "take more responsibility for their own [learning]. Because science is "not a spectator sport," they clarified, any and all students must “be actively involved” in the learning process to succeed. For example, Tim, a European American biologist, noted that most students in his general education human physiology course “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, a European American biologist, agreed that for students to do well in science courses, they “need to actually think about [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.” Finally, Natalie, a European American woman and chemist, thought students who struggle often do not make science a priority in their lives: “[T]oo many of the students don’t budget their time accordingly. They work too many hours. They have too many classes . . . They don’t have enough time to study.” Like Justine, Natalie saw hard work and dedication as keys to students’ success in science.

> [B]y the end of the first day in lab, . . . 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.

Instructors’ Pivotal Role. Many of the scientists interviewed discussed not only how students contribute to their own success or failure in science, they described the role that they as instructors play as well. Several scientists thought students’ perceptions of their instructors as fair and authentic individuals critical to promoting science for all. For example, Joe, a physicist who identified himself simply as *Homo sapien*, thought students from underrepresented groups distanced themselves from a course when they perceived their instructor as blind to issues of cultural privilege and diversity.

> I think that an instructor who ignores or deprecates the contributions of people of certain genders or ethnicities, the students of those genders and ethnicities are very aware of it . . . I think the most likely response to [instructor ignorance or deprecation] is just to shine it on, just to shine the instructor and the course and what have you on. [Students think,] “I’ll do what I have to do in order to get a grade, but this guy or gal is a jerk and I won’t relate to them.”

Elaine, a European American geologist, also thought it imperative students perceive their instructors as fair. She, however, expressed concern that an overemphasis on the interests, experiences, and contributions of women and ethnic minorities would be viewed by students as inauthentic. “It has to be an authentic approach where people don’t immediately see that it’s some sort of a political over-reach,” Elaine explained. “That’s where you alienate people rather than bring in cognizance and clarity . . . [That’s when students] won’t hear anything else that you have to say about the issue.” (Readers should note a difference between the way Elaine uses “authentic” activity and that of Cunningham & Helms, 1998; Rodriguez, 1998.)

Scientists agreed that students’ perception of instructors as evenhanded and equitable is linked to their success in science. In addition, many highlighted how instructors’ views of students influence identification of strategies useful in drawing in rather than alienating members of underrepresented groups, in “not allowing students to be outside of [their] reach and [their] work.” Some participants argued that part of the solution to differential student success is for scientists to view and treat all students the same; others explained that to help ensure all succeed in science, differences across gender and ethnic groups must be recognized and addressed; and still others thought scientists must attend to each student's needs. (Instructors' specific strategies for addressing inequities across students are discussed in our second qualitative section later.) The importance of viewing and treating all students as equally competent was underscored by Linda, a European American science educator. Echoing gender equity research findings (see Kahle, 1996, for a summary) and science education reform recommendations (see NRC, 1996b), Linda explained that instructors must not only call on, respond to, and evaluate all students in the same way, they must have high expectations for all as well.

> [Instructors can create or perpetuate inequities by] who they call on, how they respond to students' questions, how they respond to student responses ... Even if they say, "I give everybody the same tests, I give them all the same papers, I grade them all the same way." You can still perpetuate inequities in the classroom if you're not ... having the same expectations for all your students.

Other university scientists called for instructors to attend to different groups of students' background, needs, and interests; these scientists' views resonated with those of Gaskell and Hildebrand (1996) who argued for the importance of viewing students as members of particular groups (in their case, girls and boys). For example, Cynthia, an Asian American biologist, expressed concern that many faculty continued to contribute to differential student success by failing to recognize differences across gender and/or ethnic groups. Faculty who see all learners as "the same," she explained, "think they're treating everybody the same, but in actuality, they're not;" such so-called equitable treatment may discourage or deter female and ethnic minority students. Because "women do learn a little differently than men," Cynthia continued, she made an extra effort to include discussion groups in her courses and to ensure typically reserved Chicana and Vietnamese women participated.

Still other scientists thought perceiving students as individuals is an effective way to address differential student success. Theresa's approach to helping all students succeed in her biology course was clearly connected to her perception of students as diverse individuals. Before becoming involved in the Promoting Women and Scientific Literacy project, Theresa began, she viewed all students as either "good" or "bad," attributed students' success or failure to their individual effort, and thus took few extra 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 [students] didn't do their part, if they didn't put out the extra ... effort that they needed to do to really learn the material, ... I just thought, "OK that's your problem, it's not mine." ... And so the good students, of course, were the ones, didn't 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 didn't, it was because they weren't 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, "That's not my problem, that's 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."

Donna and Michael also called for scientists to view students as individuals. Like educational researchers Brickhouse, Lowery, and Schultz (2000) and Nieto (1999), however they warned against assuming too much about an individual student's prior knowledge, out-of-school interests, or current academic potential based solely on her or his gender or ethnic identity. Michael, a biology professor of mixed ethnicity, expressed concern that some professors set their expectations for ethnic minority students according to cultural stereotypes: "A business instructor told me that he hates to say this, but he's never had a Black student do well in his classes ... [T]he best they do ever is a C." Donna, a European American chemist, explained that she tried to avoid lumping all students of a given ethnicity together into one category. She knew, for example, that students from different Asian countries and different generations of American citizenship have different attitudes, experiences, and needs.

> It's terribly important not to expect that Asian students whose families have lived in this country for several generations are the same as people who are immigrants or sometimes children of immigrants. They're quite different. People from different countries are quite different. I hate lumping groups together and saying if you are in this group or this class, you always have this characteristic. I don't like being lumped into that and I don't like doing it to others.

External Actors: K-12 Education, Family Expectations, and Sociocultural Pressures. In addition to their discussions of students as active participants and instructors as pivotal players, scientists addressed how outside forces promote and constrain student academic achievement—how student success in science is partially shaped by their K-12 experiences, family expectations and responsibilities, and sociocultural norms. As with scientists' conceptions of their own role, issues of gender and ethnicity as tied to student success were often raised here. University scientists, for example, understood women and ethnic minority students to be turned off to science in middle and high school (for confirmation of this trend, see American Association of University Women, 1991). In her response to a question on the ways males and females differ in terms of science-related attitudes and experiences, Linda explained that girls start to lose interest in science during their middle school years.

> Up until middle school, [girls and boys] are going to be equally interested [in science]. They will have had different previous experiences before coming to school. Boys will be more likely to have taken things apart and built things than girls will be, but they both will like science equally. Around middle school, the girls' attitudes towards science are going to decline. Boys' attitudes will not [decline] to the same extent and that difference gets even greater in high school ... [I]t's the way it's taught.

As an educator of prospective and preservice elementary teachers, Linda thought encouraging her students to teach more science and showing them how to do so in an inclusive manner the first steps toward promoting more women in science. "Traditionally elementary school teachers don't teach science," Linda explained. "So if I can get them to feel that they will [teach science] and they're able to [so do,] then I've succeeded. And if [girls] get [science] in elementary school, then maybe they'll stay on to college and be women in science."

A second external factor seen by scientists as instrumental in shaping student participation and achievement in science was students' family expectations, roles, and responsibilities. Approximately half of the scientists interviewed discussed how current or future family expectations and/or responsibilities influenced women's decisions to pursue or avoid science majors; research has shown that many women choose undergraduate majors based on the needs and desires of those close to them (Arnold, 1995; Seymour & Hewitt, 1997). For example, Chris, a European American biologist, thought girls are discouraged by those close to them from pursuing science: "[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, a geologist of mixed ethnicity, believed some women opted out of geology as a career because research requirements conflicted with responsibilities as mothers. "[I]n a department like ours, geology, we're getting a lot of real field experiences [as major and career requirements] . . . Those requirements have a much more severe impact on women that have children, if they're the primary caregiver. [They] have to deal with that in one way or another."

Family was seen to be a particularly powerful actor in the school lives and decisions of female ethnic minority students. These women's 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 toward science careers for which they lack genuine interest and/or ability. Justine discussed how large numbers of women of color, particularly Hispanic women, left the university's biology department after their first year. She wondered aloud what she and her colleagues could or should do to stem these women's exodus from science. After all, scientists could not insist students ignore their family responsibilities or reject cultural expectations.

> [In our Department of Biology study, we found] Hispanic women really dropped out more [than other groups of students] . . . [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 it's a different story] . . . But I do think [family responsibilities] exist and I don't really know how you [intervene] . . . [Y]ou can't really knock somebody's family . . . or the[ir] culture.

Lorraine, a European American biologist, explained Vietnamese women often feel pressured by 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.

Interestingly, researchers (Brainard, 1994; Wiegand, Ginorio, & Brown, 1994) have found that women undergraduates who select a science, math, or engineering major at the encouragement of family members are less likely to persist in the major, have confidence in their academic ability, or enter a scientific or technical career than those who decide to major in science for other reasons.

Professors who identified family roles and responsibilities as influencing women and ethnic minorities' success in science often suggested "mentoring" as a way to begin negotiating conflicts they saw among the demands of family, students' own interests and talents, and science course requirements. The importance of mentoring was raised at the AAC&U national conferences attended by team members and included as recommendations in literature distributed at those meetings (in particular, Ginorio, 1995; NSF, 1996). Cynthia tried to serve “as a good role model” for the many Vietnamese and Korean women attempting to major in science. Over the years, she had been friend and confidant to a large number of these women: “I think there’s a good relationship that develops and that says, ‘Hey, you can maintain being a woman. You can maintain your own culture and yes, you can also succeed.’” Similarly, Natalie devoted extra time and energy toward helping single mothers in her course excel in science. She found many of these women constantly “worried about money.” They did “not have time to study” because they took too many classes and worked too many jobs. She tried to help them ease their financial burdens, spending “time on the internet with these students looking for scholarship money.”

Scientists identified sociocultural pressures and expectations as a third and final external actor; sociocultural pressures were grouped with K-12 education and family expectations as forces that influenced student success but remained outside the control of student or scientist. Several participants described a mismatch between the way women are socialized to think and act, and the habits of mind and skills required of scientists, particularly physical scientists and engineers. For example, Marianne, a European American chemist, remarked that “as you drift toward the physical sciences and engineering, [the] numbers [of women] go away.” (Studies [NSF, 1998; Vetter, 1996] continue to find fewer women than men in physical science and engineering majors and careers.) As girls grow up, Marianne continued, 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. Readers should note Marianne’s explanation for why fewer women pursue careers in the physical sciences resonated with one of several reasons offered by feminist science studies scholar, Schiebinger (1997)—the idea of physics as “ontologically hard” (p. 206). As a point of contrast, Ginorio (1995) cautioned that while “explanations based on the culture or subject matter of some disciplines have been offered to explain women’s underrepresentation ... the finding is not consistent across all settings, pointing to the culture of the department rather than, or in addition, to the field as a potential mediator in women’s persistence” (p. 9).

In addition to disparities between the socialization of women and the acculturation of scientists, participants identified tensions between the cultures of ethnic minority students and that of science. Joe expressed reluctance in trying to encourage members of underrepresented groups to pursue science disciplines whose cultures may be foreign to them. At present, Joe noted, students from underrepresented groups have to change themselves to fit into science; the students must balance their ethnic identities with those expected and valued in science. Was gaining entrance into and acceptance in science really worth such effort?

> I just finished reading [David] Shipler’s 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 [a traditionally Black school] and this student went down to Morehouse and spent a year there and decided to transfer ... [H]e felt that at this White school, he had to be a different person ... and he had to relate [to others] differently than he did at Morehouse ... I think that the fact that there aren’t many minorities or women in science, in the physical sciences [in particular], would tend to inhibit other people who were coming in ... [They have to say,] ”I’m 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.

Joe's understanding of cultural mismatch, readers should note, can be seen as similar to that of Ogbu (1994) and Fordham (1996), who explored the kinds of cultural conflicts experienced by ethnic minorities in schools, as well as Costa (1995) and Aikenhead and Jegede (1999), who discussed the need for ethnic minority students to cross cultural borders if they are to excel in the microculture of school science.

Several scientists who suggested differential socialization as a way to frame the problem of women and ethnic minorities' underrepresentation in science offered a solution from viewing the issue as such: They echoed Rosser (1995), Seymour and Hewitt (1997), and Tobias (1990) in suggesting changing the culture of undergraduate science education to make it less competitive and thus, more amenable to the interests and experiences of students from underrepresented groups. Tim, for example, thought scientists could do more to make introductory science courses less aggressive and more attractive to students traditionally excluded from science.

> I'm a firm believer that our science curriculum ... [is] failing miserably to present an image 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, we're trying to make it a proving ground for people and so we're really just getting students who do well in that environment and that tends to be males and not necessarily creative males ... I think that's one of the things that selects against women, for instance. I don't think they enjoy that sort of learning environment.

Robert saw the "issue of success or inclusion of women in science" most relevant to "upper division or graduate level courses which are key to succeeding in the profession." At least in his "experience of how science is taught and discussed and how scientists are groomed and educated, ... the ability to argue forcefully for a perspective or an interpretation or a meaning of data is very highly prized." He saw "that kind of interaction [as] something that males are more trained for as youths" and suggested "somehow changing the seminar environment to a way that is more a discussion than an argument, ... [to] allow more women or timid individuals to develop their self confidence and their ability to reason under fire."

Building Inclusive Science Curriculum and Instruction. As the second part of our qualitative analysis, building from perceptions and practices introduced in the Instructors' Pivotal Role earlier, we examined scientists' self-reports of pedagogical strategies employed and course content delivered to promote the participation, interest, and understanding of all students in science. To enhance teacher-directed instruction, for example, all scientists reported growing more consistent in their use of inclusive language. Many refined their questioning strategies: increasing their wait time; avoiding the use of rhetorical questions; making a conscious effort to call on women as well as men, ethnic minorities as well as European Americans; and walking around the lecture hall to be equally accessible to students. A few increased the number of demonstrations, slides, and/or videos employed. In addition, scientists expanded their repertoire of student-centered pedagogical strategies. Inclusive techniques outside the realm of lecture ranged from in-class writing assignments, to student presentations, to small group activities, to attendance at university-wide lectures or films. Course content was modified as well. Some instructors introduced accounts of scientists from underrepresented groups, others attempted to situate research findings within their social and historical contexts, and still others discussed current events to strengthen ties between school science and everyday life.

Our initial intent was to explore the range and depth of participants' pedagogical and curricular innovations, to categorize and compare scientists' views of curriculum and instruction with the models put forth by Rosser (1991, 1995, 1997) and Banks (1995, 1999). We found, however, that instructors' approaches to inclusion were difficult to align with Rosser's phases and Banks' levels: Many scientists straddled two or more phases, agreed with only some of what was proposed in a given category, or incorporated ideas piecemeal across several levels. We also recognized that attempts to categorize and critic participants' practices neither resonated with our desire to inform professional developers interested in inclusion nor with our view of participants as critical friends. Given instructors' commitment to and interest in inclusion and our reluctance to focus only on their oversights, we decided to examine the kinds of constraints encountered as scientists worked toward building a science education program for all students: to identify those constraints that limited implementation of innovative pedagogical strategies and those that prevented integration of inclusive science content (see Posner, 1995, for a list of various kinds of curricular and pedagogical constraints).

Constraints to Pedagogical Innovation. Scientists in our study identified large class size as their main impediment to instructional innovation. They described large class size as restricting them to teacher-talk in their presentation of course material and to multiple choice exams to assess student learning. For example, Daniel, a European American chemist, saw large class size as hindering his ability to engage and interact with students during his chemistry lectures: "[T]here's not much of an aspect of [student] participation in the lecture." Daniel contrasted opportunities for student involvement in large lectures to those in small labs.

> In the laboratory, I see an enormous improvement in what students are doing and how they feel about doing experiments . . . But in the lecture itself, I don't have much of a situation where I can allow students to give me much feedback other than asking me specific questions.

Marlene, a European American biologist, did not have enough time in her large human anatomy course to grade essays or end-of-semester reports. Because "over a hundred plus students" enrolled in each section of her course, she used "primarily multiple choice" exams. The simple inclusion of fill-in-the-blank questions, she noted, added significantly to the time needed to evaluate them.

There were some instructors who recognized large class size as a constraint to inclusive instruction, but still implemented a number of female-friendly and/or culturally inclusive strategies. Elaine and Robert, the two geologists in our study, are noteworthy examples. Elaine had worked hard over the years to make her general education geology course more interesting and understandable to nonscience majors. Despite the course's profile—"an introductory science lecture class that tends to have numbers of people in excess of 100"—and course setting—"a standard auditorium," Elaine "had a [weekly] 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 a very distinctively different grading opportunity than those people had had." The paper served as a vehicle for both innovative instruction and culturally inclusive content: Students were required to research a natural disaster experienced by a relative and often chose someone who lived in their country of origin. In addition, 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 Julie’s 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.

Finally, Elaine decreased the percentage of students’ grades which were based on exams; to be more inclusive and fair in her grading, her practices had “metamorphosed” over the years to include additional assessment techniques, such as research papers, in- and out-of-class writing assignments, and class participation.

Elaine and Robert made clear, however, that implementation of these innovative assignments and assessments were not without personal cost; they offered little hope of finding easy solutions to class size difficulties. Elaine explained that inclusion of in- and out-of-class writing assignments “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.” For Elaine, the problem of overload would only “be mitigated in the future by . . . being very adamant, saying, ‘I want no more than 45 students in this class.’” Robert agreed that implementation of innovative instructional strategies required a great deal of time and effort on the instructor’s part. Such time and effort would be lessened, he suggested, by providing instructors of large classes with departmental assistance in developing demonstrations and additional teaching assistants to help with grading. He had found a grading assistant invaluable during the previous semester.

Constraints to Curricular Innovation. Scientists identified a second cluster of constraints to implementing inclusive science content. Like the scientists in Rosser’s professional development work (Rosser, 1997), our participants found modifying course content to be a greater challenge than transforming instructional practices. Constraints to curricular innovation included (a) lack of time and resources to research underrepresented groups’ contributions, (b) institutional and disciplinary expectations to cover large amounts of material, and (c) mismatches between the concepts of their disciplines and the goals of the Women and Scientific Literacy project. As with their discussion of constraints to instruction, some scientists recognized the existence of content restrictions but still managed to implement course revisions. Again, no easy solutions were identified.

One set of curricular constraints identified by scientists was lack of time in interaction with lack of resources to research the contributions of women scientists, ethnic minority scientists, and/or other cultures to the breadth and depth desired. (Loucks-Horsley, Hewson, Love, & Stiles, 1998, and NSF, 1996, also found that lack of time and resources limited educators’ ability to transform their curricular and instructional practices.) For example, Daniel expressed interest 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 his oversight was the amount of content he was required to cover in his introductory chemistry course; this constraint will be discussed in greater detail later. Another was the lack of support from the chemistry textbook he used. In his preinterview, Daniel noted that the textbook did a poor job of discussing the contributions of other cultures.

> [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 ... I just don't really have too much [information from other sources].

Daniel also explained that he lacked adequate time to research the contributions of marginalized groups. He had been asked to switch chemistry courses midyear and had yet to find time to learn about and introduce historical aspects into his instruction: "I've been wanting to introduce the historical parts in freshman chemistry and then when I got stuck teaching this [other course], I didn't really have a chance to do that."

A chemist as well, Natalie recognized the limitations of textbook and time, but had worked over the course of the professional development seminar series to change the content of her remedial chemistry class. In her preinterview, Natalie explained that she talked little of past and present contributions in her chemistry lectures and that the work of scientists from underrepresented groups was not covered in her chemistry text. "[T]here's very little [in chemistry books] 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," she clarified. By her postinterview, 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 better reflect the interests and lives of her female and ethnic minority students.

> I love this [new] book of how chemistry is used in your house, even with cleaning products in the kitchen, outside, glues ... [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 time perusing newspapers and science magazines for stories of women 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" and had "collected [articles] and stuck [them] away in [her] folder to bring out for next semester."

Time to cover required content was a second curricular constraint identified by scientists; science education reformers (American Association for the Advancement of Science, 1989) as well as researchers of students' undergraduate science experiences (Seymour & Hewitt, 1997; Tobias, 1990) have long argued that science courses are overstuffed with content. For many participants in our study, content coverage took precedence over discussing scientists or other cultures' contributions; there was simply not enough time in their 16-week courses to do both. 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 are 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. Similarly, Anand, an Asian American biologist, felt constrained by the university's general education requirements and unable to include a great deal of discussion on contributions.

> [I do] 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 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. Scientists who decided to limit the number of topics covered, include content of personal relevance, and discuss contributions of underrepresented groups recognized that they were disrupting university and disciplinary norms, but saw such actions as necessary to promote inclusion. 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 [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 his general education geology course. He focused on only those chapters of relevance to his students' lives in California.

> [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 there's far too much material in the textbook to cover in a semester. You can't 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 they're the least likely to impact their lives here in California.

A third curricular constraint identified by scientists in our study related to the number and range of science topics that explicitly addressed the contributions, physical attributes, or experiences of women and ethnic minorities—the number and kinds of science topics that included a human dimension. This third curricular constraint leads into our final qualitative data section on scientists' conceptions of the nature of science. Besides discussing the work of women and ethnic minority scientists, many participants wondered how else they could introduce topics clearly tied to the interests and experiences of underrepresented groups. Scientists who taught courses in molecular biology, geology, physics, and chemistry thought themselves at a distinct disadvantage in this respect; they, like Shiebinger (1997), noted that the physical sciences require feminist scholars to use a different, less human-oriented approach. "Talking about scientists as people ... really brought in students," Justine noted. The rest of "molecular biology just is not by nature going to be real inclusive." Daniel agreed: "[M]ost of the chemistry course is about things that really are inanimate. The subject matter and the core content of the course don't have any [of] the human or psychological aspects as far as that goes." Elaine also recognized that discussions 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, 'Well what we really need to do is highlight the achievements of women and quote, unquote, minority groups.' It's really hard when you're talking about a rock to say, 'Well, this is a European rock.'"

In contrast, many scientists who taught courses related to humans—courses such as human anatomy, physiology, and immunology—were able to incorporate scientific research on sex, racial, and/or ethnic difference into their lectures. They saw the inclusion of such content an additional way to reinvision science, to promote greater access to and recognition of traditionally underrepresented groups. In his human physiology course, for example, Michael selected textbooks that included an equal number of pictures and diagrams of women and men. In his lectures, he presented research he thought of particular interest and relevance 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 discussed the controversy surrounding the existence of human races. Michael explained to students "what exactly is a race from a biological perspective" and argued that the notion of races for humans is neither "valid" nor "useful." He 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.

How Inclusive Can the Nature of Science Be Made? As stated in the closing paragraphs of Constraints to Curricular Innovation, most scientists in our study agreed that presenting the contributions of women and ethnic minority scientists an effective and reasonable way to reach students from underrepresented groups. In sharing their views on the nature of science, some scientists emphasized that women and ethnic minorities have made and continue to make significant contributions to diverse science disciplines. Chris, for example, noted that "Barbara McClintock" is a woman and "a Nobel Laureate" who has "made major contributions to genetics" (see Keller, 1983, for a biography of McClintock). Others applauded recent moves to "reassess ... the record" of scientific achievements, to "redistribute ... the intellectual capital that went into major [scientific] contributions." Elaine saw greater attention to the workers of science—the women calculators at the Harvard observatory, the amateur women rock hounds of anthropology, and the sherpas who carried equipment up Mount Everest—as a way to highlight the contributions of women and ethnic minorities far back in time. Linda agreed that to move toward the goal of inclusion, scientific achievements should be described as accomplished by large numbers of participants rather than single individuals: "When we only look at the one or two people whose names get attached to things, we tend to not see all the women and minorities ... who have gone into learning something new." Still other scientists thought women and ethnic minorities had long endured both "lack of encouragement" and "blatant discrimination" in the sciences, but that barriers and struggles were shrinking in size and number. They noted that conditions for women had substantially improved in the biological sciences and expressed concern that the number of women in the physical sciences and of ethnic minorities (except for Asian Americans) across all science fields remained low. In short, scientists' appreciation for women and ethnic minorities' contributions and their understanding of barriers to participation resonated with those expressed by science studies scholars in our Conceptual Framework (see, in particular, Harding, 1991; Kohlstedt & Longino, 1997).

While scientists agreed that descriptions of science should include the tragedies and triumphs of women and ethnic minorities, they argued over two additional recommendations for broadening conceptions of science (see the second and third paragraphs of Science Studies Scholars' Descriptions). The presence of androcentric and ethnocentric biases in scientific practices and products was debated among scientists in our study: Scientists' views ranged from seeing the production of scientific knowledge as constrained by the gender and ethnicity of its members, to science as transcending personal, social, and cultural biases. At the beginning of her involvement in the Promoting Women and Scientific Literacy project, for example, Cynthia "didn't know epistemology from an episiotomy." Her subsequent examination of feminist science scholarship, however, changed the way she viewed the design of scientific investigations and the interpretation of their findings; she grew to see the production of scientific knowledge as socially situated. Medical research into and treatment of women, Cynthia explained, "have been skewed ... by male influences or just the male point of view" for decades because most scientists have been men. In one of her courses, research into AIDS served as an example: "[F]or many years, [doctors] didn't have a definition of AIDS that applied to women ... [I]t's only been in the last 5 years that they've included vaginal yeast infections, chronic vaginal yeast infections, as a marker for an AIDS infected female." A scientist's gender not only influences the design of studies conducted, Cynthia continued, it pervades her or his interpretation of data collected.

> [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 ... [Women and men] see the same thing, but they're going to describe it differently because ... [they're] looking at it from a male viewpoint versus a female viewpoint.

Unlike Cynthia, Michael did not see discussions of gender and ethnicity as particularly relevant to present day science; he thought racism and sexism integral to science's history, but not to its present. The nineteenth-century science of craniology, Michael explained, is an example of a racist and sexist science: "I talk [to my students] 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" (see Gould, 1996, for further discussion of craniometry). Biology, Michael continued, has become less biased over the years; examples of changes in brain and primate research, as well as advances in other sciences, are 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 are 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 "don't seem to realize that there's a different way of doing things in biology." Biologists "don't have hard and fast laws [like physicists]. We have probabilities or rules; some people even call it modalities. One of the major emphases is on variation." Perhaps the methods and philosophy of physics are androcentric, he cautioned, but physics is not representative of all sciences.

Still other scientists did not see issues of gender or ethnicity as permeating the fabric of scientific research. A few rejected the notion that a scientist's gender and/or ethnicity influences the knowledge he or she produces, because they saw such claims as implying the existence of particular feminine or female ways of doing science. Daniel, for example, saw women and ethnic minorities as contributing to science as individuals, but not as collective others. "[A]s far as I'm aware, women and people of all types have contributed to science as individuals. I can't think of any way culturally or emotionally where they've contributed as a group." Daniel did not think gender influenced the way one did science and thought claims that women conducted science differently than men anti-feminist in nature: "[T]here are people that claim ... that there are specific feminine ways of doing science, but I think that's being bated into being an antifeminist." (For clarification of this last point, see Longino's, 1989, call for "doing science as a feminist" rather than working toward a "feminine science.")

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 expressed concern that feminist scholars have gone too far in trying to show the influence of gender on scientific methods and products. Yes, she agreed with feminist scholars that women have been discriminated against pursuing science careers and that women's concerns are different from men. She rejected the notion, however, that because of their gender, women conduct scientific research differently. (Longino and Hammonds, 1990, described similar reactions by practicing women scientists to feminist science studies scholarship.)

> 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.

Along epistemological lines, scientists disagreed about what should count as scientific knowledge and practices, about the extent to which the modern sciences could be considered multicultural. Some argued that the modern sciences should be considered some of many sciences while others described science as universally practiced. Joe, a physicist, thought it important for his students to recognize and appreciate not only modern science, but the sciences of other cultures: "[T]he world is diverse and the only way that we're going to get along is if people recognize that others have made contributions and others' value systems have just as much legitimacy as [the] value systems of people who are sitting in the room." For example, he explained to students in his introductory astronomy course 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, he also shared with students information about the astronomy of other cultures, such as Chinese and Mayan astronomy. (See Reiss, 1993, for additional historical examples.)

> I do point out that the Chinese astronomy was way ahead of European astronomy several thousand years ago, because 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.

Several scientists interviewed took a more moderate epistemological position, describing science as a European construct to which other cultures have and continue to substantially contribute. Elaine, for example, thought other cultures had contributed to geology 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." Since the 1960s, geologists have begun to revise their history to give proper credit to scientists 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." In recent decades, geology also has begun to pay greater attention to other cultures' understanding of the earth and its place in the universe.

> There is a lot more attention now to creation myths, to observational patterns of natural phenomena 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?

Attention to other cultures' knowledge systems is an interesting avenue of investigation, Elaine continued. To avoid controversy, however, she thought it important for geologists to clearly delineate cultures' scientific from nonscientific ideas.

> [Discussions of origins have been] mixed up with other controversial aspects of science, which is evolution versus creation in biology. There has to be, again, some middle ground. [Geologists need to clarify,] "We're looking at creation myths and early development of science in other cultures from a scientific context. There's a religious context to it too, but we're not going to look at that right now."

Other scientists in our study picked up and amplified Elaine's concerns over the use of multicultural content in science courses; these scientists cautioned against labeling knowledge generated in other cultures as science or conflating the practice of modern science around the world with the existence of different kinds of sciences in different cultures. For example, Linda, a science educator, wondered what good could come from attempts to place indigenous knowledge on an equal footing with traditional science content. Her definition of science did not encompass knowledge from indigenous peoples, like American Indian myths about the singing of corn. Moreover, she argued that calling everything science served only to further marginalize other cultures' knowledge systems.

> 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 ... [T]here's an example I know of, I forget which Indian tribe it is, but they hear the corn singing and that's when they know it's time to harvest. Well, that's fine, but that's not science in my understanding of what science [is] ... So when people say in science education that we should have multicultural science and accept all these other cultures' ways of knowing as being science, I have a hard time with that because I don't consider them sciences.

Rather than push to have science content become multicultural, Linda concluded, 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." (See science educators, Cobern & Loving, 1998, and Southerland, 2000, for further articulation of this position.)

Tim, a biologist, agreed that multiculturalism in science had its limits. While several of his colleagues discussed eastern approaches to medicine in their anatomy and physiology courses, Tim did not. He did not consider practices such as "acupuncture" to be "hard science," he explained, because they are not "the result of scientific inquiry." Tim also saw few differences between the way modern science is performed in other parts of the world and the way it is 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 different sciences in different cultures or modern science as influenced by national boundaries, he preferred to view "science [itself] as a culture" shared by scientists around the world.

> [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 ...

IMPLICATIONS

Data analyses revealed partial solutions enacted and obstacles encountered, as well as areas of consensus and disagreement along the road toward a more equitable and excellent undergraduate science education. From our findings, we crafted a series of recommendations for scientists and professional developers interested in issues of inclusion at the undergraduate level. We begin by reminding ourselves and our readers that changes in instructors' views and practices take time. Instructors' responses to our pre- and postquestionnaires made clear that their ideas and actions changed little over the yearlong professional development seminar series. We offer additional insights gleaned from interviews along the three dimensions of our Conceptual Framework: perceptions of differential student success, the implementation of inclusive curriculum and instruction, and science studies scholarship.

The Importance of Multiple Perspectives

As presented in our first data section (Can All Students Succeed in Science?), scientists identified three sets of actors who shape differential student success in science: students, their instructors, and forces outside the university. In their discussion of instructors' pivotal role, for example, some participants argued that scientists should view all students as the same: Linda explained that instructors should hold equal expectations for all students and should treat all students equally. Other scientists, like Cynthia, thought attention to the particular interests and experiences of women and ethnic minorities necessary for eliminating differential student success. Still others advocated a "what each student needs" (Ginorio, 1995, p. 1) approach. In particular, Donna expressed concern that scientists' judgments about students' academic ability, interests, and experiences rested too heavily on their ethnic identities; she called for instructors to see students as individuals, rather than lump them together into distinct groups. Thus, one recommendation drawn from participants' reasons for differential student success is the need for professional developers to discuss with scientists the potential benefits and costs of viewing students as all the same, as members of particular groups, and as individuals. In viewing students as all the same, instructors might eliminate unfair questioning practices and differential expectations, but miss opportunities to highlight the needs and experiences of members of underrepresented groups. In seeing students as individuals, instructors might avoid prematurely judging a student's ability, but remain blind to social and institutional forces that limit her or his engagement in the class. In other words, as both Ginorio (1995) and Willis (1996) made clear, different perspectives on the problem of differential student success lead to enactment of different kinds of solutions. Rather than argue scientists adopt one view, we suggest professional developers help scientists move among these three perspectives of who their students are; we argue for the simultaneous implementation of various partial solutions to the problem of underrepresentation in science education.

Participating scientists also discussed ways they could help to address external-to-the-university forces (specifically K-12 education, family roles and responsibilities, and sociocultural expectations) that prevent some students from flourishing in science courses. They called for more active involvement by scientists in K-12 settings; greater mentoring of members of underrepresented groups in undergraduate science disciplines; and the changing of climate to make university science courses more amenable to the needs, experiences, and interests of women and ethnic minorities. From this set of findings, we offer a second recommendation: We encourage professional developers and scientists to help each other appreciate the full range and complexity of factors outside the university that influence underrepresented students' decisions and actions in undergraduate science courses, and to work together to identify potential solutions to the difficulties they pose. As Lorraine and Justine queried, how can scientists help students balance family responsibilities and cultural expectations with the requirements and workload of science courses? What difference can mentoring, suggested by Cynthia and Natalie, make in the lives of individual students? What can be gained or lost by thinking as did Marianne and Joe about the ways women and ethnic minorities are socialized to hold values and skills in opposition to those of science? And as advocated by Tim and Robert, how might changes in introductory and advanced science courses make science more attractive to students from underrepresented groups? In short, professional developers and scientists must recognize that they and their students do not exist in a vacuum; undergraduate science education programs can achieve inclusion only if supported by the larger social structures in which they are embedded.

The Need for Institutional and Disciplinary Change

In the introduction to our Conceptual Framework, we stated that most research on the professional development of science educators around issues of inclusion investigated the kinds and layers of teacher resistance to awareness of equity issues and to implementation of curricular and pedagogical innovations (see McGinnis & Pearsall, 1998; Rodriguez, 1998; Southerland & Gess-Newsome, 1999). Our study, in contrast, examined scientists already committed to promoting excellence and equity; rather than resisting identification of the equity problem, many participants had already spent years attempting to promote student success in their science courses, in particular, and the university, in general. Data presented in our Constraints to Innovation sections, however, made clear that the female-friendly and culturally inclusive models proposed by Rosser (1991, 1995, 1997) and Banks (1995, 1999) are difficult to achieve. We are once again reminded that instructors' commitment coupled with professional development opportunities are not enough to achieve substantial and lasting change. As such, we join Kreinberg and Lewis (1996) in calling for professional developers to attend to institutional constraints encountered by participants outside of seminar walls.

Scientists in our study identified a series of constraints to pedagogical and curricular innovation that could not easily be addressed within the confines of our professional development seminar series. To help quell scientists' concerns of inadequate time and resources, for example, professional developers must go beyond seminars to lobby university administrators for increased institutional support. As suggested by Daniel, Marlene, and Elaine, scientists need smaller class sizes to employ instruction and assessment strategies considered more in tune with the interests and experiences of those traditionally positioned on the periphery of science. As reminded by Daniel and Natalie, scientists also require adequate release time to research and/or develop materials that are more interesting and accessible to students. To lessen pressures to cover large amounts of content in short amounts of time, professional developers must work to enact changes outside the university as well. National science organizations should be encouraged to rethink the nature and purpose of introductory courses at the undergraduate level—to reach consensus on how to balance content necessary for future science careers with that of personal relevance to students' lives, and to decide where to cut content so that innovative pedagogical strategies are used and the goal of scientific literacy for all is attained. Donna noted that introductory chemistry courses attempt to cover too many concepts, too superficially, and in too little time; chemists cannot agree about which content to eliminate. Robert presented a similar picture of geology education; he went against the current tide by cutting out entire chapters of the textbook in favor of promoting greater student interest and understanding.

This is not to say that all constraints identified by participants fell outside the realm of the professional development seminar: The third curricular constraint raised by scientists, the lack of examples related to gender and ethnic diversity in the physical sciences, provides a case in point. As explained earlier, physical scientists in our study saw few opportunities outside discussions of women and ethnic minority scientists to showcase the needs and interests of members of underrepresented groups. They understood the solution offered by their life science colleagues, to discuss scientific research related to gender and ethnic differences across humans, to be of little use in their fields of physics, chemistry, and geology. One could argue that this split between the physical and life scientists in our study is important to note in and of itself: It should remind those engaged in professional development that science is not a monolithic enterprise. Professional developers must assist scientists in tailoring curricular and pedagogical suggestions to their disciplinary needs; all approaches to inclusive content and instruction are not equally relevant to all science disciplines. (See AAC&U, 1999a, for separate lists of recommendations tailored to the life and physical sciences.) More important in our opinion, our scientists' interpretation of inclusive content solely along human lines underscores the need for professional developers to push for consideration of alternative descriptions of what counts as science. In the case of the Women and Scientific Literacy project discussed here, professional developers should have more actively encouraged participating scientists to think about inclusive content along nature of science lines. (Nature of science examples related to inclusion were presented in the Science Studies Scholars' Descriptions section of our Conceptual Framework.) Of course, providing scientists examples of inclusive content tied to descriptions of science's nature is not without its own set of challenges. It is to discussion of participants' responses to science scholars' descriptions of the nature of science that we now turn.

Building a Two-Way Street Between Science Studies Scholarship and Science

Data presented in How Inclusive Can the Nature of Science Be Made? revealed differences across scientists' descriptions of 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 Donna, for example, viewed scientific practice as unbiased; their views clashed with those of science studies scholars such as Stepan (1995), Gould (1996), and Haraway and Goodeve (2000) presented in our Conceptual Framework. Tim saw science as practiced in all cultures in identical ways; his description of the scientific culture did not match that of Traweek (1988), who documented differences in the norms and practices of Japanese and American high energy physicists. Thus, in comparing participating scientists' views with those of science studies scholars, in comparing our data to our Conceptual Framework, it appears that science studies literature could offer many of our participants a different perspective from which to view their own and others' experiences in science. As we explained in our Methods section, although participants in our study were introduced to a small sampling of this work during the yearlong professional development seminar series, few examined such constructs or claims in great depth. More tightly integrating the history, philosophy, and sociology of science into professional development opportunities—first introducing 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 greater insight into ways to address inequities in the science classroom. (We recognize this suggestion has long been made at the preservice science level. See Rutherford, 1964, for an early example.)

While we call for more serious consideration of science studies scholarship by scientists interested in issues of inclusion, we are not advocating the out-of-hand dismissal of any and all ideas put forth by scientists that contradict those of science studies scholars. We recognize that the field of science studies can be defined in various ways, that there exists many and dissenting factions within the science studies community (Driver, Leach, Millar, & Scott, 1996, make similar qualifications in their study), and that there are scientists who have read widely and yet choose to disagree with particular science studies scholars' methodology and claims. Instead, we argue that scientists, like Michael, Donna, and Linda, can raise important questions about the currency, accuracy, and generalizability of science studies' perspectives across science disciplines. We thus recommend professional developers carefully consider how to balance encouraging scientists to consider science studies' views with validating concerns they raise about such scholarship. How does one productively manage conflicts that inevitably arise when a scientist's conception of or experience in science differs from a science scholar's description? Whose conception of science should be privileged, at what times, and for what purposes? Can different standpoints taken related to the presence of gender bias in science or the existence of multiple sciences be considered equally valid? In short, to promote agency rather than alienation of scientists, professional developers must raise awareness of androcentric and ethnocentric biases in science while simultaneously respecting multiple, dissenting voices and experiences—a difficult task indeed. Providing space for scientists to develop their own responses to equity issues from their science experiences in interaction with science studies research may help to create a more just and equitable science education for all. Recommending scientists look more closely at the intersection of their views of students, educational practices, and the nature of science may begin to move undergraduate science programs toward the goal of excellence and equity for all students.

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