DOCUMENT RESUME

ED 454 059 SE 064 916

AUTHOR	Baker, Dale R., Ed.; Scantlebury, Kathryn, Ed.
TITLE	Science "Coeducation": Viewpoints from Gender, Race and Ethnic Perspectives. NARST Monograph, Number Seven.
INSTITUTION	National Association for Research in Science Teaching.
PUB DATE	1995-00-00
NOTE	242p.
AVAILABLE FROM	NARST, 1929 Kenny Road, 200E, Columbus, OH 43210-1080.
PUB TYPE	Books (010) -- Collected Works - General (020)
EDRS PRICE	MF01/PC10 Plus Postage.
DESCRIPTORS	Elementary Secondary Education; *Ethnic Relations; *Gender Issues; Higher Education; *Race; Science Education

ABSTRACT

This document is a compilation of viewpoints on gender, race, and ethnic perspectives from scholars in the field as related to science education. Papers include: (1) "Where Feminist Research and Science Education Meet" (D. Baker and K. Scantlebury); (2) "Gender Equity is Still an Issue: Refocusing the Research" (C. Mason); (3) "Developmental Psychology, Epistemology, and Gender Issues" (B. Ranks and P. Miller); (4) "Brave New World: Gender Equity, Science Education and The New Environmental Paradigm" (M. MacDonald); (5) "The Interaction of Gender with Ethnicity: A Way beyond Color in the Classroom" (D. Pickard); (6) "Learning Styles of African American Children and Problems Faced by African American Females" (C. Melear); (7) "Gender and Ethnicity Factors in Student Achievement in a Coordinated Thematic Science Course" (V. Heard and C. Cantu-Mireles); (8) "Developing a Science Curriculum that Addresses the Learning Preferences of Male and Female Middle Level Students" (M. Chrayer, K. Backe, and J. Powell); (9) "Science Is All Around: A Gender-Inclusive Science Teaching" (A. Raychoudhury, D. Tippins, K. Scantlebury); (10) "The Impact of Gender Differences on Secondary Science Teachers' Needs" (J. Bazler and D. Peugh); (11) "De-Gendering Assessment in Science" (L. Rennie and L. Parker); (12) "Is Item Format Important?" (D. Burkam and A. Burkam); (13) "Teachers, Family, and Friends: Who Makes the Difference?" (D. Baker); (14) "The Participation of Women in Science: The Road Less Traveled"(K. Davis); (15) "Survivors of the Pipeline: Factors Related to the Retention of a Group of Women in Academic Biology" (A. Scholer); and (16) "A Gendered Construction of Engineering in the Academic Context." (L. Petrides). (SAH)

NARST MONOGRAPH, Number Seven, 1995

Science "Coeducation": Viewpoints from Gender, Race and Ethnic Perspectives

Edited by

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&

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If there is any misleading concept, it is that of "co-education": that because women and men are sitting in the same classrooms, hearing the same lectures, reading the same books, performing the same laboratories, they are receiving the same education. They are not."

(Rich, A. (1979). Taking women students seriously. In A. Rich, *On lies, secrets, and silence: selected prose, 1966-1978.* (p 241.) New York: W.W. Norton & Company.)

ACKNOWLEDGMENTS

The Editors recognize the NARST Board and the Publications Committee for publishing this monograph. We would like to acknowledge the chapter authors for the high quality of their contributions. We would like to thank Dr. Bambi Bailey and Julie Benvour for proof-reading the final manuscript.

D.R.B.
K.C.S.

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To our loved ones:
Mike and Craig
and to puesta del sol.

Where Feminist Research And Science Education Meet

Dale R. Baker and Kathryn Scantlebury

There is no one all encompassing view of what feminist research is or should be nor is there agreement on how it should be done. Feminist scholarship consists of multiple and sometimes contradictory positions that in an odd way unify feminist scholarship because of the focus on situated knowing. In other words, how a person understands feminist issues, how a person does research, and how a person interprets their data is a result of who they are and how they came to be that person. Consequently, the scholarship that we do arises from and is situated in being educated, white, heterosexual women with backgrounds in biology and chemistry. Our work is and should be quite different from that of, an educated, African-American, lesbian woman with a background in Marxist philosophy. However, we and our hypothetical black colleague share, to some degree, the same perspective because we are educated women living in an affluent nation. Our perspective is of necessity different from that of poor women in the third world because our situations differ. What unites us as women and feminists worldwide is our shared status conferred upon us at birth by virtue of our sex and our striving for equality.

This striving takes many forms. Within the science education community, which tends to be conservative because of its strong affiliation with traditional scientific disciplines and their attendant norms and values, scholars are more inclined to look for ways to fix the system which is perceived as valuable despite having flaws. Scholars and writers outside of science education, especially in more radicalized fields, believe that the system can not be fixed and should be dismantled and replaced by a new and more equitable kind of science.

The papers within this monograph reflect almost the complete range of positions possible when one is a feminist and/or science educator. Each is a reflection of the way we have defined the issues of importance to us, whether we have decided that the problems are fixable, and how we define feminism for ourselves. However, all of the papers address one or more of the goals of feminist research and most employ research techniques that can be easily identified as feminist.

The goals of feminist research overlap those of traditional research and in that regard need no further explanation. However, there are some goals that are uniquely feminist. The most important of these goals is the exposure of bias in research. This exposure takes several forms. First, there is the exposure of false consciousness which is a result of

oppression. This false consciousness may lead women to think that there are no problems relating to equity and gender. Some women may not even be aware of discrimination or be able to make decisions in their best interests precisely because they have been the victims of institutionalized discrimination and oppression. For example, the decisions made by many young women in relation to their education, especially if they are avoiding science, may be in part the result of being socialized in a gender biased society. Consequently, their decisions to avoid science do not reflect their best interests but rather gender role stereotypes. Exposing false consciousness helps us understand why women can act in ways that contribute to their own oppression.

Another goal is the elimination of sexism and androcentrism in hypotheses, research design and data interpretation. Examples of sexism and androcentrism in science are well documented. Darwin, in his theory of natural selection, spoke of the active male and the passive female. Primatologists have described primate social organization in terms of male dominance and hierarchy. Anthropologists have ascribed the active hunting role to males and passive home bound roles to females. Cellular biologists have described fertilization as the sperm invading the passive egg. All these theories ignore evidence to the contrary, often gathered by female scientists, that challenge this androcentric conception of nature. We now know that female primates participate in and often control mate selection, women can actively gather more food than male hunters can kill and the female egg reaches out and encloses the sperm with projections from the cell.

Another goal is to expose how social values have effected previous research. This is especially important when it comes to the education of women, women in science and the interpretation of "female deficiencies." Historically, androcentric social values have been used to justify the oppression of women and to prevent them from obtaining an education. A once popular theory states that studying diverts blood from a women's reproductive organs and this diversion interferes with her ability to bear children. Other theories that have been used to justify women's oppression suggest that women's brain size or other aspects of their biology or "nature" make them unfit or incapable of rational thought. This battle continues today in the form of comparisons of male and female achievement scores in areas such as mathematics and spatial ability while ignoring the androcentric bias in such tests.

A further goal of feminist research is the creation of a body of research that answers questions that arise from women's lives but also encompasses the larger world. Thus, we have feminist cancer researchers agitating for more money to be allocated for studies of breast or ovarian cancer. The scholarship presented here is another good example of this goal in that we have tried to situate doing science, learning science and

teaching science by and for women and girls in the larger context of science education.

We also see this monograph fulfilling other feminist research goals such as giving marginalized people a public voice, capturing a gender specific point of view and finally helping us to "see" what really is rather than what we are suppose to see or expect to see.

Some feminist scholars believe that feminist goals can not be reached through traditional assumptions and methodological approaches. They would argue that traditional epistomologies reinforce patriarchy or male dominance and are therefore of no value in feminist work because of the blinders they impose. We believe that this position ignores and repudiates much good work, especially in science education, that has employed traditional techniques, some of which we present here. We do not eschew traditional techniques nor do we accept the argument that all feminist methodologies are as non-traditional as some claim. Many of the approaches have a long history of use in anthropology, for example. This brings us to the question of what assumptions and methodologies feminists claim as their own.

Feminist research is embedded in the perspective that social relations have an influence on what we know or can know and as such takes into account the social context and status of women. In some cases it turns the knowledge hierarchy on its head. Knowing that (propositional knowledge) is no longer more valued than knowing how (practical knowledge). Feminist research acknowledges the importance of women's experiential knowledge over propositional knowledge as an alternative form of knowing. A good example of this is the case of elementary teachers who may know much about children and their cognitive development from their own experiences of being mothers but not know anything about the work of Piaget. In the past, we did not build on this practical knowledge but dismissed it as unscientific. Now, we are taking another look at experiential knowledge, precisely because access to propositional knowledge has been and continues to be blocked to many women.

Many feminist techniques are also a revival or re-examination of earlier approaches that have been seen as alternative, meaning less good, or repressed. For example, feminists reject the idea that there should be distance between the knower and the object to be known. Barbara McClintock is an often cited example because she described herself as identifying with her corn plants and knowing them intimately. Another example would be designing research for women instead of about them. This includes consulting with women about their lives as information is gathered and during the interpretation of the information. Note that what is gathered is not called data because it is not disembodied, decontextualized or distanced from the researcher but rather the

experiences of women's lived lives. This perspective shares much with the naturalistic approach often found in anthropology but it is also clearly a political stand and as such violates the supposedly apolitical nature of traditional research approaches.

Many feminist approaches are openly political and liberationist because they purposefully violate the norms of traditional research and because they bring to bear theories and techniques to better women's lives. Feminist scholarship focuses on bringing to the forefront issues that are important to those who have been disenfranchised and those who have been silent or whose voices have been ignored.

In science education and among feminist philosophers of science the political and liberationist stance gives rise to feminist critiques of science. This position seeks a view of the world that is not available to those in the dominant culture which reflects the white, male European view of science. Feminists have an advantage in this regard because they are on the periphery of traditional science. They can more clearly see the norms and values which govern science and they can be more critical of the norms and values than can an insider.

Taking into account context is probably the most important methodological issue for feminist scholars. Consequently, many feminist studies are naturalistic or qualitative in nature. The starting point is women's day to day lives in a multiplicity of contexts that embrace personal experience. More specifically, multiple contexts include class, race, ethnicity, age, religion and sexuality. The particular and subjective of women's lives is chosen over that which is generalizable and the concept of a global or universal category of women is rejected. Thus, the work is often descriptive, especially in science education where understanding the history, condition and context is necessary for the creation of new ways of understanding. Context is frequently captured by interviews, autobiographical and biographical approaches.

Using interviews, autobiographies and biographical approaches means that feminist scholars will often check with those who are the center of the research to verify what they have said. Because we are telling the stories of women's lives, we are sensitive to issues of power, and work to make our scholarship the authority and empowerment vehicle for women to speak rather than speaking for women.

Feminist approaches frequently do not make comparisons with men or men's lives for two reasons. First, since we live in a gendered world the context and therefore the meaning of events for men and women is very different. This was made clear to most people, even outside the feminist community, by the work of Carol Gilligan when she explored the moral reasoning of young women. Second, comparisons have been, in the past, used to build deficit models in which the male is the norm and any

deviation from that norm is seen as a shortcoming. Being different has been equated with being less, often without taking into account blatant bias in assessment instruments or theoretical perspective. Within science education, some scholars continue to make comparisons in order to reveal sources of bias and to identify sources of inequities in schooling. Such work takes into account that experience is not gender neutral within cultures in which gender matters and that girls and boys in the same classroom are not treated the same.

The theories used are grounded in the values of women which arose from listening to the life stories of women. The theories acknowledge the values of women which emphasize emotion, connectedness, cooperation, subjectivity and communality as legitimate ways of knowing in contrast to those of men which emphasize logic, isolation, competition, objectivity and individuality. The theories also reflect a constructivist perspective because they take into consideration how the dominant culture constructs knowledge of women and how women construct knowledge about themselves.

Although feminist research is dominated by white women the intent has never been that feminist research should be separatist or exclusive. Men should do research within the feminist paradigm to better understand their own and women's lives with less distortion. Men can do feminist research if they educate themselves about the history, interests and issues of women and if they are willing to examine both themselves and the dominant institutions' practices critically for bias. White women scholars must go through a similar process to understand those factors associated with the lives of, for example, black or poor women and to engage in the same kind of critical scrutiny of their biases and those within the social institutions that, despite their gender, represent their interests by virtue of their skin color, education and income level.

The authors in this volume represent the full range of methodological techniques, perspectives and concerns that constitute the meeting ground for feminist research and science education. The case history and biographical approach is well represented by the papers of Kathleen Davis, Anne-Marie Scholer and Lisa Petrides. Research grounded in personal experiences uncovered through interviews is well represented by the work of Dale Baker; M. Gail Shoyer, Katherine Backe and Janet Powell; and Dawn Pickard. All of these works, many of which employ single gender samples, skillfully use interviews and present ample quotations that let women speak for themselves. Marilyn McDonald uses her own personal biography as a starting point for the arguments she makes for reforming science education. Her feminist critique of science education is influenced by ecofeminism and brings a new perspective to what we should be doing.

Two papers, one by Bridget Franks and Patricia Miller, and another by Cheryl Mason provide a review of our research to date in the area of gender and science education. Bridget Franks and Patricia Miller also provide an insightful analysis contrasting standard theoretical perspectives with feminist ones to explain the decline in motivation and achievement in science for girls.

Several contributions examine current reform movements in science education in terms of equity. David Burkam and Amy Burkam examine achievement across assessment formats for bias. Leonie Rennie and Lesley Parker also take a look at issues involved in reforming assessment, especially the effects of bottom up approaches in which teachers are empowered to make changes rather than having changes imposed upon them. Virgil Heard and Cheryl Cantu-Mireles examine the success of curriculum developed according to current reform recommendations to bring about equity in achievement.

The contributions of Virgil Heard and Cheryl Cantu-Mireles, Claudia Melear, and Dawn Pickard also address the more complicated issues arising from the interactions of gender and ethnicity. Claudia Melear's work with American black females and Dawn Pickard's work with Chaldean females from immigrant families underscore the necessity of looking at gender issues in the context of race, religion, ethnicity, culture and class.

The feminist perspective of political activism informs the work of Anita Roychoudhury, Deborah Tippins and Kathryn Scantlebury in teacher education as they describe a preservice science course for elementary teachers. A less overt position is taken by Judith Bazler and Deborah Peugh as they examine women's work in the context of teaching.

All of these works in one way or another demonstrate how difficult it is for women to participate in science. Curriculum, assessment and teachers may set up artificial barriers that some female students never overcome. Self-concept, cultural stereotypes and values as well as race become additional obstacles. Even the most scientifically inclined may be discouraged by their university experience and successfully completing an undergraduate or graduate degree in science does not mean that a woman will be welcomed into the ranks of practicing scientists. At every point along the way from learning science to teaching and practicing science women encounter difficulties. The current reforms in education, good as they may be, still fall short of dealing with gender equity in a substantive way. The call for science for all Americans is still neglecting over 50% of the population - girls and women.

Gender Equity Is Still An Issue: Refocusing The Research Agenda

Cheryl Mason

Only recently have we begun to appreciate that who does science affects the kind of science that gets done. (Schiebinger, 1993, p. 3)

Beatrice Potter, well known British authoress and illustrator, was originally an accomplished mycologist. What events intervened to cause her to refocus her career? No one is certain; however, societal factors have long been known to play a prominent role in the aspirations of individuals seeking particular career goals. Even in our more modern times there has been resistance to scientists such as Barbara McClintock, Nobel Prize Laureate in genetics, who challenged the prevailing dogma. It has been over two decades since the passage of Education Amendment Title IX, which prohibits sex discrimination in education in the United States.

As the 1990's opened, United States women made up more than 50 percent of the population, 45 percent of the work force and 16 percent of employed scientists and engineers, of these under 2 percent were minority women (McKenzie, 1993). Although we have seen progress in opportunities in science and science-related fields for women, research indicates that gender is still a critical issue in the classroom and workplace (Alper, 1993; Bornholt, Goodnow & Cooney, 1994; Sadker & Sadker, 1994; Vandell & Dempsey, 1991; Vetter, 1992; Wilson, 1992). A concerted effort to engage in collaboration for the purpose of coordinating various pieces of the existing gender equity infrastructure has to be put forth (Klein & Ortman, 1994). This is the key way to ameliorate, or at best eliminate, the current obstructions to systemic and lasting change.

Global Perspective

Science is the foundation of technologies, and the United States is recognized for its leadership in both technological and scientific research. However, it will be difficult to maintain this leadership role with the number of white males entering science, engineering and mathematics (SEM) fields on the decline. The dilemma is intensified by the fact that the paucity of females, especially of color, is still prevalent in the SEM work force. On the other hand, this does not appear to be the case in countries that are developing their science and technology programs during the 20th century. Their scientific and technological enterprises are expanding during a time when society is more open to women's

participation in what has been labeled a male domain in the more established European labor market (Women in science, 1994). Since by the year 2000 women and minorities will account for two-thirds of new workers in the United States, it is imperative that women begin to participate more heavily in scientific endeavors (Burbridge, 1991; Healy, 1992). Unfortunately AAUW's report, *How Schools Shortchange Girls* (American Association of University Women, 1992), along with other research projects, demonstrates that females still are not experiencing the same measure of success in today's science classrooms as their male counterparts.

Recent efforts toward establishing gender equity in the United States are reflected in a rise in the number of women earning science and engineering degrees during the last decade, but these numbers are starting to level off. Even more disconcerting is that women are reluctant to enter areas of emerging technologies, including communications, space, and biotechnologies (Burbridge, 1991; Wilson, 1992). These areas reflect the growing complexity of the world, not only scientifically, but socially and ethically. Despite current attempts at changing the formula, there continues to be a dearth of women acting as effectual participants in the scientific, engineering and mathematical communities.

Connecting the Pieces

There are four main challenging phases for women seeking a scientific or science-related career. The first two involve the environment of precollege and college educational settings. The third or early career stage presents another challenge, with an even greater one awaiting them during their mid- and/or late mid-career phases. Within the first phase, girls face the pipeline challenge of completing coursework adequate for entry into college so that they are not limiting their future career choices. Due to a general lack of support and mentoring during their higher education and novice professional career years, women in the United States most likely find themselves struggling to establish niches in the world of science, engineering and mathematics (SEM). Finally, veteran women discover that the "glass ceiling" can be a reality in many instances as they contend with the obstacles impeding or halting their climb up the career ladder. Along with women in the United States, frustration throughout mid- and late-career years has been shown also to exist for women in both developing and developed nations (Women in science, 1994).

In addition to the four challenging phases women experience as they seek to pursue a science or science-related career, another critical piece of the gender issue is the manner in which science content and scientific processes are approached and presented. It is important that varying standpoints, perspectives and methodologies of science not be automatically viewed as weaker, watered-down and/or less robust

when compared to others. For the most part, women create in their laboratories an atmosphere of nonhierarchical collegiality and cooperation. They also tend to produce fewer articles, but ones that are well thought out and well received. In most laboratories where a male is the head scientist, there exists a competitive attitude as his team works to publish on "hot" topics, such as HIV and cancer (Women in science, 1994).

It is vital that we consider all of the challenges throughout a woman's lifetime and systematically work toward connecting the pieces devoted to attainment of gender equity. The caveat to be considered as we address these salient points is that all girls and women do not have the same issues with which to deal. In conjunction with that we must be more aware of the diversity that exists among girls and women as we strive to establish gender equity. Broad brush strokes to deal with gender issues can be just as debilitating as neglecting to address them.

Environmental Determinism

Gender Defined:

During a recent classroom observation of a science lesson, one 4th grade girl approached the observer and asked if she could read a story that she had just written. Being told to do so, the young girl proceeded to read her science story about a bear and an eagle. When asked why she made all but one of her characters male, the 4th grader stated that men were strong and important, and she wanted her story to be taken seriously. Time and time again we find evidences of gender bias and, even worse, stereotypic behavior within our society (Wilson, 1992).

Although we all comprehend that there are two sexes, we must recognize that the physiological and morphological variety of humans is a continuum rather than a dipolar situation. This also needs to be kept in mind as we look at the issue of gender. Even more so since, unlike one's sex which is biologically determined, gender is an image or perception that is developed due to assumptions and stereotypes manifested in societal experiences and mores. As a result, it is important to understand how people think about gender, develop gender and define gender within a particular cultural context. The danger and the power of stereotypes is that they can become self-validating when individuals tailor their behaviors to match what is expected by society (Barinaga, 1993a, 1993b; Schiebinger, 1993). In science and science education it is even more critical to take a stance of open-mindedness concerning the nuances that sex differences can bring into the school and workplace. Confusing sexual differences with gender definitions can create stereotypic images that serve as discriminatory factors for women seeking a career in a science or science-related field.

Early Childhood and Adolescent Experiences:

Socialization and attitudinal factors impact children's early learning experiences within both formal and informal settings. Early socialization, which results in sex differences in work and play, may mark the beginning of differential exposure to math and science. Female, compared with male, children participate in fewer science, engineering and mathematics (SEM) activities in their early years and often are not encouraged to develop competencies needed for future work in these areas (Oliver & Simpson, 1988; Pollina & Gould, 1992; Sjoberg, 1989).

Girls tend to engage in relatively passive activities that generally involve verbal skills and social relationships, while boys, on the other hand, are more active as they manipulate objects by playing with them, building them or taking them apart. Boys' games, such as baseball, soccer, computer programs and pinball (machines), characteristically involve certain mathematical and spatial calculations that can prove useful in later science and mathematics classes. Although girls involved with sports is no longer the rare event that it used to be, there still remains a disparity in the types and extent of SEM activities in which males and females engage. Research has linked the disparity in these experiences to sex differences in both spatial skills and attitudes toward math and science (Jones & Wheatley, 1988; Reyes & Padilla, 1992). As a result, girls and boys develop sex-role stereotyped attitudes toward the appropriateness of SEM activities for them and their peers. It has also been demonstrated that there is a direct correlation between these early experiences, and later course selection and achievement in mathematics, science and technology which in turn influence career decision-making (Parker & Rennie, 1986; Schibeci, 1986).

Although improvements have been made, manipulative and career-oriented toys such as science kits, building games, computer software, tools and doctors' kits are still marketed toward boys. In advertisements, girls are shown with kitchen sets, ironing boards and baby dolls. Even the females identified as popular action *heroes* are promoted according to gender stereotypes through their dress and behaviors. Another example of gender stereotypes is of a company that produces manipulative pieces which can be used to build complicated objects such as a moving crane. Working with these pieces develops spatial ability and encourages creativity and inventiveness. In their misguided attempt to appear equitable, the company began producing these manipulatives in pink for girls, while the other pieces targeted toward boys remained in their original colors. The point is that both sexes should be made to feel comfortable engaging in activities that

interest them, rather than perceiving that only certain ones are appropriate for them.

Forces and Factors:

It seems that the forces that steer females away from science begin early in life and continue throughout their school years. Observing the paucity of female science and mathematics teachers, and female students in an elective science or mathematics class reinforces the assumption that these advanced courses are atypical for girls and are not important to their careers (Association for Women in Science, 1993; Mason & Kahle, 1988; Wilson, 1992). In addition to inadequate preparation in science and mathematics, other obstacles or forces that have been identified in hindering or preventing the participation of women in the sciences are: limited exposure to role models, inadequate counseling, and low expectations and stereotypical perceptions from teachers and parents (Beane, 1985). From infancy through adulthood, girls and women receive overt and covert signals that math, science and technology are male domains (Bornholt et al, 1994). Reid and Stephens' (1985) review of research studies on career development of females found that sex-role stereotyping of occupations was the factor most strongly discouraging young women from pursuing lucrative, nontraditional careers. Despite concerted efforts at striving toward gender equity, society is still sending messages to girls and women as to what careers and interests are appropriate for them. Television shows, movies, music and advertisements, continue to display and reinforce gender stereotypes.

Science Classroom Learning Environment:

In addition to the pervasive social and curricular perspective of SEM careers, the classroom learning environment is a major factor in attitude formation and/or change toward science and scientists (Kahle, 1988; Mason & Kahle, 1988; Parker & Rennie, 1986; Talton & Simpson, 1986). By observing and analyzing the ethos of precollege schools and schools of higher education, it has been noted that even the most egalitarian instructors unintentionally tend to react to students in a gender-stereotyped fashion. Observations and interviews indicate that there is a tendency to focus attention on the more active male students and to assume that their ability in the sciences is greater (Bornholt et al, 1994; Sadker & Sadker, 1994). The fact that girls and women tend to express a lower confidence level of attaining success in their science courses, than their male peers, reinforces this perceived lack of ability. Stereotypic and/or non-supportive environments, which perpetuate science as being a white male, competitive domain, cause many females to fail to enroll in optional science and mathematics courses, or to discontinue their initial path toward science as a career. With the existing diverse population of students, those coming from different ethnic and cultural backgrounds often face the triple challenge of being female, a person of color, and an English as a second language learner (Mason, 1993).

A recent research project demonstrated that even with science majors at a major university there exists a gender difference in perceived ability and knowledge (Mason, 1992). One data-gathering technique used in the project was journal writing. Journals were used as a means of investigating ways to assist students in understanding and interconnecting their knowledge of the sciences. In addition to sharing thoughts about science teaching and learning, the students were asked to address a specific question each week. One of the journal questions posed to these senior and graduate level science majors was to describe the level of confidence that they had concerning the breadth and depth of their knowledge of science. An overwhelming majority of females and a minority of males elaborated on the various science content areas upon which they needed to expand. On the distaff side, the majority of males wrote that they were basically confident in the extent of their knowledge and mainly expressed a minimal concern for what they perceived as some "holes" in their scientific knowledge. This observation has also been supported by other researchers studying gender differences at various educational levels (Baker, 1985; Bornholt et al, 1994; Pollina & Gould, 1992; Scott-Jones & Clark, 1992).

Scientific Community

Although there is a tremendous effort toward objectivity, science is a creation of the culture and context in which it was created. Up until recently, students were limited to learning about science from the perspective of writings by white European male scientists. The literature contained few references to the scientific findings of women since it was very difficult to insinuate themselves into the scientific community. The attitude of the times was that women were not of equal stamina and intelligence (LaFollette, 1992; Schiebinger, 1993). Even in the United States today, this white male European model of science has persevered. As a result there continues to be barriers for women seeking to successfully pursue a career in science. Many women were, and still are, serving as assistants or technicians hidden in the background rather than as prominent science researchers (LaFollette, 1992; Schiebinger, 1993; Women in science, 1993, 1994).

It is imperative that we look more into the culture of science and determine what turns so many woman off to the profession, what prevents so many from achieving their full potential, and why some elect to change and pursue a different career (Putnam, 1991; Women in science, 1993, 1994). Science is ultimately a guild, in which an experienced individual passes on skills and professional advice to novices. Although there are increasing cases where women are supported during their graduate years, the mentoring is often nonexistent at the professorial level. As women gain access to positions in the

scientific community, they tend not to be proponents for gender equity but instead become inculcated into an environment that perpetuates inequitable practices (Women in science, 1993, 1994).

As people become more sensitive to gender equity issues, young women today may not encounter the overt, unquestioned sexism that was once ubiquitous in the science community. What they now may face is a bias that may be worse because it's more subtle and, therefore, not as easily defined or proven. Today, the problem is more likely to be lack of encouragement and benign neglect than outright discouragement (Women in science, 1993, 1994).

Women, as do men, bring to science personal attributes that influence how they develop scientific questions and research design. Although the scientific paradigm has proven itself over time, successful research conducted by women should be an impetus to rethink aspects of the nature of science. The scientific community needs to: (1) reconsider how science is conducted; (2) recognize that a cooperative environment within and among science research groups often can be more productive than a competitive one; (3) comprehend the manner and context through which questions are framed in science, and how intellectual and experiential background determine what types of questions are asked; and (4) be more open to the data and patterns that appear not to fit in with the central dogmas, and willing to change foci if necessary (LaFollette, 1992; Schiebinger, 1993; Women in science, 1993, 1994). Scientific methods must be methodical and organized, while keeping in mind that scientific work is conducted through, and via, the view through the *lenses* of the scientists.

Areas For Action

Overview:

Although societal stereotyping of appropriate behaviors and careers for females and males is pervasive, efforts can be made so that there is a redefinition of what science and science education entails. Research and literature reviews have identified obstacles commonly encountered by girls and women in choosing science, engineering and mathematics (SEM) courses and careers (e.g., Brennan, 1993; Clewell & Anderson, 1991; Eccles & Jacobs, 1986; Kelly, 1987; Women in science, 1993). Based on results of these various studies, criteria have been developed for equitable the SEM activities (e.g., Adey, Bliss, Head & Shayer, 1989; Gardner, Mason & Matyas, 1989; Skolnik, Langbort & Day, 1982; Smith, Molitor, Nelson & Matthews, 1984). The literature also indicates that girls tend to be eliminated from SEM career pipeline starting in the seventh grade and continuing through high school. Seeking to prevent this leak in the pipeline and encouraging more girls to consider SEM

careers can be accomplished by focusing on science curricula, instruction transformation of instruction and career exploration targeted toward girls.

The most direct action that educators and parents can take to reduce stereotyping is to help all children become aware of sexist language, differentiation by gender, and practices that limit individual potential (Whyte, 1986). In addition, the classroom and home environments can work to counteract negative attitudes by nurturing all students' interests in SEM and by augmenting curiosity and confidence in their own ability to succeed. Studies have shown that these interventions lead to a higher motivation to succeed in the sciences (Gardner, Mason, & Matyas, 1989; Koballa, 1988; Linn & Hyde, 1989; Mason & Kahle, 1988; Oliver & Simpson, 1988; Thomas, 1986; Yager & Penick, 1986).

Changing the Science Curriculum and Context:

We must ensure that the educational system does a better job of meeting the needs of over 51 percent of the American population. Educators should work on changing the perception of, and attitudes toward, science and scientists by redesigning the learning environment to promote gender equity, and developing curriculum that reflects the backgrounds and interests of both females and males. Students will learn scientific concepts and processes much faster when they are comprehensible, and related to what is already in their existing cognitive and affective domains. Also, by promoting life skills in the context of learning science, students will recognize the relevancy of science to their everyday life experiences. In addition, educators should strive to incorporate into lessons how females and males from a variety of cultures have used or helped develop the scientific disciplines.

Students need a variety of active engagement with hands-on, minds-on activities that relate to scientific concepts and issues. Rather than using lectures as a sole means of describing science vocabulary, educators should encourage their students to learn by reading, observing actual objects or demonstrations, listening to one another, and engaging in some sort of physical activity. Visual aids, compared to lecture format, are dramatic tools for presenting information about science. Displaying scientific concepts along with descriptive pictures in the classroom, or using real examples, effectively reinforces the presented concepts for students, especially the English language learners.

Girls are rewarded early on for their quiet and docile behavior. If left unchecked, they gradually begin to exist as invisible members of classroom populations. As a result, they receive less active and direct teaching (Sadker & Sadker, 1994). Independence, self-reliance and active participation should be encouraged. Although cooperative learning, rather than isolated competitiveness, is preferred by most

females, it is important that strategies for active science learning be used to help them perform better in competitive situations. This will provide experiences necessary for future survival in most SEM careers.

Addressing Different Learning Styles:

The idea that certain learning styles are associated with specific ethnic groups and gender is both disconcerting and encouraging. It is disconcerting because it can foster stereotypes. It is encouraging to the degree it reveals gender, cultural and environmental variables that influence the way students learn (Mason, 1993). Knowledge of the various learning styles can help educators to custom design their curriculum to meet the needs of all students (Bennett, 1990). However, it is important to recognize that diversity exists within cultures and genders so teachers must be careful of stereotyping styles of learning and, instead, look at students as individuals not as a particular sex or ethnicity.

Rethinking Assessment and Evaluation:

Often times when females already feel that they don't belong in a science classroom, they consider it an unnecessary risk to answer convergent questions. Open-ended questioning allows students to become more of a part of a divergent conversation rather than having a fear of not knowing the *right* answer to a narrow question. Teachers must also involve all students and avoid the habit of calling on the 6 or 7 target students who tend to be Anglo males (Sadker, Sadker, & Klein, 1991). Teachers often confuse regurgitated memorized information with student learning. Girls often harbor talents that are not measured in the traditional classroom, therefore their supposed inability to grasp scientific concepts is reinforced by one answer/one way of thinking assessment.

To truly assess and evaluate teaching effectiveness and student learning, an educator must employ a variety of approaches. Students embed scientific concepts into a knowledge structure developed from the perspective of their own experiences. It can be perceived that the student does not understand the material rather than realizing it could be a breakdown in communication. This is a sound rationale for using a variety of measures, such as portfolios, and investigative tasks that require a background in a specific declarative and procedural knowledge.

Educating Teachers:

Promoting gender equity in classrooms can only be accomplished if instructors are aware of the environment in which they are teaching. Too often, educators do not realize the numerous ways that they reinforce gender stereotypes in the science classroom setting. To work toward resolving this problem, teacher preservice and inservice education courses and workshops need to include identification of differential treatment of males and females and equity outcome goals that are

sought. Science educators should also promote the gender equity agenda by modeling equitable teaching, and providing assignments that sensitize prospective and inservice teachers to ways of eliminating, or at least ameliorating, gender stereotyping.

Too often our role models and examples are drawn from the world of the white male. One way to encourage girls to entertain the idea of pursuing a career in science or a related field is to have information concerning careers and what is necessary to achieve such a career displayed in their classrooms. There are many commercial items geared toward overcoming stereotyping and biases, and providing the message that SEM careers are for everyone. Another way to promote SEM careers is to provide role models as guest speakers. It is important to relate to females, not only what it takes to become a scientist, but the fact that they can be both a woman and a scientist.

Succeeding in the Scientific Enterprise

The key to attracting females to careers in SEM is active recruitment and retention. Part of this proactive stance is to help girls and women perceive the corporate mentality and to gain confidence in their ability to successfully make inroads into it. Another factor is that women need more than just occupational role models; they also need to see someone living the kind of lives they envision for themselves (LaFollette, 1992; Women in science, 1993, 1994).

Historically, men have dominated conversations at scientific gatherings, and been more aggressive in the realms of attaining grants and publishing findings, giving the appearance that the women scientists are more docile and less confident in their scientific work. Females must learn to promote their ideas by being more aggressive in defending their ideas and research findings whether it is in brainstorming session at their place of work, or at a major professional meeting (Women in science, 1993, 1994). On the other hand, challenges that women face during their SEM careers will not be resolved by totally becoming like male scientists and giving up their perspectives as women. As more of a critical mass of like-minded women enter science professions, they can serve as mentors to other women and help change the way that we do and think about science.

Refocusing The Gender Equity Agenda

If the present trend continues, we will not only have a significant decline in the number of scientists, but we will have a population that is, for the most part, scientifically illiterate. As a nation, the United States needs to capitalize on the talents of all of its citizens. There is no doubt that we must overcome the present trend and encourage females, especially women of color, to become more actively involved in the pursuit of a

science or science-related career. However, it is important to keep in mind that, although we are striving to increase female representation in the scientific and technological fields, of even greater importance is our efforts to encourage this major segment of our population minimally to gain literacy in these areas. With such literacy they can make informed decisions about issues that impact their own and others' lives.

As more women enter the fields of science, engineering and mathematics there is more support and less of a feeling of isolation. However, the barriers of societal customs and biases continue to impede the way for women to enter these fields, remain in these fields and approach science in a manner different from the established dogma. Rather than trying to define whether there is a feminine or masculine science, the idea should be to make the nature of science more explicit, not less rigorous (Schiebinger, 1993; Women in science, 1993, 1994).

There is still an insufficient number of women who can, or who are willing, to serve as role models and mentors to offset the attitudes about what women can accomplish in the fields of science, engineering and mathematics. To increase these numbers, a systematic effort must be made to review the overt and covert barriers that contribute to sex discrimination and gender stereotypes, and to develop ways of eliminating them. Proven interventions and practices outlined in publications should be incorporated in private homes, educational institutions, and the private sector in a connected, supportive and collaborative manner (Astronomy on a shoestring, 1984; Calinger & Walthall, 1990; Downie, Slesnick & Stenmark, 1981; Foundational approaches, 1990; Fraser, 1982; GEMS, 1986; Hosking, 1987; Klein, 1985; Liem, 1981; McDuffie, Jr. & Anderson, 1980; Noyce, 1984; Sneider, 1986; SPACES, 1982; Strongin, 1985; Success with minority students in science, 1989). In the midst of this all, it is important to remember that gender differences are not general, but instead specific to cultural and situational contexts. Appropriate interventions should reflect individual requirements.

Everyone needs to assume a proactive stance, grappling with the issues of recruitment and retention, science teaching, images of science and scientists, and the cultivation of a science research and educational environment that supports girls and women in all phases of their lives. Girls should be inspired to be risk takers, who are curious, explorative, investigative, creative and persistent from the offset. As women in the science community, they should feel comfortable being contributory members of the scientific enterprise and confident enough to defend the bases of their scientific research with a strong voice. The goal is to encourage females to think scientifically and gain confidence in their abilities to do so.

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Developmental Psychology, Epistemology, And Gender Issues In Science Education

Bridget A. Franks and Patricia H. Miller

Educators have shown increasing concern in recent years about gender differences in science and mathematics. Adolescent women's lack of confidence and interest results in far fewer women than men in science, mathematics, and engineering. In February 1992, the American Association of University Women released *How Schools Shortchange Girls*. This report, a synthesis of research on gender and American schooling over the past twenty years, documents findings that "gender bias in our schools is shortchanging girls and compromising our country" (AAUW, 1992). In this chapter we will discuss ways in which theories in developmental psychology and feminist epistemology can help us to understand the findings from the AAUW report.

Although girls enter school with academic abilities comparable to those of boys, changes occur as their schooling continues. In many schools, competitive classroom formats, scarcity of female role models in the sciences, and lack of encouragement erode girls' self-esteem, participation, and achievement. Observational studies show that girls usually receive less attention from teachers than do boys, their questions and comments are often ignored, and they are asked fewer questions and interrupted more frequently than are boys (Sadker & Sadker, 1985; 1986; Sadker, Sadker & Thomas 1981). By high school, girls are more ambivalent about their futures, have a diminished sense of personal efficacy, and do less well than boys on the standardized SAT test (AAUW, 1992). Girls are less likely than boys to take high school courses in physics or chemistry or to major in science in college.

The change observed in girls' attitudes and competencies, especially in cognitive areas, is of particular concern to developmental psychologists because it is negative; it contradicts the usual pattern of increases in skills and self-confidence throughout childhood and into adolescence. Developmental psychology has focused on describing and explaining change, but also on facilitating change so that development can proceed in an optimal way. Feminism has always had an agenda of causing or facilitating change, both within individuals and in society at large (Franks, 1992). Developmental theories can help us to understand this negative change in girls' development, so that we can adopt the feminist agenda of restoring girls' self-confidence and encouraging their confident participation in all educational endeavors.

In this chapter we will draw on several theoretical perspectives in developmental psychology to explain declines in girls' motivation and achievement in the school years. We will focus particularly on girls' experiences in mathematics and science, since it is in these areas where the most negative changes are observed. We will also discuss some of the interventions proposed by feminist epistemologists and others with the goal of creating a more equitable learning climate for girls.

Theories of Development

Cognitive Developmental Perspectives

Piaget proposed that children construct concepts in mathematics and science through interaction with objects in the environment. They make cognitive progress by reflecting on their own actions on the objects rather than on the objects themselves. Many recent studies have illustrated, however, that both at home and in school, and particularly in science and math classes, girls and boys have very different opportunities for both acting on objects and reflecting on those actions.

Baennenger and Newcombe (1989) have observed that boys grow up in more spatially complex environments than do girls. They are usually given more freedom to explore large environmental spaces and to play with more spatially complex toys, such as building and construction toys. As Kahle (1990, p. 56) points out, "Preschool boys handle more tools, throw more balls, construct more Lego bridges, build more block towers, and tinker more with simple mechanical objects than do girls."

In school, boys get more experience than do girls in demonstrating equipment and carrying out lab experiences in science classes. Sex differences in hands-on experience with science-related objects increase as children get older. One study, for example, found that by third grade 51 percent of boys and 37 percent of girls had used microscopes; by eleventh grade, 49 percent of males and 17 percent of females had used an electricity meter (Mullis & Jenkins, 1988). Another study of science classes found that when teachers needed assistance in carrying out a demonstration, 79 percent of the demonstrations were carried out by boys (Tobin & Garnett, 1987). Since it is common in schools for boys to actually perform experiments and other science-related actions on objects, girls' opportunities for reflecting on such actions may be limited, and so may be their construction of scientific and mathematical concepts.

Piaget's theory offers no direct explanation for girls' lower competence and motivation in math and science activities. Research related to the theory, however, offers insight as to what is *not* an explanation--namely, lack of the ability to think in ways that are necessary for scientific

understanding. There is no evidence that girls fail to develop what Piaget refers to as formal operational reasoning (e.g., scientific reasoning) or develop it later than boys do; research studies with such formal operational reasoning tasks as the isolation of variables, understanding proportional relationships, and evaluating syllogisms rarely report sex differences.

Another concept from Piaget's theory, the notion of disequilibrium, may also help us to understand girls' lack of motivation for achievement in certain areas. Piaget (1952) describes disequilibrium as the mental state that arises when current ways of interacting with the world are inadequate in the face of new information. For girls, strategies that result in academic success can also have the effect of reducing popularity, because some subjects, especially mathematics, are seen by both children and adults as "male" activities that are not appropriate for girls (Armstrong, 1985; Hyde, Fennema, & Lamon, 1990). Bush and Simmons (1987) note that girls often experience stress because of conflicting demands to achieve in school and also to be successful in interpersonal relations, especially dating. Girls may experience disequilibrium when they are encouraged to strive for academic success, but are also pressured to maintain social relationships with peers who may resent or ridicule their achievement. While some girls regain equilibrium by finding peer groups (and boyfriends) who are also high achievers, girls for whom this is not possible may reduce their achievements in order to fit in.

Other cognitive-developmental psychologists have explored the development of children's understanding of gender. Kohlberg (1966) and others (see Stagnor & Ruble, 1987, for a review) have confirmed that children at different ages have different understandings of the stability and constancy of gender, but that by age 5 most children know that gender is an underlying, unchanging aspect of identity. However, children prefer sex-typed activities and behave in sex-typed ways long before this understanding is achieved (Fagot & Leinbach, 1983).

Of possibly more relevance to the decline in girls' performance in math and science is gender schema theory, which describes the developing content and organization of gender knowledge; a schema is an organized way of making sense of one's experience. As children learn more about gender, specific behaviors, roles, occupations, and traits become associated with their schemata for being male or female (Deaux & Lewis, 1983; Huston, 1983; Martin, 1993). As time passes, children organize their knowledge in more complex ways. They have more highly-developed scripts for events associated with their own gender than the opposite gender (Boston & Levy, 1991) and have difficulty remembering information that is inconsistent with gender schemata (Liben & Signorella, 1980; Martin & Halverson, 1983). Students' interest in math and science may depend on how consistent such activities are with their gender schemata. For many female students, math appears to be quite

inconsistent with these schemata; in general, girls are less likely to envision themselves using math as adults than boys are (Armstrong, 1985). But girls who reject traditional gender roles demonstrate greater math achievement than girls who hold more stereotyped views, and girls in advanced math classes tend not to see math as a "male" subject (Armstrong, 1985; Hyde, Fennema, & Lamon, 1990).

A particularly interesting finding in this type of research is the observation that as children move into the school-age years, they become more flexible in their views of which activities are appropriate for which genders (Serbin & Sprafkin, 1986; Signorella, Bigler, & Liben, 1993; Urberg, 1982). Gender stereotyping appears to peak during the preschool years and diminish somewhat during middle childhood (Golombok & Fivush, 1994). At the age when children begin school, they are moving toward a more flexible view of what is gender-appropriate than they have had in the preschool years. But as the next section will show, many of their school experiences will reinforce rather than counteract the gender stereotypes they possess.

Vygotsky's Cultural-Contextual Theory

Many concepts from Vygotsky's theory offer insights about the academic achievements and attitudes of American females. Its contextual perspective defines the "child-in-activity-in-context" as the basic unit of study. Given the social-cultural-historical context in which American girls develop, their lack of achievement and self-confidence in certain academic areas is not surprising.

Girls in the U.S. experience social pressures to excel in sex-appropriate subjects, which do not include math or science, and also to be popular and not too intelligent lest they lose friends and boyfriends. Their culture as a whole looks upon women as less intellectually able than men, teaching them that only certain behaviors are appropriate for their sex. Their culture is saturated with messages dictating specified roles for males and females. Historically, their participation in education and professional activities has been limited by both law and tradition.

Another useful aspect of Vygosky's theory is the idea that knowledge is constructed through social interaction. In Vygotsky's view, language is a social device for social contact, communication, and interpersonal influence. He emphasized the collaboration of people or ideas in the dialectical process, stressing change resulting from interaction between a child and a more skilled person, but also recognizing that the dialectical process could take place between peers (Miller, 1993, p. 379). Children internalize these language exchanges and in this way develop cognitively. Between-people (intermental) dialogues become within-person (intramental) dialogues. Teachers teach children to think scientifically by

speaking the language of science and solving scientific problems with their students.

There is much evidence that both social interactions and language use differ markedly on the basis of gender. Studies of classroom interaction patterns with both peers and teachers also indicate very different experiences for boys and girls. Boys receive more attention and instructional time from teachers from preschool through the high school years (Ebbeck, 1984; Sadker & Sadker, 1986). They demand more attention, calling out as much as eight times more than girls do, and when they call out they are answered, whereas girls are told to raise their hands first (Sadker, Sadker, & Thomas, 1981). Even when boys do not volunteer, teachers are more likely to solicit responses from them than from girls, and their comments about boys' responses include specific evaluations, praise, criticism, and remediation. Comments to girls are often simply accepted; they lack detailed feedback, and thus offer girls little insight into the strengths and weaknesses of their responses (Sadker & Sadker, 1984).

With regard to peer interactions, sex differences are found at all ages. Boys use language assertively, to boast and to take the floor, whereas girls are more likely to use language to maintain relationships and to express agreement (Maccoby & Jacklin, 1987; Sheldon, 1990). Boys initiate more conflicts than do girls, and use physical aggression and strong threats to get their way, whereas girls use such tactics as compromise, changing the subject, or clarifying the other's feelings to resolve conflicts (Miller, Danahar, & Forbes, 1980).

At the secondary and post-secondary levels, interactions between male and female students often dampen female participation in mixed-sex classes. Women are still less likely to be called on than men, their comments are disproportionately interrupted by both teachers and male students, and teachers are less likely to develop their points than those made by male students. In everyday social interactions, men not only interrupt women more than women interrupt men, but men's interruptions of women often introduce trivial or personal comments that change the focus of what women are discussing or end the discussion altogether (Houston, 1994; Zimmerman & West, 1975).

Another problem with language is that women and men tend to use different linguistic styles in their speech. Women's speech frequently contains hesitations, questioning intonations, extensive use of qualifiers, and extremely polite, deferential forms. Men's speech often includes highly assertive speech, an impersonal and abstract style, and "devil's advocate" exchange. As Houston (1994) points out, in school settings the male style is often equated with intelligence and authority, while the female style is seen as unfocused and not taken seriously. However, the male style of speaking is not usually considered appropriate for females,

and the speech patterns that are thought of as intelligent and forceful when used by men are seen as negative and hostile when used by girls and women.

Vygotsky's work has demonstrated the importance of language and social interaction in the construction of knowledge. School is a time when students are expected to be actively involved in such construction, but the research indicates that differential language use and social interaction patterns may result in very different constructions for males and females, not only with regard to content knowledge, but also to students' constructions about themselves as knowers.

Social Learning Theory

This perspective has long been used to explain the development of sex-typed behaviors. For children, the consequences of various behaviors depend strongly on their sex; boys who play with dolls, for example, are often punished, while girls are rewarded for the same behavior. Differential reinforcement of sex-typed toys, games, and activities by parents is well-documented (Block, 1983; Fagot & Leinbach, 1983; Lytton & Romney, 1991). Block (1983) has argued that this results in different play and problem-solving experiences for boys and girls, with boys' toys encouraging invention, manipulation, and understanding of the physical world, and girls' toys encouraging imitation, proximity to caretakers, and understanding of the interpersonal and social world.

Children also learn about sex-role behavior from same-sex models, and are more likely to model people of the same sex than of the opposite sex (Bandura, 1977). If girls do not see mothers, teachers, and other women or other girls engaging in science-related activities, they are unlikely to engage in these activities themselves.

The social learning perspective can help us to understand the decline in girls' interest and scores in mathematics and science, and also their generally lower academic self-confidence. One source of these problems may be textbooks and basal readers, which began to be surveyed in the 1970's. Many examples of sex bias were found; in 1971, a study of thirteen popular U.S. history texts showed that information about women comprised no more than 1 percent of any text, and that women's lives were either trivialized, distorted, or omitted altogether (Trecker, 1971).

During the 1970's and early 1980's, efforts were made to make curriculum materials more inclusive. Studies cited in a 1980 review of research on the effects of books on children's attitudes indicated that books do transmit values to young readers, that academic achievement is positively correlated with use of nonsexist and multicultural curriculum materials, and that sex-role stereotyping is reduced in students whose

curriculum portrays females and males in nonstereotypical roles (Campbell & Wirtenberg, 1980).

While textbook publishers now use guidelines for nonsexist language, curriculum materials continue to be limited in their portrayals of models of achievement for girls. More recent surveys of social studies texts show that while women are more often included, their representation tends to be of the "token" variety, with mentions of the usual "famous women," but without a balanced treatment of women and men (Tetreault, 1986). Even texts designed to fit current California guidelines for gender and race equity showed subtle language bias, neglect of scholarship on women, omission of women as developers of history and initiators of events, and absence of women from accounts of technological developments (Newsletter of the Special Interest Group on Gender and Social Justice, 1990). With regard to science curriculum, reform efforts under Project 2061 of the American Association for the Advancement of Science describe equity as a central organizing principle, but so far have not produced materials consistent with this goal. While acknowledging that scientific discoveries have been made around the world, specific referrals are only to European and American scientific history and the usual "great men;" women are no more visible in the new curriculum than in more standard science materials (AAUW, 1992; Rutherford & Ahlgren, 1989).

The examples of differential treatment by teachers mentioned earlier also have a modeling effect on students. When teachers reinforce boys for calling out by answering them, and punish girls for the same behavior by telling them to raise their hands, they give all children a model of treating boys and girls differently, and valuing boys' input more than girls.' When they give boys more opportunities to learn and succeed in math and science, they convey to girls that they are not capable of success in these areas. If girls lack models for achievement in the books they read and the lessons they are taught, and do not receive the same encouragement for achievement as boys do from their teachers, it should not be surprising that their attitudes and performance decline over the school years.

Attribution Theory

Attribution theorists have proposed that gender differences in performance on certain tasks and choices about preferred activities are caused, at least in part, by different achievement-related beliefs. Females have lower perceptions of competence and lower performance expectations than do male students in math (Eccles, 1983, 1987; Hanna & Sonnenschein, 1985; Mura, Kimball, & Cloutier, 1987). Males and females also tend to have different perceptions of the causes of their success and failure in mathematics; females are less likely than males to attribute success in mathematics to their own high ability, and are more

likely than males to attribute failure in mathematics to their own low ability (Parsons, Meece, Adler, & Kaczala, 1982; Ryckman & Peckham, 1987; Stipek, 1984). Stipek and Gralinski (1991) observed associations between these kinds of attributions and girls' beliefs that effort brings about success, the desire to avoid mathematics tasks, and future performance expectations. If a girl believes that girls have low ability in the area of science, she is not likely to see any point in putting more effort into science subjects or to select advanced science courses.

Feminist Epistemological Theories

In contrast to the theories generally recognized as developmental theories that we have just discussed, the relatively new feminist epistemological theories have as yet had little impact on developmental psychology. However, we will discuss them because they have important implications for science education for girls. Although there are many feminist epistemologies, they all challenge the Western androcentric view that scientific thinking involves an isolated, autonomous thinker, distanced from the object of thought. Traditionally, thinking involves linear causal logic and hypothesis testing about decontextualized objects. In contrast, feminist epistemologies propose that thinking may be "interconnected" (Miller, 1994). We will describe several ways in which a scientist or science student might use interconnected thinking.

First, from a feminist point of view, scientists should become close to what they are studying rather than distance themselves from it in an attempt to be "objective." When studying a scientific event one needs to "get inside of an idea," "listen to the material," and develop a "feeling for the organism" (Keller, 1983). In the words of cancer researcher Anna Brito, "Most importantly you must identify with what you are doing. If you really want to understand about a tumor, you have got to be a tumor" (Goodfield, 1982, p. 226). An immersed knower can generate plausible hypotheses by listening to what the material (poem, ear of corn, chemical compounds, etc.) has to say. A person enters into a reciprocal relationship with that which is to be known. A conversation begins. Premature hypothesis testing can distort the phenomenon because it restricts what aspects of the phenomenon the observer considers. In contrast, interconnected knowing advocates initially trying to perceive objects in their own right, with no preconceived notions about the nature of the object.

Girls may have a different preferred style of doing science--a style that does not fit into the "scientific method" as it typically is taught in the classroom. Rather than enter a scientific activity with a hypothesis to be tested, they may want to spend longer in the hypothesis-generating phase--getting to know the material they are working with and bringing in ideas from analogies in their everyday life. One example is that when generating computer programs, girls prefer an interactive, open-ended

style in which they try out a procedure and respond to feedback from the computer, which in turn leads to another move, and so on (Turkle & Papert, 1990). In contrast, boys prefer to decide ahead of time how they will proceed.

Second, interconnected thinking refers to perceiving relations between a phenomenon and its context (physical, historical, social, cultural, etc.). An example comes from the Nobel Prize winning geneticist, Barbara McClintock (Keller, 1983). McClintock emphasized how the context of a gene (i.e., other genes, the entire cell, the whole organism of which it is a part, and even features of the environment such as droughts) affects its expression and functioning. As Keller (1985, p. 168) concludes, genes are "organized functional units, whose very function is defined by their position in the organization as a whole." Girls may be more interested in science when teachers show how the phenomenon connects to the larger world and their everyday lives (Rosser, 1990).

Third, the knower is interconnected with other people. Girls may be more comfortable with notions of cooperation, collaboration, and mutual support than with notions of dominance, competition, and aggression. They may find it more plausible to view genes as interacting with their environment (as did McClintock) than to describe their action in a "master molecule," with DNA controlling and directing cellular activity (Hubbard, 1990). Also, girls may be sensitive to the equity of relationships, power, and opportunities among people in the laboratory. They may be more interested in a science classroom where cooperation and peer collaborations are emphasized over competition. Valued activities may include sharing ideas, building on each other's ideas, and nurturing and supporting the ideas of others. Ideally, this characterizes the collaborative research of real scientists.

Interconnected knowing does not violate the basic tenets of good scientific thinking; rather, it broadens the content of what is thought about and reconceptualizes the process of hypothesis construction and testing. The feminist and traditional approaches are complementary. Interconnected knowing in many ways characterizes the way that creative scientists actually do science, as opposed to how we teach children it is done.

Thus, various theories emphasize different aspects of gender-related socialization regarding science. We now turn to a consideration of how educators have attempted to alter this situation and to reduce the related limitations on girls' performance in math and science.

Interventions

The AAUW report notes that in 1991 President Bush and the Department of Education presented America 2000, a "plan to move

every community in America" toward an ambitious set of goals for educational reform. None of the strategies proposed in the plan are gender specific; educational needs specific to girls were not addressed in the process of setting the national agenda. Nevertheless, feminist epistemologists and educators have proposed numerous interventions designed to counteract negative messages and encourage girls to reach their full educational potential. Houston (1994) notes that trying to make schools gender-free is probably impossible and would in any case result in teaching girls to act like boys, thus removing the benefit for all students of girls' more cooperative, sensitive interaction style. Houston argues that a better approach is that of Martin (1981) who proposes a gender-sensitive perspective for education. This perspective suggests that we pay attention to gender when it can prevent sex bias or further sex equality. It requires careful monitoring of gender interactions and direct intervention when necessary to equalize opportunities.

In *Women's Ways of Knowing*, Belenky, Clinchy, Goldberger, and Tarule (1986) described the process of "connected knowing," in which students empathically enter into the subject they are studying, and note that many girls and women are more comfortable with this style. They recommend classrooms that emphasize collaboration and provide space for exploring different opinions.

In recent years, "cooperative learning" techniques have gained much popularity in education. They are designed to reduce the negative effects of classroom competition, promote a cooperative spirit, and improve cross-race relationships. While they have achieved some success in these goals (Devries & Edwards, 1974; Slavin, 1980, 1981; Weigle, Wiser, & Cook, 1975), it may be difficult for girls to experience the benefits of these groups. As noted earlier, the different interaction styles of girls and boys result in boys' dominating discussion in most group situations. In small groups, boys are more likely to receive requested help from girls, while girls' requests for help from boys are more likely to be ignored (Wilkinson, Lindow, & Chiang, 1985). While small groups provide boys with leadership opportunities that increase their self-esteem, girls are often seen as followers and are less likely to want to work in mixed-sex groups in the future. Some studies have found decreases in female achievement when females are placed in mixed-sex groups, and others have found that the use of small, unstructured work groups does not reduce gender stereotypes and sometimes increases them (Lockheed & Harris, 1984).

It seems likely that more intense interventions may be necessary for some time to come if girls are to become more proficient and comfortable with math and science tasks. Follow-up studies of interventions designed specifically for girls have revealed positive results. Six months after attending a one-day career conference, girls' math and science career interests and course-taking plans were higher than before the conference

(Anton & Humphreys, 1982). A three-year follow-up of a four-week summer program on math, science, and sports for minority junior high school girls found that they increased their math and science course-taking plans by an average of 40 percent, and that they did take the courses (Campbell, 1990a). A two-year follow-up of a two-week residential science institute for female high school juniors already interested in science found that the program decreased girls' stereotypes about people who are good in science, reduced their feelings of isolation, and strengthened their commitment to careers in math and science (Campbell, 1990b).

Finally, increasing numbers of parents, concerned about the effects of American education on their daughters' motivation and self-esteem, are choosing to send them to all-female schools. Enrollments in private all-female colleges have increased by 14 percent in the past three years, while enrollments at other private colleges have remained stable (NPR News, 1994). However, since this option is only a possibility for the wealthier segments of our society, most girls will not have the opportunity to learn in a same-sex environment. Efforts to reform coeducational settings must continue.

Conclusion

It appears that there are ways to help girls to believe in themselves and commit to achievement in math and science, but many characteristics of students, teachers, and the larger social-historical context in which girls develop will continue to make this a difficult task. Since developmental theories are helpful in explaining some of the difficulties, we can hope that in the future they will be more widely used in designing interventions as well.

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Brave New World: Gender Equity, Science Education And The New Environmental Paradigm

Marilyn MacDonald

"Take some more tea," the March Hare said to Alice, very earnestly.
"I've had nothing yet," Alice replied in an offended tone, "so I can't take more."
"You mean you can't take less," said the Hatter: "it's very easy to take more than nothing."
(L. Carroll, Alice's adventures in Wonderland, 1930, p. 128)

Like Alice, are women invited to the science tea party, only to find that the proverbial cup of knowledge remains empty? For me, the answer is both *no* and *yes*. *No* applies to the opportunities for science education that I've had from Grade One on. *Yes* applies to the fact that the body of knowledge, the institutions and the ideologies of science and of its siblings, engineering, technology and trades (SETT) were created over a minimum of a four hundred year period in which women were legally, politically, economically and socially marginalized. If the tea seems/is unusable, then the cup is effectively empty of benefit.

However, our increasing awareness of the problematic human-environment relationship may provide a new impetus for science education that truly includes women. In this paper, I explore some of the changes that might entail.

A personal definition of science education

To start, I will clarify my understanding of the meaning of science education, particularly as I have experienced it (in the next section, I will discuss some of the reasons for the centrality of biography and explicit statements of personal position to feminist analysis). For me, science education has had two components, one formal and the other informal. The formal component, accomplished in institutions such as public school and university and mediated by professional educators, is involved with knowing more about the natural world. It includes the acquisition of skills, behaviors and information which have been organized into disciplines (such as biology, chemistry, physics and geology). The social sciences are generally not included in science education, given our belief that the human and natural worlds overlap only slightly, and our practice of professional territoriality. Formal science education is hierarchical; students are divided into university or vocational streams, competitive autonomy is emphasized, and a

lockstep career path is favored, geared towards the middle-class, able-bodied, male lifecycle.

In terms of formal science education, I have a Baccalaureate in Biology (from a small Liberal Arts university), a Doctorate in Plant Sciences (from a large research university), and a Baccalaureate in Education to teach high school biology, chemistry and outdoor education (from another large research university). Living through it, I think that I found science education no more sexist than arts or fine arts education up to the completion of my first baccalaureate. Looking back now, I wonder why the women disappeared from teaching between school and university, why men with two years of doctoral research got government jobs while better qualified women typed theses to stay in science -- all the tacit warnings that formal education might seem accessible to women but is not.

The informal component, on the other hand, is much more experiential, affected by the position that one occupies within SETT (e.g., as experimenter or subject; as owner, worker or consumer). It is contextual, affected by changes in environmental parameters such as national objectives or states of pique and enthusiasm. It is reciprocal, running on a continuous exchange amongst the living and nonliving components. Informal science education is what all of us learn by living in a society (or a system of societies) based on SETT.

The beginning of anyone's informal science education is difficult to identify. From some accounts, mine began at around two, with an incessant "why?". It is a part of what Rachel Carson called a child's sense of wonder, and often doesn't seem to survive adolescence. My informal science education wove itself around and into the formal part, but was involved with questions for which I found the answer by myself, through reading or experiment or discussion. After the formal part finished, it continued as the learning of science in the context of work as an environmental consultant, as a government administrator of research and development, as a high school/college/university teacher. Two examples may serve to illustrate what it involved.

When I was a graduate student, I took part in the "Science for the People" movement, developing straightforward explanations of nuclear energy, environmental warfare and so on. Those explanations were limited -- what the substances were, how the processes worked -- not because of the simplicity, but because we reached the point where the ultimate 'why' about human violence seemed unanswerable. People understood and used informally learned SETT knowledge, especially when their lives depended on it.

My second example comes from teaching Adult Education courses in Grade 12 biology and chemistry. Many students were women who had

been out of school for years, had started or raised a family, and had decided to take a science course. At some point, almost all of them would exclaim, "What did I ever find hard about this [photosynthesis, kinetic molecular theory...]!" Their change in perception came from a number of sources including their own sense of purpose, their maturity, and their responsiveness to alternative pedagogies (feminist, critical, experiential and so on). Whatever they had learned informally about science had prepared them to succeed at the formal as well.

We need a definition of science education that acknowledges the formal and informal components, and that measures equity not just by the number of spaces that women have in male-dominated disciplines, but by the inclusiveness of the epistemology per se. Is this the kind of gender equity in SETT that we have sought?

Gender equity - still ain't satisfied

Reform of science education has been around for about as long as science education itself. No matter how revolutionary, reforms which ignore gender (e.g., Bruer, 1993; Cheek, 1992; Fensham & Hunwick, 1986; Gardner, Greeno, Reif, Schoenfield, deSessa & Stage, 1990; Mellin-Olsen, 1987; Morris, 1990; Postlethwaite & Wiley, 1992; Rosier & Keeves, 1992) risk perpetuating or exacerbating existing differences between boys' and girls' attraction to and retention in science (British Columbia Ministry of Education, 1993; Kelly, 1987; Rosser, 1986, 1990).

In the United States and Canada, science has been a part of formal education since the early 1800s, an important factor in justifying government-supported education and compulsory school attendance (DeBoer, 1991; Statistics Canada, 1992). Educators and politicians have sought the ideal mix of elite and general science that ensures national competitiveness, effective democracy and individual utility. Most of the issues – the topics/disciplines that constitute science, the necessity of laboratories, discovery learning versus rote memorization, the transferability of science skills – remain unresolved after a century and a half of debate (American Association for the Advancement of Science, 1990; Cheek, 1992; Connelly, Crocker & Kass, 1985; Doern, 1972; Fensham & Hunwick, 1986; Lennon & Walthall, 1992; Newman, 1985; Organization for Economic Cooperation & Development, 1969; Orpwood & Souque, 1984; Page, 1979; Roberts, 1983; Smith, 1990; United Nations Educational, Scientific and Cultural Organization, 1983, 1990; Zinberg, 1990).

Yet, for all that these debates purportedly have to do with public good, the primary focus has been on the white, male, middle-class (Arditti, Brennan & Cavrak, 1980; Freire, 1970; Gaskell, 1992; Spender, 1981). We have no idea of what science and technology would be like in the 1990s if women and minority groups had been equally included from even Confederation (1867) to the present.

Beginning in the 1860s, women in the United States and Canada won the right to attend university, and to train for such professions as medicine, teaching and the law. They met with resistance at every step. In New Brunswick in 1867, only men could teach algebra and geometry; women were restricted to teaching the three R's for an appropriately reduced salary (Statistics Canada, 1992). Women were banned from the Toronto School of Medicine and Queen's University Medical Faculty up to the turn of the century (Strong-Boag & Fellman, 1991). In many states, into the early 1900s, women could not be admitted to many professions because they were (if married) not legal persons (Dawson, 1990).

Advocates of women's science education fought against social constructions of women as frail vessels, unfit for the rigourous competition of the scientific workplace (Newman, 1985; Phillips, 1990; Schiebinger, 1989); as emotional beings, incapable of objectivity and rationality (Noble, 1992; Russett, 1989); and as dilettante workers, waiting for marriage and children (Abir-Am & Outram, 1987; Kass-Simon & Farnes, 1990). They argued that, in the complexity of the industrial world, children needed mothers who knew about hygiene, nutrition, the operation of modern appliances, and enough science to help with schoolwork. While it did open up university education to women (in the mid 1800s), this argument often resulted in the ghettoization of women's science education (Rossiter, 1982).

Feminist researchers disproved the assumption that women could not do science by rescuing from historical obscurity the stories of women in SETT, and by identifying the barriers that these women had had to overcome. As the catchphrase, 'the personal is political' suggests, this biographical research made clear the ways in which relationships of power, determined by gender, race, class, ablebodiedness and so on, operate in the lived reality of marginalized people to maintain the status quo (Ainley, 1992; Alic, 1984; Brooks, 1992; Byrne, 1993; Castenell & Pinar, 1993; Sokoloff, 1992).

In particular, a knowledge of context raised doubts about the SETT ideals of objectivity and neutrality. The questions considered important to ask, the answers considered acceptable and the ethics of the relation between researcher and researched are heavily influenced by the standpoint (worldview, paradigm) of the individual researcher and of the social system in which s/he is embedded (Harding, 1991; Keller, 1983, 1985; Longino, 1990).

To deal with this and other positivist problems, feminist and other critics of SETT have solutions ranged along a continuum from "good science/bad science" to "reconstruction". To use the "blindfolded people describing an elephant" metaphor, the first term involves the development of methodologies and values to ensure that everyone's

description is included; and the second, the questioning of the necessity of being blindfolded to doing descriptions, and of whether the elephant is who we need to know (Eichler & Lapointe, 1985; Harding & Hintikka, 1986; Hekman, 1992; Keller, 1983, 1985; Longino, 1990; Vickers, 1984; Wylie, 1990).

To return to the question of equitable science education, we can see the reforms that have come from such feminist analyses. Female-friendly science classrooms use inclusive language, give examples of women scientists, develop units that include issues of interest to girls, mix in cooperative learning and feminist pedagogy, never harass, and link up with counselors who can give girls good career advice (Briskin, 1990; Culley & Portuges, 1985; Deats, 1994; Rosser, 1986, 1990; Rothschild, 1988; Schneidewind & Maher, 1987; Weiner, 1994; Whyte, 1986). This gender-friendliness has narrowed the gap between the number of girls and boys in science and mathematics courses, (Statistics Canada, 1985) but still leaves women as only one in five of the workers in SETT in OECD countries (UN Development Programme, 1993).

Science-based jobs are amongst the most stable and remunerative (Armstrong & Armstrong, 1992; Lewis & Kelly, 1987; National Research Council, 1991, 1992; UNESCO, 1983). Yet few women *or* men go into SETT. In 1988, the percentage of science graduates (out of the total of all postsecondary graduates) was 30 percent world-wide (and for OECD countries), and 29 percent for developing countries. The percentage for women was 25 percent, and for men, 37 percent. In terms of scientists and technicians per thousand people, the world average is 22 (UNDP, 1993). We do not even have a useful measure of functional scientific literacy to know how the other 978 per thousand relate to SETT. Why?

Perhaps the stereotypic portrayal of scientist/engineer as a competitive, isolated, rationalist white male; and the doing of science as the embodiment of rationality, linearity, competition and objectivity is alienating. Feminist critics of SETT have argued that a more complete portrayal of the human-ness of doing science, of the involvement of intuition and serendipity, and of the centrality of values and relation to others would be both more realistic and more welcoming (Bleir, 1986; Gilligan, 1982; Harding, 1986; Harding & O'Barr, 1987; Longino; 1990; Tuana, 1989). They suggest that we examine the institutions, ideologies and bodies of knowledge that we consider to be science to see if the process of gendering has impoverished the nature of science (Keller, 1985; Rosser, 1990; Shepherd, 1993). Is there any indication that gender equity in science education is a possibility? For that, we need to shift our focus to a different political scene.

The brave new (sustainable) world: A New Environmental Paradigm

In the late 1970s, sociologists Catton and Dunlap reflected the concern of many sociologists with these comments.

> Because ecosystem constraints now pose serious problems both for human societies and for sociology, three assumptions quite different from the prevalent Human Exceptionalist Paradigm (HEP) have become essential. They form a New Environmental Paradigm (NEP). (1978, p. 41).

The three assumptions that characterized the Human Exceptionalist Paradigm were as follows: first, that humans are unique in having culture (assuming no tautology); second, that culture can vary a lot quickly; and third, that human differences, being social, can be altered, with limitless progress and problem solving. The HEP is also known as the Dominant Social Paradigm (DSP), characterized by a reliance on industrial science and dominion over nature, and as the Western Worldview (imperialism and neocolonialism added to the DSP). The NEP represents a set of beliefs and attitudes based on relationship, sustainability, cooperation and interdependence. Global survival was considered the motivation to change to it (Dunlap & Catton, 1979).

There are some indications that it could happen. From 1992 to 1995, several major United Nations Conferences have been, and will be held -- Environment and Development (1992), Population (1994), Economic Development (1995), and Status of Women (1995). For all of these Conferences, the issue is sustainability -- how to meet the needs and aspirations of today's generations of humans without imperilling those of future generations? To change from a nonsustainable (HEP/DSP/WWV) to a sustainable (NEP) worldview, we need a science education that accomplishes different things. In the face of exponential population growth, environmental crises and an urgent need for 'green' technologies, increasing women's participation in SETT is moving from being the ethical concern of a few to the pragmatic concern of many.

Women are seen as the primary health care guardians within their families, and the primary environmental managers, making decisions about food production, marketing, provision of daily necessities and so on. Their/our knowledge can become part of our body of scientific information, as well as being strengthened by more formal training in many of the skills and concepts of a wide range of human learning (Cheek, 1992; DeBoer, 1991; Fensham & Hunwick, 1986; UNESCO, 1990). Examples from two of the Conferences illustrate why (and to some extent, how).

At the Environment and Development Conference, delegates from over 180 countries agreed to *Agenda 21*, a (nonbinding) action plan to achieve equitable sustainable development. Chapter 24 of *Agenda 21* clearly stated that women (as half of the human population) had to be included in all decision-making about natural resource management and the state of the environment. While not directly considered, the intent of gender equitable science education is supported by the central ideas discussed -- the use of affirmative action to end discriminatory laws and customs; the assurance of equal access to education, health care and employment and of fully-recognized and recompensed credit for productive and reproductive labour; the ending of all forms of violence against women, from pornographic stereotypes to the indifferent violence of war (UNIFEM, 1993).

That women were included so prominently in *Agenda 21* was due in large part to meetings of women's groups from local to international (e.g., Global Assembly of Women and Environment: Partners in Life, and the World Women's Congress for a Healthy Planet). Women from around the world reached consensus on what successful sustainability would be, and put that consensus forward at the UN Conference.

This process reflected three lessons which women had learned that exemplify the implications of Chapter 24 for science education. (1) *make use of women's knowledge*: women deserve a fair share of the world's human-produced resources. Models of economic restructuring were 'bad science', leaving out significant factors such as volunteer and domestic labour, and thus failing to predict the impact on women. Programs and policies have to be considered in context and in their entirety, with specified timetables and resource commitments against which their success or failure can be evaluated. Too many SETT ideas were parachuted into systems inappropriately (e.g., new farming techniques taught to the nonfarmers (men) rather than the farmers (women)). Science education has to be flexible enough to be locally designed, and to incorporate community-based knowledge. (2) *get women into decision-making about environmental management*: women must control issues that affect them. Men's and women's lives are different, and women cannot rely on men to understand or give priority to women's realities. Science education should include training on group dynamics, appropriate levels of information for decision making, and strategies for effective social action. Alternatives to the lockstep career path are required that are more in keeping with people's lives. (3) *develop data bases and spread information concerning men's and women's roles in society:* women have come to recognize the multiple sources – race, language, ethnicity, (dis)ability, socioeconomic class, sexual orientation, religion -- of their marginalization, and have worked together to combat them at the local to the international level. Science education must emphasize the social construction of science and the nature of change in scientific beliefs. The preservation and transmission of scientific knowledge should include

such things as the relative importance of spousal support to career development, and the ways in which people have been affected by technological change (MacDonald, in press).

In other chapters of *Agenda 21*, specific aspects of SETT are either directly mentioned (e.g., Chapter 35 on science for sustainable development), or are considered central to an issue (e.g., Chapter 34 on transfer of environmentally sound technology). In all these cases, gender equity in science education would require that women's issues be addressed, and that women be directly involved (Rogers, 1993).

As a second example, consider the Conference on Population. In August of 1994, the United Nations' Population Fund released *The State of World Population, 1994: choices and responsibilities*, which opened with this statement:

> ...(e)mpowerment of individual women, opening a wider range of choice for both women and men, and building a basis for action at the family and community level, may be the key to social development, including the resolution of population problems ... environmental protection and economic development. (Marshall, 1994; p. 1.)

The argument, shorn of rhetoric, goes something like this: (a) our environmental impact is a combination of our numbers, our resource consumption rates, and the efficiency of our technologies in resource conversion; (b) and we know (after the UN Conference on Environment and Development) that the current population of five and a half billion people is straining the biosphere's support capacity; (c) but conservative estimates show that by 2025 we can expect to have eight and a half billion people on Earth; so (d) therefore, we should slow down population growth and resource consumption, and improve technological efficiencies; (e) but the most environmentally friendly way to slow down population growth is by birth control (rather than war, famine or plague); (f) and the most consistent and effective use of birth control has occurred when population programmes have been part of a broader development which included women-centred education and health care, and the entry of women into the paid workforce; and the conclusion, flowing not from the Report but from the subject of this monograph, would be: (g) therefore, in terms of rational self-interest, we should develop a sustainable-science education which meets the needs of the year 2025; a sustainable-science that includes women's and men's daily lives, and women and men as equally-valued workers. We have gone full circle, arriving at a new definition of science education based on a reconsideration of scientific motherhood.

Conclusion

In Carroll's story of the tea party, Alice is told to leave since she has not been invited. She protests that there are far more places at the table than the Mad Hatter, the Dormouse and the March Hare could use, and discovers that they are trapped in a world that doesn't change. The March Hare agrees that they need the extra settings so that they can move on when they have finished. They have no answer to Alice's question about what they will do when all the settings have been used (Carroll, 1930).

In many ways, we are at a crossroads, moving towards a world more fully determined by human activity than anything we've known previously. If, out of conviction or necessity, we move towards sustainability, we will exchange a worldview of interrelated concepts like progress, technological solution, dominion and competition for one of equilibrium, ecocentricity, contextual relation, and cooperation. At the same time, if we try for a world based on human rights, then women and women's knowledge, issues, history and values must be included. It is the challenge of the 1990s to science educators to come up with the ways to contribute towards our trip.

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The Interaction Of Gender With Ethnicity: A War Beyond Color In The Classroom.

Dawn. M. Pickard

> "Teachers are the hope of inner-city children. Will they have a teacher sensitive to their needs? These are my people, poor White, Black, Hispanic, Native American. If we think we're turning out teachers for middle class America - think again. We must build white teachers into the kind of teacher who is comfortable in any situation, who is culturally responsive. Period." (Hatchett, 1994)

Much has been written concerning the need for global education and an awareness of the differing educational needs of women and people of color in urban, suburban and rural school settings (Clewell, Anderson, & Thorpe, 1992). The reality is that most teachers of American elementary children are white, female and from middle class homes. High school teachers are more likely to be male than female and equally more likely to match their elementary counterparts in terms of socio-economic status and ethnicity (US Dept. of Education, 1993). Researchers continue to document the difficulties faced by educators who in socio-economic status and cultural practice differ from their students. These difficulties are apparent when the school culture and the home culture display differing mechanisms for verbal and non-verbal conversation as well as problem resolution. As a result of this dissonance, a variety of survival responses are exhibited by those caught in the crossfire of the differing expectations. Often the differences are exacerbated by the school environment (Connell, 1994; Pickard, 1992).

Glasser (1986) contends that all people have the same five basic needs that they strive to fulfill. The needs are: (1) to survive and reproduce, (2) to gain power, (3) to belong and love, (4) to be free, and, (5) to have fun. He maintains that when these needs are met in classroom settings, there are few, if any, problems and the learning environment is satisfying to all participants. When these needs are not met, inappropriate behaviors result because people are always choosing the behaviors they believe will satisfy their needs (Glasser, 1986).

Often the inappropriate behaviors exhibited in science classrooms are the result of students using strategies that "work" or are acceptable in other socio-cultural contexts. Those in power positions (i.e. teachers) are

likely to be unaware of how their responses to these diverse cultural patterns maintain and promote (often negative) stereotypes.

Compounding trans- cultural issues of social and economic status is the gender bias embedded within each culture (Tannen, 1994). It is already well documented that girls and women, particularly women of color can be disadvantaged in the American K-16 school system (Sadker & Sadker, 1994). Little, however, is written about the dilemmas faced by girls and young women in primary and secondary schools who look like typical Euro-centric, white Americans in terms of body features and dress, but come into American classrooms with vastly different language skills, cultural values and practices. What happens to these women as they try to succeed academically? This chapter discusses some of the survival strategies of ten young Chaldean women in a large urban high school as they successfully completed high school science and mathematics courses.

Background

> "I am Chaldean and proud to be. I think people have a stereotype of me as being a white girl and that's not right, I mean I am white, but not really, I am a Chaldean. ... Here we are keeping our close Chaldean ties and yet... The conflict I have is being classified as something I'm not." (Sara, 1994)

Sharing a language means more than knowing the "right" names by which to call things; it means knowing the "right" syntax in which to pose claims and questions, and even more importantly it means sharing a more or less agreed - upon understanding of what constitute legitimate questions and meaningful answers (Keller, 1985, p. 130).

Among most people groups, the problem of identity is crucial to social acceptance and cultural well being. One such group is the Chaldean community of Southeastern Michigan. Immigrating from the country of Iraq, particularly the areas around Baghdad and Telkaif, the Chaldean community has strongly impacted schools and neighborhoods in Detroit and surrounding suburbs. There is a strong commitment to the Catholic Church, the extended family, and a deep commitment to tradition and community. To understand the impact on public schools, and set the context for implications and inferences concerning the interactions of gender and ethnicity with respect to science and mathematics, a brief cultural and ethnic historic tradition follows.

The Chaldean community of southeast Michigan is the largest Chaldean community in the United States. It must be noted, however, that it is thought census figures underrepresent the community. The reasons for this underrepresentation include: 1) Middle - eastern populations are

Caucasiod and are aggregated with other white races. 2) Chaldean community members may not have identified themselves as Middle Eastern because of anti-middle eastern sentiments during the time of census data collection.

The Chaldean community is a blend of at least three cultural influences: " the village peasant culture from Telkaif, the urban culture of Baghdad and the American influence of the Detroit area" (Sengstock, 1970). Because this people group is considered Caucasian, information about school success is primarily data collected by members of the Chaldean community itself or individual schools having large numbers of Aramaic speaking students. The Chaldean population has developed and prospered in Detroit, gaining economic independence primarily by running grocery and party stores. Of late, pharmacies and drug stores are becoming part of the business community. During the racial conflicts of the sixties, the Chaldean community was often targeted for criticism or violence by other racial minorities. It was believed that the Chaldean immigrants were "taking advantage" of poorer people. Yet the truth was that while major grocery and department stores were leaving the inner city, the Chaldean community stayed, running businesses and providing services for an area economically disenfranchised by most other people (Sarafa & George, 1981).

Several studies conducted in the early and mid-eighties document the educational needs as well as the issues of bias and stereotyping faced by Chaldean students as they assimilated and accommodated the American culture (Raby, 1986). Not surprisingly, Chaldean students living in inner city environments, under severely depressed economic conditions were (and continue to be) much more likely to drop out of school than students living under less depressed economic conditions. In addition to economic stress, the studies indicated double standards for men and women. Sex roles were very well defined. Males were allowed more freedoms than females. Women dropped out of school as soon as they were able in order to marry. (Parents often arranged marriages for their daughters, by going back to Iraq finding husbands who were ten to twenty years older then the women (Raby, 1986).) Extra-curricular activities were in general not a choice for young women. Dating or mixed group activities were not permitted by most of the parents. Young women were taught to value home and family, and while education was valued, it was more important for boys than for girls. It is interesting to note that this is no longer the case in Iraq. Women are encouraged by the government to be educated. Jobs are guaranteed by the government upon graduation. Although women are fewer in number than males in tertiary education, competition appears keen among young women to attend the best universities. Admittance is based upon exam scores. The higher a student scores on an exam the better their chances for admittance to a "good" university (Student interview, 1994).

Methodology

For this study, three teachers and administrators from three large urban and suburban school districts were interviewed. All districts had significant populations of non-Eurocentric students coming from a broad range of socio-economic backgrounds. In addition to the teachers and administrators, ten academically successful Chaldean women preparing to attend college from one high school were asked to participate in the study. While some teacher and administrator comments will be referred to, the focus of this chapter will be the implications of the dialog with the ten Chaldean women.

Students were selected based upon junior or senior status, indication of a desire to attend college and academic success in mathematics and/or science courses. All students were first or second generation Americans. Those first generation women (n=6) arrived in the U.S. six months to fifteen years before being interviewed. All student interviews took place in the high school setting and were arranged by the foreign languages department.

Interview protocol consisted of three major open-ended questions: (1). Describe your home life and how you think it effects your academic performance. (2). Do you see yourself as Chaldean, American or something else?, and, (3). To what do you attribute your academic success? Other questions evolved during discourse. All interviews with the exception of one were tape recorded and were conducted during the fifty-five minutes students had for lunch or study period. Drafts of interview analyses were returned to interviewees as a check of interpretation and conclusions. All student names were changed.

Results

"Equal access" and "equal opportunity" for educational experiences do not necessarily provide equitable experiences for all children. The perceptual understanding of both teachers and students concerning school tasks and relationships between individuals in the classroom works to promote or deter learning. Likewise, stereotyping individuals of a particular group and imbuing them with a particular set of characteristics promote failure or success in learning.

If we have learned one thing from research on the interaction of curriculum and social context, it is that distributing equal amounts of the hegemonic curriculum to girls and boys, to poor children and rich children, to Black children and White children, to immigrants and native-born, to indigenous people and their colonizers, does not do the same thing for them - or to them. In education, the "how much" and the "who" can not be separated from the "what" (Connell, p. 140, 1994).

Researchers disagree as to the approaches necessary to help students from various cultural backgrounds achieve academic success (Denbo, 1990; Erickson, 1986). Some researchers suggest that ethnicity, race, culture and gender are not, and should not be central issues in the teaching/learning environment because not all cultural practices can be embedded in curriculum. Addressing these issues by determining the criteria upon which groups are judged - or what pieces of group practice or identity become part of the curriculum (they say), the educative system devalues the attachments individuals make to particular groups; racial, cultural, social, etc. that may be different than the ones presented in the curriculum and may therefore create a larger problem of identity (Wilson, 1986).

All of the women interviewed for this study had a strong sense of identity. They saw themselves as Chaldean first, then American and student. Each woman had unique characteristics and personality traits. One young woman in particular was not happy in school. She appeared uncomfortable with the way other Chaldean young women coped with public high school, believing their dress and behavior to be unseemly. She had no special friends, felt school was too easy. She'd been in the United States for two years and missed Baghdad. As soon as she could, she was "going home."

All women called Baghdad "home," even those whose parents lived in the United States for thirty years, and planned never to return "home." All women planned to get married; some knew their marriage would be arranged by family members, but all the women who were asked felt that they had the final say and could put marriage off until their schooling was complete. Only one of the women expected to leave home in order to attend college. Major career goals for these young Chaldean women who expressed a love for math and science included business, pharmacy, medicine and environmental law. One young woman saw herself as a role model for others. She made a conscious effort to be part of the high school community. She could compartmentalize her cultural heritage and make decisions outside that context. When she made a decision that she knew her family would not approve, she either did not tell them or she prevaricated.

All the women indicated that they made conscious efforts to assimilate and accommodate to the American culture. The women who were in the U.S. for less than five years mentioned specifically the placement of men in their classes, and the strangeness of working in mixed class settings. They did indicate, however, that they "got used" to the men, and were not deterred in their personal learning. They also said they felt comfortable asking questions in science and math classes.

Some first generation students were uncompromising in their view that science classes were too easy. When questioned in greater depth as to

what they meant by too easy, students mentioned multiple choice exams and lab reports as well as the practice of discussing concepts with a small group of peers. Their standard of comparison was long essay exams and daily individual recitations of information read. This was "good" teaching and learning practice. When asked why they did not request placement in more advanced science classes, the women mentioned language difficulty. In every case, there was frustration that content understanding was inhibited by this limited English proficiency.

Students felt that they had already learned the content in science classes in Baghdad; hence they felt they were not challenged intellectually. It was clear these Chaldean students were at a disadvantage because proficiency in the language of science depended on proficiency in English for in-depth concept development. In one interview, the young woman expressed the fact that she had had chemistry in Iraq. Yet when the interviewer asked her what kind of apparatus or equipment she used, she responded, "What's that? I had to study in Iraq."

The problem of understanding science language is not unique to these women. Teaching of English as a second language research indicts that first and second generation English learners often become proficient in the social language context of both the second language and the native language, but the sophisticated language of the disciplines such as mathematics and science are never developed to the point of proficiency or literacy. This occurs because students are seldom placed in academic contexts where they have the opportunity to gain fluency in using scientific language. Although they may have the intellectual capacity, because of their limited English skills, students are likely to be placed in lower academic content courses where less technical language proficiency is required.

All students mentioned the support they received from the English as a second language (ESL) teacher, not just in decoding cultural practices and language problems, but in the provision of a "place of encouragement." The women reported they were made to feel welcome and supported, beyond the classroom. Because of the high percentage of Chaldean students in the district, the bilingual teacher made it her business to acquaint herself with the Chaldean community. She visited homes and churches, and became a recognized part of the community, although she herself was not of Chaldean descent (Sardinas, 1994). She developed relationships and helped work with the community of educated Chaldean professionals to encourage and promote the value of staying in school for girls as well as boys.

This commitment of the bilingual professional had positive results, not just in the Chaldean community, but in other minority communities as well. A growing body of evidence supports the notion that where there are teachers with strong backgrounds in math and science, who provide

bilingual transitions for learners, there are learners who are less likely to drop out of school, who are more likely to take and succeed in advanced science and math courses and are more likely to set college as an attainable goal (Moase-Burke, 1994). Few school systems however, have the resources to provide transitional, content specific language courses for these learners. In those schools where ESL teachers have a strong science content background and spend time helping students learn the technical language of the discipline, students are more likely to be successful in advanced science courses (Moase- Burke, 1994).

The issue of advanced mathematics courses is similar to the dilemma of science instruction. Of the women interviewed who had been in the U.S. less than five years, none understood why they were placed in low level mathematics courses. "Numbers make sense" and "you don't need to understand English to understand numbers" was the refrain of most of the women. In further questioning, it became apparent that the school system chose where the women would be placed. Again, language appeared to be the deciding factor, not mathematical experience or ability.

In the current study, interviewee responses fell into three categories: women who recognized the difference between their family's culture and values and the school culture and values, who made conscious efforts to work within both systems to find acceptable compromises; women who followed their own personal philosophy of living, often in conflict with their cultural heritage; and women who felt uncomfortable and disenfranchised from the American culture in which they were being educated.

The women who consciously made the effort to live within both the Chaldean and American cultures were hopeful that their parents would change and adapt to American ways that they considered positive, while keeping the best practices of the Chaldean culture. The following interview excerpts exemplify this ideology:

> Sara: "I think for a Chaldean girl I have a lot of privilege - but going away to college is not one of them..." Others in the community may ask, " Why does she have to go away to college, what is she doing?..... It is very hard to have your daughter go away. It makes people think maybe you've done something wrong. It ruins your chance to marry a good guy....My parents will change in time [because] this attitude is stupid."

> Sophia: "There is a tug of war to please my parents and please myself.. My mother for instance, I want to be an environmental lawyer. She wants me to be a doctor. ..but

like, I like to debate and know environmental stuff. I guess we'll resolve the problem though."

Other women also saw the discrepancies between home and school cultures, but instead of accommodating and negotiating, made decisions reflecting their own personal ideology.

> Mara: "I take pride in my culture. If it was in my hands, I'd stay in the Middle East - I'll return there someday."
>
> Interviewer: " How have you adapted?"
>
> Mara: "I've had to make sacrifices. My parents will never agree with me. I try to find ways to please myself - if that means lying to my parents, well..."
>
> Interviewer: "You know what you want - do you do things to please your parents?"
>
> Ida: "Not my father, ...I could kill my father."
>
> Interviewer: "Why?"
>
> Ida: "Because he is so authoritarian... He forced my mother to fit a mold, he restricted her from what she wanted to do. She's an educated woman. He restricted her. He believes his values are the only values that should exist. He is allowed to experiment with and adapt to all that is American culture, my brothers too...... I want to be a zoologist - there is only one place in Michigan that has the program I want. I'll go where he says its okay for two years - but then - no matter what I'll figure out a way to do what I want."

And finally, women who felt uncomfortable in American classrooms, disenfranchised from the culture in which they were participating and separated from their homeland:

> Mary: "School is harder [in Iraq]. Freshmen take classes there that seniors take here. Is easy here. I'm going to get an "A" in here. I learn [the] same things in Iraq. Sometimes I can remember, I may not understand the language/.... I'm doing fine, I'm getting good grades here. My parents want me to go to college, become something. Some [Chaldean] parents don't want their girls to go to school, just get married. I want to go back [to Iraq]."

These women indicated that neither they nor their parents approved of young women taking part in school activities or unsupervised activities outside the home. In general they had been in the United States less than five years. Clearly, it was a struggle for these women to find their place in the American school culture:

> Beth:....."In Iraq , they think it was wrong to have school with boys."
>
> Interviewer: "What do you think?"
>
> Beth: "Sometimes I get confused, some girls change, they're different. Sometimes I feel it's good to be this way, to know how to get to know guys. But some girls take it too far and make big wrong."
>
> Interviewer: "What would you tell a young woman from Baghdad if she was here?"
>
> Beth: "Sometimes, students can do everything, like not doing the rules. Like seniors take pre-algebra, I think, oh, that's weird, eighth grade, freshmen, take these courses back home. I took [them] in Iraq."
>
> Interviewer: "You say you've felt discriminated against by students. How about teachers?"
>
> Beth: "No teachers are so good to me, they understand, [they] help me learn. My father was a soldier, in the war. My mother married when she was 14. [She] didn't finish high school. My mom doesn't want me to be like her, she wants me to be better than her."
>
> Interviewer: "Do you think your language problem was why you were placed in lower [academic] classes?"
>
> Beth: "But mathematics - you don't need language, it's just numbers, numbers make sense!"

For those young women who had been in the United States for longer periods of time, there was a clear sense of self as both Chaldean and American - and of the sometime conflict between the two.

> Sophia: "I spread myself to speak to everyone, doesn't matter if they are Chaldean or not, and that has a lot of impact. My parents have been here for thirty years. I was born here. My parents have somewhat adapted to the American tradition but, the thing that's really weird is that

I'm going away to college, but the only reason I'm going is because my brother lives there, where I want to go, he'll take care of me".

Sara: "Yes other Chaldeans say I'm strong minded, I shouldn't be that way, but I just speak my mind, I am honest. My parents always let someone step over them. My parents help people out even if my parents have been talked about by that person in a negative way, they still help. I can't stand that, I have to let them know. When I do something wrong, I know it's wrong, but.. I try to change what I can."

Interviewer: "Do I hear you say you spent a lot of time watching your parents, and have chosen not to be like them?"

Sara: "Yea, my sister is turning out just like them , she's a good person but she's going to let people walk all over her."

Interviewer: "Does your speaking out make you a bad person?"

Sara: "No... but Chaldean men don't like that."

All ten Chaldean women valued education as a way to "better themselves." Teachers were held in high esteem by these women. Some, particularly those who were new to the school system were obeying their parents by working hard in school. It was the family value being demonstrated as school commitment, to "get ahead", to have a better life than the parents. The motivating factors for all ten women appeared to be their mothers. When difficulties came up, the person who helped encourage and solve problems was Mother. When asked who supported them in their desire to attend college, their mother's sacrifices were mentioned. Each of the ten women saw themselves as part of a larger whole. Each had worked out and understood their role and place in the Chaldean community. Inevitably, each conversation, whether it was about teachers, science concepts or classes, eventually addressed the issue: "How does what I do look to the Chaldean community, and can it affect my ability to marry a "good guy?"

Because marriage and family is an important piece of the communal life, the girls were asked if they would marry outside their ethnicity. While some of the ten clearly discussed the positive and negative aspects of the idea, all ten women concluded that life would be happier for them if they married a Chaldean man. Each was acutely aware of, as Sara said, "What Chaldean men don't like".

The science classroom: Student perceptions.

According to Deborah Tannen, issues of language; pacing, pausing and attitude toward simultaneous speech are critical factors in the analysis of conversation. In science classrooms, particularly in constructivist classrooms where discourse and interaction are primary expectations, it seems likely that individual style of power (dominance) and interactional context do play important roles in the interpretation of behavior by teachers. It is in understanding these issues that can create or diffuse classroom behaviors and/or confrontations. Tannen speaks of the paradox of the ideas of closeness (or perceptions of peer or equals) and the hierarchy of distance (respect, employee/employer, teacher/student) (Tannen, 1994). The way these relationships are played out differs cross-culturally. For nine of the Chaldean women interviewed, participation in a small group, with a partner was an important factor in feeling comfortable in science and math classes. Interestingly, learning was perceived as less in science and math classes where small group work was done.

Although the cultural "norms" of the Chaldean community emphasized the importance of community and working together for the community, this norm was not transferred to the classroom. The classroom for newly immigrated Chaldean students who wished to "get ahead", to have a "better life than their parents" appeared to emphasize rote learning and the memorization of material.

According to one young woman, in Baghdad the teacher "knew everything." A good science class was defined as one where students were required to recite information and write long essays based on readings. The one strength of American science classrooms for these women lay in the ability to choose who they would work with:

> Interviewer: " I know that you work with a partner. Are you comfortable working that way? Working with a boy partner?"
>
> Ida: "We get to choose our partner. I have a friend. It's great to have a friend. Here [high school] we need friends not just to help but to give courage. In this area we need that. People are not so nice here."
>
> Interviewer: "Other students?"
>
> Ida: "Yes"

For the two women who were in advanced science courses, another issue prevailed which caused them to drop out:

"I hate physics. We weren't allowed to really experiment. I need to play with things - and I couldn't in this class. I felt it was okay to drop."

Some of the Chaldean women commented on the dissonance they felt in the American classroom culture. They expressed amazement when comparing perceptions about American stereotypes of women not being able to do math and science. This was not an issue in schools in Baghdad. Women were expected to achieve in every academic subject if they expected to have tertiary education. Students who were successful in their university studies were (are) guaranteed positions by the government. Consequently, competition was (is) great. Traditionally fewer women than men enter university training in Iraq, however, women enter math and science fields more than other fields since it is thought that training in these disciplines is more valuable than other disciplines.

Of the four Chaldean women interviewed who were born in the United States, all four mentioned uncertainty in their ability to perform well in science. In addition to their own lack of confidence in scientific abilities, women doing science in general was questioned. Of the six remaining Chaldean women, four of whom had partial academic preparation in Iraq , there was no question that women could not "do science." Examples of family members or visible women professionals in Iraq were given to support their confidence in a woman's ability to be successful:

> Interviewer: "Tia, you've mentioned, as have several other young women, that you have taken science courses in Baghdad that you're not getting credit for here. Do you feel you're treated differently here?"
>
> Tia: "No. Everybody is good to me. Teachers here are nice to me."
>
> Interviewer: "Lydia? Do you think you're treated differently in science classes?"
>
> Lydia: "No, not by teachers but by other students, usually boys. You hear them say under their breath; stupid, dumb, whenever a girl talks or asks a question. That's hard to get past."

All ten of the students remarked on the character and helpfulness of their teachers. When talking about classmates, two patterns of response became evident; 1) those who felt discriminated against, attributing negative treatment by non-Chaldeans to differences in language and culture and; 2) those who felt everyone was treated in a similar fashion, discrimination had more to do with school culture than ethnicity. To all women, teachers were not the issue, other students were. Comments

boys made were consistently referred to by most of the women, while no-one referred to other girls' comments. It may be that because Chaldean women are taught a specific cultural role, they appear, perhaps unintentionally, more likely to value comments from males. For the four women interviewed, who were born in the U.S., it took one generation in the United States to pick up the stereotype that women don't "do" science. They saw their own success in math and science as exceptions. For those who believed they were good at science, success was attributed to hard work and an inner drive to succeed, often in spite of their own cultural baggage (a woman's role is caring for home and family, not going to school, etc.) and American cultural baggage. (Women are too dumb to do science and other negative stereotypes.)

Several of the young women interviewed recognized that they would need to take additional math and science courses when they completed high school in order to fulfill requirements for math and science majors in college.

Teacher perceptions:

While students struggle to make sense of socio-cultural and academic concepts, teachers interpret specific student behaviors. In conversations with non-Chaldean teachers, some negative perceptions existed concerning the Chaldean men and women in public schools. The perception of trouble maker, uninterested in learning was persistent in at least one school district (Moase-Burke, 1994; Travis, 1994). This perception prevailed in spite of concerted efforts by administration to educate teachers in issues of cultural difference and similarity. Where teachers indicated this biased attitude, they also indicated a belief that they treated all students equally. In the district where Chaldean women were interviewed, greater percentages of minority students (including English as a second language students) were enrolled in lower track, non college prep. courses, although, for some, college was an expected goal (Pickard, 1992). Both teachers and students alike had the expectation that the women interviewed who were enrolled in lower track courses would need to take additional math and science courses when they completed high school in order to fulfill requirements for math and science majors in college.

If one believes the research evidence concerning learning modalities, one cannot escape the notion that not only is indigenous language discourse and gender discourse important but pedagogical strategies are important (Gardner, 1991). According to Connell (1994), "curriculum empowers and disempowers, authorizes and de-authorizes, recognizes and mis-recognizes different social groups and their knowledge and identities ....in a variety of ways authorized the practices and experiences of men and marginalized those of women." For women who have "learned" that the "best" learning strategy is rote memorization, it is necessary to

introduce them to other ways of concept development. Teacher awareness of preferred learning modes of students and flexibility in management is perhaps key in developing appropriate activities to accommodate all learners. For the Chaldean women in this study, for example, small group strategies were important for comfortability in classroom settings, but were perceived as less useful content learning strategies.

Summary and conclusions

An old Greek proverb states: "That which is straight is the measure for that which is both crooked and straight." As national, state and local standards become explicitly stated as legitimate goals for the K-16 education system, the issue of how to meet the standards in a culture and gender responsive way must be addressed. It is not enough to have *Benchmarks for Scientific Literacy* (AAAS, 1993). For students of the Chaldean culture, the frustration of content packaging and cultural stereotyping acts as a barrier to science and mathematics study. Nevertheless, many of the women hoped to succeed with hard work and family support. Sacrifice for the sake of knowledge was part of what was necessary to succeed. Young women who were enrolled in less rigorous science courses because of language difficulty expected to work days and attend support courses at night to build science and math skills after high school graduation. Though frustrated and somewhat angry with the American system, they were undeterred in reaching their goals of becoming science professionals. Of some concern to the author is the fact that women who come from a culture where women are not stereotyped to be "dumb in math and science," but are expected to perform well in math and science, pick up within one generation of living in the United States the American myth that women are not supposed to be able to do math and science. (For historic examples of this phenomenon see Schiebinger (1991).)

The interaction of gender with ethnicity creates learners who are constantly faced with making decisions about the rightness and wrongness of social and classroom situations and their personal behaviors. They are asked to "measure that which is straight and that which is crooked" according to at least two differing sets of standards. The women's measures were as diverse as their personalities and their individual sense of justice. For all these women, a high value was placed on being educated. In spite of "easy classes," or other students who made fun of them; they were determined to succeed. For them, there were few "barriers," only bridges which could be crossed if one had support from others and inner drive. Support came from family members, particularly mothers, or from within the school system in the form of bilingual educators, not from Chaldean peers, or other female students.

There is no easy way to document the interaction of gender with ethnicity and its implications for science learning/teaching. What appears clear is that students are constantly assessing the value of their experiences in classrooms against an internal model or definition of what is necessary to be successful. All the women interviewed for this study shared the characteristic of having a profession identified at some point in the future, a profession that directly correlated to family business and family survival.

While there are many things that teachers and school professionals have no control over, they do have control over curriculum content, the atmosphere of the context in which that content is delivered, and the strategies which develop that content. Science teachers, particularly at the high school level, have an obligation to provide "packaging" of science content in ways that are meaningful to learners. Meaningful to these women happened to be business oriented science fields. Women wanted to be pharmacists - to take over that part of the family business, lawyers, to deal with the myriad of legal problems associated with running an environmentally viable business or doctors, to care for family needs. The commitment of these young women to their families and the community at large was reflected in their choices of careers, and their commitment to advanced science and mathematics education.

The Chaldean sub-culture cannot easily be embedded in the White culture of American schools. Among every major people group are myriads of sub-cultures who do not fit the expected roles of the ethnic majority, in spite of genetic similarities. Cultural difference sometimes becomes known only when problems arise because of differing practice (See also McDade, 1988; Toupin, 1991). For these sub-culture students to participate fully in American school activities including science and mathematics courses, schools must do a better job of working with professionals within the community to find those career extensions which make sense to students and which provide impetus to keep students in school working toward goals which support the best practices in both cultural settings, and minimize those practices which are in conflict. For this war beyond color to be won, one issue must be clearly understood, the issue is survival. Survival as individuals, survival as families, as communities and as a species.

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Learning Styles Of African American Children And Problems Faced By African American Females

Claudia T. Melear

The need is clear. According to Atwater (1989) science teachers must become multicultural because while minority student populations are increasing, the number of minority teachers is decreasing. Historically, science educators have recommended that science teachers use learning style information to improve instruction (Bonnstetter, Horne, & McDonald, 1991; Kuerbis, 1988; McCaulley, 1977) but have not specifically addressed the needs of minority students within this context. However, now the NSTA policy statement on multiculturalism (1991) lists learning style as an important concern for science teachers and Claxton and Murrell (1987) say that the most important need in learning style research is to identify the learning styles of minority children.

A further need concerning minority students is in the area of gender. Grossman & Grossman (1994) say that too many gender studies include only European American students and that African American students, as well as other non-European Americans are grossly under represented in the research on gender.

In response to these needs, this chapter examines learning styles among African American females. Several scholars have addressed African American style (Boykin, 1992; Hale-Benson, 1986; Shade, 1982) but to date no science education research has attempted to reconcile these researchers' claims to existing instruments. Consequently, I have chosen to explore the theory of Hale-Benson which focuses on the cultural conflict met by children at school after leaving their cultural milieu of home. I have also chosen to present studies conducted in eastern North Carolina which have attempted to document Hale-Benson's claims of African American learning style among African American females with the Myers-Briggs Type Indicator (MBTI).

African American Heritage Theory

According to Hale-Benson, young African American children are perceived as successful in their homes, churches, and communities. A failure pattern is evident only after a few years in schools designed by and for the dominant culture. These schools reflect EuroAmerican or Western culture that is in some ways alien to the African way of life. Hale-Benson lists traits of African American children which she says are derived from the African culture. She says these traits are *culturally*

induced cognitions. Furthermore, she says that schools should pay attention to the cultural cognitions of African American children and that school achievement will improve if they do. According to Hale-Benson, young black children have a more relational, person-oriented learning style than do white children. This relational style reflects the strengths of the African culture. Some characteristics of the relational style are a tendency to be self-centered, global, emotional, over-involved in all activities, to ignore structure, and to identify the unique and discrete. African Americans also personify the abstract and perceive the field as responding to the person. They are gestalt learners, embed words in context for meaning, and have fluent spoken language with strong, colorful expressions. Responses tend to be affective.

This style is in sharp contrast to and leads to conflict in schools which value rules; standardization; conformity; control; memory for specific facts; regularity; rigid order; "normality"; precision; logical, atomistic, linear, deductive, convergent thinking; universal meaning; mechanistic approaches; hierarchical organization and scheduling. In these schools, differences equal deficits. Furthermore, descriptors of traditional science correspond to Hale-Benson's list of school descriptors. Science is reductionistic, mechanistic, logical and orderly which is in sharp contrast to African American children's learning style (person-centered, expressive, affective, values the unique versus the regular, global and movement oriented).

Not all aspects of African American learning styles need be negative in terms of school and science achievement. A summary of learning style elements described by Hale-Benson (1986), Shade (1982) and Boykin (1992) and the most important styles for science learning are described below.

Expressive: Hale-Benson says African American people place a high value on unique expression. Boykin (1992) calls this element "verve." Members of a black community often spend time developing a style of expression in both language and dress that is singularly theirs. The contrasting trait among whites is compliance. Hale-Benson says that white children have a high tolerance for monotony, whereas black children do not. While the expressive trait described by Hale-Benson is an asset and a vital element of learning in science, compliant behavior stifles science learning. Expressiveness suggests both objectivity and intellectual honesty. Minorities (and girls) have been observed not speaking out in class as much as white male students. If teachers were to encourage the expressivity which young black children bring with them, perhaps more of them will be attracted to science, because their natural learning style is to express themselves. Traditional ways of controlling children's behavior by disallowing their expressiveness may in fact be discouraging them from choosing science as a career later in their lives.

Affective: African American children are more feeling oriented than white children. They hold values and personal belief systems as more important than logic and abstractions. They like working in cooperation more than in the competitive mode. Since African culture promotes the community above the individual, cooperative learning and teamwork can be a valuable method of science instruction, especially in the early grades. Because schooling becomes more and more impersonal and less affective as children proceed from K-12, the more feeling oriented child may have a sense of isolation that leads to dropping out of school. In the world of science, the need for values and feeling oriented individuals has never been greater. Teachers who emphasize societal issues and environmental concerns and who focus on conservation issues will meet the needs of children who are affective.

Movement Oriented: African American households have fewer restrictions on movement than white households. Continual and continuous movement is encouraged especially in developing body expressiveness. People flow in and out of many African American homes, dialogue is continuous and overlapping, the radio and TV are on. In short, stimuli are numerous and movement is a part of that stimuli. Movement is a way of life. In science class, movement and adventure can occur around an exploration of nature or while designing an experiment. Teachers who allow such free movement with talking for expressive and sharing for affective needs will be providing appropriate science lessons for African American children.

Person centered: African American children have been described by some researchers as Field-Dependent (Anderson, 1994; Atwater, 1994; Shade, 1982). Person-centered describes similar characteristics associated with field dependence. Children who are person centered look to the person in authority for social cues for behavior. They are more likely to overlook cues which are spoken, unless given directly to them. Text given cues are also frequently overlooked. Person centered children look to the teacher for more direct instruction than do children who get clues from the "field" of spoken and written language. In science class, teachers who talk directly to students will be most effective with African American children. In addition, teachers who use concrete objects rather than pictures, who provide direct experiences with science materials, and who allow children to move around and talk with other children will be providing appropriate educational experiences for African American children.

African American Females

The fact that gender studies have rarely separated females according to race is a serious problem in the area of research on women and girls. This leads to the cultural universal idea of womanhood; i.e. white

womanhood is assumed to be the normalized definition whenever gender issues are discussed. Consequently, African American females are faced with a two-tiered dominating patriarchy of race and gender. African-American females are thereby doubly victimized (Fordham, 1993).

This victimization can be clearly seen in teacher behaviors. Grossman and Grossman (1994) report that teachers tend to praise African American females less and criticize them more than European American students. When they do praise African American females, the praise they give is routine rather than for a specific accomplishment or behavior, or the praise is more likely to be for good behavior rather than for good academic work.

Overall, teachers interact less often with African American students than with white students. African American females are more likely to receive classroom duties involving social responsibility rather than assignments of higher prestige. While white teachers typically demonstrate considerable concern and interest in white females' academic work, they pay less attention to African American females' academic work than to their social behavior. Fortunately, African American teachers tend to be less prejudiced than white teachers toward African American students, but many teachers in both groups are not aware of their biases.

Culturally, African Americans do not expect males and females to fulfill different societal roles to the same extent as white Americans do. Economic factors play a role in this. Research indicates that African American females tend to be brought up to be independent, aggressive, and assertive because racism has so disabled African American males economically that females cannot rely on males to the extent and in the ways that white females can (Grossman & Grossman, 1994).

Ogbu (1992) describes some behaviors of African American youth as being artifacts of living as a non-voluntary minority in a majority culture. Fordham (1993) further separates the behaviors of African American females as being a reaction to living in a two-tiered patriarchy. Fordham (1993) discusses these issues in *"Those Loud Black Girls" (Black) Women, Silence, and Gender "Passing " in the Academy"*. Loudness, Fordham says, is a metaphor for African-American women's contrariness, embodying their resistance to a "nothingness" and "powerlessness" they feel as a result of the two-tiered patriarchy: white men and white women.

Fordham's study at a high school documented that although black women are loud in the halls, that, in fact, they practice silence and invisibility in the classroom in order to gain entrance into the dominant society within a school and to be academically successful. According to Fordham (1993),They are the people "passing" for someone they are not: the white American female and, ultimately, the white American male.

Silence is implicated in their greater school success because it conceals their female voice and the resulting gender expectations (p. 23).

The Study

As can be seen from this review, issues of race, gender and science provide the context in which the following study was conceived. It should serve as a much needed starting point for discussions about the education of a population of students who have been excluded from science on two grounds; being African American and female.

This study was undertaken 1) to determine if learning style elements described by Hale-Benson (1986), could be identified among African American high school females using the Myers-Briggs Type Indicator (MBTI), and 2) to attempt a longitudinal identification of learning style differences between African American high school females today and African American female Howard University students two decades ago.

The Myers-Briggs Type Indicator

Learning styles were measured by the Myers-Briggs Type Indicator (MBTI). Numerous authors support the use of the MBTI to measure learning style (Bonnstetter, Horne, & McDonald, 1991; Claxton & Murrell, 1987; Curry, 1983; Keirsey & Bates, 1984; Kuerbis, 1988; Lawrence, 1982; Myers, 1980; McCaulley, 1977). Curry (1983) proposed the MBTI as a best measure of the personality, the "core" of one's learning style. Baker (1985) used the MBTI as a measure of the scientific personality. May (1991), Melear and Pitchford (1991), Melear and Richardson (1994, in press) and Melear (in press), have also used the MBTI with African American populations as a measure of learning style.

The MBTI is based on Carl Jung's theory of psychological types. Jung (1921) said that there are fundamental differences in the way that people perceive the world, make decisions, and in our orientation or attitude toward the world. Isabel Myers and Katherine Briggs designed an instrument to measure Jung's types. To date, cultural bias has not been charged against the MBTI. Indeed, Jung was the first to claim individual differences based solely on criteria other than race or ethnicity. Individuals of a certain MBTI type display similar characteristics, no matter whether black or white.

Attitude toward the world is described by Jung (1921) and Myers (1980) as either Extroverted (E) or Introverted (I). The Extroverted individual chooses to be outgoing and to "think out loud" by talking. The introverted individual's style is more one of reflection, of speaking when asked, and of thinking before speaking. Some of Hale-Benson descriptors of African Americans are associated with Extroversion, for example, fluent spoken language and expressiveness.

Perceptual differences, according to Jung are measured by the Sensing (S), or Intuition (N), functions; that is, whether we perceive with our senses (S), observing details and specifics with our senses - or whether we perceive with a "hunch" (N), basing our perceptions on big picture or conceptual data. Sensing (S) match some elements described by Hale-Benson as the relational style (1986).

Decision making differences are described by Jung as either Thinking (T) or Feeling (F). Thinkers use logic and analysis in coming to decisions and are less person influenced. Whereas, Feeling types tend to take personal data into account in coming to a decision. They seem to use the prevailing "field" to make decisions. They are concerned with subjectivity to a greater extent than are Thinkers. Again, characteristics associated with the relational style seem to coincide with the Myers-Briggs Type Indicator descriptors of the Feeling type.

A lifestyle dimension was added by Myers (1980) to complete the MBTI which is described as either Judging (J) or Perceiving (P). Judgers organize, plan and generally prefer an orderly lifestyle. Whereas, Perceivers prefer a spontaneous existence. Hale- Benson's descriptors of the African American relational style match the Perceiving lifestyle of Myers. Perceivers value freedom and flexibility above order. African Americans' movement orientation also matches the temperament of Perceivers but schools value the Judging lifestyle. Keirsey and Bates (1984) also report that most teachers prefer the Judging function.

Subjects

High school students in four counties in Eastern North Carolina (Halifax, Hertford, Martin, and Wayne) were measured for their learning styles. These counties are representative of North Carolina which has a high concentration of working poor (Ziehr, 1988). That is, while North Carolina has a high poverty rate, it also has a low unemployment rate, as well as low percentages of persons who are welfare recipients. Therefore, the state's poor population have jobs, are not on welfare, and still fall below the poverty level. These four counties are largely rural and most public school students are African American. Three of the counties rank in the top third on eleven quality-of-life poverty indicators, meaning that they have the lowest income, the poorest housing, health characteristics, and educational attainment. The fourth county, Wayne, ranks among the top third. Seventy-nine percent of the children in this study qualified for the National School lunch program.

Data on the male students assessed is presented elsewhere (Melear & Richardson, in press). This paper will concentrate on the female students (n = 248). Almost half of the female students were enrolled in upper division elective high school science courses. In one of the schools,

the number of females in science classes was 110, while the numbered of males was 86. These data support Grossman and Grossman's (1994) findings that African American females enroll in science and math classes more often than African American males.

Three teachers, one each from Halifax, Hertford, and Martin Counties, collected all the data from their own science classes during one 55 minute class period. All eleventh grade students in one school district (Wayne County) were measured in English classes. A 1972 MBTI study (Levy, Murphy & Carlson, 1972) of Howard University female students provided the comparison group for the high school students (n = 447). In the Levy et al. (1972) study the college students displayed a preponderance for one MBTI type. Over 62 percent of the women were Sensing-Judging (SJ). Twenty six percent were Sensing-Feeling-Judging (SFJ). Since the study was published in 1972, before much impact was felt from the civil rights movement, Levy et al. (1972) concluded that the lack of diversity among type in college women was a result of a racist society in which only a few behaviors were deemed acceptable from American Blacks such as sensing/thinking/ judging (STJ). According to Levy et al/many significant positive aspects of experience were likely excluded from the Negro's conception of self. These could only emerge as valued and integrating qualities when radical transformation of identity become possible through opportunities for validating important "excluded" aspects of the self." (p. 650).

Procedure

Comparisons were made between the African American females enrolled in upper level science and eleventh grade English classes and Howard University college women. Analysis employed the Selection Ratio Type Table (SRTT) software program (Center for Applications of Psychological Type in Gainesville, FL). The test gave the following ratio (I value) for each of the 16 MBTI categories. Percent of African American high school students enrolled in upper division science or eleventh grade English classes in the MBTI category divided by the percent of Howard University women in the MBTI category. Then, Chi-square analysis was performed on the ratios generated in each category to determine whether statistical significance exists in the differences found.

Results

Four MBTI types were found among the high school females more often than would be expected when compared to the college sample: ISFP ($p<0.01$, I=2.05), ESTP ($p<0.001$, I=3.44), ESFP ($p<0.01$, I=3.38), and ESTJ ($p<0.05$, I=1.56). Fewer high school students were categorized as ISFJ ($p<0.01$, I=0.51), ESFJ ($p<0.05$, I=0.57), and INFP ($p<0.01$, I=0.24). Table 1 displays the distribution of MBTI types for high school African

American females. The largest percent distribution by single learning style preference, two-letter preference combination and temperament, as compared to the Howard University sample are listed on the right hand side of Table 1. Table 2 is a summary of all differences.

Table 1
Type Distribution of African Amercian High School Females Compared to (I value) to Howard University Females

ISTJ n=28 (11.3%)	ISFJ n=17 (6.9%)	INFJ n=4 (1.6%)	INTJ n=4 (1.6%)
ISTP n=10 (4.0%)	ISFP n=25 (10.1%)	INFP n=4 (1.6%)	INTP n=3 (1.2%)
ESTP n=21 (8.5%)	ESFP n=30 (12.1%)	ENFP n=17 (6.9%)	ENTP n=13 (5.2%)
ESTJ n=39 (15.7%)	ESFJ n=18 (7.3%)	ENFJ n=8 (3.2%)	ENTJ n=7 (2.8%)

N	%	I Value[a]
E=153	62	1.24**
I=95	38	0.76**
S=188	76	1.21***
N=60	24	0.64***
T=125	50	1.25**
F=123	50	0.83**
J=125	50	0.80**
P=123	50	1.34**
IJ=53	21	0.67**
IP=42	17	0.91
EP=81	33	1.78***
EJ=72	19	0.93
ST=98	40	1.42**
SF=90	36	1.05
NF=33	13	0.53***
NT=27	11	0.87
SJ=102	41	0.86
SP=86	35	2.42***
NP=37	15	0.66*
NJ=23	9	0.62*
TJ = 78	31	1.17
TP = 47	19	1.41
FP = 76	31	1.30*
FJ = 47	19	0.52***
IN = 15	6	0.36***
EN = 45	18	0.87
IS = 80	32	0.96
ES = 108	44	1.51***

a. I Value (Self-Selection Index) = Ratio of % of type in group to % in Howard Unversity sample.

*p<.05, **p<.01, ***p<.001, ****p<.0001.

Table 2
Summary of Group Findings for African-American Females Myers-Briggs Type Indicator

MBTI Type	Greater Group	Lessor Group	P Value
Extroverted	High School (n=248)	>College* (n=447)	.001
Sensing	High School	>College	.001
Thinking	High School	>College	.01
Perceiving	High School	>College	.01
Extroverted & Perceiving	High School	>College	.001
Sensing & Thinking	High School	>College	.01
Sensing & Perceiving	High School	>College	.001
Feeling & Perceiving	High School	>College	.05
Extroverted & Sensing	High School	>College	.001
Introversion	College	>High School (n=248)	.01
Intuition	College	>High School	.001
Feeling	College	>High School	.001
Judging	College	>High School	.01
Introversion & Judging	College	>High School	.01
Intuition & Feeling	College	>High School	.001
Intuition & Perceiving	College	>High School	.05
Intuition & Judging	College	>High School	.05
Feeling & Judging	College	>High School	.001
Introversion & Intuition	College	>High School	.001

*Levy et, al. (1972).

Conclusions

This study found a greater variety of psychological type among African American females than reported by Levy et al.(1972) among Howard University females. According to Levy et al.(1972) the lack of diversity in MBTI types in their study may have been due to living in a "majority" dominated world. They believe that the social milieu imposed massive constraints upon the development of "innate" preferences for intuitive, perceptive modes of experience among African American children. Unfortunately, concreteness and need-for-closure of the SJ orientation is diametrically opposed to the counterparts of imagination and perception needed for academic achievement. Jensen(1987) reports that Sensing types learn best when they move from the concrete to the abstract in a step-by-step progression.

In comparison, this study found both greater diversity of type among upper level high school female students and more African American females who were Perceiving types. When the high school females were compared to the college age group, more Thinking (T) types also

emerged. Thinking (T) types value knowledge that is practical. They learn best when material is presented to them in a logical and sequential format. Thus, it seems that the latter day sample of African American females is better prepared for school than their counterparts in the past.

The Sensing-Judging type, reported by Levy et al. (1972) as problematic among college age female African Americans, is replaced among high school African American females by the Sensing-Perceiving (SP) type. In addition, when two-letter learning style preferences are examined, the Extraverted and Perceiving (EP) and the Feeling and Perceiving (FP) combinations are more represented among the high school students.

Despite the greater diversity of type, the data reported in this study support some of Hale-Benson's (1986) claims that African American children have a different learning style than majority children. Specifically, the data in this study support that African American high school females are more Sensing (S) than Intuitive and more Thinking (T) than Feeling (F). The Levy et al.(1972) study also found more Feeling (F) African American females than is found in a sample of Caucasian females.

The relational learning style was common among the high school females. Expressiveness was exemplified by the Extroverted element and was observable when high school students were compared to Howard college students. There was also a significant number of African American high school females who showed a lifestyle preference for Perceiving (P) over Judging (J). This difference suggests that these students prefer a more flexible approach to learning. Jensen(1987) states that Ps tend to view learning as a free-wheeling, flexible quest. They care less about deadlines and the completion of tasks. They prefer open and spontaneous learning environments and feel "imprisoned" in a highly structured classroom. They also like discovery type tasks and can manage emerging problems. They like to work in flexible ways, following their impulses and in informal problem solving (Lawrence, 1984). The difference in lifestyle preference and the structure of schools may be one of the many reasons why some African American students are not successful in schools.

Implications for Science Teaching

This study indicates that African American females in upper level science classes can be identified according to type as Extroverted, Sensing, Thinking and Perceiving. Science classes already support Sensing, with a focus on details, making observation using the senses and emphasizing precision. Science classes also support Thinking, with a focus on logic, use of data to come to conclusions, and analysis. However, the Extroverted and Perceiving differences need to be addressed. Most scientists are Introverted and Judging and consequently well suited to the demands of science (Baker, 1985) which raises the

question about African American female's successful participation in science and in school in general. Historically, students who were "talkative" and "freedom-loving" were seen as trouble makers who needed reining in, or changing.

With the data from this study, teachers can bring new understanding of the nature of African American females who have heretofore been viewed as recalcitrant or reluctant students because of their behavior (Extroverted and Perceiving). Instead of disciplining, we should be encouraging and creating structure for these female students to talk and to participate. This kind of encouragement can go far to help Black girls break the silence they impose on themselves in the classroom.

Jung's theory states that our differences are inborn and involuntary, so no student should be viewed as difficult if the differences between teacher and student is one of psychological type as reflected in attitude and lifestyle preferences. Rather, teachers should ask themselves how they can build on students' preferences.

Since research supports cooperative learning, science teachers should regularly design learning around opportunities to talk in groups. Teachers should also regularly ask all of their students, but especially the African American females, for their input. Teachers can offer options in type, time, and completion date of tasks or more project and assignment options to appeal to the Perceiving (P) student. Students of the Extroverted (E) and Perceiving (P) preferences also need teacher imposed structure but there is a point at which the Perceiving individual rebels against structure. Finding just the right balance, so that students perceive that they have some choice and some help, and that the requirements are not so structured that they feel fenced in or fenced out from their own preferences, is the challenge for teachers. As part of achieving this balance, teachers must let students know that they are flexible and want to meet their unique and individual needs, whenever possible.

It is probably not sensible to differentiate assignments by race and gender. Furthermore, the recommendations for African American females are in truth good pedagogy and similar to those called for by constructivists. However, special attention should be paid to encouraging African American females in high school to choose science as a college major.

Historically, Black colleges and universities have provided almost all of the encouragement to Black students and helped them succeed in science. Today, these Black institutions continue to provide most of the science professionals of color. Although the findings of this study focus on high school students, they have some direct implications for teaching some minority college and university students in majority settings, particularly

for those who tend to be more Extroverted or Affective and Perceptive. The logical, analysis oriented nature of many science instructors may seem cold and removed from the kind of interactive instruction these students find most comfortable and productive. Bryant (1990) states that if college science teachers in predominantly white institutions want to foster African American student achievement in science, they must exhibit a posture of caring and encouragement, and use of cultivating strategies rather than weeding-out strategies. Bryant (1990) further says that white Americans must take major responsibility for the phenomenon of under-represented African Americans.

Students in science

Problem oriented learning might be more palatable if some principles of mastery learning were used. Bloom's (1968, 1976) mastery learning proposes that tutoring and formative testing are important elements in effective learning. Minority students who are Extroverted, and Perceptive may benefit from a shared approach to studying science. Pairing a student with a compatible partner might increase his or her commitment to learning abstract and difficult concepts. It would make the process more like social interaction and provide a support system that is cooperative in nature. Instructors could support these students by promoting shared studying as a technique, allowing partners to turn in a single set of homework problems, or giving out a rationale for why some students may learn more effectively with a partner, in a shared studying approach.

Although this paper has focused on African American females, we should not forget that individual differences in learning style, as measured by the MBTI, are more pervasive than differences in race, class, or gender. Science educators can best serve their student population by measuring their students' learning styles and examining the learning style literature for ways to modify their instruction. As I said earlier, most of the recommendations in this and other works are very much like the kinds of constructivist and hands-on interactive approaches that are characteristic of good science instruction.

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Gender And Ethnicity Factors In Student Achievement In A Coordinated Thematic Science Course

Virgil Gale Heard and Cheryl Cantu-Mireles

With the publication of *Science for All Americans* (Rutherford & Ahlgren, 1990) and the advent of the National Science Teachers Association's *Scope, Sequence, and Coordination of Secondary Science: The Content Core,* (National Science Teachers Association,1993), there arose serious debate about the path science education reform should take. The Texas Education Agency, following the lead of the National Science Teachers Association, called for a reformation of the state secondary Science program to a coordinated thematic type of course in grades seven through ten. By coordinated, the T.E.A. meant a type of instruction which clarified the relationships among physics, earth/space science, biology, and chemistry. Thematic meant the organization of the curriculum around a unified theme of content. Science I for grade seven was described as coordinated, thematic science instruction in biology, chemistry, physics, and earth/space science accessible to all students (Jbeily, 1992). The proposed Science I thematic coordinated course approach had not been previously implemented and questions arose as to whether the coordinated or integrated courses would result in higher student performance, and whether this type of instruction would be effective with different ethnic and gender groups. Prior studies of instructional models indicate that the problem-solving thematic approaches to learning are highly effective for culturally diverse learners (Barba, 1993).

The Fort Worth Independent School District's integrated science middle school curriculum was written by a representative team of teachers with all degrees of experience. The curriculum was conceptually based and tied to the state science framework and the big ideas in the 2061 method of curriculum construction (Rutherford & Ahlgren, 1990). The material was based on a series of sixty-eight experiments in all fields of science which exemplified the science concepts these teachers identified as critical for all students to know. An attempt was made to make the material relevant to all students' daily lives, with special attention to minority students and girls. True cooperative grouping was used to make sure that all students were equipment manipulators, chief investigators, reporters and recorders regardless of gender. These concerns were concurrent with an investigation into the efficacy of integrated or coordinated science instruction as opposed to instruction in individual disciplines. Texas was one of the first states to explore this issue.

It was these research questions and a recognition that change was needed which prompted the Fort Worth Independent School District Science I course to be offered at four middle schools selected on the basis of ethnicity, and also by income level as defined by numbers of students receiving free or reduced lunch. One school's population was predominantly Black, another Anglo, and two of mixed populations. Three control schools of matched ethnicity using traditional instruction were added for comparison purposes. The five pilot teachers utilized were selected at random. All were the usual teachers in their buildings. No staff was moved because of the project. A control teacher in each building who would continue to teach the traditional life or earth science course was selected (Mireles, 1993).

The pilot curriculum also bridged to content of the following four themes identified in the Texas Framework for Science I and II (Texas Education Agency, 1990): ecology, energy, systems and structures, and changes over time. The main differences between the pilot project and the control school instruction were that the pilot classes did the following: related the concept from each experiment to one or more of the thematic areas in addition to the one in which it would traditionally be placed, structured the post laboratory discussion to elicit the concept from students who had organized and graphed their data and drawn their own conclusions, and identified contributions/applications of other science disciplines for each concept where an experiment was done.

The instructional methodology used in this project by the pilot teachers include the following: (1) The students were to do all of the experimental work themselves. This included setting up the equipment and performing "hands-on" experiments. (2) Students were to work in cooperative lab groups of 2-5 students. (3) Students were to graphically display their data on the board or transparencies for the class and discuss their data. (4) A consensus conclusion was to be reached by each lab team. (5) Teams having "outlying data" were to examine results for error and repeat the experiment if no error could be identified. (6) A final consensus conclusion was to be reached by the entire class, if possible.

A pre/post test was developed for the course and administered the first week of school and the third week in May to 490 students in Science I. The test included nine laboratory stations to specifically test process skills and forty multiple choice items over concepts and process skills.

Overall Project Results

The tests were scored electronically and the mean scores appear in the chart below for the post test given in May of 1992. This chart includes three schools used as controls which were matched for income level and ethnicity with the pilot schools and gives overall results.

Table 1
A Comparison of the Science I and Pilot Schools to Similar Schools with Traditional Instruction.

Science I	*Science I*	*Z Score*
Pilot Schools M Correct = 25.51 N= 484	Control Schools M Correct = 20.01 N= 518	 6.72**

*p<.05, **p<.01, ***p<.001, ****p<.0001.

The results in the chart above show that the coordinated thematic approach stressing process skills as exemplified in the Science I pilot project resulted in significant gains in student achievement. The above data was analyzed using a Z test for significance between means and was found to be significant at the 0.01 level of significance. The coordinated thematic approach was successful in promoting student progress in these schools (Mireles, 1993). Additional information was gathered by examination of pairs of schools matched as closely as possible for ethnicity and income level of their populations. The results are displayed in the Table 2.

Project Results by Campus

Table 2
A Comparison of Science I School Sites (S_1 through S_4) with Schools Using Traditional Curriculum (T_1 through T_2)

Science I Schools	Traditional Instruction	Z-scores
S1, M= 25.76; N= 124 80% Black 10% Hispanic 10% Anglo 69% Free Lunch	T1, M=16.13;N=40 67% Black 30% Hispanic 3% Anglo 66% Free Lunch	10.14**
S2, M= 25.76; N= 124 18% Black 10% Hispanic 72% Anglo 12% Free Lunch	T2, M=23.48;N=138 15% Black 26% Hispanic 59% Anglo 38% Free Lunch	7.6**
S3, M= 25.76; N= 124 13% Black 39% Hispanic 48% Anglo 68% Free Lunch	T3, M=18.57;N = 128 1% Black 89% Hispanic 10% Anglo 83% Free Lunch	7.33**
S4, M= 25.76; N= 124 18% Black 35% Hispanic 47% Anglo 52% Free Lunch	T4, M=18.57; N = 128 1% Black 89% Hispanic 10% Anglo 83% Free Lunch	2.52**

*p<.05. **p<.01. ***p<.001. ****p<.0001.

M= mean of the population
N= number of students in the population

The data in the chart above indicates that the Science I program increased student achievement in all four paired schools. It fell short of significance at the 0.01 level in one school pair with a mixed population. It was learned that this school schedule may have segregated higher ability students out of the pilot Science I teacher's classes. In the other three matched schools, Science I was significantly more successful. The results of the curriculum project as regards gender are summarized in Figure 1 below.

Project Results by Gender

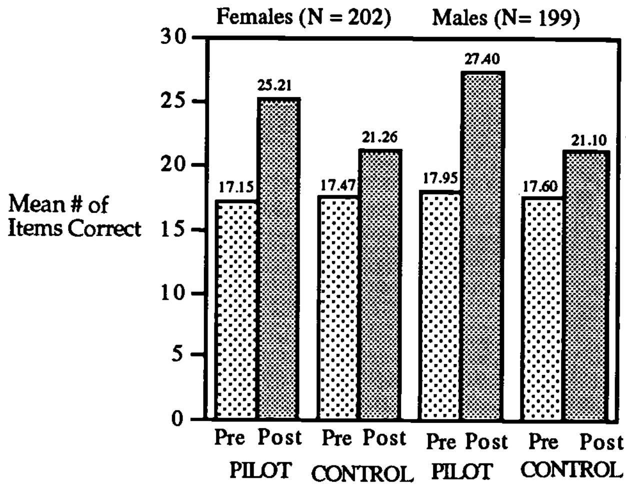

Figure 1
Overall Comparison of Pre-Post Test Means by Gender

When the pre- to post-test gains for females, 8.05, and males, 9.45 were subjected to a t test for significance at the 0.05 level with 399 d.f. they were significantly different. Since their pre- test means were not significantly different it would seem that although there were performance gains, the curriculum was not as effective for females. An examination of the testing and course materials indicated that revision to make experimental bridges and test items more related to personal experiences of the students may improve curricular performance for females.

The effect this pilot project had on the performance of students by gender with ethnicity also needs to be examined. Articles in the literature had suggested that science curriculum reform policies were not specified clearly enough to identify skills necessary for reformulation of the curriculum (Hurd, 1986). This situation has been altered in science with the publication of the NSTA's *Scope, Sequence and Coordination* materials, (NSTA, 1993), the *National Science Education Standards* (National Research Council, 1993), and the *Benchmarks for Scientific Literacy* (American Association for the Advancement of Science, 1993). Certainly one of the major questions was how testing of new criteria would impact the black and Hispanic populations since minorities traditionally receive lower scores on national assessments of science achievement (Jones, Mullis, Raizen, Weiss, & Weston, 1992).

When asked the number of experiments performed in the prior month, forty-four percent of thirteen year olds said none had been done. From this data it is indicated that many students, not just minorities lack experiences that are experimental and conceptual. Their science classes have been reduced to vocabulary and memorization lessons. If student performance is to be enhanced, students need more experiences and more time to reconstruct an adequate explanation or a new concept (Blosser, 1991). These ideas were incorporated into this Fort Worth I.S.D. study which required students to do their own work, display their data and to reach a consensus, both within their lab group and within the class, as to which was the correct experimental result.

Project Conclusions by Ethnicity

The results of this study in coordinated thematic science are summarized for ethnicity and gender in Table 3. The two sample populations were assumed to be independent and normally distributed. A pre-test was given at the beginning of the course to evaluate prior knowledge of the students and it was followed by a post test at the end. The means were computed for each group. The data is displayed by gender and ethnicity and shows that for Blacks and Anglos the thematic coordinated course was significantly better as regards performance.

Table 3
A Comparison of Thematic and Traditional Science Curriculum by Gender and by Ethnicity

	Females	t*	Males	t
Black				
Pilot	N=63		N=72	
Pre	16.23		16.04	
Post	19.80		26.56	
Control	N=20		N=14	
Pre	18.15		19.07	
Post	19.80	1.98	19.14	2.96
White				
Pilot	N=92		N=91	
Pre	18.56		19.74	
Post	26.86		28.98	
Control	N=34		N=17	
Pre	17.76		18.64	
Post	22.62	2.74	23.00	2.87
Hispanic				
Pilot	N=47		N=36	
Pre	15.63		17.25	
Post	24.40		25.11	
Control	N=7		N=9	
Pre	14.14		13.33	
Post	18.00	1.17	20.56	1.51

*t values calculated on post-score by race and gender.

The Hispanic pilot population had higher post test scores than their control groups, but they were not significantly different at the .05 level. The mean scores of the pilot group white males, black males and white females were higher at the .01 level than their control groups and the pilot group of black females was also higher at the .05 level.

Project Conclusions

This project was successful for the majority of students and compares well with our state achievement test data. TAAS, Texas Assessment of Academic Skills Test, included an eighth grade science section for the first time in 1993-94. The ethnicity results were similar to this pilot study with 60% disadvantaged, 85% not disadvantaged, 90% of whites, 56% of blacks, 79% of males, and 75.3% females scoring at mastery level ("Wide Gap," 1994). The minority student results in the pilot study showed strong performance for blacks as compared to the state tests and not so strong for Hispanics. Overall student body performance was enhanced by using coordinated thematic approaches and materials.

Project Limitations

There is a history of gang activity in some areas covered by the pilot Hispanic schools. In one Hispanic school, unknown to the investigators, the students included in the pilot study represented the lower ability and non-English speaking portion of the student body. The higher ability students had been placed in non-pilot teachers' classes. Test scores for Hispanics might reflect poor use of questioning strategies with their receiving less "wait time" for correct responses, being called on less, or not receiving their share of leadership and other roles in cooperative learning groups. These possibilities are open to further student performance research. The culture of our local Hispanic population may be unique and these results may not generalize to Hispanic populations in other areas of the country, or in other nations. Further international research will establish whether coordinated thematic science will enhance student performance across all ethnicities.

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Developing A Science Curriculum That Addresses The Learning Preferences Of Male And Female Middle Level Students

M. Gail Shroyer, Katherine Backe, and Janet C. Powell

Student attitudes toward science decline dramatically in the middle school years (Mullis & Jenkins, 1988). This trend is particularly evident in female and minority students. This unfavorable shift in attitudes and interest in science is one of many indicators of a tremendous need to improve middle school science. One critical aspect of this improvement effort is the middle school curriculum.

Before we can develop an effective curriculum, however, we must discover how to meet the unique needs of middle school students. Historically, the middle school years are an overlooked phase in children's educational lives. Solicitations and statements from the National Science Foundation (NSF) and the National Middle School Association (NMSA) drew attention to this neglected area (NSF, 1988; NMSA, 1982). But many questions remain unanswered: What causes attitudinal changes toward science in adolescents? Why is there such a large discrepancy between the attitudes, interests, and achievement in science of male, female, and minority students? What is the role of the curriculum in addressing the needs and improving the achievement records of middle school students?

The work presented in this paper is a summary of the research the Biological Sciences Curriculum Study (BSCS) conducted while developing a curriculum with funding from NSF. (See Shroyer, Backe & Powell, 1991; Shroyer, Powell, & Backe, 1992). BSCS has created an innovative science curriculum for the middle level: Middle School Science & Technology. One of the goals of the project was to increase the participation and success of middle school minority and female students in science. The work reported here was conducted in conjunction with the curriculum development efforts at BSCS. Our focus was to identify the learning preferences of male and female middle level students and science topics, activities, materials, and resources that suit those preferences.

Significance of the Study

This study is significant because of the historical record of the lack of interest and achievement by female students in science classes at all levels, but particularly the middle grade level (Kahle & Rennie, 1993; Humrich, 1992; Kahle & Lakes, 1983). According to results from the

National Assessment of Educational Progress (NAEP), gender differences in overall science proficiency do not become pronounced until 8th grade. The number of science content areas in which males hold an achievement advantage increases with each grade assessed (Jones, Mullis, Raizen, Weiss, & Weston, 1992; Mullis, Owens, & Phillips, 1990). In addition, more recent assessment data indicates that males tend to have more positive attitudes toward science than females. While interest levels drop for both genders, this drop is much more pronounced in female students as they progress through school (AAUW, 1991 & 1992; Weiss, Nelson, Boyd, & Huden, 1989). At 4th grade, 80 percent of the students reported they liked science without significant differences between the sexes.

> At 8th grade, 64 percent of females reported liking science, a significantly lower percentage than the 72 percent of males who liked science. At 12th grade, only 57 percent of females reported liking science, a substantially lower percentage than the 74 percent of male 12th graders who reported that they liked science (Jones et al., 1992, p. 80).

NAEP results also indicate that attitudes correlate positively with proficiency in science (Jones et al., 1992; Mullis & Jenkins, 1988). Understanding students' attitudes and creating a curriculum that improves these attitudes will, therefore, benefit all students, especially females. Given the research evidence (Oakes & The Rand Corporation, 1990; Vetter & Babco, 1989; NSF, 1986) that females are less likely than males to enroll in high school science classes, or enter careers in science and engineering, understanding and addressing females' unique attitudes and interests should be a critical component of current reform efforts in science education.

Review of Related Literature

As previously mentioned, females have historically been under-represented and under-served in science (Holloway, 1993; Oakes & The Rand Corporation, 1990; NSF, 1986; Kahle, 1983; National Science Board, 1982). Many reports indicate that women are not receiving the science skills and understanding they need to be citizens and job holders in the technological world (AAUW, 1992; Mullis, Owens, & Phillips, 1990; Oakes, 1990; Rutherford & Ahlgren, 1990; Weiss, Nelson, Boyd & Hudson, 1989; Lockheed, 1985). The achievement and interest level is lower for women than for their male peers, (Jones et al., 1992; AAUW, 1992 & 1991; Oakes & The Rand Corporation, 1990; Mullis & Jenkins, 1988), they have fewer experiences with science in and out of the classroom, (Weiss et al., 1989; Mullis & Jenkins, 1988; Kahle, 1983; Kahle & Lakes, 1983), and females are significantly under-represented in science courses at the upper high school level (AAUW, 1991; Cross, 1988; Fox, 1976). This inadequate preparation consistently prohibits

women from entering college programs in science and consequently they are under-represented in the science and engineering professions (NSF, 1990 & 1986; Vetter & Babco, 1989; Dix, 1987). Many studies have shown that students with a high interest in science are more likely to continue in advanced science courses and careers (Berryman, 1983; Entwistel & Duckworth, 1977).

Several studies have also demonstrated stereotypical differences in male and female interests in science (Kahle & Meece, 1994). Ormerod (1979) documented a female aversion to physical science. Entwistel and Duckworth (1977) have shown that boys are more oriented toward "hard" sciences (physics, chemistry, etc.) while girls prefer "soft" subjects such as human physiology, plant life, zoology, etc. Male preference for physical science and female preference for life science has been supported by studies of eleven–year–old boys and girls (Kelly & Smail, 1985; Kelly, Whyte, & Smail, 1984). Male and female enrollment patterns also demonstrate this biology/physics dichotomy (Cross, 1988). Vockell and Lubonc (1981) stated that both boys and girls see physical science as more masculine than biology. Blin-Stoyle (1983) concluded that physics is remote from humans and related to military and industry and, therefore, shows a male bias; and, biology is related to values and emotions and consequently represents female interests. Rennie, Parker, and Hutchinson (1985) documented a male preference for matter and energy and a female preference for plants and animals. They noted several exceptions to this pattern, which lead them to conclude that both boys and girls had similar high levels of interest in science and the stereotypical patterns of interest were related to out-school experiences. Stereotyped preference for subjects in science may, therefore, be related to life experiences, educational experiences, socialization factors, gender role expectations, or differences in what is perceived as relevant to males and females (Kahle & Meece, 1994; Noddings, 1992; Frederick & Nicholson, 1991; Hegarty-Hazel, 1991; Kahle, 1989; Baker, 1988). Girls may be encouraged in science by seeing it as normal and appropriate for females and relevant to female experiences and interests (Kahle, 1985; Kelly, 1985; Erickson & Erickson, 1984; Fox, 1976).

Achievement in science also affects student beliefs regarding the appropriateness of the subject (Kahle, 1987). Girls appear to lack self-confidence in science (Parker, 1993; AAUW, 1991; Dynan, Parker, & Ryan, 1978). They reach high school with fewer experiences in science, more anxiety about science, and less confidence in their ability to do science (Weiss et al., 1989; Kahle, 1985; Kahle & Lakes, 1983). It is, therefore, important for the classroom environment to stimulate female interest, curiosity, and confidence in science (Matyas, 1983). To accomplish this goal and enhance both male and female attitudes toward science, we must first gain a better understanding of how

students perceive, use, and value science teaching and learning (Charron, 1991).

It also has been suggested that the decline in females' attitudes toward science may be related to the teaching of science rather than the nature of the subject itself (Cipra, 1991; Tobias, 1990; Gardner, Mason, & Matyas, 1989; Mason, 1983). Certain instructional interventions and efforts to sensitize teachers have been shown to be effective in encouraging females to pursue further science courses (Frederick & Nicholson, 1991; Kahle, 1987 & 1985; Mason, 1986 & 1983; Smith & Erb, 1986; Kreinberg, 1982; Doran & Sellers, 1978). Females show a preference for inquiry learning and, therefore, may be encouraged by a greater emphasis on inquiry within the science classroom (Tobin, Kahle, & Fraser, 1990). Girls also may be encouraged by cooperative rather than competitive learning activities (Kahle & Meece, 1994). Rosser (1990) suggests that female friendly science is relevant science with connections to students' lives and their environment. Both male and female students recommend the use of more open-ended, less restrictive inquiry and experimentation in the science classroom, multiple methods to teach science concepts, a more relevant, understandable approach to science teaching and a critical examination of the science textbook (Charron, 1991). Female and male attitudes toward science may improve if the experiences are humanistic and socially and personally relevant, and discussions and activities are integrated into science lessons (Kelly et al., 1984; Fox, 1976).

It is obvious that attitudes toward science are multidimensional and complex. We cannot be certain that an increase in attitude will increase female achievement or representation in the field of science. It also appears obvious that any effort to encourage females in science must address the issue of attitude. We must determine what the differences in male and female interests are in science, what these differences represent, and how the science curriculum can address these differences. To gain this understanding, we must listen to the messages students give us regarding the conditions which they believe support their own science interests and learning.

Desgin and Procedure

Design

This research was based on the assumption that we, as science educators, must be informed about the impressions and feelings of the children we wish to educate. We selected a research strategy that would maximize our opportunity to understand students' preferences for their own science learning. We prepared several assistants who conducted thorough and lengthy interviews to gain a deeper and more complete

understanding of student attitudes toward science and science teaching. We used both structured and unstructured interview questions. We designed the unstructured open-ended questions to obtain a wider range of answers and to avoid preconceived assumptions regarding anticipated answers. We employed the structured questions to determine the general patterns of student response across sex, race, culture, and community size. Students were prompted to explain and justify responses to all structured and unstructured questions in order to provide a richer, more holistic perspective of their responses.

We collected and analyzed the data based on the concept of triangulation that Denzin (1989) defines, "the combination of methodologies in the study of the same phenomenon," (p. 291). Triangulation involves collecting and double-checking all findings using multiple sources and modes of evidence in the process of verification. This process increases the validity and reliability of the findings (Denzin, 1989).

We used triangulation by collecting interview data from 72 students to represent boys and girls from distinct geographical regions, school sizes, races, and cultures. The use of structured and unstructured questions supported the triangulation because it allowed us to cross-check responses from both types of questions. The last component of our triangulation was to use both quantitative and qualitative analysis techniques. Qualitative analysis provided a broader, more complex understanding of student responses and provided the opportunity to discover new unexpected patterns and trends. Quantitative analysis techniques helped to verify such patterns and trends and enhanced the transferability of the study results. The purpose of the study was to examine male and female attitudes toward science and science instruction. Specifically, we wanted to identify science topics, activities, materials and resources that address the learning preferences of male and female middle level students. The study was conducted to provide new insights for developing a curriculum capable of increasing the participation and success of middle school minority and female students in science.

Population

The population for this study was 10,000 students enrolled in schools where teachers planned to field test the new BSCS curriculum. We randomly selected and interviewed a sample of 72 students (37 female, 35 male) from this population. We selected the initial sample student population to represent distinct geographical areas of the country, a variety of races and cultures, and a range of school sizes from large metropolitan to rural centers. We sampled a set number of students from field-test sites in California, Colorado, Florida, Kansas, New York, and Ohio.

Data Collection

Project members designed the interview protocol. They designed the interview questions to assess student interest and attitudes toward science, technology, and science education. The staff specifically focused on student preferences regarding topics in science and technology and the use of materials and resources to support teaching/learning strategies. The interview included 26 questions. This instrument was subjected to a validation process by staff review, an advisory panel review, pilot testing, revisions, and a final staff review. To choose participants for the interview, we worked from lists of all students in grades 6, 7, and 8 at each site and used a random number table to choose three boys and three girls per grade level from the master list at each site. (Only two girls and two boys were interviewed, the third was selected as a back-up.) Each child was interviewed in a quiet location in the school. All of the student interviews were tape recorded and then transcribed at BSCS. The authors analyzed the data for a better understanding of student interest in science and preferences for science topics, we asked students several open-ended questions regarding their favorite and least favorite classes and science topics. Students were asked to explain and justify all preferences and comments. We also asked students to review a list of 31 topics which were being considered for the proposed middle school curriculum (Table 1). The students were asked to identify topics they were interested in finding out more about and then to identify topics they would definitely not be interested in studying. They also were asked to explain and justify these selections. To assess preferences for science activities, materials and resources, we asked students several open-ended questions regarding their favorite and least favorite ways to learn science. We also presented students with a list of science activities, materials and resources and asked them to respond positively or negatively to each item as it was read to them (Table 2). Students were asked to explain and justify their choices.

Data Analysis

We analyzed the interview data using both qualitative and quantitative techniques. As part of our qualitative strategy, we coded and used content analysis on open-ended responses and on the explanations that accompanied the structured checklist responses (Krippendorff, 1980). The content analysis produced categories that represented trends and patterns in responses (Lincoln & Guba, 1985; Miles & Huberman, 1984). We then analyzed these trends and patterns for similarities and differences by sex.

As part of our quantitative analysis we calculated frequency distribution and percentages for information on the structured checklist questions for males and females. Student responses to science topics, activities and

materials also were rank ordered by girls and boys. Data analysis was completed using the constant comparative method that allows for constant movement between data collection, identification of categories on which to focus, and development of theories to explain the data (Bogdan & Beklin, 1992).

Results

We began the interview by asking students to list their two favorite classes in school for the current year. Thirty-one percent of the boys named science as their favorite class and 14 percent listed it as their second favorite class. Thirty-two percent of the girls listed science as their favorite class and 16 percent listed it second. When asked why science was considered a favorite class the students said it was fun, interesting, and that they liked the experiments. Boys tended to mention that they liked science because of the topics covered in class (space, chemistry, nature, the human body, and dissections). Girls tended not to mention topics as the reason they found science class interesting. They appeared to be more interested in "why" things happen as they do.

When asked specifically to recall one science topic that was particularly interesting, made them think, and made them want to know more, students described a wide range of topics. We grouped these topics into life science topics and physical science topics, and found that the student preferences were evenly divided, both as a group and by sex. Both boys and girls identified topics from biology, physical science, and earth science, such as plants, animals, people, space, oceanography, prehistoric life, and chemistry. In addition, girls mentioned technology, diseases, climate and future studies, while boys mentioned several physics and geology topics, such as rocks, earthquakes, and electricity.

We asked the students to describe what made their chosen topics so interesting. The male and female responses to this question were very similar. The responses revealed a level of interest and curiosity in themselves and the world around them. These students defined the world very concretely as things they could see and touch. Both girls (30 percent) and boys (20 percent) stated that they liked to learn new information so they could discover how and why the world worked. They also defined interesting topics as those that were personally and socially relevant. Representative comments about topics students wanted to find out more about included: the human body, how we came into the world, how we grow, how electricity goes through things, why the lights go on, why California has earthquakes, and how animals are like us and have to struggle to survive?

A second pattern we noted about the topics that interested students was their desire to be actively involved with these topics. Boys and girls responded similarly in their descriptions of active involvement. Their

comments included such things as the following: going places, looking at trees, finding bones, making things, using microscopes, doing experiments, and watching stars.

When asked to describe a topic that was not at all interesting, the girls listed 22 topics and the boys listed 16. Both girls and boys described physical science topics as uninteresting (59 percent females, 57 percent males) more frequently than life science topics (41 percent females, 43 percent males).

The students were not very explicit when describing what it was about the topics that made them not interesting. They made general comments, such as the topic was boring, difficult, or not interesting. Nine students were able to be more specific in their criticisms of the strategies used to teach undesirable topics. They did not like having to memorize lots of information, listen to lectures, read from the book as a major part of the lesson, or dissect animals.

After the students shared their open responses about their interests in science, we asked them to review a list of 31 topics likely to be included in the proposed curriculum. The list also was read aloud to the students and then we asked them to identify topics they would be interested in finding out more about. Second, they were asked to identify topics they would definitely not be interested in studying. The frequency distribution and rank ordering of male and female preferences for science topics is located in Table 1.

Table 1
Students' Preferences for Science Topics by Gender
Rank Ordering of Positive Responses

Female Rank Ordering of Topic	%	N = 37	Male Rank Ordering of Topic	%	N = 35	Total Rank Ordering of Topic	%	N = 72
Animals That Are Becoming Extinct (Endangered Species)	76	28	Space Travel	54	19	Animals That Are Becoming Extinct (Endangered Species)	60	43
All Kinds of Drugs and Their Effects	70	26	Earthquakes, Volcanoes, Hurricanes & Other Natural Events	51	18	All Kinds of Drugs and Their Effects	58	42
Earthquakes, Volcanoes, Hurricanes & Other Natural Events	62	23	All Kinds of Drugs and Their Effects	46	16	Earthquakes, Volcanoes, Hurricanes & Other Natural Events	57	41
Information about AIDS	62	23	Plants & Animals, and Where They Live (Ecology)	46	16	Space Travel	50	36
How Animals Live & Survive	54	20	Animals That Are Becoming Extinct (Endangered Species)	43	15	How Animals Live & Survive	47	34
Ancient & Native People and How they Lived	54	20	How Animals Live & Survive	40	14	Information about AIDS	46	33
How The Human Body Works	51	19	How to Design, Make & Test Things	40	14	How to Design, Make & Test Things	46	33
How to Design, Make & Test Things	51	19	Ways to Save Energy	34	12	How The Human Body Works	40	29
The Stars & Planets	49	18	Causes & Effects of Pollution	31	11	Plants & Animals, and Where They Live (Ecology	40	29
Space Travel	46	17	Effects on the Earth's Atmosphere (The Ozone Layer)	31	11	Ancient & Native People and How They Lived	40	29

Table 1 (cont.)
Students' Preferences for Science Topics by Gender
Rank Ordering of Positive Responses

Female Rank Ordering of Topic	%	N= 37	Male Rank Ordering of Topic	%	N= 35	Total Rank Ordering of Topic	%	N= 72
How Traits Are Inherited (Genetics)	46	17	Famous Scientists or Inventions	31	11	Effects on the Earth's Atmosphere (The Ozone Layer)	38	27
How Different Living Things Might Have Come to Be	46	17	How The Human Body Works	29	10	The Stars & Planets	38	27
Effects on the Earth's Atmosphere (The Ozone Layer)	43	16	Information About AIDS	29	10	Diseases and How People get Them	36	26
Diseases and How People get Them	43	16	Diseases and How People get Them	29	10	Famous Scientists or Inventions	36	26
Understanding People's Feelings or Emotions	41	15	Why Weather Happens	29	10	How Different Living Things Might Have Come to Be	36	26
Famous Scientists or Inventions	41	15	The Stars & Planets	26	9	Causes & Effects of Pollution	35	25
Causes & Effects of Pollution	38	14	How Different Living Things Might Have Come to Be	26	9	Ways to Save Energy	31	22
Staying Healthy	38	14	Ancient & Native People and How They Lived	26	9	Staying Healthy	31	22
Plants & Animals, and Where They Live (Ecology)	35	13	Staying Healthy	23	8	How Traits Are Inherited (Genetics)	29	21
Tropical Rainforests	32	12	How People Explain Things in Science	23	8	Why Weather Happens	28	20

Table 1 (cont.)
Students' Preferences for Science Topics by Gender
Rank Ordering of Positive Responses

Female Rank Ordering of Topic	%	N=37	Male Rank Ordering of Topic	%	N=35	Total Rank Ordering of Topic	%	N=72
Ways to Save Energy	27	10	Collecting & Figuring Out Scientific Information	20	7	Tropical Rainforests	25	18
Differences Between People's Personalities & Backgrounds	27	10	Atoms & Molecules	20	7	Understanding People's Feelings or Emotions	24	17
Why Weather Happens	27	10	Tropical Rainforests	17	6	How People Explain things in Science	22	16
Atoms & Molecules	24	9	Different Plants & How They Grow	17	6	Atoms & Molecules	22	16
Different Plants & How They Grow	22	8	Jobs in Science	17	6	Collecting & Figuring Out Scientific Information	21	15
How Our Bodies Grow & Develop Differently	22	8	Where Energy & Natural Resources Come From	14	5	Different Plants & How They Grow	19	14
Collecting and Figuring Out Scientific Information	22	8	How Our Bodies Grow & Develop Differently	14	5	Differences Between People's Personalities & Backgrounds	19	14
How People Explain Things in Science	22	8	Differences Between People's Personalities & Backgrounds	11	4	How Our Bodies Grow & Develop Differently	18	13
Where Energy & Natural Resource Come From	16	6	How Traits Are Inherited (Genetics)	11	4	Jobs in Science	17	12
Jobs in Science	16	6	Sex & Reproduction	9	3	Where Energy & Natural Resources Come From	15	11
Sex & Reproduction	14	5	Understanding People's Feelings or Emotions	5	2	Sex & Reproduction	11	8

The most striking pattern that emerged from the responses to this list was that girls indicated more interest in a greater number of science topics than the boys did. The girls frequently chose more topics and indicated some interest in most of the topics. Twenty-eight girls expressed interest in their number one topic, endangered species, while only 19 boys expressed interest in their number one topic, space travel. Overall, the 37 female subjects chose 450 topics they were interested in learning more about. The 35 male subjects chose a total of 295 topics, 34 percent fewer topics than the girls chose. Table 1 shows a great deal of variation in male and female interest in science topics, particularly in the frequency distribution of responses. Due to the high level of female interest, there is a large percentage difference between male and female preferences for most topics. Girls are particularly more interested than boys in information about AIDS, how traits are inherited (genetics), and understanding peoples' feelings or emotions. A closer examination of the rank orderings of positive responses to topics implied similarity of interests. Although male and female rank ordering of topics are considerably different, several topics appear in the top ranks for both genders. Three topics are found in common in the top five choices for both boys and girls. Similarly, five topics are found in common in the list of top ten choices for both genders. It also should be noted that the highest and lowest ranked topics for boys and girls are not in direct opposition to one another. Therefore, the most interesting topics for one sex are not the least interesting for the other sex.

No topics evoked strong negative responses when the students were asked to indicate which topics they would not be interested in studying. Girls indicated slightly stronger negative responses than the boys did, but the most disliked topic (atoms and molecules) elicited only 11 responses (30 percent). Seventy percent of the girls did **not** mark it negatively. Seven boys (20 percent) indicated that they were not interested in studying ancient and native people and how they lived, but eighty percent of the boys did not show a negative reaction to this topic. No other topics were identified as uninteresting by more than 14 percent of either boys or girls.

After students chose topics according to the questions described above, we asked them why they chose the topics they did. As with earlier questions, the students' answers about why certain topics were not interesting were vague, not very revealing, and similar between boys and girls. Typical responses included: "it's boring", "I'm not interested", or "I don't like it". Interestingly, only boys mentioned that a topic was difficult or complicated. The male trend was to blame the subject for any academic difficulties. Girls were more likely to personalize academic difficulties and say that they did not understand a topic, thus, blaming themselves for any lack of understanding. We also asked students several open-ended questions regarding their preferences for science activities, resources, and materials. We found very similar trends

in male and female responses to these questions. Student responses to the open-ended question asking for their favorite science activity revealed a strong preference for activity-based instruction. The most frequently mentioned activities for both boys and girls were to do an experiment, lab activity, or project. Students mentioned a wide variety of additional action-oriented activities such as: launching rockets, playing games and contests, role playing, taking field trips, growing plants, bringing in live animals, dissecting, making models, and producing plays. Both boys and girls also shared a desire to work with friends in class. There were no large discrepancies between male and female preferences from the content analysis of the open-ended responses. The content analysis of open-ended explanations for most favorite and least favorite materials and resources demonstrated that students have strong feelings for what they like and what they don't like in school.

The students described textbooks, worksheets, and workbooks as boring, hard to understand, and useless. Students expressed a strong dislike for these resources and said they were "repetitious" and they "didn't learn anything from them." One student commented that he "didn't use his brain" when completing worksheets and reading the textbook. Boys most frequently listed computers and field trips, while girls most frequently mentioned field trips, guest speakers, and films and videos as their favorite resources for science learning. The students explained their preferences with statements such as, "they were easier to learn from," and "they provided first-hand experiences." We did not find any discrepancies between male and female explanations. Both girls and boys mentioned wanting to "do things for themselves," "to see things alive," "up close," and "in person" and a desire to go places away from the school.

We also asked students to review a list of resources and materials being considered by BSCS for the middle school curriculum. Students were asked to select from this list the items they were most interested in using and the items they were least interested in using and to explain their selections. Table 2 presents the rank ordering of positive responses to preferred activities and materials by gender. Similar trends can be found in both male and female positive responses. Students' favorite activities were to do a lab activity or experiment, to go on a field trip, and to watch a video or movie. Students' lowest-ranked activities were to write essays or short stories, to use a hand calculator, to be the teacher in class, and to do worksheets.

Table 2
Students' Preferences for Science Activities by Gender Rank Ordering of Positive Responses

Female Rank Ordering Of Responses	*N*=37	*Male Rank Ordering Of Responses*	*N*=35	*Total Rank Ordering Of Responses*	*N*= 72
Do a lab activity or experiment	33	Do a lab activity or experiment	31	Do a lab activity or experiment	64
Go on a field trip	30	Go on a field trip	31	Go on a field trip	61
Watch a video or movie	29	Watch a video or movie	31	Watch a video or movie	60
Do a science project	26	Dissect a plant or animal	25	Work or discuss in small groups	47
Work or discuss in small groups	24	Work or discuss in small groups	23	Do a science project	46
Have a whole class discussion	22	Have a whole class discussion	22	Have a whole class discussion	44
Have group contests	20	Do a science project	20	Dissect a plant or animal	42
Use a computer	18	Have group contests	20	Have group contests	40
Watch the teacher doing a demonstration or experiment	18	Use a computer	20	Use a computer	38
Dissect a plant or animal	17	Watch the teacher doing a demonstration or experiment	19	Watch the teacher doing a demonstration or experiment	37
Read aloud	15	Read a book or magazine	16	Listen to the teacher	29
Listen to the teacher	13	Listen to the teacher	16	Read aloud	28
Make a collection	12	Read aloud	13	Read a book or magazine	24
Play a learning game	12	Make a collection	12	Make a collection	24
Do a worksheet	8	Play a learning game	12	Play a learning game	24
Read a book or magazine	8	Do a worksheet	8	Do a worksheet	16
Be the teacher in class	6	Be the teacher in class	5	Be the teacher in class	11
Write essay or short stories	3	Write essay or short stories	5	Write essay or short stories	8

Conclusions and Implications

There are minor differences between male and female preferences for science activities. Boys indicated a higher level of interest in reading a book or magazine, dissecting a plant or animal, and using a telescope or planetarium. Girls were more interested in doing a science project and using a camera and weather instruments. Both boys and girls identified textbooks, worksheets, and workbooks as their least favorite resources in science class. Our analysis of student interest in science topics revealed that both middle school boys and girls like science when asked open-ended questions regarding science as an area of study. Both sexes were very curious about themselves and the world around them. They describe their interests in science very concretely as what they can see and touch. Topics of highest interest were those that are personally and socially relevant to their lives. Both girls and boys were also intrigued by the discovery of "how" and "why" science works. They showed a strong desire to be actively involved in exploration and discovery.

Although many similarities exist, boys and girls also are interested in different types of topics and even different aspects of similar topics. Girls indicated much stronger interests in socially relevant topics, while boys focused on concepts that were personally engaging. The dominant trend in comments made by boys was that science is interesting when it relates to doing things that are personally interesting. Girls focused less on doing and more on understanding. They tended to (see science as interesting because of its importance to the environment and people. The female comments revealed a sense of "social obligation" to understand science and apply this knowledge to social conditions. Male comments indicated a personal desire or need to understand science. Girls were also more likely to internalize academic difficulties with science by "blaming" themselves for any lack of understanding. Boys were more likely to externalize academic difficulties with science by "blaming" the subject for any lack of understanding. These trends in responses to science topics can be interpreted in terms of the scholarship on female psychology, learning, and development (Gilligan, 1985; Noddings, 1992; Belenky, Clinchy, Goldberger & Tarule, 1986). This scholarship provides us with a perspective of females as relational, connected learners following an ethics of care and responsibility as compared to the more separate and independent male perspective. Although gender differences were noted in preferences for science topics, an examination of student preferences for science activities, materials, and resources demonstrated very similar preferences for both genders. In areas where discrepancies exist, male and female interests are not in direct opposition. Males show a stronger preference for reading books or magazines and dissecting, but these are not their favorite activities, nor are they the females' least favorite activities. Girls are more interested in

doing a science project and using a camera and weather instruments, but boys are also interested in these activities and materials.

Overall, the positive implication from the study is that middle school students have a strong interest in a wide variety of science topics. Students, especially girls, also expressed positive attitudes about topics that fit the science-technology-society framework often talked about in science education. An equally important trend is that males and females are most interested in activities and resources that are not a common part of traditional middle school science classes. Similarly, males and females are both disinterested in activities and resources commonly found in middle school teaching. Male and female responses demonstrated a shared preference for a wide variety hands-on, activity-oriented strategies. Both girls and boys favored group work, lab activities, experiments, field trips, videos, films, guest speakers, and the use of video recorders. Both sexes were disinterested in lecture, memorization, textbooks, worksheets, and workbooks that are the focus of most middle school science courses (Bybee et al., 1990; Weiss et al., 1989). It is important to remember that student disinterest in a topic, activity, or resource does not mean that teachers should abandon these strategies. Studies have shown that lack of experience in a topic may lead to initial disinterest that diminishes with increased exposure to that topic (Kahle, Anderson & Damnjanovic, 1991; Rennie et al., 1985). Females have considerably less experience with certain pieces of science equipment such as telescopes, barometers, electricity meters, meter sticks, compasses, and stop watches (Weiss et al., 1989; Kahle & Lakes, 1983). A lower female preference for resources such as telescopes and planetariums should, therefore, not indicate that these resources are inappropriate for girls. Similarly, students' lesser interest in writing essays or using hand calculators does not outweigh the importance of these strategies. On the other hand, students' strong preference for hands-on, activity-based approaches has tremendous support from the science education community and fits well with the needs of the early adolescent learner (Bybee et al., 1990). Student preferences documented in this study also lend support for increasing the range of topics, strategies, and materials used in middle school science, common theme in middle school recommendations (Carnegie, 1989). Our findings also reinforce the importance of understanding how girls see themselves as learners and how they view science as a topic of study. The middle school science curriculum must address these female perspectives if we are going to increase the participation and success of girls in science. While many gender studies have focussed on the discrepancies between boys' and girls' attitudes and performance in science, our work indicates that these differences may be symptoms of our current science teaching strategies rather than deficiencies in middle school students. The implications from this study seem to fall into two major categories: teacher education and curriculum development. Much work should be done in helping teachers employ the recommendations that have been a

part of the science education literature for many years. Science classrooms should be active places where all the students are taking part in hands–on, minds-on activities placed in a relevant context, as defined by girls as well as boys. These findings also impact curriculum development. Science programs should not be encyclopedic approaches to all the topics known in the scientific world. Curriculum programs should be carefully crafted approaches to meaningful topics. For middle school students this means a balance of personally and socially relevant topics taught in an interdisciplinary manner. One reasonable way to approach this is to organize the curriculum around major themes. In order to keep both girls and boys interested in science, these themes should lend themselves to topics and approaches for which both sexes have a natural curiosity. For many years we have observed discouraging trends in the attitudes and performance in science of middle school students, particularly females (Mullis & Jenkins, 1988). Perhaps, it is not a lack of interest in science, but rather a lack of interest in the way science is taught that is reflected in the middle school decline in attitudes toward science. Science, as a discipline, piques both boys' and girls' interests. This study clearly indicates that boys and girls have strong preferences for a variety of topics, activities, and resources within the science classroom.

These perceptions are substantiated by quantitative as well as qualitative research techniques. And, although interest in science topics varies according to gender, there is a strong similarity in boys' and girls' perceptions regarding how they prefer to learn science. Science educators need to listen to these messages and capitalize on the positive things students are saying to us. The major implication of this study is that a dynamic, relevant, activity-oriented curriculum that incorporates cooperative learning strategies and uses a variety of themes, resources, and materials should increase both male and female interests in science.

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Science Is All Around: A Gender-Inclusive Science Teaching

Anita Roychoudhury, Deborah Tippins, and Kathryn Scantlebury

Studies indicate that there is minimal or no difference in the science interests of elementary age boys and girls. However throughout their years of schooling girls seem to lose this interest and by the time they reach high school the gender difference between boys' and girls' science interests and course choices becomes prominent (Owen, 1993). It is important to attempt to bring these girls back into science. One possible strategy is to provide girls with the necessary self-esteem to maintain their interest in science throughout the 'tough' periods of time when science's masculine image challenges their own self-esteem and self concept.

Teachers are important individuals in developing the self-esteem and self-confidence of students. However, elementary school teachers often have low-self esteem and confidence with regards to teaching science. Also, the majority of elementary teachers are women who perceive science as a masculine preserve (Rennie, 1986). Considering these issues may help science educators to understand why science is neglected at the elementary level and why girls would lose interest as they progress through their academic career.

Overview

One major criticism of science is its claim to value-neutrality and objectivity (Brickhouse, Carter & Scantlebury, 1990). Science is portrayed as a representation of the truth about nature. The tentativeness manifested in the modification of various scientific theories and the influence of social conditions on the research questions are indicative of how the value-ladenness and subjectivity of science are generally underplayed (Code, 1991; Harding, 1991; Shepherd, 1993). Objectivist, reductionist, and value-neutral ways of learning are highly esteemed attributes in science. These attributes are strongly associated with masculinism. In contrast, subjectivist, connected, value-sensitive attributes are considered a part of feminine approach toward knowing and are generally devalued in scientific endeavors (Campbell & Greenberg, 1993; Code, 1991; Harding, 1986, 1991; Keller, 1985; Rosser 1990; Shepherd, 1993). In the past two decades, researchers have suggested that this inherent masculinism of science may be partially responsible for girls' lack of interest in science (Kahle & Meece, 1994).

The separation of the knower and the known -- so highly esteemed in the objectivist view of science -- is considered as a partial view by feminist

theorists (Code, 1991; Harding, 1991; Keller, 1985; Rosser, 1990). Feminists suggest that placing an emphasis on connections is an important for female learners (Keller, 1985; Rosser 1990). Subjectivity, as a legitimate aspect of scholarship, is a fundamental concept of all versions of feminist theories.

Studies have indicated that all students, especially girls enjoy and appreciate the opportunity to connect science to real-life phenomena (Harding, 1985; Klein, 1989; Roychoudhury, Tippins, & Nichols, 1993-94). For women and girls, it is important that there is a connection between themselves, the subject matter they are studying, and the human race. As science is often portrayed and perceived as detached from the human, it is quite possible for those who need to feel a connection with the subject matter to be turned off from the detached ways of science. Using some of these basic tenets as a lens, we have viewed the gender issues in science education

A traditional approach toward improving women's achievement in science has been to focus on providing equal experiences so that they could change themselves and acquire the same skills and level of performances as men (Pollard, 1993). The basic assumption here being a change in women is necessary to emulate male performances. This idea is being challenged by feminist scholars and the need for accommodating feminine epistemology within academic pursuits is being emphasized. The emerging ideas about feminine epistemology suggest that educators need to adjust instruction according to diverse learning styles of women (Belenky, Clinchy, Goldberger, & Tarule, 1986). It is possible for discerning teachers/educators to adjust instructional activities based on their knowledge of the learning needs of their students to make experience meaningful for them. For example, preservice elementary teacher educators are well aware of the disinterest and anxiety their students bring to science classes. This knowledge coupled with the fact that most of these students are females can help teacher educators to design courses incorporating feminist theories to help students reduce their science anxiety and possibly develop an interest in science.

The critiques of the masculine image of science are focused on science research, the questions scientists ask, the interpretation of those questions, the practice of science, and the overall social context of science. However, these criticisms have rarely encompassed discussions about science education, and in particular the undergraduate preparation of science teachers (Martin, 1991). In this chapter, we will describe our attempts to incorporate feminist perspectives in a science course for preservice elementary school teachers. We modified our pedagogical approaches by interpreting our students' formal and informal comments through the lens of radical feminism. Our acquired knowledge informed us that these students were typically unaware of any connection between their daily lives and science. These students

were excited by their developing ability to connect and construct a relationship between these two concepts. Informed by feminist discussions on objectivity versus subjectivity we attempted to provide experiences that might help students relate science to their life and feel comfortable with the subject.

Purpose

This study was inspired by student comments about somewhat similar attempts during previous semesters, the purpose being to explore student reactions to the pedagogical perspectives guided by feminist discussion of the pursuit of science. Additionally, through our research we hope to begin a new line of conversation about gender issues in science education. We believe, along with Biklen and Pollard (1993), that conversation constitutes a contextual framework for all scholarship and will help enrich the relevant research.

Method

Neither objectivity nor distancing ourselves as researchers from the students was the goal of this study. Consonant with the primary trend of research on women that eschews the distance between subject and researcher and the distrust of self-reported experiences, we adopted descriptive accounts by both students and instructors as valuable sources in understanding the study (Campbell & Greenberg, 1993). Our main goal was to understand and interpret the students' reactions through a feminist critique of science.

Data sources and analysis

Student reflection was the primary source of our understanding. We were aware that student comments, especially from female students, about a course may be overly positive when they respond to the instructor (the first author of this chapter). To elicit honest comments from students the tentativeness in the structure of the course was elucidated. It was explained to them how in this course, every semester, attempts were made to incorporate student comments to improve the instruction and make experiences more meaningful for them. Examples of modifications based on student suggestions were cited to help them understand their responsibility. Thus, it was in their interest to provide genuine reactions so that the course could be modified to better suit their needs and interest. Twice during the semester, students were asked to write their reflections on their experiences. (See Figure 1.) These reflections were about any aspect of the course that they found meaningful or useless.

Use the following statements to guide your reflections about learning in this course.

Write about the experiences that you consider helpful in raising student interest. Please keep in mind your comments will be used to modify the course. So write in detail about the features you would like to be continued. Also give suggestions wherever necessary. Give reasons for your comments and suggestions. Also write about the features of the course that you found rather useless and would not like to be continued. Please give reasons to justify your comments.

Figure 1
Reflective Writing Assignment

In addition to student reflections, our initial constructions of student reactions were triangulated by collecting the instructor's journal and video-tapes of classroom discussion. We used constant comparative analysis method to analyze the texts generated from the various data sources (Strauss, 1987). After the initial categories were developed from an iterative analysis of the data we checked for negative cases that contradict the initial categories. The final categories that emerged from the iterative analysis are presented under "Our learning".

Context of the Study

The study was conducted during the fall semester of a physical science course at a midwestern university. The curriculum for the course consists of several basic topics of physics and chemistry and partially fulfills the physical science requirement for an elementary teaching certification. The course design includes two concept introduction cum discussion sessions of 75 minutes each and a two-hour laboratory period every week.

Typically in this course, the concept introduction sessions are primarily interactive, where students have opportunities to engage in discussion on their readings and observations made inside or outside the classroom. The instructor's role is to provide explanations for new concepts or for confusing observations, and to ask guiding questions that would enable students to express or elaborate their ideas. During the previous two semesters students had made positive comments about their scope of connecting science to daily life. Encouraged by student enthusiasm, overt attempt was made to enable students to connect scientific principles to day-to-day events. Over half of the laboratory activities were open-ended. The professor structured the remainder. The structured laboratory experiences were used mostly during the beginning of the semester to help students get used to the various novel demands

of the course. For the open-ended activities students had to select a focus question and design an experiment to study it. All laboratory activities were performed in cooperative groups of four students.

Participants:

Thirty-eight students enrolled in the two sections of a physical science course during the fall semester participated in the study. All the students were white and came mostly from middle class families. The majority of the students were females and had very little science background as indicated in Table 1. A large number of students (66%) expressed some anxiety toward learning science at the beginning of the course. This finding is fairly consistent over the semesters. At the beginning of every semester a questionnaire was given to collect some information about science background of the students and to develop some sense of their initial feelings about science. The findings from the questionnaire are summarized in Table 1.

Table 1
Description of the Participants

Physical Science Course (N=38)	Male (N=4)	Female (N=34)
Number of students that had taken more than two high school science courses.	3	18
Number of students that expressed science anxiety	1	24
Number of students that expressed an interest in science	3	6
Number of non-traditional students	1	8

The nature of the anxiety and the percentage of students expressing it are very similar across the semesters. Typically male students do not express any overt anxiety, rather they indicate a feeling of disinterest toward the subject. This semester, however, one male student, Ronald, was apprehensive about the course. Before the course began, he sought suggestions from the instructor about study skills. He came back to college after a gap of 21 years and was concerned about his performance in the course. This is a common concern of non-traditional students, who come back to college after a hiatus in their academic career.

Pedagogical perspectives guided by feminist discussions of science

Cooperative learning:

Rosser (1990), based on her discussion of science teaching and learning from a feminist perspective, suggested a cooperative learning environment for science courses since women prefer cooperation to

competition. In this course students worked in groups of four for all laboratory assignments and submitted one group report.

Members of each group had assigned roles to follow for each laboratory experiment. Their roles were rotated so that all students received equal opportunity to perform various tasks. In addition, group interaction skills were taught at the beginning of the semester and monitored during the laboratory periods. The instructor moved from group to group during the laboratory period to ensure equity in interaction and task sharing. Students were also encouraged to form study groups outside the class and a majority of the students did so. For the connecting science with events from daily life assignments, they had the freedom to form their groups and in most cases they maintained the same group as their laboratory ones. Those who preferred to work alone were allowed to do so only on this assignment. Only one male and two female of the 38 students chose to make individual observations.

<u>Connecting science with events from daily life:</u>

To help students connect science with their daily life they were asked to observe things and events around them and attempt to connect those to what they have learned in class. This decision was informed by findings of research indicating that inclusion of examples appropriate for girls may not result in the desired effect. Kelly (1985) reported an attempt to raise interest of girls by using examples from domestic life such as vacuum cleaner, cooking, domestic heating had very little appeal to young girls. This is not surprising if teacher has the sole responsibility in deciding what example is suitable for students. Furthermore, such examples chosen by teachers can also reinforce a stereotype view of women's lives. In this study, the instructor's decision was to allow students to connect science to their lived experiences in the manner they deemed appropriate. Each week a group was assigned to make an observation and share relevant ideas with the class. A brief guideline was given to help them focus on the task. (See Figure 2.)

Guidelines for interpreting everyday phenomena in terms of scientific principles

1. *Select an observation about things around you - something that strikes you as curious - and think about it. If possible observe it several times.*
2. *Does it seem to relate to any scientific principle that you know?*
3. *Try to explain your observation in terms of any scientific theories or principles.*

Do not worry about being wrong, just try to see if you are consistent with the theory or principles that you are using. Does your explanation make sense to you? There is no penalty for being wrong. You will discuss your observation in class. This will be a learning experience for all of us. We would like to learn from your experience.

Figure 2
Guidelines given to preservice elementary teachers for interpreting everyday phenomena in terms of scientific principles

There were five groups and one individual student in one section, and four groups and two individual students in the other. This allowed each group or individual to make three or four observations during the semester. Each week a designated group shared their observation and interpretation with the class followed by questions and comments from other students as well as the instructor. During this period, the instructor's role was to ask guiding questions so that students could relate appropriate scientific principles with their observations. Also the inconsistencies between student assumptions and observations were pointed out through the instructor's questions and/or comments. A few examples of the events selected by students are listed in Figure 3.

- *Apparent wet patch on the road on hot summer days.*
- *"Heat rising" from the road.*
- *Does hot water freeze quicker in the freezer?*
- *Fogging of bathroom mirror.*
- *The river shines differently at different places.*
- *Two-way mirror.*
- *Pasta in boiling water.*
- *Christmas lights: parallel and series connections.*
- *Dish detergent changes color with some food.*

Figure 3
Examples of observations students discussed in class

In the section below, we will provide examples of students views about their experiences in the course. Their comments indicated that they considered the "events from daily life" and cooperative grouping to be most useful experiences. We will discuss student comments regarding these two aspects of the course in the section below.

Reactions to group learning:

Much has been written about the merits and shortcomings of cooperative learning; we will, therefore, limit our discussion of this topic as our study corroborates some of the previous research. Some studies indicate that group learning becomes productive when students have been taught to participate in a group, share task, and are held accountable for their roles (Johnson & Johnson, 1979; Slavin, 1983). On the other hand, if not monitored, group learning can foster status difference, and anxiety (Linn & Burbules, 1993). In our study student reaction in favor of group learning seems reasonable since group work and interactions were frequently monitored and supervised. The majority (80%) of the students considered peer support and various interactions (e.g. discussion, debate, and explanation) to be valuable learning experiences. One male student considered group work to be a burden and two female students felt constrained by the time needed for additional group meetings. To complete lab reports, groups often met outside the class periods -- this necessitated adjustment in work schedule of some students. Overall, student comments endorse cooperative groups.

Reactions to course:

We discuss student reactions to course assignments in the following section. Student reactions are grouped according to their basic similarity and we will present comments from several students to illustrate the diversity of views. All through the chapter pseudonyms are used to maintain the anonymity of the students.

Three strands emerged from the grouping of student comments. The first view indicates a feeling of interest but students expressing this did not go to a deeper level of analysis. They only expressed interest in the subject. We report their views under the sub-heading Interesting because that was the label we used to group the similar comments during the analysis. Likewise, we will present the other views under the sub-headings used for labeling the categories that emerged during the data analysis. The second view is presented under the sub-heading "Cognitive utility" because some students appreciated the course assignments because they enhanced their understanding of related concepts. The third view included the most mature analysis and is labeled by "Cognitive" as well as "Pedagogical Utility" since both of these were considered by students. The fourth view was labeled as

"Overwhelming and Unnecessary" since some students were not enthusiastic about this experience, they considered demonstrations and traditional laboratory experiences more helpful. Finally we will present some other points in the sections labeled other relevant observations.

Interesting:
Some students (17%) indicated their liking for the events from daily life activities, but their comments did not extend beyond mere a statement of interest; hardly any rationale was provided to justify their interest. The reflection of this group students were very sketchy and basically indicated the new learning experiences in this course were different from their high school science classes.

The reaction of these students can be illustrated by Amy's reflection. Amy had taken a physical science and a life science course during junior high and high school and indicated a dislike for science in the background questionnaire. The following excerpt from her reflection represents her and several other students' views.

> "I was never taught science in a non-traditional way, but I do believe this information that I learned from the real-life events will stay with me much longer because this is more interesting. It makes me take a new interest in science."

It should be noted here that this group of students consisted of regular students that are going through college right after high school, two of the four male students were in this group. In other words, there was no non-traditional students in this group.

Cognitive utility:
This group of students (26%) considered the new activities to be useful and wanted this to be continued because of the facilitation of learning. In their view, these activities made them think about the connection between science and life which also made understanding the concepts easier.

Angie's reflection illustrates this point and is corroborated by others. Angie is a traditional student, going through university immediately after graduating from high school. She had taken three science classes during junior high and high school and expressed an interest in science at the beginning of the course.
In Angie's words,

> "I pay more attention to things around me. I did quite well in high school science courses but I never thought about relating it to my life. I knew technology and science have a lot to do with our life. This (course) makes me curious about what is happening around me. For example, when I

> see water boiling I think about how it happens, phase change and other things. If you did not have us do this I really do not think many people, including myself, would run out and investigate them. Also I think this helps in understanding the scientific ideas better".

Angie performed well on high school science tests and had an interest in science from the beginning of the course but some other students who expressed a similar view did not have a strong science background and had expressed an anxiety. In addition, a male and three female non-traditional students also expressed similar views as that of Angie's. It should be noted here that all these non-traditional students began with a science anxiety and they were unsure of their ability to learn science. They considered science formidable, but the connection between science and life kindled their interest.

Cognitive as well as pedagogical utility:

Another group of students (31%) provided a more thorough rationale for their suggestion for continuing the assignment of relating science to daily life. There was almost an equal number of traditional and non-traditional students in this group. Among them Lisa's comments are most significant since she started with a declared lack of interest in science. Lisa came back to college after a gap of 12 years in her academic career. She had taken some science classes during her high school but remembers nothing other than her dislike for the subject. She began her experience in this course with a strong anxiety toward science.

> "This course is a surprise to me. I really have to work hard. The real life events make me think and understand better. When I study I try to find an example from real life whenever I can. This really helps me to understand. I know I will teach science very differently than the way I was taught. In fact when I think about it I look forward to teaching science. I think the kids will really enjoy doing things like this. They are always asking questions. If I hadn't taken this course I would have probably avoided teaching science as much as possible".

Cindy and several other students also considered that the absence of the pressure to be correct in their explanations facilitated their learning. Cindy is a non-traditional student with great apprehension for science, who re-entered academic life after a hiatus of 8 years. In Cindy's view, which was shared by several other students, the assignments helped them understand that the thinking behind the process was important. She wrote,

"For me, it was important to know that I did not have to give a correct explanation. It made it easier to try. This made me understand that the thinking is important and gave me a reason to understand things to the best of my aptitude. I think it will be important for the kids to feel that way. This kind of activity will make the kids think".

For these students, the course assignments made them realize that science learning becomes interesting when it is related to real life. This not only facilitated their understanding but also provided them with a pedagogical approach that will be useful when they become teachers. They consider this approach to fit with children's curiosity about their surroundings and make them think spontaneously. They also considered the non- threatening nature of these assignments and its importance for generating student interest.

Overwhelming and unnecessary:
A percentage (26%) of the students preferred traditional ways of learning. For them, relating science to daily life generated too much frustration to be interesting. They believed that hands-on activities like traditional high school laboratory experiments are sufficient for learning science. Laurie, a traditional student with no expressed liking or disliking for science, wrote,

"Science is hard to understand and confusing for most people. It is not easy to relate what we read in the book to daily life because we are not experienced. It takes a long time to find something that is related to science. This can be frustrating and students might dislike the course. I do not understand how kids will be able to do this. They are curious about things but they cannot find explanations. It is better if the teacher explains things for them."

Melinda, another traditional student with no interest in science, shared similar feelings. She wrote,

"I don't think we need to do these events from daily life activities. Hands-on activities or labs should help us."

Inherent in these comments is the view that students are passive recipients of knowledge and the teacher as a source of knowledge needs to give the necessary information. Also, to these students, learning is a smooth process without uncertainty and frustration associated with it, thus structured activities designed by the teacher were preferable to them.

Other relevant observations:

In addition to student reflections, there were other evidences of student interest in the real life events. For example, voluntary discussion of such events became quite common as the semester progressed. This, in our view, constituted evidence of student interest. During each class period, only one group was required to discuss their observation of an event and provide explanation. Video tapes of the discussion sessions and instructor's daily journal indicated that after the first three/four weeks, students started asking questions over and beyond their assignment. Students, other than the designated group, cited events that were of interest to them. Instructor's journal entries reflect that on an average two to four extra events were discussed during each class period.

Implications for teacher education

This study was guided by the feminist assumption that making a connection between science and events from daily life will be something that female students will particularly enjoy. Student reflections and their voluntary attempts to make such connections indicated their interest in the matter. We would like to underscore, here, that generalization or drawing definitive conclusion is not the purpose of this study. Rather, our intention is to share our experiences regarding the course and our subjective interpretation grounded in feminist theories so that this can begin a dialogue about research on gender issues in science. Most of the female students – a majority of the traditional and all of the non- traditional students considered that relating science to real life enhanced their understanding and increased their interest in the subject matter. The most significant aspect of this study was that a large number of participants began with a declared science anxiety which according to of many of them changed into an interest in science during the course. They considered the connection between real life events and science as the most facilitating aspect of the course. One can contend that student comments regarding the course do not necessarily indicate an actual interest. While we agree with that, we would like to point out that students could express their interest in other aspects of the course and not necessarily in assignments.

An interesting part of our learning stemmed from the observation that along with others, the non-traditional female students, who had the most pronounced science anxiety and who believed that science was not for them, became enthusiastic about making connections between science and life. This corroborates the feminist claim that women, due to their nurturing and caring role in life, develop a penchant for making connections. In the context of learning situations it is quite likely for women to feel the same need for connecting with what they are learning. If this is used as a framework for understanding, we can easily make

sense of the interest of these students. The non-traditional students being older than the traditional college students and generally with families are likely to have more prominent traits influenced by gender-specific roles. The nurturing and caring they need to give to their families in their personal lives might make their need to be connected stronger than other students. In such a case, the opportunity to relate science to life would be more interesting than mere learning of the concepts.

Student interest is probably enhanced by their active involvement in making connections. It is in this respect our study is different from previous studies, where teachers decided what would be interesting for female students (Kelly, 1985). Here the student connects science to life. The responsibility of making science gender-inclusive was not monopolized by the instructor. Thus, it is reasonable to speculate that student involvement in the course might be somewhat responsible for the enhancement of their interest.

We refrain from discussing in detail the reflections of male students because their reactions were not incompatible with that of the others. Out of four male students only one did not appreciate the course assignments. His reflections are very brief and do not provide any rationale for his comments. Male students' interest is not unusual, since most students would tend to like topics that are related to their personal experiences. Probably this will be the primary ground for devising gender inclusive classroom experiences.

It appears from this study that pedagogical perspectives needs to provide room for female epistemological differences. We need to attempt to change the masculine image of science and provide students with experiences that help them feel science is accessible, not a remote and detached subject. A subjective way of learning science needs to be blended with the existing claims to objectivity particularly for those who have lost interest in the subject. Additionally, as student comments indicate, a non-threatening framework may be essential for any new and challenging assignment, because many of these students began with a feeling that they were not suitable for science or that it is inherently difficult for most people to learn science.

Creating situations that make students comfortable offering their ideas and theories is of paramount interest. The question remains whether student interests expressed in class are sustainable or not. Further studies, particularly longitudinal ones are necessary to answer this question. But it is logical to assume that the impression of one course may not last very long without appropriate reinforcement in subsequent science and methods courses. If we hope to change the ongoing trend of girls' decreasing interest in science, we need to pay serious attention to elementary teacher education. In addition to the traditional attempts to solve this problem we need to extend our attempts to include new

perspectives, because the science interest of elementary teachers remains a pervasive and persistent problem.

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The Impact Of Gender Differences On Secondary Science Teachers' Needs

Judith A. Bazler and Deborah J. Peugh

According to The Council of Chief State School Officers, only 45% of all secondary mathematics, 37% of all biology, 34% of all chemistry, 22% of all physics teachers are women; however, 52% of new science teachers are women (1993). An understanding of the aspects in which male and female science teachers differ, if any, would lead to higher success in fulfilling the needs of science teachers when implementing programs and supervising teachers. Thus, it would follow that, when science teachers are more stimulated and satisfied with their assignments, they transfer better science education to their students. If male and female secondary science teachers are found to have the same needs and attitudes, then equitable treatment of men and women would be justified.

Hobbs and colleagues (1979) found that female secondary science teachers asked for more inservice training than men. Lawrenz and Welch (1983) reported that men had taken more science courses, had been teaching longer, and ranked their professional support higher than did their female colleagues. They found no differences in professionalism or perceptions of curriculum or facilities. Douglass, Matyas, and Kahle (1985) reported that more women than men were in the upper and lower brackets in years of experience as biology teachers. They also found that men were more likely to teach at larger schools and to teach more of the advanced classes. In the same study, more male biology teachers than female attended national professional meetings and received financial assistance from their institutions to do so.

Although many studies have investigated the needs of science teachers in general, relatively few attempted to compare any differences between male and female secondary science teachers. Those that did explore this question sampled only biology teachers. (See Douglass, Matyas, and Kahle, (1985).) This research investigated whether certain characteristics, concerns, and perceived needs are different for male and female secondary science teachers.

Method

In June of 1990, the Lehigh Valley Educational Cooperative (LVEC), with funding from the Pennsylvania Department of Education, developed and distributed comprehensive assessment instruments evaluating the professional and curricular needs of science, mathematics, and computer

science educators in Grades K-12. Three different questionnaires, developed for each discipline, were distributed to middle and high school teachers.

A 69-item questionnaire (see Table 1 for major areas addressed) was developed using the Montana Statewide Needs Assessment (Briggs, 1985) as a model. Questionnaires were sent to two eastern Pennsylvania Intermediate Units (IUs) representing a total of 251 teachers. (An intermediate unit provides support and coordinates services between the state Department of Education and local school districts.) Middle school was defined as Grades 6-8 or 7-9 and high school as Grades 9-12 or 10-12.

The data were treated as an opinion poll. The 5-point, Likert-type response scale was collapsed to a 3-point or 2-point scale and percentages of responses reported. The results were categorized into four groups: demographics, safety and computer inservice concerns, instructional needs, and professionalism. Teacher professionalism was observed through organizational participation and activities outside of the school environment. For ease of review, and based on Pennsylvania certification standards, middle and high school teachers were grouped together as secondary teachers.

Table 1
Major Items Addressed in 69-item Questionnaire:

1.	Do male and female secondary science teachers differ in demographic characteristics such as experience, age, advanced degrees, and types of courses taught?
2.	Do male and female secondary science teachers have different attitudes about safety in the science classroom?
3.	Do male and female secondary science teachers have different attitudes concerning computer use?
4.	Do male and female secondary science teachers differ in their inservice preferences and degree of support for attending them?
5.	Do male and female secondary science teachers have different instructional needs, such as facilities, texts, and budgets?
6.	Do male and female secondary science teachers have different rates of participation in professional activities and organizations?

Analysis

The raw data from the questionnaire were separated by gender of respondents. Frequency and percentages were computed for statistical analysis (see Table 2). The resulting frequencies of each question were subjected to the chi-square test to determine whether the results showed a statistically significant correlation between the questions' results and gender. The "Explore" computer program was used to carry out the calculations of the inferential statistics. The N data does not always add to 251 due to incomplete questionnaires.

Results

Demographics

Chi-square tests indicated that male and female secondary science teachers differed significantly on six out of 23 questionnaire items: a) male secondary science teachers were generally older than female secondary science teachers; b) male teachers had more years of teaching experience than female; c) males accrued more years of teaching in their current school systems; d) males taught at large schools (2,000+ students) whereas female secondary science teachers worked in medium-sized schools (301-2,000 students); e) more male secondary science teachers held master's degrees than females; and f) male secondary science teachers took more graduate-level courses than female secondary science teachers.

Male and female secondary science teachers differed somewhat in their areas of certification; more males are certified in physical science and physics than women, and more women are certified in biology and chemistry.

Safety Concerns

Chi-square tests indicated that male and female secondary science teachers differed significantly in two areas of safety concerns: a) female secondary science teachers were significantly more interested in receiving safety training than male secondary science teachers (94% versus 78%); and b) more female secondary science teachers than male (71% versus 53%) stated that their overall safety conditions were not adequate.

Computer Concerns

No significant differences were found regarding computer concerns. Male and female teachers had similar opinions regarding availability of equipment, labs, and instructional value of computers.

Inservice Concerns

Male and female secondary science teachers significantly differed on two items of inservice concern: a) male secondary science teachers preferred weekday inservices more than female secondary science teachers, whereas women preferred college and local summer inservices; and b) more men than women felt that an activity approach to science was important. There was relative agreement regarding inservice providers, adequacy of current programs, and other matters concerning inservices.

Instructional Needs

Males and females significantly differed on only one indicator of instructional needs: more male science teachers than female science teachers said their audio-visual materials were adequate.

Professionalism

Only one aspect of professionalism was significantly different for male and female secondary science teachers: more female secondary science teachers than male secondary science teachers were members of a national science organization.

Table 2
Questionnaire items that have statistical significance

Item		Male N	Male %	Female N	Female %
Age	20-29	13	7	18	27
	30-39	50	27	18	2
	40 +	120	65	31	
Total years teaching	1-10	27	15	31	46
	11-16	40	22	15	22
	17+	117	64	21	31
Years in current system	1-10	41	23	43	64
	11-16	35	15	8	12
	17+	108	58	16	23
School Size Student Enrollment	1-300	4	2	3	4
	301-2000	78	43	63	94
	2000 +	100	55	1	1
Masters' Degree	Yes	117	64	33	50
	No	65	36	33	50
Hours Graduate Study	0-9	29	27	24	55
	10-18	26	25	7	15
	19+	51	48	13	29
Interest in safety training	Yes	144	78	63	94
	No	38	21	4	6
Adequate overall safety conditions	Yes	130	71	63	94
	No	51	48	13	29
First choice of inservice format	Weekday	129	71	37	55
	Weekend	3	2	0	0
	evening	14	8	3	4
	College (summer)	7	4	11	16
	Local (Summer)	29	16	16	24
Hands-on science approach	important.	180	99	64	96
	not impt	1	1	3	4
AV materials adequate	Yes	119	65	34	51
	No	57	31	28	42
Belong to National Science Organization	Yes	100	39	30	45
	No	44	60	37	55

Discussion

A review of some general, persistent trends in our society may provide an explanation for some of the results of this study. Even as recently as 1991, men were the primary contributors to household incomes which may explain why they remained in teaching longer than women and take more graduate courses to increase their salary. This assumption appears to be supported by the fact that men -- more than women -- listed the most important incentive for attending inservices as a pay increase. Conversely, inequality in pay, which tends to relegate a woman's income to secondary status in the family, may explain why they do not appear motivated to earn more money. In addition, women tend to carry the bulk of the tasks of childrearing and maintenance of their households, and thus they may not have had as much time, energy, or money available to pursue graduate work, teach for uninterrupted stretches of time, or attend professional meetings.

It seems to follow that, for women to gain the same teaching experience and graduate-level knowledge, fundamental changes in society must occur. A woman's career and pursuit of coursework should not be secondary, but rather should be raised to be of equal importance to that of males. Support from society and family is crucial to achieve this end. A greater number of knowledgeable female science teachers in the school system to act as role models for female students could/would benefit those students and ultimately increase the chances for more experienced female teachers in the future.

Throughout this research, men were generally more satisfied overall (e.g., computer materials, current inservices and safety conditions, textbooks, and facilities). Perhaps the differences between men and women were due to the males' years of experience. Men may have had time to accumulate more materials and/or knowledge about ways to effectively use less than ideal resources, or possibly may even have lower expectations due to growing more complacent over the years. Women, on the other hand, perhaps due to less experience and previous training, were more interested in receiving safety training and increasing their knowledge and professionalism.

Implications

This research could have many effects on the treatment of and planning for secondary science teachers. Since women have less advanced coursework and also feel a greater need for inservices, greater incentives should be given to allow more women to close those gaps. Multiple types of incentives, including time off to attend national professional conferences, full paid sabbatical leaves for further professional development, and graduate credit remissions should be available so that

both men and women can satisfy their different needs. Both sexes would benefit from such valuable extra opportunities.

Future inservices and other programs and materials should address the gaps that women feel exist in their profession, such as safety training. In addition to varying the incentives and content of inservices or programs, alternative formats (weekends, weekdays, summers, after-school, sabbatical leaves) should be considered since male and female teachers stated different preferences.

Varying program accommodations would then, ultimately, encourage and enable more participation by teachers of both sexes. Given that male secondary science teachers tend to be older and more experienced, active recruitment measures should be the priority at all higher education institutions who prepare science teachers to ensure that women will pursue educating young people as long as men. With this will follow higher salaries for these experienced women, thus closing the overall gap that exists between the average earnings of male and females. Moreover, longer experience will lead to better teaching.

Incentives to attract women to the larger schools -- where men tend to gravitate more often than women -- should be implemented in order to equalize the ratio of male and female science teachers. If not, students at these schools will see fewer female science teachers as role models.

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De-Gendering Assessment In Science

Léonie J. Rennie and Lesley H. Parker

Assessment plays a crucial role in the decision-making that determines which people will pursue which studies or careers. In this context, it is critical that students' scores on assessment tasks genuinely reflect the level of cognitive, affective or psychomotor skills which the tasks are designed to measure, and not cultural, social or other life experiences or expectations based on gender. If the assessment procedures do not allow students to exhibit their full capacity, this is reflected in depressed scores which discourage students from pursuing the most challenging careers of which they are capable, and perhaps even prevent them qualifying for entry to such careers.

This paper reports the results of a study in which the objectives were

i. to characterize what constitutes gender bias in the context of an assessment task,
ii. to develop a schema or framework which will enable teachers to screen assessment tasks for potential gender bias, and
iii. to produce a set of guidelines, including exemplary assessment tasks, for the construction of assessment tasks which are free of gender bias.

The outcomes of this study places into the hands of teachers and teacher educators a means to improve their assessment practice by making it more gender-inclusive.

Background to the Study

If performance on an assessment task is dependent in part on some characteristic other than the knowledge or skill the task is designed to measure, then the resulting scores are invalid. When gender is that irrelevant characteristic, then the task contains gender bias. The possibility of gender bias in assessment has become a topic of research interest following consistent findings that females performed better than males on continuous school-based assessment, though performing less well compared to males in standardized or other externally prepared tests (Linn, 1992; Parker, 1992). Such contradictory findings indicate that these different kinds of assessment are measuring different things, or that gender interacts with the nature of the assessment tasks. There is evidence for both, and in their thorough review of gender differences in

achievement, Gipps and Murphy (1994) point out that the situation is complex.

Part of the gender difference in performance may be attributed to the format of the assessment task, particularly whether it is multiple-choice or extended answer. However, the science content of the assessment task, and the context in which it is presented has also been shown to be important. For example, ex post facto analyses of large data sets, such as those obtained by the National Assessment of Educational Performance (Kahle & Lakes, 1983) and the Assessment of Performance Unit (APU) in the United Kingdom (Johnson, 1987), revealed that sex-related differences in performance are associated with sex-related differences in background and out-of-school experiences. Other work focusing on the context of the assessment items compared items where the sex-related differences were large with those where they were small, and concluded that the context (as distinct from the science concept being tested) of many items was male-oriented, that is, the items were more likely to be in the area of knowledge or content familiar to males than females (Bateson & Parsons-Chatman, 1989; Erickson & Erickson, 1984).

Chipman, Marshall and Scott (1991) searched for explanations of sex-related differences using an experimental research design. They investigated the effect of sex-stereotype and familiarity of the content of mathematics problems and found that sex-stereotype of item content was not associated with performance, but familiarity was, and importantly, familiarity was a good index of item difficulty. They hypothesised that, when testing conditions were associated with important consequences and thus were more stressful, familiarity with the item content could assume even more importance. In other research associated with the Computer as Laboratory Partner (CPL) Project, Linn and her colleagues suggest that item format can interact with the nature of the knowledge being tested. Linn (1992) found that females perform better on measures of integrated understanding, which is often more easy to assess with extended answer questions, while males performed better on multiple-choice questions covering a range of general scientific phenomena. It seems that format, the cognitive content, and the context in which the item is presented may all interact with gender to affect performance on the task.

At the present time, constructivist and gender-inclusive frameworks are guiding major curriculum reforms aimed at improving instruction. The reforms take cognizance of students' current understandings and conceptual frameworks and attempt to put new learning into that context. However, it has been argued that to be successful, change in curriculum and instruction must be accompanied by change in assessment (Kulm & Malcom, 1991; Parker & Rennie, 1992; 1994; Rennie & Parker, 1994). If assessment tasks are to be consistent with the

changing curriculum, they too must incorporate a greater consideration of the context in which the knowledge and skills are learned.

If all students are to have maximum opportunity to demonstrate their learning, then a variety of assessment formats will be required (Linn, 1992). If gender bias is to be avoided in the increasingly contextual nature of the curriculum, instruction and assessment, it must be better understood, particularly by teachers. Thus research into the possibility of gender bias in item context must move into the school situation and become more concerned with teacher-designed assessment tasks. The research reported in this paper attempted to clarify the factors which contribute to gender bias in the context of assessment tasks and to enhance teachers' understanding of it.

Physics was chosen as the focus subject in this study for three reasons. First, it is historically the science subject in which sex-related differences have been shown to be greatest (Comber & Keeves, 1973; Erickson & Erickson, 1984; Johnson, 1987; Keeves & Kotte, in press). Second, the perusal of a large number of physics assessment tasks indicated that very few were set into any context at all (Rennie & Parker, 1991). Third, our State was about to introduce a new physics curriculum which aimed to increase awareness of physics in a "real world" context and thus teachers needed to develop new skills to create matching assessment tasks. Although physics is the focus of the study reported here, it is expected that the guidelines resulting from the study will be generalizable to other subjects.

Method

The study took place in several stages. First, a literature review and synthesis of the factors which may contribute to the gender orientation of an assessment task was undertaken to prepare a draft framework to describe possible sources of gender bias in the context of the task (Bateson & Parsons-Chatman, 1989; Chipman, Marshall & Scott, 1991; Erickson & Erickson, 1984; Murphy, 1988).

Second, a series of workshops was conducted with physics teachers to present and discuss the draft framework, and to screen a number of physics assessment tasks actually used in schools. After each of three workshops with between 20 and 30 volunteer physics teachers, the framework was revised. During two further workshops, a fourth group of 15 physics teachers helped to devise and test a number of assessment tasks in order to determine whether the framework could be operationalized into assessment tasks. (This part of the research is described in more detail by Parker & Rennie, 1993.)

In the third stage of the research, these tasks, and others written for the purpose, were field-tested. A comprehensive set of assessment tasks

was distributed to all teachers who had been involved in any of the workshops. Two months later, a survey form was posted to teachers in order to obtain feedback about the assessment tasks. A second field test involved a small sample of high school physics students. Four girls and four boys completed five matched pairs of tasks, one with the context structured to be gender-inclusive according to the framework developed and the other with minimal context. After completion of the tasks, students were interviewed to determine their reaction to each assessment task.

Results

Development of the Framework

The framework characterizing the gender-orientation of assessment tasks contains descriptors in four categories: language, portrayal of sex-stereotypes, appeal to background knowledge and non-physics content. Early versions of the framework included male, female and neutral orientations. Initially, the latter was considered to favor neither males nor females, but further work revealed that genderless persons and plural pronouns, intended to invoke a neutral response, were generally interpreted to mean "male" (Scott & Shau, 1985). The "neutral" orientation thus was relabelled "allegedly-neutral" and the gender-inclusive category added (Rennie & Parker, 1993). This framework, presented in Table 1, is considered to be dynamic; we expect it to evolve as teachers test it through use in their assessment practice.

Table 1
The Gender Orientation of Assessment Items:
An Evolving Classification

Criteria	Male Orientation	Female Orientation	Allegedly Neutral Orientation	Gender-Inclusive Orientation
Language	uses he, him, his	uses she, her, hers	uses they, them, their; uses role (eg a sprinter .....)	uses name of person; uses "you"
Portrayal of stereotypes	males in active role, females in passive role	females in active role, males in passive role	genderless people in active role (eg a scientist .....)	both males and females in active and passive roles
Appeal to background experiences	relevant to stereotyped male experiences	relevant to stereotyped female experiences	not relevant to human experiences	relevant to males and females equally
Context	de-contextualized, abstract	human, social,	concrete setting	human, social, environ-mental

Using the Framework to Work with Teachers

The workshops with the physics teachers were a rich part of the study. With an impending change to a more contextual physics curriculum, teachers were very interested in discussing what the changes might mean for their current teaching and assessment practice. Considerable time was needed to discuss not only the gender aspects of assessment tasks but a range of other issues which relate to good assessment practice. One issue which arose was a general disbelief by teachers that girls could perform as well as boys in physics, despite unequivocal evidence based on State-wide data. That school-based assessment apparently favors girls was explained away in terms of their "neat work" or their quiet and cooperative classroom behavior. Interestingly, such beliefs are quite in contrast to findings that the same piece of science work is graded higher when it is attributed to a male than a female (Spear, 1984), or that better performance by girls in English or mathematics cannot explained by better organizational and presentation skills (Gipps & Murphy, 1994, p. 268).

It became clear that change in teachers' assessment practice requires considerable effort by them. Recognition of the possibility of gender

bias, its sources, and the adoption of methods to counter it require a process of deconstruction and then reconstruction of teachers' views about assessment. During the workshops most teachers were able to examine their current assessment practice to some extent and develop skills in preparing contextually-based assessment tasks.

Field-testing the Tasks

The survey requesting feedback about the sets of physics assessment tasks had a response rate of about 70%. The reaction was very positive, but it is possible that teachers not responding had a more negative experience. Feedback from the teachers on general course issues indicated that many had found it difficult and time-consuming to consider the contextual aspects of the physics they taught.

Field-testing with students of the matched pairs of assessment tasks revealed that seven of the eight students performed slightly better on the problems they completed second, regardless of whether the second set had gender-inclusive context or minimal context. Their comments in interview suggested that this may be explained by greater familiarity with the physics content requirement of the task, having done a similar task before. Boys' and girls' scores on the tasks were equivalent.

Students' reactions to the tasks in terms of the presence or absence of context indicate that "interesting" was the most common reaction to the contextual problems with gender-inclusive orientation, whereas "hard to visualize" was the most common reaction to problems without context. They found that problems with context were generally easier "to visualize", or "to figure out what is happening". Students' comments indicated that writing context-based items is not simply a matter of adding words or diagrams to put the physics into "real-life" context. Often, adding information creates interest, and frequently it also clarifies what is happening. However, if the information added is contrived or irrelevant to the actual physics concept, it can be confusing. Clearly, the skill of the assessor is critical to communicating the requirements of the task.

The difficulty of an individual task with and without context was generally regarded by students as equivalent. Students reported that their teachers often explained physics content by relating it to real-world contexts, but when they began to work problems, they usually dealt with decontextualized objects. This suggests that providing context can be a useful explanatory tool, but teachers do not consider it to be of value in assessment, a finding quite consistent with the difficulty the workshop teachers experienced in coming to grips with the issue of gender-inclusive assessment.

Tasks requiring written answers rather than calculations were perceived by students to be more difficult. Our students explained this by pointing out that you had to understand the concept to write an answer, whereas in calculations, you could isolate the variables and find a formula to fit. Further, our students claimed that it wasn't clear "how deep" you should go with your answer to a written question, and it was easier to get full marks for calculations. All of the boys much preferred tasks requiring calculations rather than explanations. All of the girls qualified their preference by saying that it depended whether you could relate to what was happening and could do the problem. These findings are consistent with those from Linn's CPL Project where girls were found to deal better with problems requiring integrated understanding (Linn, 1992).

Discussion

This study has identified some of the aspects of the context of an assessment task which may interact with gender and affect performance. A framework which can be used to screen assessment tasks in terms of their gender-orientation was developed and tested. Physics assessment tasks prepared using the descriptors of the framework were found to be acceptable and useful to teachers and girls and boys completed them equally well. The ability "to visualize" what the problem is asking is an important aspect of successful problem solving, and real-life context can play an important role in this aspect of task performance. The apparent gender difference in preference for tasks requiring calculation and explanation underscores the importance of considering item format, as well as context, when preparing gender-inclusive assessment tasks.

Screening assessment tasks using the framework developed in this study may assist to de-gender assessment where contextually-based tasks are used. However, simply providing a workable model for gender-inclusive assessment is insufficient to encourage teachers to change their way of assessment. Before they are willing to make changes in their current practice, teachers may also need help to recognise that their methods may not always be gender-fair, and adequate time and support are essential for assisting them to develop more equitable practice.

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Is Item Format Important?

David T. Burkam and Amy S. Burkam

During the past decade, educational assessment policies at the state and national levels have been in a period of rapid transformation. Efforts to align assessment practices with desirable educational goals have resulted in changes to the nature and use of traditional multiple-choice tests. In many content areas, multiple-choice tests now emphasize critical thinking and problem solving instead of mechanical skills or memorized facts. These multiple-choice instruments remain widely accepted as quality indicators of valued performances.

Measurement experts and educators are concerned that excluding alternative forms of assessment from large-scale programs communicates the message that multiple-choice measures encompass all desirable instructional outcomes. Increased emphasis on the use of large-scale assessment for accountability has led to a plea for assessment instruments that involve the performance of tasks that model exemplary instructional activities. The direct assessment of more complex performances through the use of open- ended problems, essays, hands-on activities, and portfolios of student work has become the vision guiding educational reform efforts. Changes in the emphasis and format of large-scale assessment measures will precipitate new concerns about equity. With expanded emphasis on critical thinking and problem solving in assessment programs, the male performance advantage thought to be disappearing may reappear. The purpose of this study is to determine how item format affects the gender disparity in standardized science achievement at grades 4, 8, and 12. The potential for differential gender differences across test formats is of particular interest given the current movement to replace multiple-choice items with more "authentic" measures. Since these "authentic" assessment measures require a constructed response and tend to emphasize problem-solving, there is uncertainty as to how the current trends in testing practices will affect gender differences

Gender Differences in Math and Science Achievement

Over the past 30 years, concerns about the disproportionately low numbers of women entering science and math-related fields have precipitated a barrage of research to determine if achievement and aptitude in math and science are related to gender (see Oakes, 1990, for a detailed review of the literature). The proliferation of such studies now allows for the studies themselves to be statistically analyzed for

trends. Consequently, these quantitative syntheses, or meta-analyses, summarize large bodies of research.

Math achievement

Friedman (1989) analyzed 98 pre-college studies of the gender gap in math, and concluded that (a) overall gender differences in math achievement have been closing over time; (b) the gender gap grows with students' age; (c) studies focusing on gifted children show a substantially larger gender gap; (d) the male advantage is larger in problem solving and college entrance exams than in other areas; (e) the gender gap is smaller among minority students; and (f) foreign students show a larger gender gap than U.S. studies. In another meta-analysis, Hyde, Fennema, & Lamon (1990) confirmed the above findings on the overall decline in sex diferences over the past 20 years and the apparent increase in sex differences with student age. Hyde et al., also found that the male advantage increased as the samples became more selective (extending through high school to the college level).

Science achievement:

Although far more attention has been paid in the research literature to gender differences in math achievement (Oakes, 1990), Steinkamp and Maehr's (1983, 1984) quantitative syntheses found small, average correlations between gender and science achievement which seemed to vary across science domain and level of schooling, although almost all favored boys. The largest gender differences occured in physics and general science achievement. In addition, they found overall gender differences in science achievement to be larger at the junior high school level than at either the elementary or high school level. Using recent methodological advances, Becker (1989) reexamained Steinkamp and Maehr's earlier analyses, focusing on the importance of subject matter and grade level in determing gender differences in science achievement. Becker supported Steinkamp and Maehr's finding that subject matter affected gender differences, but found no support for change in gender differences across grade levels. Unfortunately, the bulk of this research, including the promising shrinkage of the gender gap in math achievement, is based on traditional assessment measures (e.g., multiple choice tests) without the use of emerging technology (e.g. graphing calculators, computers).

Effects of Assessment Practices on Gender Differences

Effects of calculators

Since the mid-1970s, members of the mathematics education community have expressed a desire to increase the use of calculators in the math

curriculum (Jones, 1990). The National Council of Teachers of Mathematics (NCTM) suggested that calculators should be permitted and even required in assessment and program evaluation systems (NCTM, 1989). Morgan and Stevens (1991) administered Advanced Placement Calculus examinations to nearly 7,000 students from more than 400 high schools and found that "calculator-active" items (those more easily solved with a calculator) were more difficult for girls than boys. While calculator use led to higher overall test scores, it increased the gender disparity in performance and increased the male advantage.

Multiple-choice and free-response items:

One proposed explanation for the male advantage on certain objective measures is the possibility that different item formats measure separate constructs. Two studies (Fiske, 1990; Nickerson, 1989) explored this possibility by examining the equivalence of multiple-choice and free-response math items. The results of factor analyses led to single-factor solutions which the authors claimed as evidence that the two formats assessed the same construct. Fredricksen (1984, 1990) argued that the findings of Fiske (1990) and Nickerson (1989) were due to the fact that the free-response items used in these studies were adaptations of the multiple-choice items and therefore measured the same limited skills.

In a more recent study, Bennet, Rock, & Wang (1991) explored the relationship between free-response and multiple-choice items used on the College Board's Advanced Placement Computer Science (APBS) examination. The free-response items used on the APBS were developed to measure certain content more deeply than the multiple-choice items. The content covered by a single free-response item might be covered by a combination of 50 multiple-choice items. Results of their factor analysis showed that the items do not separate into groups based on item format. A single factor provided the most parsimonious fit, suggesting that the two formats assessed the same construct. Thus, the findings of Bennet et al. (1991) support Fiske and Nickerson's claims that multiple-choice and free-response formats measure essentially the same construct. Although these and other data suggest that multiple-choice and free-response items are equivalent in that the two formats appear to measure similar constructs (Bennet, et al. 1991), the separate item formats may function differently depending upon the gender of the examinee (Bolger, 1984; Bolger & Kellaghan, 1990; Campbell & Fiske, 1959).

Item format and test-taking strategies:

Another potential for gender differences attributed to item format is the possibility that some students are more likely than others to employ effective test-taking strategies on multiple-choice measures. To investigate this possibility, Rowley (1974) administered measures of achievement motivation, risk-taking, "testwiseness" and math achievement to a group of 154 ninth grade students. High risk-takers

(defined as subjects who claimed certainty for incorrect answers) had a significant advantage over low risk-takers on the multiple-choice items. Rowley did not investigate the the gender of high and low risk-takers. However, other studies (e.g., Swineford, 1941; Harris, 1971, cited in Bolger & Kellaghan, 1990) reported evidence demonstrating that boys are more likely than girls to take risks in testing situations.

While there is a fair amount of research examining the differential distribution of effective strategies for completing multiple-choice questions, similar research concerning strategies for essay examinations is absent. In a study comparing student performance on college entrance exams, Breland and Griswold (1982) concluded that "women achieve higher [college grades] than multiple-choice tests predict because they write better and because writing is an important aspect of achievement."

Summary

Much of what we know about gender difference in math and science achievement is based on traditional testing procedures. In the wake of the current reform efforts, alternative assessment practices are becoming more common. Will these "authentic" assessment tools impact on the gender inequities in standardized testing? There is some evidence to suggest that part of the disparity in math achievement between boys and girls is attributable to item format. Males appear to have a small, but systematic advantage on multiple-choice items as compared with items requiring a constructed response. This advantage may be the result of differential guessing tendencies and/or risk-taking behaviors. Existing research intimates that the abandonment of multiple-choice may reduce gender differences in math, while increased emphasis on problem solving and the use of calculators may increase the gender gap.

Research Questions

In light of the current trends in national and state assessment to include non-traditional modes of testing, our research on gender equity focuses on two questions: (1) Does item format, (e.g., multiple-choice, free-response or performance events) affect the gender disparity in standardized science achievement between boys and girls at grades 4, 8, and 12? (2) If so, for which item formats do girls excel; for which do boys excel?

Method

Data Source

Instruments:

This study examines the results of the 1993 science portion of the statewide testing program in a midwestern state, grades 4, 8, and 12. These tests are developed by Advanced Systems in Measurement and Evaluation, Inc. under the direction of the state's Department of Education and committees of educators. The testing program was established in response to a legislated reform act calling for changes to the educational system statewide. These exams test students' proficiency and understanding in science, mathematics, social studies, arts and humanities, practical living skills, and vocational studies. At each grade level, the science portion of the test draws from over 200 multiple-choice items, 15 free-response items and 3 performance events, with twenty multiple-choice and three free-response items common to all forms of the test. The free response items are developed to measure content more deeply than a single multiple-choice item. Generally, 10-15 multiple- choice items would be needed to cover the same content covered by a single free-response item. Free-response items are expected to elicit written responses of approximately one half to three quarters of a page. The performance events actively engage students in activities requiring the use of equipment beyond paper and pencil and each event is administered to a different random sample of students. Students are permitted to use a calculator to complete the math and science portion of the assessment. Calculators are provided to all students who do not have an approved instrument. In addition to the tests, all students complete a brief questionnaire at the end of the examination period. Students in grades four or eight complete identical surveys, describing their reaction to the tests, frequency of certain in-school activities, and selected academically-oriented self-descriptions. Twelfth grade students complete a similar questionnaire which also includes information about course-taking and grades.

Subjects

With the exception of foreign exchange students, non-English speaking students and special education students whose Individualized Education Plan indicates that participation in testing could be detrimental to the student, all fourth, eighth, and twelfth graders attending the state's public schools participate in the testing. Only those students at each grade level who are selected at random to complete one of the three performance events are included in the sample for this study.

Thus, the fourth grade sample includes all students who completed one of the three performance events. All of these fourth graders completed the multiple- choice and free-response portions of the science exam. The eighth and twelfth grade samples are similarly structured.

Measures

Dependent variables:

At all grade levels, three science test scores are available for each student: a free-response score (the sum based on five items, each scored from 0-4); a multiple-choice score (number correct out of twenty items); and a performance event score. While there are three different performance events, each student in this sample completed only one of the tasks. Full scales for the performance tasks are dependent on both grade level and task: some tasks were scored from 0-4, while others were scored from 0-16. Each outcome measure is (fairly) normally distributed.

Independent variables:

The most important independent variable is *gender* [coded 1 = female, 0 = male]. In addition, we include certain other measures from the student questionnaire as covariates. Three covariates are available for students at all three grades (4, 8 and 12): minority status [coded 1 = Black or Hispanic, 0 = other]; frequency of calculator use in school [coded from 1 = never, to 4 = twice or more a week]; use of calculator on science exam [distinguishing between use of school calculator, own calculator, or no calculator]. Two additional covariates are available for students at grades 4 and 8: student-reported school coverage of test material [distingushing between "most covered," "some covered," and "none covered"]; reading exposure score [composite score based on student's self-assessment of reading ability, number of books at home, frequency of reading books of the student's choosing, and frequency of writing (journals, stories, other); z-score, mean = 0, standard deviation (SD) = 1]. Two additional covariates are available for students at grade 12: student- reported grades [Coded from 1 = mostly D or lower, to 4 = mostly A]; student-reported number of science courses.

Analytic Models

After a preliminary discussion of unadjusted gender differences, we compute adjusted gender differences using hierarchical regression models. In addition to adjusting for the selected covariates, we consider the possibility of gender-by-covariate interactions on test scores. We compute product terms and introduce all potential interaction terms into the regression models, reporting only the significant interactions (see Aiken & West, 1991; Cohen & Cohen ,1983; and Jaccard, Turrisi & Wan,

1990 for a complete discussion of testing interations with regression). Interaction terms reflect the extent to which the gender disparity is affected by the covariates (e.g., is the gender disparity affected by calculator use, reading exposure, etc.?).

Results and Discussion

Description of Sample

Unadjusted gender differences in science achievement:

Table 1 summarizes the unadjusted gender differences across item formats for each of the three grade levels. Samples include 8512 fourth graders, 6433 eighth graders, and 3505 twelfth graders. Slightly over half of the students at each grade level are girls. Table 1 includes mean scores (in the original metrics) and effect sizes [i.e. standard deviation units, ES]. A postive effect size reflects a female advantage; a negative effect size reflects a male advantage. Most gender differences in Table 1 are small, but significant. At grades 4 and 8, girls outperform boys on the free-response portion of the science exam (ES = .048 and .148 respectively), but boys outperform girls on the multiple-choice portion (ES = -.094 and -.092 respectively). At grade 12, boys score better than girls on both the free-response and the multiple-choice (ES = -.069 and -.364 repectively). The gender disparity on the twelfth grade multiple-choice test is the largest difference displayed in Table 1.

Table 1
Science Performance at Grades 4, 8, and 12 By Gender and Item Format

Sample Size	Grade 4	4.334	4.178	
	Grade 8	3.325	3.108	
	Grade 12	1.919	1.586	
Mean, Free-Response (0-20)[a]		9.69*[d]	9.57	.048*
		8.90***	8.49	.148***
		7.94	8.13*	-.069*
Mean, Multiple-Choice (0-20)[b]		12.6	12.9***	-.094***
		9.64	9.91***	-.092***
		11.5	12.8***	-.364***
Mean, Performance Events[c]				
Item 1		2.04***	1.93	.135***
		7.74	7.73	.008
		6.50***	5.96	.268***
Item 2		2.19*	2.10	.091*
		8.26*	8.12	.088*
		10.1	9.98	.060
Item 3		2.29***.	2.15	.171***
		3.61	3.55	.049
		9.15	8.96	.067

[a] Sum based on 5 free-response items, each scored from 0-4. Items differ by grade level.
[b] Sum based on 20 multiple-choice items, number correct. Items differ by grade level.
[c] At each grade level, one of three performance events was completed by a distinct random subsample of students. Items differ by grade level.
[d] Indicates significantly higher mean scores (* $p < .05$; ** $p < .01$; *** $p < .001$.)

There are no significant gender differences on several of the performance tasks, but all significant differences favor girls. Indeed, all gender differences on the performance events (significant or not) favor girls, even at grade 12 where the boys outperform the girls on both the free-response and the multiple-choice portions of the science exam. The results in Table 1 suggest that item format does affect the gender disparity in standardized science achievement: except for grade 12, girls do better than boys on questions requiring a constructed response (i.e.,

free-response and performance events) while boys do better than girls on the traditional multiple-choice questions.

Gender differences in covariates:

Table 2 presents descriptive information on the covariates, broken down by gender and grade level. At all grade levels, fewer than ten percent of the students come from minority groups (Black or Hispanic). Two distinct trends are apparent concerning the frequency of calculator use in school: girls tend to report more frequent calculator use than boys (at all grades), and calculator use becomes more polarized in later grades (more students never use calculators, but those who use them do so more frequently). Girls use a calculator on the science exam more often than boys, and calculator use is lowest on the eighth grade exam.

Table 2
Student Characteristics, Grades 4, 8 and 12 By Gender

		Female	Male
% Minority (Black or Hispanic)	Grade 4	8.5	7.8
	Grade 8	9.1	8.3
	Grade 12	8.2	6.9
Use of Calculator in School			
% Twice or more a week		39.6	33.3
		58.9	51.3
		59.3	51.2
% About once a week		33.8	32.9
		23.6	25.5
		14.5	15.7
% About once a month		22.2	27.2
		13.3	15.6
		13.1	16.0
% Never		4.3	6.4
		4.1	7.6
		13.1	17.0
Calculator Use on Science Exam			
% Not Used Calculator		69.2	74.1
		80.3	79.4
		65.6	71.8
% Used School Calculator		26.8	22.0
		13.6	15.0
		11.7	12.8
% Used Own Calculator		3.9	3.8
		6.1	5.6
		22.7	15.5
Student-Reported Coverage of Science Test Material	(4 and 8 only)		
% Most Covered in Class		52.1	52.0
		34.6	39.7
% Some Covered in Class		41.2	38.8
		54.1	47.4
% None Covered in Class		6.7	9.1
		11.3	12.9
Reading/Writing Exposure	(4 and 8 only)	.169	-.175
		.251	-.267
Student Reported H.S. Grades (12 only)		3.01	2.74
Number of Science Courses (12 only)		2.93	2.84

At grade 4, the majority of all students feel that the most of the test material has been covered in their science courses. At grade 8, however, the majority of all students feel that only some of the material has been covered. [Students in grade 12 were not asked to compare the test material with course material.] Girls in grades 4 and 8 report substantially higher reading exposure scores than boys (ES = .344 and .518 respectively). [Reading exposure scores were not available for twelfth graders.] Twelfth grade girls report somewhat higher overall grades than boys (3.01 and 2.74 respectively) and take slightly more science courses on average than boys (2.93 and 2.83 respectively).

Because the choice of covariates are identical at grades 4 and 8, we discuss the results for these levels together. The results for grade 12 (which include controls for student's science course-taking and high school grades) are discussed separately. In order to simplify discussion across outcomes, we standardized all test scores (mean = 0, SD = 1) before estimating the regression effects. One result of these standardizations is that the regression coefficients estimating the gender disparity are already in effect sizes, or standard deviation units. Our focus is on the gender disparity in achievement, rather than on the individual effects of the covariates. The covariates are introduced primarily as statistical controls, and are individually discussed only when the gender differences are conditioned on them (i.e., in the presence of a gender-by-covariate interaction). We include dummy-coded controls for minority status, calculator use on the exam (compared to "no calculator use"), amount of test topics covered in class (compared to "none"), as well as the continuous covariates. All continuous covariates -- frequency of calculator use in school (grades 4 and 8 only), reading exposure score (grades 4 and 8 only), high school grades (grade 12 only), and number of science courses (grade 12 only) -- are also standardized in these multivariate models.

Science achievement in Grades 4 and 8

Multiple-choice scores:

Table 3 presents the results of the three-step hierarchical regression models for the multiple-choice science scores (one for grade 4, one for grade 8). The initial male advantages displayed at step one of the models (identical to the effect sizes presented in Table 1) increase at step two when the covariates are introduced. This suggests an even wider gender disparity than the original unadjusted scores.

Table 3
Multiple-Choice Scores, Grades 4 and 8 (OLS Regression Models)

	Step 1	Step 2	Step 3
Female	-.094***[a]	-.167***	-.019
	-.092***[b]	-.216***	-.114-
Minority		-.534***	-.545***
		-.309***	-.311***
Used School Calculator		-.089***	-.080*
		-.325***	-.445***
Used Own Calculator		-.101~	-.209**
		-.161**	-.376***
Most Topics		.528***	.621***
		.200***	.274***
Some Topics		.439***	.491***
		.077*	.179***
Reading/Writing		.213***	.210***
		.218***	.191***
Frequency of Calculator Use		-.039***	-.047**
		.077***	.107***
Female x School Calculator			---
			.248***
Female x Own Calculator			.212*
			.405**
Female x Most Topics			-.207**
			-.162*
Female x Some Topics			-.125~
			-.205*
Female x Reading/Writing			---
			.057*
Female x Frequency of Calculator Use			---
			-.064**
Intercept	.048**	-.287***	-.353***
	.047**	.083*	.033
R2	.002***	.104***	.106***
	.002***	.088***	.094***
Change-R2	.002***	.102*	.002*
		.002***	.086***

a Regression coefficient, Grade 4.
b Regression coefficient, Grade 8.
~ $p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

Interactions:

The male advantage on the multiple-choice portion of the exam is complicated by the presence of several significant interactions at both grade levels (see step three). Untangling the meaning of these interactions is a complicated process. In general, the second-order terms estimate the extent to which the first-order gender disparity is conditioned by values of the covariates. For example, we focus on the conditional effect of topics covered on the gender disparity in eighth grade performance. The first-order gender difference (b = -.114, in step 3) indicates that among students who claimed that "none" of the test topics were covered in classwork, boys outperformed girls (ES = -.114). This male advantage, however, widens as students' self-report of the topics covered increases (e.g., among students who were exposed to "some" of the test topics, the male advantage grows to -.309 = [-.019 + (-.162)]). That is, among students with broader classroom exposure, boys outperform girls at a higher rate than they do when exposure is minimal. This appears to be true at both the fourth and eighth grades. Contrary to earlier research on calculator use on mathematics exams (Morgan & Stevens, 1991), calculator use on the multiple-choice portion of the science exam reverses the gender disparity to favor girls. That is, among students who used either their own calculator or a school calculator, the girls outperformed the boys. At grade 8, the male advantage on the multiple-choice widens among students with more frequent calulator use in school, but reverses to favor girls among frequent readers/writers.

Free-response scores:

Table 4 presents the results of the parallel multivariate models for the free-response science scores (as before, one for grade 4 and one for grade 8). The initial female advantages displayed at step one of the models are reduced to zero at step two when the covariates are introduced into the multivariate models. This suggests that the girls' higher scores on the free-response portion of the science exam may be a reflection of some other trait captured by the covariates. It is not surprising to discover that the female advantage in these items requiring a constructed response is most likely attributable to their substantially higher level of reading/writing experience. When step 2 of these multivariate models are estimated without controlling for the student's reading exposure, the female advantage remains small but significant (ES = .042 at grade 4 and .131 at grade 8). This supports the conjecture that girls will do better at more open-ended questions, precisely because of their greater exposure to reading and writing.

Table 4
Free-Response Scores, Grades 4 and 8 (OLS Regression Models)

	Step 1	Step 2	Step 3
Female	.048*[a] .148***[b]	-.0.26 .000	.118- -.120-
Minority		-.440*** -.357***	-.443*** -.322***
Used School Calculator		-.065** .277***	-.071* -.359***
Used Own Calculator		-.061 .168***	-.179* -.171***
Most Topics		.446*** .180***	.524*** .256***
Some Topics		.334*** .092*	.413*** .165***
Reading/Writing		.210*** .259***	.186*** .223***
Frequency of Calculator Use		-.014*** .086***	-.004 .118***
Female x School Calculator			------ .171*
Female x Own Calculator			.227* ------
Female x Most Topics			-.174* -.167*
Female x Some Topics			-.172* -.154*
Female x Reading/Writing			.052* .074**
Female x Frequency of Calculator Use			------ -.069**
Intercept	-.025 -.077***	-.291*** -.031	-.358*** -.092*
R2	.001* .005***	.085*** .110***	.087*** .114**
Change-R2	.001* .005***	.084*** .105***	.002* .004**

a. Regression coefficient, Grade 4.
b. Regression coefficient, Grade 8.
~ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Interactions:

As in the case of the multiple-choice portion, the presence of several significant interactions further complicates the gender disparity on the free-response items, although the conditioning effects are identical across the two item formats. Once again, as students' classroom exposure to science topics increases or as students spend more time in class using calculators, the gender disparity tends to favor males even on these free-response items. Calculator use, however, bolsters the girls' advantage. Likewise girls who read more frequently outperform their males peers on free-response questions to a larger degree than girls of average reading frequency outperfrom their male peers.

Performance events:

Girls score significantly higher than boys on all three of the science performance events at grade 4, and one of the performance events at grade 8 (see Table 1). After controlling for the additional student characteristics, the female advantage remains on two of the eighth grade items (ES = .089 and .129). There is no evidence of any gender-by-covariate interactions with the performance events. As before, controlling for the student's reading experience diminishes the gender disparity (without controlling for reading, the significant effects remain near the unadjusted levels, ES = .132 and .169). On all performance events girls outperform boys.

Summary

The evidence strongly suggests that item format affects the gender disparity in science achievement at grades 4 and 8. Boys excel at multiple-choice format science exams, while girls excel on tests which require a constructed response (i.e., free-response and performance events). A substantial proportion of the female advantage on these "authentic" measures appears to be their greater reading exposure. Several other factors condition the gender disparity: regardless of item format, the female advantage increases when calculators are used on the exam and among those with greater reading exposure; and the male advantage increases among students with classroom exposure to more science topics and among students who frequently use calculators in the classroom.

Science Achievement in Grade 12

Science achievement in grade 12 differs from earlier grades in that boys outperform girls on both the multiple-choice and free-response questions (see Table 1). Only on performance events do girls perform as well or better than boys. Analytic models for twelfth grade achievement reveal a persistent male advantage, even after controlling for additional student characteristics (ES = -.503 for multiple-choice and -.226 for free-response, see Tables 5 and 6 respectively). The adjusted gender disparities are actually larger than the unadjusted differences, due in large part to the "suppression" effect of high school grades. Gender differences in math and science performance tend to increase after controlling for girls' (typically higher) course grades (see, for example, Pallas & Alexander, 1983). There was no evidence of any gender-by-covariate interactions on twelfth grade science performance

Table 5
Multiple-Choice Scores, Grade 12 (OLS Regression Model)

	Step 1	Step 2	Step 3	Step 4
Female	-.364***[a]	-.398***	-.419***	-.503***
Minority		-.524***	-.516***	-.424***
Used School Calculator		-.110*	-.098*	-.087~
Used Own Calculator		.178***	.127**	.117**
Frequency of Calculator Use		.160***	.077***	.058***
Science Courses			.343***	.269***
H.S. Grades			.250***	
Intercept	.199***	.237**	.257***	.296***
R2	.033***	.088***	.197***	.250***
Change-R2	.033***	.055***	.109***	.053***

Table 6
Free-Response Scores, Grade 12 (OLS Regression Model)

	Step 1	Step 2	Step 3	Step 4
Female	-.069*[a]	-.106**	-.128**	-.226***
Minority		-.487***	-.479***	-.372***
Used School Calculator		-.088~	-.076	-.063
Used Own Calculator		.176***	.123**	.112**
Frequency of Calculator Use		.184***	.100***	.078***
Science Courses			.350***	.265***
H.S. Grades				.289***
Intercept	.038	.073**	.092***	.138***
R2	.001*	.062***	.175***	.247***
Change-R2	.001*	.061***	.113***	.072***

a. Regression coefficient, Grade 12.
~ $p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$.

Despite the substantial male advantage on the twelfth grade multiple-choice and free-response portions of the exam, boys and and girls scored more equitably on the performance events. Controlling for additional student characteristics does not alter the results found in Table 1; on two events, there is no gender differences, and the third event reveals a small female advantage (ES = .215).

Conclusion

Previous research has suggested that boys may have an advantage when the item format is multiple-choice and when the test content emphasizes critical thinking skills (e.g., problem solving in mathematics). Girls excel when instruments stress lower order skills (e.g., mathematical computation) and when the test format requires a constructed response. These patterns are echoed in our results. At earlier grade levels, boys outperform girls on science exams composed of multiple-choice items, where girls outperform boys on free-response and performance events. By twelfth grade, however, the males display a noticeable advantage on both multiple- choice and free-response questions, although the gender disparity on free- response items is half as large (ES = -.503 and -.226 respectively). In addition, our results suggest that the female advantage with constructed responses are due, in large part, to their greater exposure to reading and writing.

At this time, no reliable large-scale data are available on the use of portfolios to assess science achievement. As efforts to incorporate this mode of assessment into large-scale programs become successful, it will be important to include portfolio data in future research on differential item functioning. Understanding how our educational assessment practices affect gender disparities is not simply an academic exercise. Success on standardized exams continues to be a critical filter through which all students must pass in order to graduate from high school, gain admission to post-secondary institutions, and receive scholarships. Incorporating a wider array of testing formats should inarguably provide a more comprehensive evaluation of a student's knowledge and understanding. This is equally true for classroom exams where the multiple-choice format often continues to dominate.

Further investigation of the relationship between gender and item format is clearly necessary. Are the trends uncovered here dependent upon subject domain? Will performance in mathematics or language arts testing reveal similar patterns? Certain conditioning factors deserve additional attention. The technology explosion almost guarantees that calculators or computers are available to a large proportion of students, and many standardized exams are already requiring their use. We are beginning to understand their general impact on student performance. Meanwhile, their potential for differential effects needs to be further documented.

Although we used minority status in this study only as a covariate, questions of the racial/ethnic differences are equally important as gender differences, even if less frequently investigated (Oakes, 1990). We are currently at work extending this research to investigate whether item format affects achievement disparities between minority and non-minority students.

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Teachers, Family And Friends: Who Makes The Difference ?

Dale R. Baker

Over the years school and social factors have been investigated to understand why so few women choose science careers. However, despite many studies, we know little about what influences girls to choose or reject a scientific career. The causal models developed by Ethington and Wolf (1988) and Peng and Jaffe (1979) to determine the predictors of a quantitative undergraduate major illustrate the lack of power of variables such as achievement, attitudes, SES, course taking behavior, self-concept and family influences. Ethington and Wolfe's (1989) model explained only 8.9% of the variance in the choice of a quantitative major and Peng and Jaffe's model explained only 6%.

Consequently, I have turned to research that indicates that women make decisions differently than men (Angrist & Almquist, 1975; Almquist, Angrist & Mickelsen, 1980, Arnold, 1992). These decisions arise from expectations of multiple life roles, self-identity, and ways of interacting. Women make career plans in terms of personal life scripts which consist of anticipated personal and professional roles (Nardi, 1983). Even highly achieving, successful women described themselves in terms of relationships. Identity resided in their roles as mothers, wives, lovers, and children and not in academic or professional success. They tended to judge success in terms of relationships and made decisions that balanced work and family life (Arnold, 1992; Gilligan, 1982). Younger girls and adolescents also describe their world in terms of relationships (Brown & Gilligan, 1992).

Eccles (1986) concludes that women choose less technical fields because they are more attractive and are therefore proactive choices. These choices are based on short and long term goals, self-identity, and psychological needs which are different from but equal to those of men. One of these needs is the inner sense of connection with others that Brown and Gilligan (1992) see as the central organizing feature of female development. So too, Markus and Oyserman (1989) argue that womens' self-concept is embedded in and arises from interactions and interpersonal experiences.

Belenky, Clinchy, Goldberger and Tarule (1986) also speak of the importance of connections and relationships. In their framework, a woman who is a constructed knower creates her own knowledge from both objective and subjective experiences. Knowing is based on connections with people, ideas, objects and the written word. Further evidence of the importance of relationships is found in Brown and

Gilligan's (1992) sample of school girls. Girls with strong voices (a sense of self and inner knowledge) could deal with the need to stand up for who they were and what they believed, in the face of culturally constructed ideals of the feminine, because they had close confiding relationships with their mothers who served as alternative role models.

Within science, despite strong socialization to the contrary, women work in ways that emphasizes relationships and connectedness to the objects of study and the members of their research teams (Sheperd, 1993). This connectedness has led to breakthroughs in fields such as primatology and genetics but women report that it also leads to conflict with male mentors and colleagues, isolation, and slower rates of promotion. In extreme cases, the conflict between doing science in a related and connected way and the norms of science which emphasize hierarchy, distance, and objectivity, lead to dropping out of science (Sheperd, 1993).

Methodological Issues

Feminist scholars have moved away from quantitative analysis toward a more qualitative and contextualized understanding because it provides a truer picture of women. For example, gender differences in knowledge of science and technology were found using a questionnaire but were not found in interviews with the same girls and boys (Solomon & Harrison, 1991). Interviews by Baker (1990) and Baker, Leary, and Trammell (1992) indicated that attitudinal differences toward science between girls and boys are small and that they are alike in what they would like to learn about in science. Interviews provide researchers with a vehicle through which they hear and understand women's voices. Life stories told are imbued with powerful emotions that are as important to understanding women's lives as less value laden but thinner data sources (Brown & Gilligan, 1992).

Feminists also prefer to study just women. This approach avoids using a deficit model, or the assumption that male behavior is the norm, and allows the data to be understood in light of women's social psychological reality (Campbell, 1988). It avoids the trap of non-comparable, simplistic either/or categories that do not capture the sense of the data (Brown & Gilligan, 1992). For these reasons, the sample consisted of forty girls in grades 2, 5, 8, and 11. They were asked to talk about science, careers, peer and parental support, how science is taught, and how they would teach science to girls or boys. To gain further insight, the girls were also asked to respond to the questions pretending to be a boy. The transcribed texts of the interviews were read, discussed and coded for emerging themes using Textbase Alpha (Tesch, Sommerlund & Kristensen, 1989). Equity, school, and social themes were identified as the central conceptual components that were present to varying degrees within all of the interviews.

Results

The data reveal that the girls' attitude toward science are associated with what happens in school, the influence of society in general, and strong feelings of equity. These categories sound very much like those used in more traditional research. However, the critical differences lies in examining what the girls say through the lens of relationships and connections. Although there were some grade level differences, most views emerging at second grade remained constant across grade levels.

School Science

The girls were strongly positive about school science and enjoyed the cognitive demands of learning science. A positive reaction to science was sometimes tempered by the teacher, instructional formats, learning styles or topics being studied.
Second graders identified biological topics (plants, animals, themselves) as their favorite subject matter.

> S1: "We have this science book and it's real fun because you can learn about animals."
>
> Interviewer: "Do you like animals?"
>
> S1: "Umm hmm."
>
> Interviewer: "What do you think would be your favorite thing to learn about?"
>
> S2: "Animals and trees. "

The fifth through eleventh grade girls mentioned both physical and biological topics as being among their favorites.

> S1: "... we learned about stuff like Newton's Law of Motion and stuff like that . . . Usually it's pretty fun."
>
> S2: "I like the pH and the pOH and all that stuff, and the bonding and stuff, and how chemicals really fit together, and materials."
>
> S3: "Basically, I like all the science classes here."

Once the students got beyond the second grade relevance became an issue. The girls recognized that science is a part of their everyday lives and they wanted to see that connection made in school rather than learn science out of context.

S1: "Probably talk about more up to date things and things that are in most of our lives. Maybe something about the environment or something that's a hot topic and yeah, something that matters more. That'll help us more. Cause, some people think that science isn't used very much in everyday life unless you're a scientist. But that's not true. Science is used in like all different fields."

The girls also had strong feelings about how science should be taught. They showed a preference for problem solving and hands-on activities. By fifth grade, the girls began to express a strong preference for experiments and projects in place of reading and writing activities. They wanted to do more experiments so that they could learn for themselves and "figure things out."

Interviewer: "What are the things you like?"

S1: "When we get to actually do the experiment instead of drawing it and writing about it."

Interviewer: "What do you do during the labs that you think is fun?"

S2: "How you, how the experiment is. You know, you get to see different things and how things work."

The older girls, (8th and 11th grade) expressed strong feelings for more interaction with their peers in repeated requests for group work, partners, and discussions.

Interviewer: "Why more activities?"

S1: "Because lecture, you just, I mean when she lectures you, she just goes on and on and on and I can't stand sitting for that long and, and if I was a teacher I would understand how my students felt that they couldn't sit for that long."

Interviewer: "What kind of group, why did you say group activities?"

S2: "Cause it's fun working with different people and seeing what they do and what they like."

Interviewer: "What do you think kids would like to do?"

S3: "Well, not as much like assignments and more like class work altogether or partners. Not just individuals."

By eighth grade the teacher had assumed an important role in the science classroom. Attitudes toward science were often dependent on whether or not the teacher made the subject fun or boring. When science was perceived as boring or irrelevant the blame was often placed on the teacher.

> Interviewer: "What makes science fun?"
>
> S1: "Probably Mr. X. He's like, he's really funny and he's smart. He's really funny and he teaches science really good."
>
> Interviewer: "What happened in sixth grade that made you decide you didn't like science?"
>
> S1: "Umm, my teacher was boring. She was a boring teacher and she didn't know how to teach, so ever since that I hated it. And my seventh grade teacher used to always yell at us and he used to give us a ton of work so I hate it. She'll be like, "Well, I taught that to you. I expect you to know it".

The cognitive demands of science did not result in negative attitudes. The girls, especially in eighth and eleventh grade, were confident and not afraid of the challenge of the work or of making mistakes.

> Interviewer: "What happens to you when you make mistakes in science class?"
>
> S: "I make mistakes."
>
> Interviewer: "What do you do?"
>
> S: "I correct them. I mean I don't think anything of that. I just think , "Oops." Either I knew it or I didn't and if I knew it and I got it wrong, I just thought, "God why didn't I think of that?" But, if I got it wrong and I did know it, I'm just like, "Well, I'll remember that."

Pedagogy that isolated the girls and forced them to work separately and seatbound was disliked. This was especially true in the 8th grade where there was a heavy reliance on lectures, note taking, and the textbook.

> Interviewer: "What does he do that you really don't like in science?"

S: "I hate his lectures. Ohhh, I hate his note lectures. It's just a pain. He always goes like, eight pages of notes, notes for every chapter and I just hate it. It's a pain to do all that."

The girls were positive about science in school as well as confident in their ability to do science despite the absence of role models. Statements by the girls suggested that schools provided few role models or activities that highlighted women's contributions to science.

Interviewer: "Do kids ever do reports on women scientists?"

S1: "Some."

Interviewer: "Do they do them on men scientists?"

S1: "Yeah. Uhh, lots of times we're doing them on like the Indians or the animals, the nervous system, camouflage for animals."

S2: "Oh there have been women scientists. I don't know any you know off the top of my head."

Despite this absence of school role models many of the girls aspired to science or related professions. These goals were often based on a desire to help people, animals, plants, or the earth.

S1: "Be a nurse and help, like I want to be a nurse that helps umm, animals and stuff."

S2: "I'd probably be a veterinarian cause I really like animals."

S3: "Well I'll probably want to come and work with the earth like help the people to like go in a party to work and everything where, where it can save our earth and not die."

Biologically based careers were seldom seen as science because of the absence of chemicals and electricity.

S1: "Well, I don't know if what I plan to do is called a scientist. I plan to study zoology, animal behavior. I want to work with animals."

Interviewer: "Would you like to be a scientist when you're an adult?"

S2: "Umm, close to a scientist, but ..."

Interviewer: "Okay, what's the difference?"

S2: "I would say, like a professional scientist? Well, I mean, it's in the area of science but maybe a scientist does more with chemicals and chemicals and stuff like that than a vet would do."

Many of the girls, had narrow and unclear ideas about science related careers and a scientist's work.

S: "Well, I don't know if what I plan to do is called a scientist. I plan to study zoology, animal behavior? I want to work with animals. I want to save animals. I want to protect animals. See, what I want to do is, I want to, I'm very against animal cruelty, stuff like that, and I want to like help the extinct animals. I want to work them, I want to help. I want to work with the people explaining, you know, why not to kill the elephants for their tusks and all that."

Few girls at any grade level could relate the study of science in school to their personal career goals even when those goals included science.

Interviewer: "Do you think science is important?"

S: "Well if you're going to be a scientist, yeah, you need to learn a lot about it but if you're not gonna be a scientist or have anything to do with science I don't really know.

Despite the fact that these girls failed to make the connection between school science and their future careers, they planned to study more science based on general interest or liking science in school. This was particularly true for the second and fifth graders.

Interviewer: "Do you think you'll pick science all four years?"

S1: "Umm, well I'd try it the first year and if I really liked it then I would do it for the other years."

The eighth grade girls were looking forward to high school and planned to take science because that's what you do in high school. Most were looking forward to studying biology.

S1: "Mostly bio, I take advance biology my freshman year and I have to take four years of science so it'll be biology.

I'll keep goin for my four years and then hopefully I can get into CEU with my college courses."

In 11th grade the focus shifted to college. The girls planned to study science to get into college not just because of an intrinsic interest in science.

> S1: "Well it will look good for college to have all this science background. It will probably help me in some college classes. "

In addition to having a poor sense of the relationship of school science to future careers, the girls often failed to see the relationship between science and math.

> Interviewer: "So do you think you're gonna need math if you're a scientist?"
>
> S1: "I do okay in math and I think math for certain parts but it's not as important to me as it is to my parents. The science part of is more important to me than the math."

<u>Summary</u>

School science was perceived positively by all girls. They liked science, planned to study more science, and were confident in their ability. They would, however, like to see science taught differently. When the girls were positive about pedagogy it is was because it met their needs for relationships and connection. Despite liking science, they did not see the link between school science and their careers goals or between science and math. The failure to see connections may be the result of the curriculum. The girls were provided with few role models and what they learned in school was not linked to their lives.

Societal Factors

The girls did not receive all of their information about science from school. Much of it came from their families and society at large. Girls who did science at home, read about or who watched science related television shows or movies mentioned these as experiences contributing to their interest in science.

> Interviewer: "What do you like to study?"
>
> S: "Rocks. I uhh, I uhm, I collect them and I love to look at them and see what the sand and wind and water did to them and stuff, and I love, and I have a whole big

collection. There's a, I have this big huge case and it's from the ceiling to the wall or the ground."

Interviewer: "Where did you get them all?"

S: "We have a cabin and right across the street is a creek and it has no water in it and, we collect rocks."

One girl's choice of literature, along with her other interests, directly influenced her understanding of science.

Interviewer: "Well you said you like science, tell me more about that."

S2: "You see, I read this book, "Michael Faraday", and he was a scientist and I read about all the things he discovered and you know, where he made this, I can't remember what, he just kept going on and it was element or electricity and I got interested in that and I'd always been interested in zoology and veterinarian cause I had my own ranch and a lot of animals and a colt and stuff."

The girls in this study had high career aspirations. Half had chosen science. But parents had little influence over career choices unless the parents were involved in scientific careers themselves and thus provide some connection between science and their daughters' lives. When the career choices were science related they were frequently based on the biological sciences.

Interviewer: "Would you rather take chemistry or biology?"

S1: "Biology."

Interviewer: "How come?"

S1: " It's umm, let me try to explain this. Umm, you see my mom? She died when I was seven and umm, she loved animals just like I do and she always uhh, she always said try to do the best you can and you know, she says, once she said I majored, she majored in music, biology and something else? She said that it's, biology is different from chemistry because, it's hard to explain."

Interviewer: "Do you think your mom would have been happy to know that you want to be a scientist?"

S1: "She knew I did."

The girls often gave affective and altruistic reasons for their choices stating that they want to help people, animals, plants, or the earth. Many of the responses were emotionally charged. On the whole, laboratory based sciences and the physical sciences were rejected because the girls could not make these affective links. The few instances in which the girls chose a physical science career were all based on having experienced that science with a loved one.

> Interviewer: "An astronomer?"
>
> S1: "Yeah."
>
> Interviewer: "Why did you pick that?"
>
> S1: "Oh cause I like the stars you know, it's just neat. My grandpa, you know, he used to take me, well he still does a little bit but you know, he takes me out on his wooden deck, cause he lives on the beach you know, on the cliffs, and you know, takes me out in the middle of the night, dresses me up in sweaters and he'll go, "Oh look there's Mars." and boy-oh-boy, you know, I really used to like that. So that's probably why I like it."
>
> S2: "I know a lot about chemistry now. My, my mom's like, she's smart, she's like, really smart and she like, has no trouble cause like, I know I sometimes have problems in working, like she just (snaps her fingers) does them like that. So hopefully I'll grow up to be her."

Peer support for a career in science varied by grade level. Second grade girls felt that their peers would support them if they chose to become scientists. By the fifth grade, only half the students felt that their friends would support them. In the 8th grade most felt that their friends would not be supportive. By the eleventh grade, the girls again felt that their friends would support their choice of a science career.

Eigth grade:

> Interviewer: "What would your friends say if you told them you were going to be a scientist?"
>
> S1: " They'd probably ask me to think twice. I think there's a stereotype scientist usually who's always mixing chemicals and things like that and they really get under my skin and that's . . . depends on which kind of scientist I would become."

Interviewer: "Do you have any friends who want to become scientists?"

S2: "No."

Interviewer: "What would you say if a friend of yours wanted to be a scientist?"

S2: "I'd say that's a dumb occupation."

Eleventh Grade:

S: "They would probably support me too. They'd probably want to know more like why and would it, what led you to this?"

The girls were well aware of the negative cultural stereotypes of science and of scientists and readily cited examples. Most negative stereotypes were associated with the physical sciences. The eighth graders held the strongest stereotyped views and the 11th graders recognized that one of the stereotypes of science is that science is a male profession. However, despite their awareness of stereotypes or because of it, scientists were seen, especially by older girls, as normal people.

S1: "A scientist can look anything, be any person. It's just someone who knows a lot about science and works on making new things."

Interviewer: "Could it be a man or a woman?"

S1: "Doesn't matter."

The girls at all grade levels frequently used the expression "scientist, scientist" to distinguish between individuals working in the biological sciences and the physical sciences.

Interviewer: "What's a scientist scientist?"

S1: "Scientist scientist is like the scientists that work at NASA with chemicals and stuff so, so, you know, they work with the periodic table and stuff like that."

S2: "I wouldn't want to be a scientist scientist. I mean, I don't like chemicals and if you work with chemicals you could create bombs. Bombs create wars, you know?"

These girls had little or no association with women in science careers who could serve as role models. Only a few were able to cite examples and these were immediate family members. The media, while affecting

the girls' attitudes toward science and scientists, provided few role models of women in science. The images of scientists presented were both positive and negative. This mixture then required the girls at all grade levels to sort through the messages.

> Interviewer: "Do you think there are more boy scientists or girl scientists?"
>
> S1: "More boy scientists because you know, you always see like on TV or anything, TV movies it's always like boys are scientists."
>
> Interviewer: "Why do you think there are more boy scientists on TV?"
>
> S1: "Well because umm, like on TV they always show like scientists as being an adventurous job and then they just always pick like boys that can, well are more masculine or something so that they can like work better."

When positive female role models were provided they made a lasting impression.

> S1: "Well, what really made it was when I saw "Gorillas in the Mist." the movie. When I saw her working with the animals and saving them she just like became my hero. I really admired her for that and I want to do that too so that clenched it. I like knew right then that I wanted to. But all my life I just, I loved animals you know, but I `didn't know I wanted to make a career out of it."

Science careers were rarely discussed in the home except in the cases where one or both parents were themselves engaged in science. Nevertheless, most students felt that their parents would be supportive of their choice to pursue a science related career. Girls who had a family member in a science related career were most likely to consider careers in science.

> Interviewer: "Do they (your parents) ever talk to you about what they'd like you to do?"
>
> S1: "No. They just say, "What ever you want to do."
>
> Interviewer: What would your mother say if you told her you wanted to be a scientist?"
>
> S2: "My mother, she'd probably like that. She is really into math because my parents are both math teachers and

they'd like me to be in the subject of math, but she also knows that's a big part of science too, and so she'd probably like that."

Summary

These girls received mixed messages about scientists. In the media scientists were often portrayed as strange looking males doing bizarre things in laboratories. Stereotypes of science and of scientists were prominent but when asked to reflect, the older girls acknowledged that scientists are just ordinary people. Positive messages could be very influential.

The girls also lacked information on the variety of scientific careers available and on the relationship of science to other careers. It was clear that the mixed messages which the girls were receiving were in turn confusing their own thoughts. Only those girls who had a close friend or family member engaged in science refrained from stereotypes and presented positive images of both scientists and science related careers.

Equity

Throughout the interviews girls made strong equity statements. They repeatedly stated that liking science, achievement in science, and choosing a scientific career depended upon the individual, not upon one's gender. They adamantly disagreed with the statements that girls can't do science or that girls can't be scientists. They repeatedly stated that girls and boys are equal. When asked to respond as if they were a boy, the girls did not alter their positions. Overall, the girls did not see any differences between girls and boys vis a vis science.

> Interviewer: "Okay. Pretend you're a boy. If you were a boy do you think you'd like science."
>
> S1: "Umm, yes."
>
> Interviewer: "Do you think you'd like it better than if you were a girl?"
>
> S1: "No."

None of the girls agreed with the statement that girls cannot be scientists. They repeatedly said that girls are the equal of boys, that girls do science as well as or better than boys, and that doing well or liking science is dependent on the individual not on one's gender.

> Interviewer: "Some people say that girls don't make very good scientists. What do you think?"

S1: "I think that girls could if they really wanted to. They can do just as good as boys."

Interviewer: "Okay. Umm, what makes you think that?

S1: Because they're people too and they're just equal."

Nevertheless, eighth and eleventh graders were also aware of cultural gender stereotypes and held many such views themselves.

Interviewer: "Do you think girls like life science more than boys?"

S1: "No. Cause we had to just dissect stuff and you know guys were all showin the eyeballs to everybody so girls didn't like the dissecting part."

S1: "Cause they, cause they think it's gross, you know, like, "Ohhhh, it's an eye!" you know."

Interviewer: "And the boys don't?"

S1: "No, they're like, "Oh let me rip into the worm, you know."

The girls were asked how their friends felt about science and science careers. The answers for friends and for self were the same for the 2nd graders. They felt that their friends liked science, would choose to become scientists, and that their friends would support them if they choose to become scientists.

But by the fifth grade only half the students felt that their friends would support them if they decided to become scientists. In the 8th grade most of the girls felt that their friends would not be supportive of a girl's career choice in science. However, they believed that girls in general like science.

Interviewer: "What would your friends say if you told them you were going to be a scientist?"

S1: "They'd probably ask me to think twice. I think there's a stereotype scientist usually who's always mixing chemicals and things like that and they really get under my skin and that's . . . depends on which kind of scientist I would become."

Interviewer: "Do you have any friends who want to be scientists?"

S1: "No. "

This trend reversed for the 11th grade girls. They felt that their friends would support their choice of a science career but also believed that many girls do not like science.

Interviewer: "What do the girls say about science?"

S1: "Well they just think it's boring and stupid cause they have to sit and listen to lecture for so long and there are a million other things they'd rather do."

Interviewer: "Like?"

S1: "Like, I don't know. Girl things like shopping ..."

Interviewer: "What do you think your friends would say if you told them that you were going be a scientist?"

S1: "They would probably support me too. They'd probably want to know more like why and what led you to this?"

Conclusions

Even though these girls took strong equity positions, they were aware of and held many gender stereotypes. Like the girls in Brown & Gilligan's (1992) study, our respondents are caught in a paradox. They are struggling with establishing and standing up for who they are and the cultural feminine ideal.

Many of the girls in this study seem to be good candidates for careers in science. However, we know that despite interest and intentions few of these girls will end up in science. Looking at what the girls say through the lens of relationships and connections helps us understand why the girls are drawn to science and what may also lead them away.

Relationships, which include caring, and responsibility provide the standard by which these girls make judgments concerning science. Their strong equity position can be interpreted as a rejection of competition and the hierarchical ordering of individuals which make positive interpersonal relationships difficult to establish and maintain. Equals are more likely to be friends and reducing competition results in working together better. The expression of negative gender stereotypes can be

interpreted as the intrusion of cultural values into this expression of psychological needs.

The response to how science is taught and the role of the teacher is also mediated by relational and affective needs. The girls dislike instruction that isolates them, such as reading the textbook or taking notes while listening to lectures. They prefer instruction that permits them to interact with others, such as working in groups or discussing the issues with their classmates. The teacher who connects with the students is a "fun guy" and the one who does not is boring.

Both physical and biological science are interesting but physical science careers are avoided because they seem unrelated to the girls' concerns. Biological science careers are perceived as helping people, animals, and the earth. It is the potential to be helpful that draws girls to these careers. The puzzle solving given by males as a reason for their interest in science is, for the girls, replaced by relational and affective needs.

The girls with the strongest commitment to scientific careers learned to love science through the love of a parent or grandparent involved in science. The descriptions of these experiences are emotionally charged and focus more on the interpersonal relationships than on science itself. The girls do not separate their feelings about the mother who had died, the mother who "teaches me everything", or the grandparent who explains the stars on cold evenings from their feelings for science. When the emotional impact is strong enough, a movie, such as "Gorillas in the Mist", can have the same effect.

Relational values such as cooperation and helping others are characteristics of women in general (Belenky, Clinchy, Goldberger, & Tarule, 1986) but are also important to women working in technical fields (CCT & CCE, 1991; Sjoberg & Imsen, 1983). However, according to Rhode (cited in Noddings, 1990) these values have been undervalued in science and are missing in professional schools and organizations. The absence of relational values during the training of women scientists and in their professional lives may account for the low number of women in science. Dropping out of science is not necessarily related to achievement or interest but occurs because women's psychological needs and goals such as marriage and children are more important than their need for high status careers (Arnold, 1992; Eccles, 1986).

These data speak strongly about how girls see science and the need for science educators to address the female perspective. One such study has been conducted by Martinez (1992) who enhanced uninteresting experiments by increasing their social appeal. Not surprisingly, he found that the girls in the study responded positively to these enhanced experiments. More information is needed on how these relational and affective dimensions influence girls' life choices as well as information on

how to integrate these dimensions into science classrooms and the scientific workplace.

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The Participation Of Women In Science : The Road Less Traveled

Kathleen Davis

The guard waved her in and Dr. Lynn Smith[1] after only a few hours of sleep, drove slowly through the gate of the laboratory. It was a quarter after twelve on Sunday morning and snow was falling slowly and silently onto the trees and roadway. She had left only a few hours before, too tired to proceed any further; "zomboid," just staring at the stuff with which she was working. Now as she walked in, she was still tired.

"I was the only person that knew how to run this computer to figure out the stuff. At 11:30 [P.M.] my telephone rang and they said, 'You have to come down to look at this stuff and run these computer codes."' She knew this would cause trouble with her husband; he was pretty upset that she was returning to work with so little sleep. Over the last few days, she had worked day and night and slept at the lab. "I was just a physical and mental wreck." At least he is also a scientist. She could come home and tell him how exciting it was and he could partially understand. She thought experiences such as these must do something to the divorce rate.

But this was "the excitement of big science at work." This experience was especially exciting because this was the only time in her career that she had the opportunity of "sitting right in the forefront and to have the whole world to go after." Her research team was working hard to be the first to know the composition of the superconductor. Their motivation was high, as there were big stakes to be had-the words "Nobel Prize" drifted in and out of conversations in the lab-and the opportunity might not come by again. For the woman scientist, this time in science "was tremendously exciting."

Dr. Lynn Smith is one of few women who choose a life-time career in science. Through her stories and experiences and those of two other successful women scientists, this paper will present many of the key issues surrounding the participation of women and girls in science and science education. In addition, it will elicit factors that are critical in order to provide women and girls with full access to participation within these communities. Today, though women represent 45% of all employed individuals, they comprise only 16% of professional scientists (National Science Foundation (NSF), 1992). Few women choose science-related careers, especially in fields such as physics and engineering. Although women are represented in greater numbers in the natural sciences (i.e. 27.8% of employed life scientists are women) their numbers are still not equal to their representation in the working community (NSF, 1992).

For females, attrition from the science pipeline begins early in their pre-college experience, and the potential for "leakages" is greater for females than males (NSF, 1992). Girls often avoid science coursework, especially the physical sciences and advanced chemistry. Fewer women are choosing college majors in science and engineering (Mullis & Jenkins, 1988; Oakes, 1990) and the high school and college dropout rate in science for equally prepared females is higher than that of males (Oakes,

1990). The literature suggests many reasons as to why women and girls do not participate in science careers and what obstacles to science and science education they encounter. Traditionally, and even today amidst the implementation of progressive science education reform, schools "shortchange girls" by establishing policies and teaching strategies that are "gender-blind" (AAUW, 1992; Martin, 1992). "Gender-blind" institutions and individuals often attempt to achieve educational equity by treating both genders equally. As a result, they perpetuate "gender bias" and the "invisibility" of girls in the science curriculum and in curricular decisions (AAUW, 1992; Martin, 1992).

Girls and women are "shortchanged" in their education through "gender-blind" policies that: 1) fail to encourage them in coursework and in practices that are necessary in order to enter professional fields (Kelly, 1987); 2) ignore them for their contributions and achievements (Harding, 1991; Delamont, 1989; Martin, 1992); 3) do not take them seriously for their thoughts, concerns, and ideas (Gilligan, 1990); and 4) fail to address their victimization that results from harassment, bias, sexism, stereotyping and violence in today's schools (AAUW, 1992, 1993; Martin, 1992; Sadker, Sadker, & Klein, 1991). In addition, it is important to consider that as we encourage and bring women into the science community, some women see much of science that they do not like, thus discouraging them from entering or remaining in the community (Harding, 1991). Critics of "science as usual" find fault with the whole science enterprise: its purposes, practices, functions, ethics, and goals. Among other things, "science as usual" is criticized as being 1) sexist in its descriptions of nature and scientific inquiry, 2) biased in its selection of scientific and technological research agendas, and 3) privileging research approaches that are abstract, separate, disinterested, and impersonal (Harding, 1991).

"Science as usual" creates multiple barriers for women who view science as for and about men, and who perceive that the science process has been outlined by men. These women find little place for themselves in the fields of science, whether it be in the classroom or in the laboratory (Keller, 1982, 1985; Rosser, 1988, 1990). Therefore, the lack of women participants in science is not a question of what is wrong with women, but "what is wrong with science and science teaching that it fails to attract females?" (Rosser, 1990, p. 54).

There are several reasons why educators need to be concerned about the low participation of women and girls in science. First, women present a potential pool for scientists (Oakes, 1990). Missing such a source of knowledge, creativity, and ingenuity, this area of the economy, industry, and academia cannot be developed to its potential. As women continue to be absent in large numbers from the fields of science and technology, the nation is deprived of "half the talent that could hasten the solution to its technological and medical problems" (Vetter, 1992, p. 19). Secondly,

we live in a technological age where daily decisions are often based on scientific knowledge. Therefore, all individuals need a working knowledge of science (AAAS, 1989). This knowledge is key in the daily decision making in our homes, communities, the nation, and the world (AAAS, 1989). Women and girls may self-select out of science and math coursework and as a result filter themselves out of scientific and technological careers. Those who do not participate may not fully develop to their potential whether this means giving one a sense of "control" within our technological society, becoming involved in science and technology planning, acquiring knowledge and understanding about the world, and/or obtaining well-paid and secure jobs (Kelly, 1987). The National Commission of Working Women reports that 43% of women are working in jobs that pay below the poverty level (EQUALS, 1989). Despite the fact that women earn lower salaries than men in scientific and technological fields (Vetter, 1992), such careers provide higher salaries for those women participating in that workforce (Kelly, 1987). In addition, equal access to participation within the science community is important as it suggests an open door to sources of knowledge and understanding through increased involvement within practicing communities. Lave and Wenger (1991) describe such participation as both legitimate and peripheral. They define legitimate peripheral participation as "engagement in social practice" that includes "...multiple, varied, more- or less-engaged and -inclusive ways of being" and "belonging" where learning is an important component (Lave & Wenger, 1991, p. 35, 36). Peripheral (not partial) participation is about "being located in the social world,...changing locations and perspectives" as members develop identities and forms of membership, and approaching "full participation" in "the diversity of relations involved in varying forms of community membership" (p. 36, 37). Therefore, importantly, equal access to legitimate peripheral participation for all individuals can lead to an equitable distribution of knowledge, capital, and power across the population.

Purpose of the Study

Though much has been presented in the literature as to why many women and girls do not participate in science careers, few researchers have actually interviewed and described the stories of women who are successful scientists. Harding (1991) emphasizes that feminist research should be located within the day-to-day experiences of women. Describing experiences from the standpoint of women can reveal underlying beliefs and practices that are hard to see, and through women's stories, we can show a perspective not heard before and make "the familiar, different" (Delamont, 1989). Therefore, women who are working in science can provide useful information about their experiences that might lead to a clearer understanding of why some women choose and continue to pursue science careers and of the difficulties that they encounter. What do these women say about their recruitment, success,

and the rewards of their careers? How do they view science and the practice of their profession? What barriers to achievement and advancement have they experienced? The factors that have influenced the lives of women scientists may better inform educators about how to motivate and assist women and girls to pursue interests and careers in science and how to bring about important and necessary change within science and science education.

Procedure

For this study I interviewed three successful women scientists in order to examine the major themes in their personal life histories. My questions focused on these women's perceptions of the nature of science, their descriptions of their own scientific work, their assessment of what motivated them to enter into their particular scientific fields, their opinions of the influences of their familial and academic backgrounds on their career choices, their descriptions of how they entered into their particular scientific disciplines, the factors that encouraged or discouraged them in their pursuit of science participation, and their perceptions of how their careers currently suit them. The women studied were Dr. Elizabeth Lind, Dr. Lynn Smith, and Dr. Jeanne Franklin. These three women were working in research science in a large, mid-western city. They are white and are from both working-class and middle-class backgrounds. Dr. Elizabeth Lind is a university professor of nursing. Her work in the area of gerontology is focused on depression, procedural and non-procedural touch, and reminiscence. Much of her time is devoted to her research, working with graduate students, and serving on committees within the college of nursing, the graduate college, and the university. Dr. Lynn Smith is a solid-states physicist at a national laboratory. As previously described, at one point in her career she was a member of a research team that explored the composition of the superconductor. Her work today involves "working on the beam line...putting in samples and doing a run", feeding data she has collected into computer programs, and completing the subsequent analyses.

Dr. Jeanne Franklin, geneticist and molecular biologist, also does her research at a national laboratory. Franklin studies the process of photosynthesis using DNA that has been extracted from photosynthetic bacteria. Though she derives her greatest pleasure from "working in the lab," the proportion of time she spends doing "bench work" is "probably not even as high as 40%." Her time is consumed by writing grant proposals so that she can fund the research that she wants to do. As volunteers in this study, these women were willing to spend considerable time sharing their stories through in-depth interviews. Though the small number of subjects in this study limits the generalizability of the results, providing such an analysis was not the intent of the study. Working with a small number of women, who work in diverse fields of science, allowed me the opportunity to provide a more in-depth and rich

description of these women's lives and to develop more questions for further research about this issue. In addition, it is hoped that this study may provide direction for the selection of future informants in follow-up studies. These women's stories were written in the form of three case studies, portions of which are presented in this work. Each informant read her case study and provided feedback which was incorporated into the final writing.

Themes of the Study

Through their words and stories, my informants articulated several themes in the course of this study. They are: 1) the questioning and problem-solving of scientific work is fascinating and compelling to me; 2) parental attitudes influenced my career path; 3) teachers played critical roles in the formation of my self-concept and the selection of my career; 4) mathematics is/was an integral part of my career path in science; 5) the self-actualization of my personal potential and the development and maintenance of my personal relationships are conflicting; 6) the isolation that I feel and have felt as a scientist conflicts with the need I feel to work with others; 7) sexism, stereotyping, and biases and institutional barriers within the science profession, academia, and government have negatively impacted my professional progress.

Due to the space permitted here, this paper will discuss the study's themes that directly relate to the contexts of schools and these women's careers in science. In the conclusion, educational implications are presented and discussed based upon the themes that emerged from the life histories of these women.

The Fascination with Questioning and Problem Solving

> "I loved books. I loved questions. I used to sit and ask my mother, "How can glass be made from sand when it's so clear?" Her pat answer to these very unanswerable questions--"If I could answer that, I wouldn't be standing here ironing your father's shirt. Go look it up. Go to the library." So I did!" (p. 31)

Evident in the experiences of these women is how the processes of questioning and problem solving serve as driving forces that have brought them to science and keep them going from day to day. Smith relates, "One of the things that drives me and other people who do science is the thrill of finding something unique. How this is happening and why it turns out." She talks about a "real high" that comes from "...seeing a problem and...saying...I'd really like to know whatever [and when an answer is found]...know[ing] I'm the only one in the world who knows...there's really a fascination with it."

Weiner (1984) has discussed the intrinsic motivation individuals have to seek information and how it reinforces more learning. Jeanne Franklin states,

> "It's very satisfying when you can ask questions and you can do an experiment that will give you an answer. This may be an answer that you haven't anticipated, or you know will be interesting to the rest of your field, or you will find out something that people didn't know before. That's exciting! ...It's like a puzzle. The experiments you do give you more pieces for solving the puzzle, which is something that I've always liked to do!"

Lind shares that the human body and how it works was a constant source of questions for her. One of the reasons that she went into nursing was to find the answers to her questions.

> "I was so attracted to surgery because I've always been attracted to the human body; that's the science part of me. In high school, I was the one that did all the dissections; I was the one that did all the cadavers in my doctoral study. As a child, I was always intrigued when I poked myself. What am I touching? What's in there? ...[P]art of why I went into nursing is that I wanted all of these questions answered."

The process of posing questions and finding answers motivated these women towards careers in science, and today they continue to seek solutions through their scientific research. Lind states, "[T]here is never an answer. There is never an end. Every answer brings up three more questions."

<u>The role of teachers:</u>

As the three women in this study embarked upon their academic careers, the roles and influences of teachers and advisors were evident. According to the women scientists, teachers greatly impacted the formation of their self-image and career choice. These women believe that their teachers assisted them as students entering scientific careers and changed their lives. Elizabeth Lind talks about the teachers in her life.

> "Nobody does it on their own. Everybody does it because of someone else. I have some very special people who did some very special things for a woman in science without whom I could not be where I am today. There are walls

> there and there are certain people who find doors that open them for you."

As an example of this, Lind relates a situation when she was recovering from a long illness while in her bachelor's degree program. Due to scheduling, she was unable to make up four semester hours of zoology. However, a professor gave up his Saturdays to give her course time that allowed her to graduate. "Without him, I wouldn't have my B.S.N.; without that I wouldn't have anything else." Throughout much of Lynn Smith's early education, she was given the impression by her teachers that she would not be able to succeed. 'We were told that we weren't going to be able to do it. We were going to have a rough time." She describes her early school years as a time where it was acceptable to be passive and where she was not taken seriously. Often she would not go to class, or she would just sit there.

> "I would say that in high school I always did OK, but I was never taken very seriously. In part I went to a very, very bad school. Nobody took anybody seriously...So you go along and nobody ever says to you that you can do that stuff. You never get the impression that you're anything outside of run-of-the-mill and why you should be able to do it if no one else can."

Smith recalls a situation in a high school math class.

> "I remember this problem that was assigned as homework and nobody could do it and of course I hadn't even written down the problem number. The math teacher couldn't do it either. I just looked at it and in three seconds I knew how to do it, so I told him how to do it, but he didn't even understand 'til quite near the end of the problem. I remember he was very surprised, but he never turned around to me and said, "Hey, that was pretty good of you to figure that out" ...that's all it would have taken...to reinforce something like that."

For a good portion of her early education, Smith did not have a true concept of her potential. She was not noticed; she was not taken seriously. It was not until she entered a technical school in Canada that she was given the idea "that it would ever be any different from that...I would say that [at the technical school] was the first time people took my contributions seriously." One of Smith's instructors there proved to be instrumental when she decided to enter a nearby university. She had completed only 12 years of schooling and 13 years were required for admission to the Canadian university. The instructor said to her, "Well, if you're interested in going on, I would go to the place where I went to school." He knew the Dean and got her an interview. Smith states,

"... the Dean said that he was permitting me special entry, I was a special student. He was very concerned about me. He didn't think that I would be able to do OK. He called me back in as soon as I started and said, "If you think things aren't going well, if you think you're lost, come and see me right away." He was really worried, but they gave me the chance to do that. [When I first entered the university,] I skipped the first two years...I walked into a quantum mechanics class, never having seen an integral sign. That was it! ...I knew...right then that I wasn't going to stop, 'cause it was just so neat! It taught me so much 'cause there was so much to learn! That's part of why I liked it so much. If it hadn't been for this fellow [her instructor], I never would have been able to go to his university...he took an interest...said, "Hey, maybe you could do something." ...Actually, I owe that guy a lot."

In thinking about what brought her to science, Jeanne Franklin reflects back to junior high school and recalls how a science teacher actively engaged her in scientific observation and investigation.

"I really enjoyed math and science. In junior high, I had a great science teacher. He was an amateur astronomer and he took us on field trips at night out into subdivisions that were just being built so there weren't a whole lot of street lights. He'd bring his telescope and we'd look at Mars and Venus and Jupiter and Saturn. He took us to a planetarium. There was a lunar eclipse one night, and we all came back to school and set up our cameras in the window and took progression photos. Oh, he just designed neat experiments! We had goldfish and we'd put the tail of the goldfish under the microscope and see the blood...circulating in its veins. These things made an impression on me."

Much later, during graduate school, Franklin's advisor was her "mentor." She points out that,

"He was a good motivator. He was a very enthusiastic individual...enthused about what was going on with your project. He loved what was going on in his lab. He loved his research. If you told him you had some results, he would be wondering if you had the answer yet. He never dampened your enthusiasm by reminding you of all these other things that you left out...that you should have done. He wanted your own contribution to the direction the project was going to take in the future. You had to become

independent. As far as the thinking and planning the project, I was expected to do most of that. If I hadn't chosen that research advisor, I wouldn't be who I am today."

In Franklin's case, her advisor facilitated an environment in which she could voice her ideas and express and choose her individual approaches. Her ideas were taken seriously and were incorporated in the problem-solving process. She commented, "I like to ask questions; I like to find answers. I'm independent; I like to decide the course of action myself." Throughout these case studies there were numerous examples where male teachers served as gatekeepers to the progress of women in their careers in science. These men were powerful in that not only could they enable these women to move forward in their careers, but they could also impede their progress. Often these men guarded the gate, held the key, and limited or discouraged women's admittance and participation in the community environment and in its practices. Elizabeth Lind had several experiences while in graduate school that exemplify the "guarding of the gate." During her first year of graduate school, her advisor placed her in a chemistry course which required a background in mathematics for which she was unprepared.

> "I ended up in a chemistry course in which I needed trigonometry. It was 'quant' and 'qual' in one semester. I had no background for this and I was drowning, drowning! Angrily, she asked her advisor. Why on earth did you put me in this course? You knew I couldn't do it! [He replied,] "Because you're a nurse and you're not going to make it here. You're a woman and you don't belong here." My fury was unbelievable! I went back and got a B out of the course because a [male] teaching assistant was very caring and literally walked me through the course."

In another instance, Lind's master's thesis advisor provided her with a lab to do her research. Once she completed her graduate studies, he failed to provide her with recommendations that would enable her to continue on with her work. Instead, another male faculty member in her department provided her with the necessary letters. She was then able to go on to a research institution where she successfully set up a kidney biopsy lab. Lind's experience with her first-year advisor illustrates Mallow's (1986) contention that teachers often have the attitude that women do not do science or are not suited for science careers. Both Lind's first year advisor and her master's thesis advisor exhibited behaviors and attitudes that reflect a "chilly classroom climate" where women often report being neglected and overlooked and are not taken seriously (Hall & Sandler, 1982). Sexism, evident in Lind's academic experiences, was a barrier to her advancement. What was critical to Lind was the support that she did receive from those professors and

teaching assistants who opened doors with help and encouragement so that she could continue on with her research.

Conflicts between achieving personal goals and developing personal relationships:

Some women will attempt to have both family and career, and the three women in this study experienced various conflicts as they sought to develop personal relationships while they pursued personal career goals. Lynn Smith talks about her struggles to maintain "a balance" between family and career.

> "Not many years ago I learned it's a balance and that the idea is to take the different parts and to try to do your best with them but to make yourself at 5:30, no matter how exciting it is, you have to walk out of it and at 10 o'clock in the morning no matter how great it is at home, you got to get out of there too...It's part of growing up to understand that there are limits."

However, as Smith described it, the balancing act is not always simple.

> "It's very precarious...it shifts around and it's not easily maintained." She said, "Now that I have a family, I enjoy being home a lot. So in the morning, when I'm getting ready to go to work, I think I'm going to quit. I just don't want to go in. When I'm on my way home from work every night, when I'm getting ready to leave, I think, 'I'd just love to stay.' Why do I have to go? It's just two completely different lives. I like them both a lot. I have a very significant guilt thing because I go home and maybe my son isn't very friendly with me and I'm just desperate to regain that interaction with my kid, but, at the same time, if things have gone well, I'm very involved with work. So it's really unpleasant actually. I sometimes really hate it."

This struggle between home and career can be examined in several ways. Feeling connected with others and establishing relationships are of great importance to most women and girls (Gilligan, 1982; 1990). Women more often than men are socialized to be connected, concerned, and partial to the interests of family and friends (Clinchy, 1990; Gilligan, 1982; 1990; Harding 1991). Harding (1991) describes the ways and practices of many women within our society as arising "from a variety of social conditions that are more characteristic of women's lives than of the lives of men..." (p. 47).

> She continues: "One argument is that men in...dominant groups assign to women...certain kinds of human activity

> that they do not want to do themselves. They assign to women the care of all bodies...the local places where bodies exist (houses, offices...), the care of young children, and 'emotional work'—the processing of men's and everyone else's feelings" (p. 47).

However, Martin (1992) contends that care, concern, and connection need to be the business of everyone and not just that of women and girls. In addition, Harding (1991) points out that within society, "'woman as knower' (like 'woman scientist') appears to be a contradiction of terms" (p. 47). The role of women as "agents of knowledge" and as "actors on the stage of history" (Harding 1991) has been denied repeatedly throughout history within the intellectual disciplines and society (Martin, 1992, 1981). So, not only are women socialized to be the sole caregivers and caretakers in society, but in addition, they are denied the role of "knower." As a result, women's efforts to acquire and construct knowledge and to fulfill one's potential in and of itself may create conflict. Therefore, the combination of such efforts in addition to maintaining the responsibility for care, concern, and connection of others may often create even further conflict.

When Smith recalls the events that occurred when she worked with her research team on the superconductor and reflects on whether she kept balance in her life at that time, she admits that she "didn't have it then." She didn't have children then either. "I worked day and night. We slept there. We never went home. It was tremendously exciting at the time!...I couldn't do that now." When asked what she would do if such an opportunity came up again, Smith replies, "I hope that never happens. I probably would do it for awhile..but I wouldn't do it with the joy that I did before...I'd just be wracked with guilt." Smith, the woman scientist, acknowledges that the interests of self are indeed legitimate, yet still struggles with the responsibility she feels towards her family and her desire to further both her personal and professional goals.

Gilligan (1982) states that as women invest themselves in a world of relationships, they often participate in self-sacrifice. For example, as Lind considered beginning a doctoral program, she appeared willing to sacrifice her career for marriage.

> When I spoke about getting my doctoral degree, we were talking marriage. I said, "I want to get my degree and what's this going to do [to] us? Hours and hours of working in the lab, what's that going to do [to] a new marriage?"

Her fiancé, her microbiology teaching assistant and "mentor," said, "I understand. It's no problem" (p.34). They did get married, and Lind began to work on a doctoral degree in anatomy, but she pledged:

"I'm not working nights, I'm not working weekends. My marriage is more important to me and I'm willing that if I can't do it on those terms, then I don't get the degree."

Her husband continued his support even when she felt that she was not going to make it, and she did complete her degree.

Though Franklin changed graduate schools in order to marry, she never set aside her career goals. However, her refusal to minimize her success and her husband's uncertainty about his own future led to marital conflict.

"As I got more successful in that things were going well in my research and publications were starting to come out, he (my husband) was more and more resentful of my success. He was not certain which way he wanted to go...even though he's a much brighter person than I am... he had the practical side...When a paper was published, it got to the point where I didn't want to come home and say that it was published because I knew he would go off into a depression. So he wasn't real supportive. He was never trying to get me to stop, but I could see that inwardly...he felt that my successes emphasized his failures or his indecision. It just made him sad. I think this is what split us up."

In sum, women often experience conflict between achieving professional goals and developing and maintaining personal relationships, between having a career and also a family (Gilligan, 1988; Holland & Eisenhart, 1990). Often, girls and women perceive that choosing a career such as science results in giving up personal relationships and the hopes of having a family, and they do not see how they can have both.

<u>The importance of interaction with others and the isolation in scientific work:</u>

Institutional barriers, intense competition within the science community, and the specialization of the disciplines have lead to isolation in science work for two of these women. Both Lind and Smith have struggled with working alone. Smith indicates that "for the most part, science is...a lonely kind of job" and that isolation is "something you have to deal with; it's essential..." However, she relates that

"Women, it seems to me, are taught to be fairly social, where [you] are outgoing and share your life around you. Always up until the time I started graduate school I had

> best friends and I miss that. My personality isn't totally at one with this job...I'm more a social person."

In other occupations, communicating with colleagues often can be accomplished by walking across the office or down the hall, but in Smith's kind of science, communication takes place long distance, either by telephone or through publication.

> "But when you are sitting there and you discover something that is kind of unique...It is really lonely to walk out into the hall and there is nobody to tell and [to whom] you could say 'Hey, I discovered this thing!' There's no one to be happy with or to talk with and that bothers me a lot. Most people with whom I work, want to work by themselves."

Because they are so specialized in their fields, her colleagues find it difficult to communicate with those outside their specialty. In addition, though competition within the science community can be exciting, isolation can also result from the "intense" competition scientists. When it comes to publishing the results of research, lone scientists need not worry about sharing the credit with a list of other authors or about not being first. "The notion of whoever is the first author reaps all the benefits [i.e. funding recognition] keeps people from working in groups," shares Smith. Elizabeth Lind thinks about how her science research and her graduate degrees in anatomy made her a "maverick" in the nursing profession and how institutional barriers produced career obstacles which resulted in situations of isolation for her. The rigidity of the nursing profession placed obstacles in her path by not providing for her individual talents and abilities and by not providing her with enough science coursework within her course of study in nursing. This forced her to seek it outside her chosen field of nursing. Once she did this, she was "ostracized" in that there was no functioning position within the college of nursing where she belonged. Without advanced nursing degrees, she could not teach. If she had pursued nursing degrees, she would not have had access to the science coursework she desired. As a result, for ten years she was "ostracized in essence because I didn't belong anywhere...I had no students. I could not do the undergraduate... teaching because I didn't have my Master's in nursing...I don't have my Ph.D. in nursing..."

Today, college policies have changed and Lind now teaches. It is evident that her interactions with others are important to her. "I love my teaching...I love my students...There's something in me that I want to interact with the person." In addition to the impediments placed in Lind's path by her profession early in her career, she also felt that she would be ostracized by the science community if her nursing background was made known. She said, "I never let anyone know my identity." Knowledge of her nursing identity would have threatened her chance for

funding and support for her research. Thus, tacit in both government funding policies and schools of nursing were biases and confusing messages about the worth of both her nursing degree and her Ph.D. in anatomy. Both government and nursing institutions placed obstacles in her career path which resulted in isolation within and between the communities of professional nursing and research science .

<u>The impact of sexism, stereotyping, and biases:</u>

Sexism, stereotyping, and biases, whether in personal or institutional situations, created numerous barriers to these women as they sought to reach their potential in science. Such experiences resulted in situations that not only increased their isolation within the community but also served to limit access to full participation in the science community and therefore to lessen their opportunities for participation in coursework, for advancement, and for financial support. As described earlier, Lind experienced bias and sexism in her graduate school experiences and within the nursing profession. As she began her laboratory research on the aging process in humans, she found difficulty getting financial support through government funding agencies such as the National Institutes of Health (NIH).

> "[W]omen in nursing were very low priority because nursing had its own division within NIH, but the Division of Nursing would not fund nurses; they funded what they considered nursing research. I was doing aging brains in hamsters...what does that have to do with giving a bath?"

She submitted numerous proposals, many revisions, with the support of colleagues in the department of medicine and anatomy, guided by critiques provided by NIH, and "I came back disapproved." She decided that "there was no sense in trying to beat my head against the wall anymore, and so that's when I decided to go into human research."

Institutional bias is also present at the national laboratory where Franklin works. She relates how the discrepancy between the salaries of men and women in science still prevails today and compounds the financial crunch that is felt in scientific research.

> "After I'd been here two years, I got this huge raise and I was told that it was because I was wonderful. I started talking to my friends and [we discovered that] the...men got their usual 5.5% [salary increase] and the women had anywhere from 10-15%...[In a] meeting they were told it was because there were inequities between women's pay and men's pay...I was furious!

> Human resources will say today that the equalization process is not finished... that there is still some discrepancy...I said, 'What's the problem? How long is it going to take? What is the big deal here?'...What possible justification could there be for paying women less? They don't expect any less of me."

In 1990, women with bachelor's degrees and some additional graduate study earned salaries that amounted to less than 70% of the salaries of men with the same amount of education (Vetter, 1992). Only recently have women college graduates earned more than male high school graduates. Continued differences in salaries between men and women, is "denigrating to women" and creates a primary barrier for women to the professions. As salaries are "generally equated with worth," women, like men, "need to be assured that society values their abilities, their work, and their achievements" (Vetter, 1992, p. 5).

Implications For Education And Science Educators

The stories of these three successful women scientists reveal important information about their perceptions of science, the rewards of their careers, and the passageways and obstacles to achievement and advancement that they have experienced. As a result, key implications for science and science education which potentially impact the participation of women, girls, and all students in science can be drawn. These include: 1) The process of scientific inquiry and problem solving is key to engaging individuals in science. 2) Continuous educational experiences in mathematics can provide students with confidence to utilize a tool that is critical to science work. 3) Working in isolation can create conflict for those who value working with others. 4) Within the context of the home, classroom, school, and laboratory and through classroom pedagogy, adults convey both explicit and implicit messages to students about what types and levels of participation in the community are desirable and achievable for students. 5) The structure of the science and science education communities may serve to facilitate access to legitimate participation or may impede that process.

As these women share the scientific work that they do today, it appears that a large part of what draws them to the profession is the questioning and problem solving process. Often students view science as a great wealth of facts that they need to learn, yet are known only to scientists (Mallow, 1985; 1986; Songer & Linn, 1991). In fact, science is a dynamic process that students, especially women, are not often allowed to experience, especially in the elementary years (Sprung, 1985).

A curriculum which focuses on questioning and problem solving may better acknowledge and encourage this curiosity. As scientists self-design their own experiments, it may be beneficial and motivating

for students to self-design their own methods of answering questions and solving problems and then to test them out. It was important for Franklin to design her own research project during her graduate studies, a project that she found interesting and which was also acknowledged as valuable by her graduate advisor.

It is important that teachers facilitate such an environment where students interact and voice their ideas, as well as express and choose their individual approaches, and where students' ideas are taken seriously and are incorporated into the problem-solving process. Smith points out how this was missing from much of her educational experience. This process of interaction appears to be important in developing a positive self-image, especially for girls (Gilligan, 1988).

Secondly, mathematics was instrumental in the career paths of all three of the women in this study. All experienced some problem relating to mathematics, but it was not because they were unable to do the math. For example, for Lind the missing trigonometry background resulted in an anxiety-ridden situation when she was enrolled in a chemistry course that required it. Yet her efforts, coupled with the encouragement of a "caring" teaching assistant, produced a successful experience. Lack of effective instruction and consistent math coursework did not keep Lynn Smith out of a science career, but it did affect her confidence in her abilities. She stated, "It's not that I couldn't do the work, [but that] I didn't have the confidence." Smith's giftedness and perseverance in mathematics has enabled her to pursue and to successfully participate in science, as mathematics is part of her daily science work. Mathematics is an important tool in the practice of science and, without math coursework, students are filtered out of scientific and technological careers (Sells, 1982). However, women and girls are often told that girls do not do math or that girls are not good in math. Girls often drop out of math courses because they do not see how it is relevant or necessary for their present or future lives; they perceive that they do not have the ability to do math; and/or they perceive that math is something that only males do and that it is not feminine (AAUW, 1992; Kaseburg, Kreinberg, & Downie, 1980). Therefore, it might prove beneficial for all students if math were a continual part of the educational experience, integrated with science, and incorporated as a regular tool for problem-solving within the classroom.

Another theme that emerged from this study was the isolation of scientists in their work. Two of the women scientists found that at some points in their careers, science was "a lonely kind of job." Institutional bias, competition within the community, and the specialization within science disciplines appeared as major factors that created and intensified the isolation of these women within their communities. Curricular strategies that provide for frequent interactions with others, such as cooperative learning, may serve to lessen the propensity for

isolation in scientific research. Cooperative learning allows students to work together towards a common goal in contrast to working against each other, to hear their own voice as they express their thinking, and to utilize each others' ideas and build on them, leading to a better understanding of problems and to effective solutions (Resnick, 1992; Rosser, 1990).

In addition, institutional biases, sex-role stereotyping, and sexism continue to be barriers to students in reaching their potential in science, as evidenced by Lind's experiences in graduate school, her attempts to access funding for her research, and her isolation within her profession, by Smith's poor early educational experiences, and by Franklin's present inequitable salary. Franklin states that "if things go wrong, women tend to blame themselves...they question their intellectual ability..." Therefore, it is important that students be made aware of biases, individual and institutional (Weiler, 1988). Instead of questioning themselves, saying "What's wrong with me?" students may come to question and challenge the prejudicial motives of individuals or institutional practices. Students need to become more politically aware of discriminatory biases in order to question their existence and to aid in their removal.

It is important for educators to understand the social dynamics that are present in the classroom in order to create change (Anderson, 1992). Boys that fail are encouraged to try harder by teachers, whereas girls are often expected to do less and are permitted to remain silent (Sadker, Sadker, & Klein, 1991) or to engage in passive roles in the classroom (Rosser, 1988).

In addition, bias is still alive and well in the form of sex-role stereotyping by teachers who indicate that women do not do science or that it is not feminine (Mallow, 1986). It is important, therefore, that teachers ensure a more equitable and engaging classroom environment for all students. Kahle (1992) reports that students have viewed teachers as critical influences in their continuation in science, "that good teachers make a difference" (p. 70). Teaching practices that provide direct involvement in laboratory activities, career information, and academic counseling were found to be effective for retaining girls in science. The explicit and implicit curriculum should reflect a commitment to developing human potential and equity. Teachers, parents, and other adults need to consider their own practices within the home and within the educational setting as the sex-roles presented early to young people appear to have a potentially important impact in achieving personal career goals later in life (MacDonald & MacDonald, 1988). It is important that adults take time to talk honestly with girls about the fact that most of them will work for a living during their lifetimes, to talk with them about their plans for the future and about their progress towards goals that they have set, and to take their ideas seriously (Kaseburg et. al, 1980; Girls Inc., 1990).

The social structure and the power relations within a community can open or close access to the amount and kind of knowledge and capital that is required by the community. Throughout these case studies, there are numerous examples of teachers, primarily men, who served as door-openers and also gatekeepers to the progress of women in their careers in science. These men were powerful in that not only could they enable these women to move forward in their careers, but they could also impede their progress. What was critical to the careers of these women was the support that they did receive from male professors, teaching assistants, and research advisors who opened doors with encouragement and assistance so that these women could continue with their work. It was evident that all three women scientists in this study lacked female role models and mentors as they pursued their educational endeavors and scientific research. It important that women also serve in these supportive roles, as "historically, mentoring has been the exclusive domain of the male" (Cullen & Luna, 1992, p. 3) and men primarily support the progress of promising male students (Hewitt & Seymour, 1991).

There are significant advantages for women mentoring girls and women (Cullen & Luna, 1992). The woman scientist and science educator can act as an ally for women and girls and provide access to legitimate participation within the science community and to the acquisition of necessary knowledge and capital. For example, geneticist Barbara McClintock provided other women with mentoring. When Harriet Creighton came to Cornell University in 1929,

> "...McClintock advised her as to what to study, where to live, when and what to avoid. 'It was the best steering anyone could have given me,' [Creighton] recalls" (Keller, 1983, p. 53).

In sum, it appears that what happens in the educational environment and in daily life sets the stage for what girls and all students see for themselves in the future. There is much for the science educator to consider in creating and maintaining an environment that will represent science and science careers as not only open to all, but also as desirable avenues to explore.

Notes

1. Pseudonyms have been used throughout to protect the anonymity of the informants.
2. All informant quotes come from Davis, K. S. (1991). *The participation of women in science: The road less traveled.* Unpublished Masters' Thesis, Evanston: National-Louis University.
3. The aspects of participation are described later in this section.

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Survivors Of The Pipeline: Factors Related To The Retention Of A Group Of Women In Academic Biology

Ann Marie Scholer

Data from the National Science Foundation (1992) show an attrition of women from the study of the life sciences at the transition from college to graduate school, during graduate school, and after training is complete. This attrition results in women being an increasing minority in advanced levels of training and career levels. Previous studies have related certain factors to women selecting and pursuing nontraditional careers: parental support and role modeling (Betz & Fitzgerald, 1987; Hegarty-Hazel, 1991; Oakes, 1990), self esteem (DeBoer, 1984a, 1987; National Science Foundation, 1992), and the perception that young women have that it is currently difficult to manage a career and also have a family (Betz & Fitzgerald, 1987; Hewitt & Seymour, 1991; Rayman & Brett, 1993). As scientific research is a non-traditional career for women, the above factors may contribute to the attrition or retention of women in the advanced levels of the sciences.

This hypothesis generating study explored factors related to the retention of women in the sciences, through the interviews of twenty female academic biological researchers. Educational and career histories were collected to look for factors reportedly or implicitly associated with sustaining these women during their pursuit of scientific training. Analysis of these factors may be useful in understanding which qualities and supports might aid in improving training in the sciences.

Sample

This study involves a sample of twenty women who were successful in becoming academic biologists. Success is defined as having an academic position and conducting biological research. The chosen definition was my original career goal, and is not meant to imply that any other outcome is unsuccessful. The subjects are divided into three groups: faculty within two years of receiving a tenure-track appointment, faculty who are up for tenure or have just received tenure, and established faculty who are at least six years post-tenure. The subjects were identified by networking through the suggestions of advisors, colleagues, or subjects. The sample is distributed between four-year colleges, universities and medical schools. However, due to the small sample size, the results can not be claimed to represent all women in academic science.

Methodology

Qualitative methodology is used to elucidate the nature of a person's experiences, and her motivations. This process does not allow for large samples, or for generalization beyond the sample. However it provides depth of insight, the nature of a person's experiences behind the demographics (Bogden & Biklen, 1982; Strauss & Corbin, 1990). Each of the subjects was interviewed once, using semi-directive questions to allow the subject to report context and issues which she believed important. The interviews were tape-recorded, and the transcripts were submitted to the subjects for corrections and approval. These procedures provide the subjects with control over their contributions to the project, and also enable later reflection on the topics discussed (Bogden & Biklen, 1982; Mishler, 1986). Once the transcripts were altered and approved, the transcripts were then coded, and analyzed individually and collectively for themes. Reported personal histories are subjective in nature. Researcher bias was controlled through the use of systematic collection and analysis of data during hypothesis formation (Bogden & Biklen, 1982; Strauss & Corbin, 1990).

Results

The results of this study implicate several factors as having sustained the subjects of this study in their pursuit of careers in biological research. A universal factor is the attraction to research science. Other apparent factors are a positive self esteem, an independent nature, supportive relationships, and positive interactions with individuals within the scientific community.

The Appeal of Research

An attraction to research science is the most obvious supportive factor among the women in this study. Included in the research schedule is the question, "How would you describe the essence of science?" The responses are noticeably animated in tone and wording. How do things work? And why do they work?

> "Science has been my approach to life, I think ever since I was a little kid" (subject number 016).

> "What fun science is. Even through all the pain and heartache and everything. That one moment when something falls together, it's like Christmas. New Years. All rolled up into one. What fun it is too, to see younger scientists develop. It's marvelous to watch" (010).

After recounting frustrations with her training, a peri-tenure woman added: "I can't think of anything that I would really rather be doing. To

me it's still fun" (012). This enthusiasm for science and scientific research was universal among all of the subjects, including those who described serious difficulties with current or previous stages of their career.

Of particular interest, three women did not discover science until college. For these women, interest in science came from college courses, and the career commitment resulted from experience with actual laboratory research. One of these women recalled wandering from course to course until starting her master's program. "...when I actually did research, that was it" (023) (also 004 and 012). This enjoyment of research and realization of science as a career matches the pattern of career commitment found in the eminent male scientists studied by Roe (1973). Some of her subjects reported an accidental discovery that experiments could be a source of information. The experience with laboratory science and the realization that research could be a career can be critical in choosing to pursue science.

Influences of Parents and Teachers

Most of the subjects discovered science while young, and still in the care of parents and school teachers. These women reported either encouragement or a lack of discouragement from the relevant authority figures. One woman recalled all sorts of experimentation at home and in school with her friends.

> "...we were allowed to do all sorts of experiments in the science labs (in high school), ones that we thought of doing. Some of them, of course were dreadful. (laughs). This gave me the idea that you could play at this stuff, and a *number of us did*." [emphasis hers] (015)

She also recalled clearing her neighborhood of nutmeg for homemade fireworks. The daughter of a biologist and a physician recalled:

> "And I remember my parents (I can't remember if my mother or my father), would give me when I got old enough, things like 'Marie Curie' and 'Microbe Hunters', and things like that to read. (laughs) So you might say I was encouraged in that direction."

A peri-tenure woman was particularly inspired by a woman who taught her high school chemistry

> "She was a brilliant chemist who was ahead of her time, and was teaching high school as a result, and was just very good at it. ...and she was such an inspiration. And she taught us so much advanced biochemistry at that young

> age, that I was convinced this was the hottest thing that I had ever heard." (017)

Many of the women referred to teachers, parents or both as positive influences in their pursuit of science. In contrast, three of the women reported being discouraged from continuing by college instructors (009, 020, 0222). Two of these women switched from their initial majors, (physics and chemistry) to others, and then eventually to biology. Such positive and negative reports indicate that teachers and family members can have a major impact on the career decisions of young women.

Self Esteem and Independence

In addition to the inherent rewards of a career in science, many of the women interviewed showed evidence of a positive self-esteem, and an independent nature. Self esteem is inferred through the response to the questions: "Do you consider yourself successful?" and "What do you consider to be your career milestones?" One established professor answered:

> "...I have decided what is successful for me. And I certainly think that I have achieved most of what I want to do. And getting paid for my hobby. How much more successful can you be?" (011).

A peri-tenure woman who had nearly left science more than once, responded: "...I think just surviving has been the milestone" (018). When asked about serving as a role model, another peri-tenure woman indicated a low self-esteem.

> "But I find it very difficult to offer myself as a mentor...when I feel like I have not succeeded. Like I would be a poor role model." (023).

She referred back to these comments, when asked if she was successful. A young faculty member couched her response in conditional terms.

> "I don't consider myself to be a success, but I think a lot of the people around me will consider me to be a success. I don't know how much of it is that my own security has been eroded over the years, or how much of it is wanting to have continued self-approval. How much of it is good, and how much of it is pathological. But I keep saying, 'Well, I'll be successful if.."

A peri-tenure woman at a high-profile institution indicated that her location was having some effect on her self view

"... the environment that I'm in...is not conducive to viewing myself as successful. On the other hand , there are clear and strong values that I have about science, that I am living up to. And...in that sense, I *am* successful. And I would not want to be any other way." [emphasis hers] (019).

Self esteem is evident in some answers, in the subject's self description. Evidence for a positive self image (or the absence of such) can also be found in the absence of conditionals for future success, and in the attribution of success to internal qualities. Independence is inferred through the coping methods reported by subjects to deal with conflicts, and with failed experiments.

"As a graduate student, I was so mixed up, that half of the time I would just work through the night. That never really produced the appropriate amount of awesome data at the other end that I thought it would. But it made me feel less guilty." (017).

Another source of evidence for independence is the reported use of internal standards for self-evaluation.

"...I used to look at myself and say, I don't produce enough papers. ...But I tend to be very encompassing. And I tend to do things very thoroughly. And I now have come to appreciate what I do myself." (010) (see also 019, above).

For several women, the reported self esteem and amount of independence improved over time. This may be a result of accumulated success, or of distance from graduate school experiences.

Several studies have shown that women experience lower self esteem than their male peers, especially in competitive, male-dominated, and ability-comparing fields (Betz & Fitzgerald, 1987). In Hewitt and Seymour's (1991) study of college students in science, math and engineering majors, 77% of the females and 43% of the males who switched out of these majors reported a loss of self-esteem while they were in the major. Those students with internal standards of excellence are more likely to stay with science (DeBoer, 1984b; Hewitt & Seymour, 1991). The gender differential in self-esteem may be related to the greater attrition of women from science, through self-elected departure.

Lower female self-esteem may also be related to the apparent need of women for female role models and other supports, and possibly to the lower publication rates of women. The latter could be due to excessive self-censorship, and to scientists who are running too many control

studies before publication (Aisenberg & Harrington, 1988; in-house study cited by 009).

Support within the Scientific Community

For several women, a major factor of continuation was the support of other people. In addition to support from family and high school teachers, these women reported finding advice and encouragement from peers and academic authority figures.

> "I'm sure I would have quit, had I not either been married [to a graduate student], or had strong friends, or had strong advisors. There was always someone that sort of stepped in, right at a time that I was kind of...throwing up my hands." (018).

When asked about female role models, a senior professor described a group of female peers, with whom she met over the years.

> "There are certainly women that I've come to admire enormously, but more of them are of the same generation that I am. It's a lateral sort of thing. And we did mentor each other."(015)

A peri-tenure woman reflected on her negative experiences in graduate school and reported:

> "I think if I had not gone to the lab in (another country), I probably would not have stayed in science. He (her post-doctoral advisor) taught me how to survive and what science was really about. Hopefully you get that when you're doing a Ph.D., but talking to many of my colleagues, it sure doesn't happen very often." (012).

Such support from within the scientific community has been reported as essential by many of the women in this study. One major use for support by scientific colleagues is role modeling, including advice regarding the balancing of a career and a family. One peri-tenure woman realized the importance of role models in graduate school, while she had been observing a female professor.

> "I realized when she became pregnant, that up until then I had taken it for granted that you could be a woman and be a professor, but it had never occurred to me that you could also be pregnant and be a professor." (019).

Another woman of the same age is still debating whether or not to have children.

> "I've spent hours talking to my peers, who are women who have children: 'How did you do it? What were the ways in which you could actually interweave these problems?'" (017)

The potential conflict between family and a research career was a reported concern for most of the new and the peri-tenure subjects in this study.

> "My being a role model in this sense is actually not entirely positive; because there are people who see me, and they say to me, 'You know, I'm not going to do what you're doing. That's too hard.' And it is hard. ... It is very difficult to juggle a time-intensive job like this with two young children." (019)

Some women also voiced concern about finding the time needed to maintain personal lives with spouses or friends. Concerns about the time and energy commitment necessary for science, and their resulting impact on a personal life have also been observed among college and post-college women in science (Rayman & Brett, 1993; Hewitt & Seymour, 1991).

The use of interpersonal support systems within or outside of the scientific community was commonly, but not universally reported by the subjects of this study. However, such supports do match recent findings on peer support among college students who remain in the sciences. Hewitt and Seymour (1991) found that the students who remained in science, mathematics and engineering majors were more likely to have made use of the support of student clubs, science dormitories and faculty advice. Astin and Astin (1992) found that the retention of students by a particular major corresponded to the number of students within that major. The authors speculate that a minimum 'critical mass' of students is needed for peer support, including study groups and lateral role modeling. One subject of this study concurs:

> "Institutions which allow a kind of village culture for young scientists are very good. Where there are groups of people, either peers or mentors...that allow people to talk about science, and to compare their experience with other people. ...we all seem to need a kind of social factor...when you strike out to do something."(015).

Another subject described envy for the supports given to the medical students at her graduate school.

"I think if we had something like [the medical school support systems] for graduate students...instead of having everyone isolated, by themselves in a lab for five years, or six years. And you know, you start to...I think it really erodes a lot of self-confidence."(022)

Most of the women in this study did not directly address the topic of social support during graduate training in the sciences. However, several women did either directly or indirectly indicate that they experienced some degree of alienation or isolation during the start of their advanced training.

Summary and Conclusions

For the subjects of this study, the most commonly reported influences for pursuing and remaining in a scientific career were the desire to practice scientific research and the associated academic rewards. Most women reported a general interest in science, originating in childhood. Such interests were often encouraged by parents and/or teachers. Several women reported making the critical decision after a first experience with self-designed experimentation. In three cases, such experiences did not occur until college study.

Many of the subjects showed evidence of independence and a healthy self-esteem. These qualities were more in evidence among the more senior faculty than with the new faculty. This may be due in part to negative experiences reported by some subjects in graduate school. Another contributing factor may be the loss of self-esteem among college women which has been reported in several studies, perhaps in part because training in teaching methodology and gender-inclusive issues are rare among college faculty in the 'hard' sciences.

Many of the women in this study reported support by their peers, as well as faculty and other members of the scientific community. Peers were reportedly sources of lateral role modeling and information, and as collaborators and networking contacts in later stages of the career. A few women did not report any personal support, and in addition exhibited or described periods of low self-esteem. This is of some concern, at least in part due to the description one woman gave of graduate school:

"...science doesn't work eighty or ninety percent of the time; and so you're miserable (in graduate school), because that's all you do, and it doesn't work." (021)

The results of this study indicate a few possible areas through which some women may be aided in their pursuit of a career in science. Exposure to open-ended experimental opportunities appears to be

important for some of those who are now scientists. A few women reported such experiences as critical for choosing a career. It is impractical to have every high school student intern in a research laboratory. However, one or more multi-session, open-ended classroom laboratory experience may enable the average student to better appreciate the scientific process.

Another area of concern is the increased attrition of women in advanced training in the life sciences. The educational experiences of female and male science majors might be further examined. In addition, the concerns of such women (and men) about their potential future lives as scientists could be directly addressed during class or in workshops, while still in college. As a possible source of support, inter-peer and inter-level meetings with other female scientists could be organized. A few colleges are now experimenting with all science residence halls and all female science residence halls (Daie, 1994). Departmental encouragement of both formal and informal gatherings, such as those that occur in medical schools, would aid in countering the isolation often reported by graduate students. This is particularly important, since most graduate students live off-campus. Such meetings could also aid in the creation of mentoring and role model relationships, especially between those groups which are chronologically close but do not often meet, such as the college and the graduate student.

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A Gendered Construction Of Engineering In The Academic Context

Lisa Ann Petrides

After nearly three decades of research and reforms that were intended to increase the flow of women in the engineering pipeline, there are still relatively few women in graduate engineering programs. In this paper, I argue that the gendered construction of the engineering profession and disciplines is a neglected factor in explaining the dearth of women in graduate engineering programs. I hypothesize that the gendered construction of engineering which is experienced by women and men in these programs, renders engineering graduate school unattractive to women.[1] I believe that the study of women's and men's experience in these programs helps us to operationalize the gendered construction of the engineering academic context and understand how gender inequalities are perpetuated (Farganis, 1989; Smith, 1987).

The study combines literature from two disciplines, labor economics and organizational theory, both of which have been previously used to explain the absence of women's participation in science and engineering fields. The link between these two disciplines may provide new insight into how the gendered construction of the engineering academic context in graduate programs is negotiated differently by women and men in engineering programs. Therefore this exploratory study relies on the experience of women and men as a window into the engineering academic context and provides an understanding of how experience within the educational system ultimately shapes the supply of women for entry into the profession.

This paper combines an analysis of gender distribution across several engineering concentrations, with the results of a study based on the responses of 60 graduate engineering students (30 male/30 female) to several open-ended questions on a survey administered in May 1994. The data are a subset (taken by random sample) of a larger study which surveyed 1000 female and male masters and Ph.D. students across five concentrations of engineering at "Green University."[2] The goal of this paper is to discover emerging patterns in the experience of men and women in these programs which will guide the future analysis of the larger study. In choosing this select group from the start, I have limited myself to studying only those who are currently inside the engineering pipeline and therefore cannot account for those who are not. Additionally, surveying students at only one university limits the understanding of possible school and departmental effects. However,

focusing on this one site provides rich detail into the experience of men and women in one particular academic setting.

The first section presents the conceptual framework for the study, including a brief review of relevant literature. The second section presents a quantitative analysis of gender segregation and wage differentiation in engineering and the third section of this paper explores the existence of a gendered construction in the graduate school environment as reported by the experience of female and male graduate students.

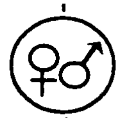
Conceptual Framework

Several empirical studies have provided post-hoc theories of the barriers responsible for the absence of women in engineering (Eccles & Jacobs, 1986; Vetter, 1992): role models, test scores, parental encouragement, and the myth of male math genes as possible explanations for the relatively small number of women in engineering (Benbow & Stanley, 1980; Hyde, Fennema & Lamon, 1990; Linn & Hyde, 1989). Recommendations from these studies have generally encouraged girls to take more math and science in school and to improve the visibility of role models for girls. These studies assumed that programs that increased the representation of women in math and science would ultimately produce a larger supply of women in the engineering pipeline. However, the relatively low numbers of women in engineering professions twenty years later indicates the need to re-examine factors thought to contribute to this phenomenon.

The following section provides a brief overview of the conceptual framework used to help interpret the findings of this paper. The model below contains two components which suggest a possible link between gender distribution within engineering concentrations and aspects of the graduate school environment. I suggest that the interaction between these two components can be used to represent the gendered construction (the way gender is both constructed and experienced) in the engineering academic context. (See Figure 1.) I hypothesize that interaction effects may either negatively or positively affect the experience of women and men within engineering concentrations.

ENGINEERING CONCENTRATION

Prestige and Status
Gender Distribution



ASPECTS OF GRADUATE SCHOOL ENVIRONMENT

Tokenism
Sexualization of Learning Environment
Access to Social and Professional Networks

Figure 1
The Gendered Construction of the Engineering Academic Context

The component engineering concentration is comprised of two parts: its perceived status and prestige, and the distribution of gender within the concentration. Occupational segregation theory, which explains how it is decided which gender takes the prominent role in particular occupations and describes the forces that stabilize this gender composition, will be used as a way to examine the forces within engineering concentrations which prevent an equal gender composition, not only relative to other disciplines, but also across concentrations within engineering (Blau & Ferber, 1992; Strober, 1992; Walby, 1988). Additionally, patterns of wage inequities are frequently found in occupations that are nominally integrated (Jacobs, 1986; Strober, 1992). Therefore gender segregation within engineering concentrations in graduate school may contribute to and perpetuate a higher percentage of women and minorities in occupations that have less prestige, status and pay.

It has been found that women who attempt to defy the norms of occupational segregation by entering non-traditional professions, are confined to positions of lower status and visibility with fewer opportunities for promotion (Epstein, 1974; Kanter, 1977; Strober, 1992).

The second component of this model is aspects of the graduate school environment that are explained in organizational theories: tokenism, sexualization of the learning environment, and access to social and

professional networks. Tokenism theory is used to examine social roles and relationships of power within an organization where there is a minority population (Epstein, 1988; Kanter, 1977; Zimmer, 1988)[3]. Effects of tokenism take their toll on women when they enter an all-male profession because tokens are judged more critically and have to work harder to prove their competence (Kanter, 1977). Research on tokenism within organizations has shown that the percentage of tokens affects the experience of the token individual in terms of such things as isolation and discrimination (Kanter 1977; Yoder, 1991). For example, there may be very little resistance to tokens within an organization if they comprise a small percentage of the total, but as that percentage increases, the majority group may become resentful, resulting in hostile or defensive actions which may negatively affect the experience of the token individuals (O'Farrell & Harlan, 1982).

Gender politics in engineering often do not support women in engineering education. For example, researchers have noted a "chilly climate" for women in the workforce and in graduate school where the structures of engineering hierarchies have not given into the pressures for the acceptance of women (Hall & Sandler, 1982). I will look for tokenism and its effects on the token's experience in engineering as demonstrated by lack of role models, negative interactions with faculty members, performance pressures, discrimination and isolation (Izraeli, 1983; Yoder, 1991).

Kanter (1977) has shown that unequal access to social and professional networks result in isolation from peers in work and lab groups, and a potential loss of future opportunity provided by "old boys" networks. Women often find it extremely difficult to enter into the "old boy networks" in the workplace. These networks are often the place to learn the ins and outs of the profession, such as learning how business works as far as earning promotions and raises (Gibbons, 1992; Hall & Sandler 1982). Additionally, unequal access to social and professional networks is an outcome of the gendered construction of engineering graduate education which contributes to the lack of mentors and role models, and limits the type of interactions with faculty and advisors that may be available to students (Vetter, 1992).

Sexualization of the learning environment occurs when there exists behavior and culture which objectifies or sexualizes women, such as sexual harassment (Enarson, 1984). Additionally, sexualization of the learning environment creates cultural contradictions which can be internalized by women in the process of negotiating opposing demands of the culture (Fee, 1991). This behavior, which is manifested in the gendered construction of engineering, will be measured by incidents of unwanted sexual interactions with faculty and peers, as well as by evidence of a culture which promotes this behavior (Swerdlow, 1989).

This paper is a preliminary sketch that depicts how the elements of a complex picture might fit together in order to explain how the experiences, beliefs and expectations of men and women shape the academic context in which they pursue graduate education. I intend to identify interactions among these two components in order to understand how women and men experience and negotiate the gendered construction of the engineering academic context. For example, the dotted line which represents a possible connection between engineering concentration and aspects of the graduate school environment could be verified if it is shown that women have greater access to social and professional networks in concentrations that have relatively few women (e.g. 4%); or that there exists some percentage threshold of gender distribution (e.g. over 15%), after which women experience less discrimination and decreased effects of tokenism.

The Engineering Concentration

This section provides a quantitative overview of two gender patterns within engineering concentrations: segregation and wage differentiation among engineering degree recipients in the workforce. These two patterns provide insight into the construction of status and prestige across engineering concentrations which will be reexamined in context of the experiences of women and men in engineering graduate programs in the final section of this paper.

Although the number of women receiving engineering bachelor's degrees has increased over the past 20 years, the percentage of women in M.S. and Ph.D. engineering programs is still extremely low. In 1990, women received 15.4 percent of the bachelor's degrees granted in engineering (up from 10.1% in 1980), 13.6 percent of master's degrees in engineering (up from 7% in 1980), and 8.5 percent of the doctorates in engineering (up from 3.6% in 1980)

In 1983, engineering schools experienced a dramatic surge in female undergraduate enrollment, and observers thought this increase would appear in the supply of women doctorates in 8-9 years (National Research Council, 1993). These predictions proved false. Today, only 2 percent of engineering school faculty members are women (Nobbe, 1990), and the latest findings of a National Science Foundation study reveal that in 1990, only 3.5 percent of all women who were awarded a doctorate degree received an engineering Ph.D. (versus 19.5 percent for men) (NSF, 1992a). The percentage of female doctoral scientists in engineering is the lowest of all academic fields (Brush, 1991), and according to the Bureau of Labor Statistics, only 8.2 percent of employed engineers in the United States are women (Shinberg, 1992).

Table 1 shows the number of graduates who received a B.S. in 1992 by eight engineering concentrations. Column (1) shows the total number of bachelor degrees received in each of the eight fields. The numbers in column (2) are the percentages of women across the eight concentrations, ranging widely, from 10.6 percent (in mechanical) to 31.8 percent (in chemical). It is interesting to note that the two largest concentrations, mechanical and electrical (14,737 and 18,337 from column (1)), have two of the smallest percentages of women, 10.6% and 12.2% respectively as shown in column (2). The two highest concentrations of women as a percentage of the total as shown in column (2) are chemical (31.8%) and industrial (28.3%). Columns (3) and (4) show the percentages of all engineering graduates accounted for by a particular concentration. While mechanical and electrical combined account for over 54% of the total men, but only 37% of the women. Chemical and industrial are the only concentrations where the percentage of women as a percentage of the total number of women in engineering is higher than the percentage of men as a percentage of the total number of men in engineering. In civil engineering the percentages of men as a percentage of the total number of men are comparable for women (13.2% and 13.4%).

Table 1
Percent Of Graduates Receiving B.S. Degree in 1992, By Engineering Concentration and By Gender

	Total B.S. 1992 (1)	Women as % of Total (2)	Men as % of Total Men (3)	Women as % of Total Women (4)
Aerospace	2,915	11.7%	4.8%	4.6%
Chemical	3,849	31.8%	4.9%	12.3%
Industrial	4,083	28.3%	5.5%	11.6%
Civil	8,413	15.9%	13.2%	13.4%
Mechanical	14,737	10.6%	24.5%	15.7%
Electrical	18,337	12.2%	30.0%	22.4%
TOTAL:	53,895	100.0%	100.0%	100.0%

Source: Engineering Manpower Commission, 1992 Degree Survey.

Table 2 shows the number of graduates who received a Ph.D. degree in 1990 by the eight engineering concentrations listed in Table 1. The percentage of women ranges from 2 percent in aerospace to 17.8 percent in biomedical (column 2). Since the number of B.S. degrees granted in certain concentrations is correlated with the number of Ph.D.'s granted (the pool of Ph.D. applicants comes from B.S. recipients), it is not

surprising that the numbers in Tables 1 and 2 have similar patterns. For example, a comparison of column (2) in the two tables shows that women as a percentage of the total drops approximately 60 percent for each concentration, with two exceptions (biomedical decreases by only 2 percent and aerospace decreases by 82 percent). A comparison between column (4) of Table 1 and Table 2 shows that the distribution of women as a percentage of total women changes quite dramatically in several concentrations between the B.S. and Ph.D.[4] Increases are shown in materials science (2% to 10.3%), biomedical (2.4% to 7.9%), and chemical (12.3% to 24%). Small decreases occur in three concentrations, aerospace (4.6% to 1.4%), industrial (11.6% to 8.6%) and mechanical (15.7% to 10.3 %).[5]

Table 2
Percent Of Graduates Receiving Ph.D. Degree in 1990, By Engineering Concentration and By Gender

	Total Ph.D. 1990	Women as % of Total	Men as % of Total Men	Women as % of Total Women
	(1)	(2)	(3)	(4)
Industrial	151	16.6%	3.7%	8.6%
Aerospace	192	2.1%	5.5%	1.4%
Materials Science	306	9.8%	8.0%	10.3%
Civil	505	7.9%	13.6%	13.7%
Chemical	560	12.5%	14.3%	24.0%
Mechanical	771	3.9%	21.6%	10.3%
Electrical	1,110	6.3%	30.3%	24.0%
TOTAL	3,724	100.0%	100.0%	100.0%

Source: National Science Foundation (1992).

Certain concentrations within engineering command higher status and prestige than others. For example, electrical engineering is perceived as being more innovative and technically sophisticated, whereas mechanical engineering is seen as standardized and predictable (Noble, 1977; Mcilwee & Robinson, 1992). Additionally, biomedical, industrial and chemical are perceived to be the most qualitative of the engineering concentrations. Biomedical and chemical have their origins in the biology and health professions which tend to have larger numbers of women in them. Industrial engineering is often perceived as having the lowest status in the profession due to its "non-scientific" and less technical nature.

A study by Nobbe (1990) of male and female engineers indicated that female engineers often end up in more service-oriented jobs with less status. A service job in engineering may require a person to do experiments or test samples of other people's projects. However there is higher perceived status if a person has her or his own lab or project. Many women engineers are encouraged to go into service jobs such as engineering marketing, especially if they want to be in management positions. Men tend to have the more prestigious jobs such as working in labs, while women are more likely to hold marketing and manufacturing positions which have lower status and pay. Mary Anne Cline from the organization Women in Electronics says, "Many women get out of engineering after a few years and go into sales and marketing because many companies prefer their sales people to have an engineering background. Women tend to do very well there" (Nobbe, 1990).

Salary Differentiation

Table 3 shows median annual salaries for males and females with doctorates in engineering. Column (3) presents female salary as a percentage of male salary. The highest Female/Male (F/M) salary ratios are in the concentrations where women are least likely to be found: electrical, aeronautical and mechanical. This directly contradicts classical economic theory which supposes that rational choices would result in both women and men pursuing the opportunity which has the highest payoff to them.

Table 3
Median Annual Salaries by Concentration

	Male (1)	Female (2)	Female/Male Salary Ratio (x100) (3)
Chemical	$63,700	$51,700	81.16%
Materials	$62,100	$52,600	84.70%
Civil	$58,600	$50,300	85.84%
Electrical	$67,400	$58,500	86.80%
Aeronautical	$61,000	$55,000	90.16%
Mechanical	$60,700	$57,000	93.90%

Source: National Science Foundation: 1991.

Table 4 shows median salaries by employment sector. While I have been unable to locate the actual numbers of women and men who are in each of these sectors, the figures in column (3) indicate that female/male salary ratios tend to be lowest in sectors where there is a higher percentage of women, such as in management and administration positions. Additionally, the highest F/M salary ratio is found in applied

research and development as is shown in column (3), which is a sector typically comprised of a smaller percentage of women. These findings are supported by several other studies which draw similar conclusions (Mcilwee & Robinson, 1992; Nobbe, 1990; Shinberg, 1992). A study by the Engineering Manpower Commission notes that women engineers are often in more task oriented areas such as inspection, statistical reporting, computing and teaching, which are less prestigious and lucrative (Shinberg, 1992).

Table 4
Median Salaries by Employment Sector Type

	Male (1)	Female (2)	F/M Salary Ratio (3)
Research & Development	$55,600	$45,300	81.47%
Basic Research	$54,200	$42,500	78.41%
Applied Research	$55,500	$47,000	84.68%
Development	$60,000	$50,500	84.17%
Management of Research & Development	$74,300	$57,900	77.93%
Management general	$64,300	$48,300	75.12%

Source: National Science Foundation Median Salaries 1991

The figures and tables in this section illustrate gender segregation within engineering education (which then gets passed on to the workforce), as well as gender wage differentiation by concentration and by job sector. While these figures raise more questions than answers, I suggest that these factors provide insight into the experiences of women within engineering concentrations by showing how the effects of social and economic forces play a role in how gender gets constructed in engineering, and how this manifests differently across concentrations. For example, if women are disproportionately in engineering concentrations which are perceived as low status (therefore attracting fewer men), does tokenism play as critical a factor in the experience of women, as compared to a concentration such as aerospace which has a very small percentage of women?

Aspects Of Graduate School Environment

This section reports the responses to several open-ended questions from female and male graduate students in engineering programs at Green University. The questions, which were intended to be exploratory in nature, asked students: 1) to describe the culture of graduate school in their area of concentration; 2) to discuss what they like and dislike about engineering; 3) to describe the types of pressures which were

experienced with regard to their performance in class and in labs and; 4) to report experiences of discrimination. The open-ended question format captured the richness and complexity of experience within the various concentrations. The breakdown of respondents by concentration is listed in Table 5.[6]

Table 5
Respondents at Green University

	Women	Men	Women as % of Total Students in Concentration Green [7]
Aerospace	3	2	5%
Chemical	3	3	31%
Electrical	9	12	10%
Industrial	4	4	25%
Mechanical	11	9	12%
Total	30	30	

Due to the small sample sizes used for this paper, I have combined the five concentrations into two categories in order to maintain the anonymity of students' responses. Aerospace, electrical and mechanical are grouped together as "extremely low," (which refers to the number of women in these concentrations), and chemical and industrial as "low."

Culture

The most significant concentration differences were found in student responses to the question which asked them to describe the culture in their concentration. These divisions were further subdivided by gender. For example, while the culture was in some cases reported by women to be more friendly and cooperative in the "low" concentrations, other factors such as likes and dislikes of engineering, pressures to perform, and discrimination were still reported to be about the same across both categories. Answers to the question on culture demonstrated the existence of a wide range of understanding and interpretation of "culture." Several emergent themes arose from these data, which I have broadly categorized as descriptions of culture and impact of culture. They include competitiveness, cooperativeness, faculty versus students, an all-consuming work load (i.e., a 7 day work week), and gender and minority imbalances.

Six women (20 percent) of the total women said that the culture was very competitive, and four women (13 percent) mentioned that their concentration was extremely male-dominated (all of these women were in the "extremely low" concentrations). Said one woman,

"The strong gender imbalance has negative effects on me. [I] feel isolated being a minority."

Inversely, women in the "low" category consistently noted that their concentration was quite relaxed in terms of faculty-student relations and that while, individually, some students put immense pressure on themselves, the atmosphere in general was not competitive. One woman noted,

"There are great students with good student interaction and support. [Although there are also] inaccessible faculty who want to minimize time and effort with students."

This response is consistent with theories of tokenism discussed earlier which suggest that a "token" (in this case a women) will experience a greater degree of isolation based on the degree to which that person is a token individual. Men in "extremely low" concentrations often described the culture as, "exciting, motivating, intellectually stimulating, and interesting." Several men remarked that the culture lent itself to being a "very self-motivated, confident, creative and eccentric place to study." Women in the "extremely low" concentrations tended to be slightly more extreme in their comments about culture often describing it as "very conservative" and "extremely male-dominated." Men in the "extremely low " concentration also often noted that the culture was, "a very rigorous environment that leaves little room for outside activities. In my concentration, the graduate environment is very professional and formal." Whereas one man in a "low" concentration noted that, "the culture was tolerant of diverse opinions and supportive, there are cooperative attitudes among students."

Women among the "low" concentrations seemed to express a wider range of experience, often feeling more comfortable in the surroundings than women in the "extremely low" concentrations. For example, while they tended to be quite self-aware of the isolation experienced as graduate students, they were more willing to try and play by the rules of the game. One woman said,

"Most students strive for excellence but are willing to help each other. I have heard it compared to being comrades in a war. We all struggle together."

Yet another woman complained,

"It's kind of a good ol' boy network culture--lots of chumming up to profs and playing 'see who comes in the earliest and stays the latest.'"
Alienation from the "good old boy network" was also experienced among minority men. Said one minority man in an "extremely low" concentration,

> "Professors are subjective, biased, white and made of the 'old boy' school."

It is interesting to note that in this sample, the "extremely low" concentrations enroll the largest number of students, and that several men in these concentrations commented that "largeness" of the program resulted in a lack of cohesion among students. Said one man,

> "In our specific lab the culture is pretty good. The students are able to freely converse and share ideas. My advisor keeps the inter-student rivalries to a minimum. In the department as a whole, it sucks. It is so large that there is NO camaraderie."

Both men and women across all concentrations made reference to the long work hours and arduous work load, and the lack of outside life. Eight men (over 25 percent) noted that the culture forced them to care about nothing other than work, while 6 women (20 percent) also noted that the culture was competitive and exhausting with little time for social life. One woman explained,

> "The culture drains enthusiasm for research and success from initially ambitious graduate students."

Many women in this sample tended to describe and interpret culture as something that they had no choice but to experience from day-to-day whereas men more often tended to define and interpret culture as something outside of what they experienced. For example, more men were apt to simply say that the culture was poor or non-existent, whereas women often gave longer descriptions of culture and its implications for them as members within it. Six women and twelve men left the question on culture blank, and another six men said there was no culture or that they were "too busy to have much culture," whereas only one woman responded to the question in that way.

Additionally, women and minority men were similar in that they reported several experiences of token status in their concentrations. Both groups mentioned the "old boys" mentality that was ingrained in the culture and how they felt that it discriminated against them. While several students experienced token status, it will take a further analysis along gender and concentration lines to determine the extent to which these factors prove salient.

Further research and analysis will be done in order to examine more carefully the differences between culture which is specific to engineering versus the culture of being in graduate school in general. Other themes for further investigation include lack of faculty support, and feelings of

being overworked and exhausted in terms of common graduate student experience which may cross disciplines in other areas of higher education.

Likes And Dislikes

Students were asked two separate questions about what they liked and disliked about engineering. Across all concentrations, over half of the women said that they liked the problem-solving nature of engineering. Six women (20 percent) cited the objectivity, the logic, and the predictability of engineering. Several women also noted that they like to "tinker with things" and to "make real things work." One woman said,

> "You can try to find solutions to a problem in a concrete, logical way, even if the solutions don't exist. I don't like thinking about questions that are abstract and that can have millions of conflicting answers, such as the ones you encounter in English or philosophy."

Almost all of the women sampled said that they liked engineering because it was "rigorous" and "fun," and a few of the women said that they liked making things that would make the lives of people better. Women across all concentrations reported that they liked engineering because it was very practical and results oriented. Several women also noted they would be able to enter industry from a variety of angles by having a broad scientific view.

Similarly there were no differences across concentrations as reported by the men with regard to their likes and dislikes in engineering. Twelve men (40 percent) men said that they liked engineering because of its problem-solving nature. Six men (20 percent) said they liked engineering because it was logical and objective, had clear and rational objectives, applied science to real life problems and that it was creative, that it "opens to us the world of science while still being close to the applications." Five men said that what they liked about engineering was that it was technically challenging, and that it helped to push the boundaries of science. Said one man, "It allows me to make my hobby into my career." Another man commented that,

> "everyone develops a balanced sense of creativity and pragmatism. It's a cooperative discipline. It seems to attract (or create?) people who are trustworthy, reliable, and personally conservative in behavior."

Several women reported that they disliked the competitiveness and pressure in engineering, and that engineering was not paid as highly as it should be given the investment of education required. Eight women (27 percent) also noted that they disliked the fact that there were so few

women in the field, and two women disliked how their field of concentration required prior exposure to certain subjects which they did not have. Said one,

> "When you work in a male-dominated field, some males (especially older ones) are reluctant to give a woman anything mechanical to do (I'm referring to summer internship experiences.) Also, it's hard to have the hands-on experience that the male students have because dads typically show their sons how mechanical things work."

Seven men reported that they disliked the long hours and tedious workload of engineering and another six men commented that the salary compensation was not commensurate with the years of study required. A small percentage of the men disliked the lack of social interaction in their concentration, and also disliked the politics of funding for engineering projects. Several other comments included references to the constantly changing technology which was difficult to keep up with, the lack of women in the field, and the narrow-mindedness of people within engineering. Said one man,

> "We [engineers] are out of the limelight, not understood by the public, and [we] are not considered as important as medicine or law."

It appears that both men and women who pursue graduate school in engineering have similar likes and dislikes in terms of their predilection for the "problem-solving " and "logic oriented" nature of engineering. Also the rigorousness and practicality of engineering emerged as prominent themes for the majority of all students. Twenty-five percentage of the men reportedly disliked the long hours they had to spend in their engineering program, twenty percent of the women gave a similar response. Conversely, women were alone in their dislike for the competitiveness in the field. Additionally, women disliked the fact that there were so few women in their graduate programs and tended to experience a greater sense of isolation because of it. It is interesting to note that men and women reported very similar "likes" in engineering in regards to their approach to subject matter (i.e., the problem-solving nature of engineering), but that only women mainly expressed their discontent for the social context in which engineering is practiced, namely, the competitiveness and isolation they experienced as women.

Pressures

Students were asked what types of pressures they experience with regard to their performance in class and labs. Over half of the men and women commented that self-imposed pressure or the internal pressure to be "perfect" was the main type of pressure experienced. Additionally,

several students also noted that they often felt the need "to be one of the best or better than everyone else." Six men and six women said that they felt under extreme pressure to keep up with the "other exceptional people here." As one man noted,

> "There is pressure to be flawless, nothing short of brilliant. Most of the pressure though, comes from the competitive drive of fellow students."

Other pressures included the difficulty of life as a student and as a husband/father or wife/mother. Several other themes arose with regard to academic work in general such as the pressure of doing research and coursework at the same time, getting good grades, parental expectation, publishing research and the pressure to finish graduate school. One woman commented,

> "The pressure is academic. You have to be brilliant, intelligent and be up-to-date. You are not supposed to have bad days or weeks."

Three women, and all of the minority men said that their minority status in some way added an increased pressure to their work. Said one woman,

> "Because there are so many Ph.D. students under my advisor and because I am receiving funding specially earmarked for a female Ph.D. candidate, I feel a lot of pressure to stand out in the crowd."

And a minority male student commented,

> "[The pressure of] being one of a small number of black students in engineering higher education is both motivating and a burden."

It is hard at this point to discern how and if the pressures experienced in engineering are different across concentrations. Therefore it is difficult to determine for example, how pressures experienced in engineering are really any different for students in biology or education. What is evident from the findings is that men and women in engineering are under a great deal of self-imposed pressure to be the best at what they do, and that minority status has an additional significant effect on academic pressure experienced by the minority student.

Discrimination

Twenty women (67 percent) reported that they had not experienced anything which they had perceived as discrimination in their program,

while two women (7 percent) reported that they had experienced discrimination. An additional eight women (27 percent) answered "not really" and then went on to describe a feeling or situation. It was left to the reader to decide if these feelings and situations were considered examples of the presence of discrimination. For example one woman said that she felt that her advisor was "especially 'generous'" and felt uncomfortably singled out for additional praise just because she was female. Another woman in the "not really" category commented that, "some professors are going out of their way to point out every mistake I make, even when there were not mistakes to begin with."

Another in the "not really" category remarked, "Discrimination is too overt. I'm ignored and abandoned mostly [by faculty members]" Yet several women noted that they were bothered by "too much attention." Women who did experience discrimination also reported having difficulty expressing specific incidents of discrimination and often referred to it as a "subtle" or "symbolic." For example one woman said,

> "It's probably more symbolic stuff than anything--like one woman graduating with a Ph.D. was introduced as "Mrs." instead of "Dr." at her graduation! Arrrghhhh!!!!"

As mentioned earlier, "standing out in the crowd," as a minority (either as a woman or as a minority man) was reported to have a negative effect on student experience. One woman said,

> "I have not really experienced discrimination, but I feel being female makes me very visible. My mistakes and accomplishments are both highlighted. Although sometimes I feel I have to prove myself more than the average male student to new students."

One woman articulated the distinction between the subtle and the not-so-subtle. She explained,

> "[Male] students and professors tend to make me feel like I have to prove my knowledge before taking me seriously. Although sometimes it is less subtle...[An] overhead of [a] woman in lingerie during a seminar (I'm the only female student)...[And then the] lack of understanding to my protest/complaint."

While one women reported a less subtle experience,

> "I know of one woman whose professor would throw bachelor's parties with strippers for the men in the group and would take the men to topless bars while the group

was at conferences. Some [women] have also had troubles with 'Playboy' pictures around the labs."

Women in "low" concentrations did not report experiences of discrimination. One woman observed,

> "Not at all. We have nearly 50% females [in my lab group]. I'm one of the first students to take a maternity leave this early in graduate school and yet the entire faculty/staff is very very supportive. They've given me the liberty to take off as much time needed to get settled in my life. There was no pressure to hurry back and start working."

Men were also asked if they had experienced anything that they had perceived as discrimination in their department and if they knew of other students who had experienced discrimination. Twenty-four men (80 percent) reported no discrimination. Of this group, almost all just wrote "no" without any commentary. Several men did report incidents of discrimination of women that they had known who had been in their departments. One man said,

> "In our department the few women who try [to make it through the program] seem to have, generally speaking, a harder time than most men, and I attribute that to our faculty, sad enough."

Additionally, six men (20 percent) reported personal experiences of discrimination. Half of those cases were cases of discrimination against minority men and the other half reported reverse discrimination. Said one minority man,

> "I have repeatedly experienced a very condescending attitude from several professors and students. It seems that my Hispanic origin is an indication to some that I have a lower mental capacity that those of European ancestry."

Another minority man expressed,

> "There are expectations beyond normal, since I am looked down upon immediately by most white male professors."

Reported incidents of reverse discrimination came from only the medium percentage concentrations. One man remarked,

> "Yes, I have seen women and minorities who are less well qualified have opportunities which were denied me."

And another added,

> "Yes, welcoming events that allowed only women to attend. If they (women's support groups) want to improve conditions for women then perhaps they should promote inclusion."

There were also a couple of adverse comments to the question in general. Said one man,

> "No and I think the questions previously about discrimination are absurd! No, this is ridiculous! We'd love to have more women and 'minorities' outnumber whites."

Based on my findings, there were very few self-reported incidents of discrimination. However the number of ambiguous responses to question (the "not really" category), indicates that there are many uncomfortable situations that women face. These situations are not necessarily self-categorized as discrimination, and women tend to deal with these experiences as they see appropriate. Additionally, it appears that women in the "low" concentrations may experience little or no discrimination.

While the findings of this study in no way provide neat categories of gender differences and similarities, they do add insight into the experiences of men and women in these fields. For example, the findings indicate that men and women in engineering are remarkably alike in their predilection for engineering, but differ in terms of how they negotiate the dominant culture of engineering in terms of their experiences of culture and discrimination.

While the effects of "extremely low" and "low" concentrations on student experiences are inconclusive in this study, several themes emerged from this research which will guide further analysis. For example it appears that the "low" concentrations are more congenial and less competitive for both men and women, although it is not clear if it is due to issues of prestige and status of the concentration (as my framework suggests), or rather if it is the organizational structure and departmental culture. Additionally, the intersection of minority status and gender appears to play a significant role in terms of the experience of graduate students.

Implications

In my quest for insight into how these issues may confound women and men in a changing and challenging cultural environment, it is my intention to respect, maintain and accurately represent the nature of engineering

culture and the people within it. One woman who scribbled this note on the back of her survey envelope best expresses my concluding thoughts :

> "I hope you are making an effort to understand the complexity of the issues involved and recognize that we have the intelligence and the ability to deal with their issues within our own context. Too often, fingers are pointed at engineering by people who are unfamiliar with the engineering culture and thereby misinterpreting their own data."

A comprehensive examination of gender segregation within engineering and its concentrations will enable those responsible for education and policy decisions to focus more effectively on the reduction of factors that may hinder the flow of women inside the engineering pipeline. This study draws upon the experience of women and men as an exploratory effort to reconceptualize the underrepresentation of women in engineering. For example, although women who are now in engineering graduate programs have overcome numerous obstacles along the way and should more than likely have the strongest set of attributes for success in the engineering professions, a high percentage of women pursuing engineering degrees still remain skeptical and unsure about their long-term involvement in engineering (Petrides, 1993). Why is this so? I believe that there is insight to be gained from the experience of men and women who are still inside the education system.

Notes

[1]The term "gendered construction" is used as an analytical tool that makes a conscious decision to recognize that the category "gender" is created by a process which is historically, socially and politically constructed.

[2]Green University is a pseudonym. The five disciplines surveyed were aeronautical, electrical, mechanical, chemical and industrial. These five concentrations vary by the degree of segregation within engineering. For example, aeronautical was chosen because it has the smallest percentage of women; electrical and mechanical because they are two of the largest concentrations (of total students), and chemical and industrial engineering because they have the largest representation of women. The percentages of women in the five concentrations at Green are representative of national averages. The larger study is a survey of 1000 male and female students in engineering MA and Ph.D. programs among the five concentrations listed. The response rate for the survey was 55 percent. These data are still in the process of being analyzed.

[3]A minority population can be defined by gender, class or race, or any other characteristic which is not of the dominant group.

[4]These figures must be interpreted as estimates since the people receiving Ph.D.'s in 1990 can obviously not be the same cohort that received a B.S. in 1992.

[5]Figures for men as a percentage of total men show negligible change between B.S. and Ph.D. except for chemical which increases from 4.9% to 14.3% and materials (from 1.3% to 8%).

[6]Of the self-reported minorities, four were female and three were male.

[7]These figures are similar to national averages.

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