Understanding Girls
Quantitative and Qualitative Research

Dale Rose Baker
Arizona State University, USA

Understanding Girls: Quantitative and Qualitative Research is a retrospective of the author’s research that led to receiving the 2013 Distinguished Contributions Award to Science Education through Research. This book includes selected articles that document changes in her research approaches and theoretical frameworks. The articles represent the evolution of her thinking about the issue of girls in science as well as her impact on science education. The author’s work is placed in the context of science education research at the time of publication, research in education and psychology, and the culture of the times. She pulls back the curtain that often makes the messy work of research seem straightforward and linear to reveal why she did the research and the methodological decisions she faced. She describes the serendipitous nature of some of the work as well as her frustrations in trying to understand data, and struggles to insure that she accurately and respectfully presented the voices of girls and their teachers. The book also includes some of the earliest research in engineering education preceding the focus on engineering practices found in the Next Generation Science and Engineering Standards. Understanding Girls provides insights into why girls may or may not decide to participate in science and engineering and what can be done to increase their participation. It provides evidence that we have increased girls’ participation and the challenges that remain to insure that every girl who wants to become a scientist or engineer has the opportunity to do so.
Understanding Girls
CULTURAL AND HISTORICAL PERSPECTIVES ON SCIENCE EDUCATION:
DISTINGUISHED CONTRIBUTORS

Volume 6

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Cultural and Historical Perspectives on Science Education: Distinguished Contributors features a profile of scholarly products selected from across the career of an outstanding science education researcher. Although there are several variants in regard to what is included in the volumes of the series the most basic form consists of republication of 8-10 of the scholar’s most significant publications along with a critical review and commentary of these pieces in terms of the field at the time of doing the work, the theories underpinning the research and the methods employed, and the extent to which the work made an impact in science education and beyond. Another genre of Key Works republishes the most influential research in a selected area of interest to science educators. Examples of the areas we will feature include science teacher education, science teaching, language in science, equity, the social nature of scientific knowledge, and conceptions and conceptual change. Collections of articles are placed in an historical context and the rationale for changing perspectives is provided and analyzed in relation to advances and changing priorities in science education. Each volume shows how individuals shaped and were shaped by the cultural context of science education, including its historical unfolding.
Understanding Girls

Quantitative and Qualitative Research

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This book is dedicated to my husband Dr. Michael Dee Piburn. His love and support have made my career possible.
TABLE OF CONTENTS

Introduction xi

Chapter 1: Can the Differences between Male and Female Science Majors Account for the Low Number of Women at the Doctoral Level in Science? 1
   Why I Conducted the Study 1
   Methodological Decisions 2
   Science Education at the Time of the Study 3
   Research into Gender in the Wider Field of Education 4
   The Culture and the Times 6
   Impact of My Work 7
   Research in College Science Teaching: Can the Difference between Male and Female Science Majors Account for the Low Number of Women at the Doctoral Level in Science?, by Dale R. Baker (reprinted article) 9

Chapter 2: The Influence of Role-Specific Self-Concept and Sex-Role Conflict on Career Choices in Science 23
   Why I Conducted the Study 23
   Methodological Decisions 23
   Science Education at the Time of the Study 25
   Research in the Wider Field of Education 26
   The Culture of the Times 28
   Impact of My Work 29
   The Influence of Role-Specific Self-Concept and Sex-Role Identity on Career Choices in Science, by Dale R. Baker (reprinted article) 31

Chapter 3: Sex Differences in Classroom Interactions in Secondary Science 51
   Why I Conducted the Study 51
   Methodological Decisions 51
   Science Education at the Time of the Study 52
   Research in the Wider Field of Education 53
   The Culture of the Times 54
   Impact of My Work 54
   Sex Differences in Classroom Interactions in Secondary Science, by Dale R. Baker (reprinted article) 56
# TABLE OF CONTENTS

Chapter 4: Sex Differences in Formal Reasoning Ability: Task and Interviewer Effects 69
  - Why I Conducted the Study 69
  - Methodological Decisions 70
  - Science Education at the Time of the Study 71
  - Research in the Wider Field of Education 72
  - The Culture of the Times 73
  - Impact of My Work 74
  - Sex Differences in Formal Reasoning Ability: Task and Interviewer Effects, by Michael D. Piburn and Dale R. Baker (reprinted article) 76

Chapter 5: Letting Girls Speak Out about Science 89
  - Why I Conducted This Study 89
  - Methodological Decisions 89
  - Science Education at the Time of the Study 90
  - Research into Gender in the Wider Field of Education 92
  - The Culture and the Times 92
  - Impact of My Work 93
  - Letting Girls Speak Out about Science, by Dale Baker and Rosemary Leary (reprinted article) 94

Chapter 6: Equity Issues in Science Education 127
  - Why I Conducted the Study 127
  - Methodological Decisions 127
  - Science Education at the Time of the Study 128
  - Research into Gender in the Wider Field of Education 129
  - The Culture of the Times 131
  - Impact of My Work 132
  - Equity Issues in Science Education, by Dale R. Baker (reprinted article) 134

Chapter 7: An Intervention to Address Gender Issues in a Course on Design, Engineering, and Technology for Science Educators 161
  - Why I Conducted the Study 161
  - Methodological Decisions 162
  - Science Education at the Time of the Study 162
  - Research in the Wider Field of Education 164
  - The Culture of the Times 166
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>What Works: Using Curriculum and Pedagogy to Increase Girls’ Interest and Participation in Science and Engineering</td>
<td>197-203</td>
</tr>
<tr>
<td>9</td>
<td>Girls’ Summer Lab: An Intervention</td>
<td>213-218</td>
</tr>
<tr>
<td>10</td>
<td>Good Intentions: An Experiment in Middle School Single-Sex Science and Mathematics Classrooms with High Minority Enrollment</td>
<td>219-225</td>
</tr>
<tr>
<td>11</td>
<td>Summary: What Does It All Mean?</td>
<td>227-231</td>
</tr>
</tbody>
</table>
INTRODUCTION

The articles reprinted in this volume represent my career long interest in doing research on a topic that is rooted in my own experiences as a women interested in science. Some of those experiences were negative, some were positive, and some were puzzling. Some experiences reflected the social expectations for women in the 1950s and 1960s when my interest in science was developing. Other experiences were rooted in the open classroom movement of the 1970s during which I discovered that girls responded positively to science when it was interactive and aligned with topics that were relevant and interesting.

My experiences led to many questions for which I had no answers. Every college bound student in my high school studied science so I wondered why there were so few women in my science classes at the university. When I began to teach, I didn’t understand why many elementary teachers avoided teaching science, when I loved it. As I considered graduate school I was faced with trying to understand how my past experiences led me to make the career choice that I did; science education rather than pure science.

Studying girls and women in science was personal. It was an effort to make sense of my own experiences and those of many other girls and women and to answer the questions these experiences raised. I was driven to investigate what influenced women’s career choices. I wanted to know if there really were male and female differences in attitudes toward science. I wanted to explain the male female differences in rates of participation in science. I wanted to make sense of the conflicting data of girls’ achievement in science. And finally, I wondered if anything could be done about increasing the participation of women in science.

I struggled with biological, psychological, and sociocultural theories to frame my research. Each study I conducted or read made me reconsider the relative influence of biology, psychology, and sociocultural factors on women and girls in relation to their participation in science. My struggles were fueled by the implications derived from these theories. I was uncomfortable with biology as destiny, but I was equally disturbed by the thought that girls were being socialized in ways that limited their choices. Even more daunting was the thought that biology, psychology, society, and culture all played a part in explaining attitudes, choices, achievement, and rates of participation of girls and women in science. How would I ever sort this out?

Over the course of my career I have employed a variety of analytical techniques to make sense of data. Despite a degree in anthropology and experience doing fieldwork, my early science education research was quantitative. Anthropological fieldwork was hard work for which I was ill suited as a young researcher. In comparison, I found statistical analysis relatively easy. Furthermore, the questions I was asking early in my career were best answered using quantitative data analysis.
INTRODUCTION

However, as I began to ask different questions it became clear that I would have to use qualitative techniques to collect and understand my data. Fortunately, by this time, I was confident enough as a scholar to overcome the difficulties I had experienced earlier. At thirty-five plus years into my career, I am neither a proponent of the quantitative or qualitative approach. I am a survivor of the paradigm wars of the 1980s when heated battles were fought over the “positivist evils” of quantitative research and the “lack of rigor” of a qualitative approach. As such, my current position is that of a pragmatist. I use any analytical tool that helps make sense of the data.

Although comparing males and females can provide useful insights, I am always mindful that such comparisons run the risk of using a deficit model where the male is the norm and the female is found lacking. Although I have done many comparison studies, my most important breakthrough was when I ignored the data from males. I did not ignore the male data out of a conviction that one should not make male female comparisons. Nor, was I ignoring the male data for strong theoretical reasons. Rather, the reason was simpler. I could not make sense of the data by comparing male and female students, so instead, I put the male data aside and began to read about possible theories to justify this decision. Analyzing only the female interviews using feminist theory was a revelation. Patterns that had been obscured became clear. This led to the publication of my most important work (Baker, D., & Leary, R. (1995). Letting girls speak out about science. *Journal of Research in Science Teaching, 1*, 3–27), and the most cited. It was selected as among the twelve most influential papers published in the *Journal of Research in Science Teaching* and reprinted in a special issue celebrating the 40th anniversary of the journal in 2003.

I have conducted research in many settings and with students at many grade levels and in countries other than the United States. Some studies have looked at grade level changes from kindergarten through twelfth grade. Others have focused exclusively on high school or middle school students. Some studies have been conducted with university undergraduates and others with graduate students. There have also been studies that focused on teachers. In addition to generating my own original data, I have written reviews of research that attempted to capture what we know about equity issues world-wide and what the research tells us about curriculum and pedagogy to increase girls’ participation in science.

The choice of research questions and settings was just as likely to be serendipitous as it was to be planned. A presentation to teachers resulted in an invitation to come study their school’s experiment in single sex science and mathematics classes. Another study was the result of participating in a larger project led by other researchers. A third study arose from a grant funded intervention. Other studies were initiated by me to answer a question that was intriguing. The review articles were invitations from editors.

Data gathering tools have been varied and reflect the times in which the study took place. Early work employed paper and pencil assessments to quantify
INTRODUCTION

psychological variables such as masculinity, femininity and androgyny; personality, self-efficacy, self-concept, and formal reasoning. Test scores were used to measured mathematical, verbal, and spatial ability. Transitional work turned classroom observations of teacher student interactions into categorical data for quantitative analysis or used clinical interviews with subjects engaged in solving tasks. Later work used qualitative data gathering tools such as long term classroom observations, interviews, and artifact analysis.

After spending many years of doing research on girls and women in science, I began to work with colleagues in engineering. These colleagues were also concerned about rates of female participation as reflected in the low number of women choosing to study engineering as a university major. My engineering colleagues were also concerned that high school students and teachers had little knowledge about what engineers do. They thought that helping teachers understand engineering and teach design, engineering, and technology would increase the number of both males and females choosing engineering as a career long before we had the Next Generation Science Standards.

This new line of research was closely aligned with my earlier work. Science courses (biology, chemistry, and physics) as well as advanced mathematics are part of the foundational knowledge needed to be an engineer. In addition, engineering is gender stereotyped as a male domain. The largest number of women can be found in biomedical engineering with a clear role in helping others as opposed to computer engineering. However, the overall number of undergraduate degrees award to women across all fields of engineering has remained at approximately 18% for many years despite efforts to increase this number. So, although my focus has broadened to include engineering, the questions and struggles remain the same.

If there is any criticism of my research, it is that it is narrowly focused on girls and women. On the whole, race and ethnicity have not been explored. This limitation does affect generalizability but it also reflects the state of research into gender issues when I began my career. I leave it to the current and future generation of scholars to unravel the knot of intersectionality.

The articles selected for this volume are by no means all I have written. All but one article, represents work that I have contributed the most to as the first author or only author. The work where I am second author (Piburn, M., & Baker, D. (1989). Sex Differences in Formal Reasoning Ability: Task and Interviewer Effects. Science Education, 73, 101–113), is research where both authors contributed equally. This research also won an award.

The articles in this volume are mostly organized in chronological order, starting with a publication that was based on my dissertation and ends with a recent review article. This chronological order is deliberate. It provides insight in to my thinking about gender issues over the span of a career. It allows me, in the commentary that follows each article, to place the work in context. The commentary explains the rationale for choosing or abandoning a particular theoretical framework, the strengths and weaknesses of the analytical techniques, and provides me with an opportunity
INTRODUCTION

to evaluate the contribution of the work to science education. Best of all, it allows me to pull back the curtain and reveal the messiness behind conducting the research that is never addressed in the more linear retelling that constitutes a journal article.

Sadly, two of my most interesting articles could not be included in this volume. They are Baker, D. (2002). Good Intentions: An Experiment in Single-Sex Science and Mathematics Classrooms with High Minority Enrollment. *Journal of Women and Minorities in Science and Engineering, 8*, 1–24 and Baker, D., Lindsey, R., & Blair, C. (1999). Girls’ Summer Lab: An Intervention. *Journal of Women and Minorities in Science and Engineering, 5*, 79–95. The publisher of the *Journal of Women and Minorities in Science and Engineering*, Begell House, does not allow reprints of articles in their entirety. That being the case, I encourage you to seek them out and read them. I will however, describe them in the next to last chapters of the book and place them in context as I do for the reprinted articles. Both studies resulted from invitations to study the phenomena and have counter intuitive outcomes.

I place my work in the context of science education at the time of publication as well as research in the wider field of education and the culture of the times. As such, I had to make decisions about what to review and search. I examined scholarly books and journal articles published around the time of each article and reliable websites that provided timelines for major cultural events. I chose not to review articles in the *Journal of Science Teacher Education*. Although this is an excellent journal the narrow focus on pre-service and in-service research on teachers would have skewed the larger picture of what was happening in science education. Furthermore, although I have conducted research in teacher education, the work I present does not address science teacher preparation or professional development.

Despite having published in the *Journal of College Science Teaching* (see Chapter 1), I chose not to include studies from this excellent journal. Most of the work published in the *Journal of College Science Teaching* is narrowly focused on improving undergraduate college teaching, especially for non majors. It has a strong focus on disseminating ideas that contribute to college science teaching and has a practical orientation. Including studies from this journal would also have skewed the picture of what was happening in the broader field of science education which has by and large conducted less research in undergraduate settings and even less focusing on the college science instructor.

I hope you enjoy reading this book as much as I have enjoyed writing the commentary that accompanies the reprinted articles. It was a wonderful journey down memory lane.
CHAPTER 1

CAN THE DIFFERENCES BETWEEN MALE AND FEMALE SCIENCE MAJORS ACCOUNT FOR THE LOW NUMBER OF WOMEN AT THE DOCTORAL LEVEL IN SCIENCE?

WHY I CONDUCTED THE STUDY

This article comes from my doctoral dissertation. I decided on this study after writing two other dissertation proposals that built on my interest in neurophysiology and my work identifying the aggression center in the brains of cats as well as my interest in studying why there were so few women in science. The first proposal I wrote is best forgotten. The second, required a pilot study in which I built a rear screen projection tachistoscope to measure verbal and spatial processing in the left and right hemispheres of the brain. I intended to use hemispheric differentiation as a way to predict who would choose science as a college major in a population of males and females. The pilot study indicated that this second proposal was not feasible due to measurement issues. After a year of data gathering, I concluded that I could not obtain the level of accuracy and consistency I needed. As a result, I set out to develop the third proposal.

The questions I settled on in the third proposal arose partly from my own negative experiences in science and my need to understand these experiences. Why was I told at a college admissions interview that the department did not waste space and resources on women because they would get married? Why was there only one other female student in my undergraduate geology course? Why didn’t I have a single female professor in the sciences? Why were professors reluctant to write me letters of recommendation for graduate school even though I was an excellent student? Why was I getting messages that I did not belong?

Certainly, the prevailing view when I embarked on graduate studies in the 1970s was that women did not have the spatial, mathematical, and personality traits that would allow them to be successful in science. I wanted to know if these prevailing views were correct. I knew that it would be impossible to increase the number of women who liked science, excelled at science, and chose science as a career, if we did not know the root causes for male-female differences in rates of participation. I was also puzzled by research that found that females had more negative attitudes toward science than males. My own experience as a teacher showed me that females did like science, especially hands-on science. Furthermore, I liked science despite
my own negative experiences. Yet, I chose the path of science education rather than lab or field science. Clearly, attitude deserved further investigation.

And then there was the question of gender roles and femininity. The work of Helen Austin (1969) indicated that marriage and family were not obstacles to a scientific career for women who received their doctorates in the late 1950s. But what about women who did not choose science? Were they more traditionally feminine? Research at this time using the Personal Attributes Scale (Spence & Helmreich, 1978) indicated that female scientists perceive themselves as having both masculine and feminine characteristics (46% androgynous) or having masculine (23%) characteristics. This was in contrast to college women in general. Women in engineering were found to be more masculine than women in home economics (Tanico, Hardin, & McLaughlin, 1978) and college women who perceived themselves to be androgynous expected to do better in mathematics and science than women who perceived themselves to be feminine (Brewer & Blum, 1978). Maybe, I thought, it was not ability but how invested in traditional gender roles a woman was that affected her career choice.

METHODOLOGICAL DECISIONS

This was a quantitative study. There were three reasons for my methodological choice. First, I wanted a large sample (n = 180) in order to do multiple contrasts of males and females majoring in the physical and biological sciences and non-science areas such as English. Second, I wanted to see if my selection of variables were predictive of a college major which required a statistical technique called discriminant analysis. I also wanted to know whether there were differences in mean scores for each group which required analysis of variance or differences in the frequency of majors by perceived masculinity, femininity, and androgyny which dictated chi square analysis. Third, except for Piagetian studies, no one in science education at this time was doing qualitative studies. In fact, I do not recall that a qualitative inquiry course was even offered in my doctoral program. Since the prevailing analytical paradigm was quantitative, it never occurred to me to design a study that would not use statistical analysis.

In keeping with the interests and questions that led to the study, I used popular measures of the time. These were the Myers-Briggs Type Indicator (Myers, 1962) a Jungian measure of personality; the Scholastic Aptitude Test as a measure of mathematics and verbal ability; the Personal Attributes Questionnaire (Spence & Helmreich, 1978) to measure masculinity, femininity, and androgyny; and a spatial rotations task taken from the Kit of Factor Referenced Cognitive Tests (Ekstrom, French Harman, & Derman, 1976). Since existing attitude measures did not assess what I wanted to know, I asked four questions I created about the degree to which the participants in the study liked science and were committed to a career in science.

As I reflect on the decisions I made in the design of the study, I do not think I would make any changes. The work was embedded in the research paradigms of
the time and allowed me to answer the questions I was posing. A qualitative design
would not have been appropriate and reviewers would probably have rejected the
manuscript. And, although the Myers-Briggs Type Indicator has been criticized for
being theoretically weak so perhaps another measure of personality could have been
chosen, the criticisms came long after I and others used it.

SCIENCE EDUCATION AT THE TIME OF THE STUDY

Although the study Can the Differences Between Male and Female Science Majors
Account for the Low number of Women at the Doctoral Level in Science was published
in 1983, it was conceived, conducted, and written between 1977 and 1980. The
research at the time of the study was overwhelmingly quantitative. An examination
of articles published in the Journal of Research in Science Teaching from 1977 to
1979 revealed only two purely qualitative studies. Nine studies used both qualitative
and quantitative techniques either to compare the results of paper and pencil
assessments of Piagetian levels to results from clinical interviews or to create non-
clinical Piagetian tests that could be analyzed statistically. About 60% of the studies
focused on the K-12 system and the remainder on postsecondary education. Among
the postsecondary studies, two took place at the community college level.

Students were the focus of most of the studies in science education journals,
followed by teachers. Few studies looked at both the student and teacher. University
faculty were rarely studied. Pre-service elementary teachers received the most
research attention while studies of pre-service secondary teachers and studies of the
professional development of teachers were conspicuously absent. A bit more than
half of the studies had a biology content focus with Earth science and chemistry
receiving little attention.

Piagetian theory was the dominant theoretical paradigm and studies focused
on developing paper and pencil tests for Piagetian interview tasks or increasing
Piagetian reasoning levels through interventions. There was also considerable
research into the National Science Foundation funded curricula developed in the late
sixties and early seventies such as Elementary Science Study (SCIS) and Science a
Process Approach (SAPA). Along with an interest in Science a Process Approach,
process skills in general and inquiry in particular were a focus of study. Studies about
attitude toward science were also popular as were studies reporting test development
and the psychometric properties of tests.

Some studies took sex into consideration and looked for male female differences.
However, this aspect of the studies seemed like an afterthought. Sex was just one of
many variables examined and not the primary question driving the research. These
studies found few sex differences in performance. Two studies stand out in particular
for their insensitivity to issues of gender. Overall, issues of gender were not a concern
of the research community. When the research community was asked to set research
priorities, sex differences in performance and the low number of females in science
majors and careers did not appear on the list (Butts et al., 1978; Yaeger, 1978).
The journals of the American Educational Research Association published little that addressed sex differences in performance or rates of participation of women in science majors or careers. There were no articles in the 1977, 1978 or 1979 issues of the *Review of Educational Research* investigating gender differences, science participation of females, or spatial and mathematical ability. In the 1979 *American Educational Research Journal* there was one article about women who entered male dominated fields (Peng & Jaffe, 1979). In the 1978 issue there was one book review for a book examining sex bias in schools (Lockheed, 1978), and in 1977 there were two articles by mathematics researchers Elizabeth Fenema and Julia Sherman examining attitude, spatial visualization, and mathematics achievement (Fenema & Sherman, 1977; Sherman & Fenema, 1977).

In contrast to the field of education, the fields of psychology, sociology, and medicine were exploring a variety of biological, social, and psychological theories to examine sex difference in cognitive abilities and male female rates of participation in science. There were several books that were particularly influential in helping me conceive of this study and made an impact on the study of sex differences. These were *Fair Science: Women in the Scientific Community* (Cole, 1979), *Sociology of Science* (Gaston, 1978), the *Psychology of Women* (Gullahorn, 1979), *Masculinity and Femininity: Their Psychological Dimensions, Correlates, and Antecedents* (Spence & Helmreich, 1978), *Psychology of Sex* (Maccoby & Jacklin, 1974), *Sex Related Cognitive Differences* (Sherman, 1978), *Female and Male: Psychological Perspectives* (Unger, 1979), and *Man & Woman, Boy & Girl: The Differentiation and Dimorphism of Gender Identity from Conception to Maturity* (Money & Ehrhardt, 1975). In addition, the work of Bem on masculinity and femininity (1977) and her colleague Lenny (1976), as well as Spence and Helmreich (1978) informed my thinking.

Bem (1977), Bem and Lenny (1976), and Spence and Helmreich (1978), turned to conceptions of masculinity and femininity as an alternative explanation to biological differences to understand male female differences in a variety of arenas. The measures these scholars devised had strong predictive power, especially the Personal Attributes Questionnaire (PAQ) developed by Spence and Helmreich (1978). The PAQ has masculinity (M) and femininity (F) scales. The masculinity scale measures instrumental traits and the femininity scale measures expressive traits. However, if an individual is high on both M and F scales Spence and Helmreich deemed the person as androgynous. Spence and Helmreich (1978) found that androgyne and masculinity in females was correlated with egalitarian attitudes, self-esteem, personal adjustment, competitiveness, achievement measures, mastery, and aggressiveness. Lack of emotional vulnerability, another androgynous characteristic, was correlated with scientific success and choice of a career for women. In contrast, femininity was negatively correlated with a scientific career for women. A majority of the sample
of women scientists Spence and Helmreich studied were found to be androgynous (46%) or masculine (23%).

Cole (1979), addressed the issue of female participation in science from a different perspective using the lens of the sociology of science. He asked whether science is really a meritocracy given that women held lower rank than men and women were more likely than men to be in postdoctoral positions than tenure track positions. To answer his question, he examined sex based discrimination in science, accumulated disadvantage of females, social and self-selection in and out of science, scientific productivity, IQ, sex differences in ability, work family priorities, teaching focus, and reputational standing among peers. He concluded that there was no difference in ability, marriage and children did not account for lower rates of publishing, and that productivity and quality were not correlated with rank since women were not promoted as often as men with equal publication records. He also speculated on the causes of women’s lower scholarly productivity but had no clear cut data to explain this finding. He suspected that subtle factors more difficult to measure than those he examined, such as socially structured motivation, mentor/student relationships, and access to old boy networks were the possible causes.

Another sociologist of science (Reskin, 1978) reviewed the research about women in science and somewhat surprisingly found that

…the term discrimination rarely appeared in titles, and the debate was carried out circumspectly in the articles’ concluding pages. (Reskin, 1978, p. 7)

Despite the covert nature of the debate, Reskin found that discrepancies in collegial roles (e.g. networks, collaboration, division of labor), with women at lower status, accounted for sex differences in productivity and the full integration of women into the scientific enterprise. He concluded that the status inequality of women outside of scientific roles and traditional sex roles in society were models for male/female interactions within science.

The data for biological theories of male superiority was also examined carefully, especially in mathematics and spatial ability, since these abilities are very important to success in science. Scholars looked at the performance gap between males and females in mathematics and spatial ability using theories of brain lateralization, hormones, sex linked traits, and rates of maturation (Gullahorn, 1979; Money & Ehrhardt, 1975; Sherman, 1978). These scholars concluded that overall, biological theories were disconfirmed. As a further note, some of the work of John Money on the biological origins of sex differences, which was very influential at the time, has been discredited because of misrepresentation of data (Switzer, 2005).

Despite the disconfirmation of biological theories, scholars have found persistent but small differences in performance between males and females. Females have better verbal skills than males and males have better spatial visualization skills, dis-embedding skills, and mathematical skills than females (Maccoby & Jacklin, 1974; Unger, 1979). Despite the differences, Sherman (1978) in particular,
concluded that the differences were meaningless. They were too small, and in some cases contradictory, to account for the large difference in the rates of participation. Almost a decade later, Marcia Linn and Janet Hyde (1989) were also arguing that the differences were small, did not explain career choices, and could be attributed to situational and cultural effects as well as course enrollment and training.

THE CULTURE AND THE TIMES

Despite both male and female ambivalence to women working and an endorsement of traditional sex roles in families where women expected to enter and leave the work force because of childbearing (Komarovsky, 1979), the roles of women were changing. It was the end of the second wave of feminism (Gamble, 2001) and women such as Golda Meir and Indira Gandhi (Pogrebin, 2009) were leading nations. In the United States, Robin Morgan, Kate Millet, Gloria Steinem, Betty Friedan (Langston, 2002), Betty Ford (National First Ladies Library, n.d.), Shirley Chisholm (Office of the Historian, n.d.), Bella Abzug (Cook, 2009), and Elizabeth Holtzman (Lederhendler, 2009) were advocating for women’s rights through writing, lecturing, demonstrating, and crafting legislation.

Even the United Nations was cognizant of the need to acknowledge women’s rights and established the International Year of the Women with a conference in Mexico City in 1975. In the United States, President Gerald Ford signed an executive order in response to the International Year of the Women establishing a commission to promote equality between men and women. This was followed by legislation introduced by congresswomen Bella Abzug and Patsy Mink to support a National Women’s conference. President James Carter then appointed Bella Abzug to head the commission on the observance of International Women’s year resulting, in 1977, with the first United States National Women’s Conference held in Houston, Texas. The conference was chaired by Bella Abzug and created an action plan with 25 resolutions on women’s rights, including elderly, minority, disabled, sexual orientation, child care, and reproductive rights. Subsequently, President Carter fired Bella Abzug as commission chair under political pressure (Cottrell, 2010).

Legislation to support the rights of girls and women was also passed in the 1970s. In 1972, title IX was signed into law. However, it was not being enforced. In response to lax enforcement, the National Coalition of Women and Girls in Education was formed in 1975 (2015). The American Association of University Women also saw that the regulations were not being enforced and published Monitoring title IX: A Guide to Action for the Volunteer Organization (American Association of University Women, 1977). This was a how to manual that was used when making campus visits to monitor implementation of the regulation. American Association of University Women campus visitors, using the guide, were met with compliance to outright defiance. Despite defiance there were large increases in girl’s and women’s participation in sports. Before passage of the legislation, only about 300,000 (one out of every 27 girls) nationwide participated in high school sports but by 1977 there
CAN THE DIFFERENCES BETWEEN MALE AND FEMALE SCIENCE MAJORS ACCOUNT

were 2,400,000 or one out of every three girls participating in high school sports. Between 1971 and 1977 the increase in female college athletes was approximately 35% (Cahn, 2001).

The Equal Rights Amendment (ERA) was also introduced in congress in 1972 but by the late 1970s it was running out of time for ratification by the states. This spurred the National Organization of Women to sponsor a march in 1978 to support the Equal Rights Amendment (Barakso, 2004). One hundred thousand people came out to march and the time limit for ratification was extended from 1979 to 1982. However, the amendment was never ratified. The early seventies also saw the establishment of women’s studies departments and by the mid-seventies there were 80 women’s studies departments nationwide. The increase in women’s studies departments led, in 1977, to the founding of National Women’s Studies Association (Napikoski, 2015).

The 1970s also saw the rise of the conservative movement with neoconservatives, the religious right, and Reagan Democrats joining the movement supported by think tanks like the Heritage Foundation. The Moral Majority and Jerry Falwell represented the new right in politics. The conservative movement was fueled by social change embodied by the women’s movement, abortion rights, and sexual freedom as well as a resurgence of evangelical Christianity. Opposition to the Equal Rights Amendment by traditional values groups and Phyllis Schlafly was particularly strong. Religious conservatives feared that the Equal Rights Amendment would result in the reduction of privacy rights, gay marriage, abortion rights, and women in combat. Businesses opposed the Equal Rights Amendment for financial reasons because insurance rates would go up. States saw the Equal Rights Amendment as an incursion on states’ rights (Girr, 2001; Gross, Medvetz, & Russell, 2011).

IMPACT OF MY WORK

My work contributed to the body of research that made biological explanations for the low rates of women’s participation in science unconvincing. Furthermore, the data indicated that mathematical ability was not as much of a barrier to choosing a science undergraduate major then was previously thought. Males and females within majors were alike, refuting the idea that sex was the determining factor. Males in non science majors were self-selecting out of science based on the same set of variables as women. Rather than sex, there were clear personality characteristics such as attitude; perceptions of masculinity, femininity, and androgyny; and approaches to decision making that were strong predictors of who would or would not choose science as a major. The data clearly supported socialization and the power of traditional gender roles rather than biology. Despite the small to non-existent sex differences in abilities, the culture at large, even until very recently, found biological explanations more compelling than socialization explanations. Data, is often unconvincing in the face of strongly held beliefs. However, this work in concert with the work of others, contributed to changes in perceptions, dispelling the myths.
of innate female inadequacies, and led to the development of programs aimed at increasing the participation of women in science. A look at the most recent survey of *Women, Minorities and Persons with Disabilities in Science and Engineering* (National Science Foundation, 2012a) indicated that there is strong evidence that few people feel that biology is destiny. Women now comprise 50.5% of all science and engineering undergraduate majors. If we look at just science majors, that number jumps to 56.6% with biology majors at 59.3%. However, only 18.2% of women majored in computer science. Thus, the overall picture is good but there are still majors in which men and women have not reached parity.
Can the Difference between Male and Female Science Majors Account for the Low Number of Women at the Doctoral Level in Science?

ABSTRACT

One hundred and eighty (180) subjects were tested to determine which factors related to success in science were present among biological, physical science, and nonscience majors. Factors examined were mathematical and spatial ability, personality, masculinity, femininity, and attitude toward science. The subjects were given Cube Comparisons, The Personal Attributes Questionnaire, and the Myers-Briggs Type Indicator. SAT quantitative scores were used to measure mathematical ability and a questionnaire measured attitude. Results indicate that the personality of males was different from females primarily in terms of decision making. Males had higher mathematics scores than females and science majors had higher mathematics scores than nonscience majors. Science majors had a “scientific” personality while nonscience majors did not. Male and female physical science majors were “masculine.” Female nonscience majors were “feminine” and female biology majors were distributed between the masculine and feminine categories. Science majors had a positive attitude toward science and nonscience majors a negative attitude. There were no differences in spatial ability.

Approximately half of all undergraduate majors in science are female [24] yet only 10.6 percent of the doctoral degrees in the physical sciences and 23.4 percent of the degrees in the biological sciences are awarded to women [18]. Why do so few females who major in science go on to do graduate work at the doctoral level? When they do go on, why do more females choose the biological rather than the physical sciences? Are female undergraduate science majors somehow different from their male counterparts?

Some researchers would have us believe that they are different, especially in the area of mathematics [1,19], while others dispute the extent of such findings [7,14]. Spatial ability is another area in which most researchers report male/female differences [5,10], the magnitude of which depends upon the degree to which an individual is stereotypically masculine or feminine [5], the type of test [3], and experience [21]. Attitude toward science has clearer sex differences: From an early age, girls think that science is a male-only field [9,21].
Since attitude toward science is strongly related to achievement, as is mathematical and spatial ability [9,21], any differences between males and females in these areas could account for the small number of women choosing graduate-level work in science.

A further explanation may be sought in personality theory. Holland suggests that individuals choose careers because their personality characteristics fit the characteristics of the career [8]. The poorer the match, the greater the likelihood that the individual will be unsuccessful and dissatisfied, and leave the field.

Research with the Myers-Briggs Type Indicator suggests that individuals who choose science and do well in science have a specific personality type. They are likely to be intuitive and introverted, preferring to base decisions on logical analysis. They prefer to remain open and curious to understand events. In contrast, individuals in the helping professions and the humanities tend to be fact-minded, realistic, and extroverted, preferring to base decisions on values and feelings. They like to order and control events [12,13]. In addition, the scientific personality type has been found to outperform other personality types on science achievement tests [16]. Females, perceiving science as a male field and perceiving themselves as having female characteristics, may be correct in not choosing science. Most characteristics associated with the scientific personality are exaggerated masculine characteristics such as dominance, aloofness, detachment, and taciturnity [4,17]. Spence and Helmreich [20] found that female scientists were more “androgynous,” that is, exhibited both stereotypical masculine and feminine characteristics, and were more “masculine” than college women in general. Women engineering majors have also been found to be more “masculine” than women in home economics [23], and androgynous women in college expect to do better in math and science than do “feminine” women [2]. In general, women found in male-dominated occupations have traits that are stereotypical of men [11]. However, within science, biology is seen to be less masculine and less likely to conflict with the female personality characteristics than the physical sciences [25]. This would account for the greater number of female Ph.D.’s in biology than physics.

Subjects were given two personality tests: the Myers-Briggs Type Indicator, based on Jungian typologies [15], which measures the scientific personality, and the Personal Attributes Questionnaire, which measures the degree to which individuals perceive themselves as having stereotypical masculine, feminine, or androgynous characteristics [20]. The scales on the Myers-Briggs Type Indicator are as follows: The extroversion-introversion scale measures a preference for relating to the outer world of people (E) or the inner world of ideas (I). The sensing-intuition scale measures a preference for working with known facts (S) or possibilities and relationships (N). The thinking-feeling scale measures a preference for basing judgments on impersonal analysis and logic (T) or personal values (F). The judging-perceiving scale measures a preference for a planned, orderly life (J) or a spontaneous, flexible life (P).
The Personal Attributes Questionnaire allows an individual to have masculine and feminine characteristics simultaneously. An individual is classified as androgynous if his or her score is above the median on both the masculine (M) and feminine (F) scales. Subjects scoring below the median on the M and F scales are “undifferentiated.” A score above the median on just the M scale classifies the subject as masculine, and a score above the median on the F scale classifies the subject as feminine. There is also a bipolar scale (M-F) on which individuals can rate themselves as closer to the masculine or feminine end of the scale for a given trait.

Subjects were also given a spatial-rotation task, based on Thurstone’s cubes [6]. The Scholastic Aptitude Test was used as the measure of mathematical and verbal ability. Attitude was measured by the response to four questions that assessed the degree to which the subject liked science and the degree of commitment to a scientific career the subject showed.

This study addresses the question of whether or not males and females majoring in the biological and physical sciences really are different in terms of mathematical, spatial, attitudinal, and personality characteristics. One hundred and eighty (180) juniors and seniors in college were tested: 30 male and 30 female physical science majors, 30 male and 30 female biological science majors, and 30 male and 30 female nonscience majors. The nonscience group was used as a control against which the other groups were compared and contrasted.

**Mechanics of the Study.** Subjects were recruited through class announcements and advertisements in the school newspaper. Each subject was screened for major and class rank (junior or senior). Qualified students were then paid five dollars for their participation in the study. Declared majors at the junior and senior levels were selected on the assumption that they represented the pool of potential graduate students in science. This assumption was based on several observations. First, entrance to the university at which this study was undertaken is highly competitive. Normally, only those students in the top 10 percent of their high school graduating class are accepted. Second, the combined SAT scores for all groups in the study was above 1,000, except for female biology and female nonscience majors; their scores were above 900. These scores suggest that this was a group of students with the potential to do rigorous academic work. Third, these students had obtained sufficient competence in their majors to enroll in upper-division courses. Finally, this was a group of students who had persisted in taking courses in science for all or almost all of their college careers. That is, they did not just indicate an interest in studying science, as perhaps a freshman might; they had acted upon their interest in science and maintained that interest beyond lower-division courses that frequently act as filtering mechanisms for those who lack the ability or real interest to go on.

**SEX DIFFERENCES**

Although there were sex differences between males and females when all groups (science and nonscience) were combined, the differences were few.
Males did have higher mathematics scores than females. They also differed in one personality aspect of the Myers-Briggs Type Indicator: Males preferred a logical, analytical approach to decision making (the scientific mode) while females preferred to base decisions on personal values. Table 1 is the analysis of variance for mathematics and the thinking-feeling scale. Significant differences for the main effects and sex indicate that the differences are between males and females, not between majors. Examination of the means for the male SAT math scores (579.43) and female SAT math scores (509.45) indicate the direction of the significant difference. There was no significant sex-by-major interaction. The female mean for the thinking-feeling scale was 102.73. The male mean for the thinking-feeling scale was 91.73. There was no sex-by-major interaction on the thinking-feeling scale; and there were no sex differences for spatial ability, verbal ability, or attitude toward science.

Table 1. Analysis of Variance for Sex Differences in Mathematics and Personality.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>Ms</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main Effects</td>
<td>303879.880</td>
<td>3</td>
<td>101293.250</td>
<td>6.82&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sex</td>
<td>298284.000</td>
<td>1</td>
<td>202284.000</td>
<td>14.03&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Major</td>
<td>95595.880</td>
<td>2</td>
<td>47797.940</td>
<td>3.22&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Two-way Interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex by Major</td>
<td>2951.430</td>
<td>5</td>
<td>1475.720</td>
<td>.10</td>
</tr>
<tr>
<td>Thinking-Feeling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main Effects</td>
<td>7620.219</td>
<td>3</td>
<td>2540.073</td>
<td>6.23&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sex</td>
<td>5205.688</td>
<td>1</td>
<td>5205.688</td>
<td>12.76&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Major</td>
<td>2414.533</td>
<td>2</td>
<td>1207.267</td>
<td>2.96</td>
</tr>
<tr>
<td>Two-way Interaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex by Major</td>
<td>268.047</td>
<td>2</td>
<td>134.230</td>
<td>.33</td>
</tr>
</tbody>
</table>

<sup>a</sup> p < .001  
<sup>b</sup> p < .05

Males, as one would expect, were most often classified as stereotypically masculine and females as stereotypically feminine (see Table 2). Table 2 is the chi-square analysis of the distribution of males and females in the masculine, feminine, androgynous, and undifferentiated categories. The fairly equitable distribution of males and females in the androgynous and undifferentiated categories as compared with the distribution of males and females in the masculine and feminine categories indicates the significant differences between males and females are in these latter two categories.
DIFFERENCES ACROSS MAJORS

Table 3 is the post hoc analysis of the analysis of variance presented in Table 2. Table 3 indicates that physical science majors had higher SAT mathematics scores than either biological science majors or nonscience majors. In fact, the mathematics scores of the biological science majors were not statistically different from nonscience majors. Both science majors had better spatial ability than nonscience majors and a more favorable attitude toward science and a scientific career. Majors grouped in the same subset have means which are not statistically significantly different from each other. Groups found in different subsets do have means that are statistically significantly different from each other.

Table 2. Chi-Square Analysis of Males and Females by Personal Attributes Questionnaire Categories.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Androgynous Absolute</th>
<th>Androgynous %</th>
<th>Undifferentiated Absolute</th>
<th>Undifferentiated %</th>
<th>Masculine Absolute</th>
<th>Masculine %</th>
<th>Feminine Absolute</th>
<th>Feminine %</th>
<th>Row Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>23</td>
<td>25.6</td>
<td>25</td>
<td>27.8</td>
<td>12</td>
<td>13.3</td>
<td>30</td>
<td>33.3</td>
<td>90</td>
</tr>
<tr>
<td>Male</td>
<td>26</td>
<td>28.9</td>
<td>21</td>
<td>23.3</td>
<td>32</td>
<td>35.6</td>
<td>11</td>
<td>12.2</td>
<td>90</td>
</tr>
<tr>
<td>Column Total</td>
<td>49</td>
<td>46</td>
<td>44</td>
<td>41</td>
<td>180</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[x^2 = 18.43, \text{df} = 3.00, p < .001.\]

Not surprisingly, the science majors had the personality characteristics associated with science. They were intuitive, analytical, and logical, with the ability to impose order on and come to conclusions from data. Female nonscience majors, in general, preferred to base decisions on personal values, while the male nonscience majors preferred a logical and analytical approach to decision making.

Table 4 is the chi-square analysis of the distribution of females with biological, physical science, or nonscience majors. It indicates that female nonscience majors were more often classified as feminine than female science majors. Within science, the female physical science majors had more individuals classified as stereotypically masculine than the biological science majors, and the biological science majors had more individuals classified as androgynous (having high scores on both the masculine and feminine scales) than the physical science majors.

SEX DIFFERENCES WITHIN MAJORS

Within the physical and biological sciences, there were few sex differences. Both males and females had the scientific personality, liked science, and were planning a scientific career. There was no difference in verbal, spatial, or mathematical ability.
CHAPTER 1

Female biological science majors were equally distributed in the stereotypically masculine and feminine categories. More female physical science majors were classified as masculine than feminine, and all nonscience females were classified as stereotypically feminine (see Table 4). Males of all majors were most often classified as stereotypically masculine or androgynous (see Table 2).

DIFFERENCES AMONG THE FOUR GROUPS

Table 5 is the discriminant analysis for male and female biological, physical science, and nonscience majors. It indicates that the four groups can be differentiated on the basis of eight variables. Attitude is the most important discriminating variable, followed by the M and F scales, SAT mathematics, the JP and TF scales, SAT verbal, and the M-F scale. One would be most likely to correctly classify females, especially biological science majors, on the basis of these variables, and least likely
to correctly classify males, especially biological science majors, on the basis of these variables. Summary profiles of each group are presented in Table 6.

Table 4. Chi-Square Analysis of Females by Major and Personal Attributes Questionnaire Categories.

<table>
<thead>
<tr>
<th>Major</th>
<th>Androgynous</th>
<th>Undifferentiated</th>
<th>Masculine</th>
<th>Feminine</th>
<th>Row Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Absolute</td>
<td>%</td>
<td>Absolute</td>
<td>%</td>
<td>Absolute</td>
</tr>
<tr>
<td>Nonscience</td>
<td>8</td>
<td>26.7</td>
<td>6</td>
<td>20.0</td>
<td>2</td>
</tr>
<tr>
<td>Biology</td>
<td>11</td>
<td>36.7</td>
<td>10</td>
<td>33.3</td>
<td>2</td>
</tr>
<tr>
<td>Physical Science</td>
<td>4</td>
<td>13.3</td>
<td>9</td>
<td>30.0</td>
<td>8</td>
</tr>
<tr>
<td>Column Total</td>
<td>23</td>
<td>25</td>
<td>12</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

\[ \chi^2 = 12.86. \text{ df} = 6.00. \text{ } p < .05 \]

**IMPLICATIONS**

It is clear from summary Table 6 that the differences between males and females in the sciences were few. More to the point, the size of the differences that do exist are not large enough to account for the differences in number found at the doctoral level. Although it is true that females in the physical sciences were more often classified as stereotypically masculine than females in the biological sciences, this difference is slight and can hardly account for the difference in the number of Ph.D.’s in each field. The same can be said for the nonsignificant differences found in the mathematical abilities of females in the biological and physical sciences.

Why then do so many able women with characteristics no different from their male counterparts foreshorten their scientific careers at the undergraduate level? If the answer is not cognitive ability, personality, or attitude, it must be socialization. Our society as a whole is still telling young women that careers requiring years of schooling are more appropriate for males. Even some women at the most prestigious schools in the nation see careers as something to do before children are born or after they are grown, or as a way to put a husband through graduate school [22]. Many feel uncertain that the roles of wife and mother are compatible with a career as demanding in terms of time and effort as science.

Until we both accept and encourage young women to consider the rewards of a scientific career, we cannot expect more than a few of our female undergraduate science majors to pursue a doctorate in science. However, the mood of the country does not seem to be moving in that direction. Legislative action to amend Title IX, the defeat of the ERA, and a return to more traditional values are not likely to encourage young women to choose nontraditional careers.
Table 5. Discriminant Analysis of Male and Female Biological, Physical Science, and Nonscience Majors.

<table>
<thead>
<tr>
<th>Order of Variables</th>
<th>Rao’s V</th>
<th>Canonical Function 1</th>
<th>Canonical Function 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude</td>
<td>69.52</td>
<td>−.88</td>
<td>.43</td>
</tr>
<tr>
<td>M</td>
<td>95.55</td>
<td>.40</td>
<td>−.40</td>
</tr>
<tr>
<td>F</td>
<td>121.80</td>
<td>.16</td>
<td>.21</td>
</tr>
<tr>
<td>SAT Math</td>
<td>143.80</td>
<td>−.35</td>
<td>−.87</td>
</tr>
<tr>
<td>JP</td>
<td>159.00</td>
<td>−.28</td>
<td>−.35</td>
</tr>
<tr>
<td>TF</td>
<td>173.60</td>
<td>.24</td>
<td>.32</td>
</tr>
<tr>
<td>SAT Verbal</td>
<td>186.90</td>
<td>.04</td>
<td>.63</td>
</tr>
<tr>
<td>M-F</td>
<td>198.90</td>
<td>−.05</td>
<td>.35</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group Centroids</th>
<th>Function 1</th>
<th>Function 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Biological Science Major</td>
<td>−.16</td>
<td>.88</td>
</tr>
<tr>
<td>Female Physical Science Major</td>
<td>−.64</td>
<td>.54</td>
</tr>
<tr>
<td>Female Nonscience Major</td>
<td>1.40</td>
<td>.40</td>
</tr>
<tr>
<td>Male Biological Science Major</td>
<td>−.78</td>
<td>−.40</td>
</tr>
<tr>
<td>Male Physical Science Major</td>
<td>−.46</td>
<td>−.71</td>
</tr>
<tr>
<td>Male Nonscience Major</td>
<td>.64</td>
<td>−.90</td>
</tr>
</tbody>
</table>

Correct Classification Percentages

<table>
<thead>
<tr>
<th>Correct Classification</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Biological Science Major</td>
<td>69.2</td>
</tr>
<tr>
<td>Female Physical Science Major</td>
<td>66.7</td>
</tr>
<tr>
<td>Female Nonscience Major</td>
<td>66.7</td>
</tr>
<tr>
<td>Male Biological Science Major</td>
<td>35.7</td>
</tr>
<tr>
<td>Male Physical Science Major</td>
<td>48.3</td>
</tr>
<tr>
<td>Male Nonscience Major</td>
<td>53.3</td>
</tr>
</tbody>
</table>

a Nonsignificant variables were not included.

Further research should focus on the doctoral student in science, especially in the area of mathematics and affiliation needs. Some researchers have concluded that the reason fewer women than men choose to study science is that they inherently are poorer in mathematical ability than men. However, if we find sex differences in mathematical ability still exist at the doctoral level, then this differential in abilities can be discounted as a factor in preventing women from studying science. Also, if women pursuing the doctorate in science were found to have lower affiliative needs, then one could conclude that they were less affected by or disagreed with socialization pressures that suggest that scientific careers are incompatible with the female role.
### Table 6. Profiles of Male and Female Biological, Physical Science, and Nonscience Majors.

<table>
<thead>
<tr>
<th>Group</th>
<th>T</th>
<th>F</th>
<th>J</th>
<th>P</th>
<th>M</th>
<th>Fa</th>
<th>Female Traits</th>
<th>Male Traits</th>
<th>Attitude</th>
<th>Math</th>
<th>Verbal</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Biological Science</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>51.7</td>
<td>48.3</td>
<td></td>
<td></td>
<td></td>
<td>Prefers logical analysis in decision making; planned orderly life. More feminine than masculine; positive attitude toward science; good math and verbal.</td>
</tr>
<tr>
<td>%</td>
<td>51.7</td>
<td>48.3</td>
<td>62.1</td>
<td>37.9</td>
<td>6.7</td>
<td>23.3</td>
<td>50.00</td>
<td>50.00</td>
<td>0</td>
<td>0</td>
<td>20.7</td>
<td>79.3</td>
</tr>
<tr>
<td>x̄</td>
<td>105.66</td>
<td>18.43</td>
<td>97.13</td>
<td>23.97</td>
<td>19.23</td>
<td>23.83</td>
<td>18.56</td>
<td>4.97</td>
<td>3.20</td>
<td>1.63</td>
<td></td>
<td>496.66 478.67 115.17 127.84</td>
</tr>
<tr>
<td>s.d.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>105.66</td>
<td>18.43</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male Biological Science</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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(Continued)
Table 6. (Continued)

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Female Prefers logical analysis in decision making; planned orderly life. More masculine than feminine; positive attitude toward science; good math and verbal.

Male Prefers logical analysis in decision making; spontaneous life. As likely to have masculine characteristics as feminine. Positive attitude toward science; excellent math; good verbal.
<table>
<thead>
<tr>
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<th>Female Nonscience</th>
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<tr>
<td></td>
<td>%</td>
<td>%</td>
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<tr>
<td></td>
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<td>485.33  477.00</td>
<td>131.04  118.27</td>
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- Prefers logical analysis in decision making; spontaneous life. More masculine than feminine. As likely to dislike or be indifferent to science as to like science; good math and verbal.
- Prefers basing decisions on personal values; spontaneous life. More feminine than masculine. Dislikes or indifferent to science; poor math; good verbal.

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\[ \text{Percentages don’t add to 100% because percent androgynous and percent undifferentiated are not shown.} \]

\[ \text{“Masculine” was determined by adding the percentage classified as M and the percentage having masculine traits on the M-F scale.} \]

\[ \text{“Feminine” was determined by adding the percentage classified as F and percentage having feminine traits on the M-F scale.} \]
REFERENCES

NOTES


2 See Table 6 for the means, deviations, and percentages for those variables that distinguish among male and female biological, physical, and nonscience majors.
WHY I CONDUCTED THE STUDY

When I began conceiving this study there was little research in the science education literature about role-specific self-concept and sex-role identity as factors influencing career choices in science for women. Cognitive rather than sociological theories drove science education research. However, at the time of this study there was a great deal of evidence that women were not choosing science careers but instead selecting more traditional careers despite evidence that women had the capacity to do well in science careers. Why then, were they not choosing science? Earlier work that colleagues and I conducted in mathematics (Peterson, Baker, & Burton, 1983) found that role-specific self-concept influenced women’s mathematical career choices. Other research in mathematics was also helpful in my decision to look at both role-specific self-concept and future mathematics course taking (Chipman, Brush, & Wilson, 1985). Since role-specific self-concept was important in mathematics, I felt that role-specific self-concept might also be a factor in science career choice as well. There was also strong interest in sex-role stereotyping in the psychological literature at the time of this study as an explanation for why so few women chose science careers. I had found, in an earlier study, that the more stereotypical traits a women perceived herself to have the less likely she would choose a career that she perceived as nontraditional for a women or more appropriate for males (Baker, 1983). However, how the two factors of role-specific self-concept and sex-role identity worked together to influence women’s career choices had not been investigated. Thus, I thought looking at the relative contribution of each factor as well as the impact of both factors in combination on career choices in science would be worth studying.

METHODOLOGICAL DECISIONS

Role-specific self-concept and sex-role identity were operationalized by the instruments I chose to use. Role-specific self-concept was defined as having the traits of either an ideal science learner or lacking the traits of an ideal science learner. Role-specific self-concept is different from general self-concept in that an
individual can have an overall good self-concept but still think that they are not good at specific tasks such as learning science or playing tennis. Role-specific self-concept in science was measured by the Peterson Yaakobi Q-Sort (Peterson, Kauchak, & Yaakobi, 1980). The Q-Sort consisted of 20 cards with statements such as concerned about grades or reads about science outside of class. To obtain data about role-specific self-concept, students do two sorts: one for their perception of the ideal learner and one that reflects themselves as real learners. First students place the cards in order from most to least like an ideal science learner. The second sort is based on their perceptions of themselves ordering the cards from most like themselves to least like themselves. This provides a way to examine the differences in ranking of ideal and real traits. It provides insight into the degree to which students think they are different from or like an ideal science learner.

This technique was chosen because it used the students’ own perceptions of an ideal science learner rather than the perceptions of researchers or a group of students unrelated to the population under study. Thus, the instrument does not have to be re-normed when used with different populations. It is also a motivating format because it is different from a paper and pencil assessment and allows students to revise the order of the cards easily until they are satisfied that the ordering reflected what they thought was the ideal learner and what order described themselves as science learners.

The Bem Sex-Role Inventory (BSRI) (Bem, 1974) was used extensively, at the time of this study to examine sex-role identity in relation to many factors including career choice. It was one of two instruments available to measure sex-role identity and had high reliability. Since I had already used the lesser known Personal Attributes Questionnaire (Spence & Helmreich, 1978) in a previous study, I chose the more widely used BSRI for this study.

Since I was still tied to my Piagetian roots, I included a test of logical thinking. The TOLT (Tobin & Capie, 1981) was used to determine the effect of reasoning ability on career choice. Reasoning was and still is an important component of success in science. The TOLT was also a way to confirm or disconfirm if the perceptions of the students themselves as a real science learner were accurate. It would also help to determine whether sex-role identity was immaterial, if one did not have the logical ability to succeed in science.

The final instrument used in the study was a simple questionnaire to again determine students’ perceptions of their ability in science (basic, intermediate or advanced), the number of science and mathematics course they intended to take in the future, and career preferences. Since this study was conducted in Australia where school leaving age was tenth grade, students who were not going on to 11th and 12th grade were dropped from the study.

Students in the study were seventeen years old and in grade 10. Less than 1% were nonwhite. Only data from the 356 students in the mathematics and science course who intended to stay in school for grades 11 and 12 were used. Mathematics and science courses were assigned a number to reflect the level of difficulty in the
Australian school system with higher numbers indicating greater difficulty. Career preferences were grouped according to categories that took into consideration the gendered nature of careers in Australia. The five categories were science, non science, allied health, nontraditional non science, and traditional. Both male and female students were included in the study since I was still at the point where I was comparing male and females across the same characteristics. I had not yet come to the realization that such comparisons might not provide me with the information I was seeking or that such comparisons might reinforce a deficit model for women and girls.

I was still using statistical analysis in my work and sought a large sample. However, there were not enough students indicating they wanted a science career to do a regression analysis given the number of variables in the study. Consequently, I conducted both an analysis of variance and a discriminant analysis. At the time, discriminant analysis was my statistical tool of choice. I liked it because it allowed me to see if the variables I had chosen as important to career choice successfully predicted group membership (e. g. students choosing science or non-science careers). Since this study was still influenced by a positivist perspective, I generated hypotheses based on the previous research literature to predict the outcomes of the study.

SCIENCE EDUCATION AT THE TIME OF THE STUDY

Role-specific self-concept, sex roles, and science career choices of women and girls were not topics of study in science education when I undertook this research. The question of why so few women were choosing science careers was still the purview of psychology. Jane Butler Kahle, a science educator, was one of the few exceptions. She wrote *Women in Science* (1985). The chapters of her book focused on women and girls, scientists and science teachers, and took an international and historical perspective. Kahle identified obstacles for girls and women, the double problem of race and femaleness, and described pedagogy that teachers could use as well as interventions to increase female participation.

As with the research on women and girls, there were few studies that examined other under-represented groups such as African Americans or Latino students. Intersectionality was not a concept or an analytical framework. Although more scholars were including gender as a variable in their studies, they did so in order to compare the performance, attitudes, and interests of males and females. The most prevalent topic for research in the science education journals was the examination of student achievement in content areas. Biology was the most frequently studied content area followed by physics/physical science, and chemistry. It was rare to see a study focusing on achievement in Earth and space science. Technology was a concern and there were two special issues of the *Journal of Research in Science Teaching* (24, 4 and 24, 5) addressing research on the cognitive consequences of technology in science education.
A Piagetian theoretical framework still held sway but change was coming. Driver, Guesne and Tiberghien (1985) in *Children’s Ideas in Science* examined how children’s ideas about natural phenomena develop by looking at their misconceptions/alternative conceptions of scientific phenomena foreshadowing the larger body of research on misconceptions to come. Siegler (1986) also was interested in the development of children’s thinking and examined perceptual, language, memory, conceptual, and academic skill development through both a Piagetian and information processing lens. Both Driver et al. (1985) and Siegler (1986) were part of the beginning of a shift away from a Piagetian theoretical perspective.

Researchers also continued to examine the impact of the alphabet soup curricula such as SAPA (Science a Process Approach). There were many studies that looked at students’ ability to engage in science processes such as controlling variables and problem solving. Some scholars were also beginning to use large data bases such as the NAEP (National Assessment of Educational Progress) and High School and Beyond to determine the status of science achievement across the United States.

A brief look at what was published in the *Journal of Research in Science Teaching* at this time indicates that most studies focused on students at the high school level followed by studies of university, elementary, and junior high students. Few of the studies had samples of community college students. Studies of pre-service teachers, classroom teachers, or teacher education comprised approximately 20% of the research despite the fact that most science educators then and now are engaged in teacher education at some level. Publications in *Science Education* were grouped into areas of learning, science teacher education, science education generally, current issues and trends, and international science education with similar grade level and content area emphases. Researchers were most likely to use quantitative analysis and there were few truly qualitative studies. Quantitative studies occasionally used supporting evidence from qualitative data such as interview data to support paper and pencil assessments. However, these studies were not true mixed methods as we currently understand this technique.

**RESEARCH IN THE WIDER FIELD OF EDUCATION**

Mathematics educators had been grappling with the low level of participation of women in mathematics and were ahead of science educators in their concern about female participation. Chipman, Brush and Wilson (1985) in *Women and Mathematics: Balancing the Equation* undertook a systematic review of the research that examined a variety of factors (cognitive, affective, spatial, hormonal, school and home experiences, early intervention programs, self-perceptions, math task perceptions) to account for sex differences in achievement in mathematics. They concluded that the achievement gap was actually small and did not explain male female differences in rates of participation. Furthermore, they found that a student’s sex was twice as important as math scores for selecting majors. From the research, they identified a set of predictive variables such as previous mathematics achievement, the perceived
utility of mathematics, teacher and parental encouragement, perception of the utility of mathematics, aspirations for a mathematics career, and confidence in ability. Not all of these variables proved to be predictive. They found that more females than males believed that mathematics was open to both males and females but there were no sex differences in liking or interest in mathematics, or teacher or parental encouragement.

Other fields were also moving away from a Piagetian theoretical framework. In the field of the psychology of women Carol Gilligan challenged the Piagetian research on moral reasoning and the female deficit model that it supported. She wrote In a Different Voice (1982) in response to studies that found women were at lower stage in maturity of moral development as compared to males, as measured by Kohlberg’s tasks. She concluded, based on her research, that females were not inferior to males but rather, that males and females see a different moral problem when given the same moral dilemma. As a consequence, males and females used different reasoning to make decisions. Females used the preservation of relationships and the impact on people as a basis for decisions and males used logic and justice arguments. Gilligan concluded that women’s morality was based on caring and a sense of self in a network of making and maintaining relationships. Counselling psychology and vocational behavior was another area in which there were studies that examined sex-role orientation and self-efficacy in relation to choosing non-traditional and masculine careers that included STEM fields (e.g. Fassinger, 1985; Foss & Slaney, 1986; Gianakos & Subich, 1986; Post-Krammer & Smith, 1986).

An examination of the work published in the American Educational Research Journal and Review of Educational Research revealed some interesting patterns. In 1985 there were a few studies in the American Educational Research Journal that looked at self-concept but none that addressed the variables in my study of science careers, logic, role-specific self-concept as a science learner, or femininity and masculinity. One study did conclude that the relationship between self-concept and academic achievement depended upon the area of self-concept that was considered (Marsh, Parker, & Barnes, 1985). Research that looked at sex differences focused on mathematics and the role these differences played in career choice for high ability students as well as the role of pedagogy in achievement (Boli, Allen, & Payne, 1985; Peterson & Fenema, 1985).

The 1986 and 1987 issues of American Educational Research Journal also published a few studies exploring sex differences in mathematics (Benbow & Minor, 1986; Brandon, Newton, & Hammond, 1987) but Review of Educational Research publish no review articles on the topic of sex differences in science. However, Carl Grant and Christine Sleeter (1986) argued for examining gender, race and social class together in educational research without specifically addressing issues in science or other content areas. Also noteworthy is that this paper was among the first to call for studying intersectionality, although Grant and Sleeter did not use the term intersectionality in their review. Research published in Review of Educational Research on self-concept and sex-role identity was also scare at the time of my study.
CHAPTER 2

While science education and education in general was neglecting women in science, female scientists were not. Many books were written during this time by female scientists such as Evelyn Fox Keller, a mathematical biophysicist; and Ruth Bleier, a neurophysiologist and physician. These books were decidedly feminist and challenged the masculine nature of science and reflected the women’s movement of the time. Evelyn Fox Keller described her book *Reflections on Gender and Science* (1985) as examining the

historic conjunction of science, masculinity, and the equally historic disjunction between science and femininity. (p. 5)

In a similar vein, Ruth Bleier in *Science and Gender: A Critique of Biology and its Theories on Women* (1984) wrote

This book is concerned with the role of science and the creation of an elaborate mythology of women’s biological inferiority as an explanation for their subordinate position in the cultures of Western civilization. (Bleier, 1984, p. vii)

These books written from a feminist perspective rejected divisions of public/private, impersonal/personal, masculine/feminine and especially the dichotomy that labels objectivity, reason, and the mind as masculine and subjectivity, feeling, and nature as feminine. They refuted theories of sociobiology, biological determinism, brain and human nature, hormones, and sex differences, man the hunter as evolutionary explanations, sexuality, ideology and patriarchy, and patriarchal science.

Vivian Gornick an essayist and social critic also wrote about women in science in *Women in Science: Portraits from a World in Transition* (1983) and documented their challenges and decisions and how they made a place for themselves within science. Based upon interviews with women scientists, she explored the impact of the women’s movement on careers, and the differences in experiences by generation. She concluded that women do not do science differently than men and despite difficulties, they loved their life in science.

THE CULTURE OF THE TIMES

From 1981 to 1989, the conservative Reagan administration was in power in the United States. Ronald Reagan had restored confidence in the presidency and contributed to the end of the cold war by asking the leader of the Soviet Union, Mikhail Gorbachev, in a speech at the Berlin wall, to tear the wall down. President Reagan was an adept politician who was able to put together a political coalition of religious, national security, and economic/libertarian conservatives (Hunter, 2012) based on fears that the liberals would gain control of government.

These fears did have some basis in reality. The right to life movement was slowing and women’s rights supporters (feminists) were the majority of voters, opposition to a constitutional amendment banning abortions was increasing (62%) as was support

28
for the Equal Rights amendment (75%). Eighty-four percent of respondents to a Harris poll supported equal pay for women and 68% supported affirmative action in employment (Feminist Majority Foundation, 2014a, 2014b). Buoyed by some of the 1986 election victories and changing public sentiment, national women’s groups presented congress with an agenda addressing the eroding rights of women and minorities. They advocated for the passage of (1) the Civil Rights Restoration Act, (2) a Federal pay equity bill, (3) the Family and Medical Leave Act, (4) welfare reforms, (5) increases in the minimum wage, (6) funding for reproductive health care for women, and (7) funding for affordable and accessible child care and dependent care. In addition, women’s groups advocated for the reintroduction of the Equal Rights Amendment to the constitution. There was, as expected, a backlash from conservative groups. Abortion clinics were bombed, anti-abortion legislation was introduced by Congressman Henry Hyde (R-IL), Kiwanis international rejected the admission of women, and a 20 million dollars sex discrimination case against SEARS was dismissed (Feminist Majority Foundation, 2014a, 2014b).

IMPACT OF MY WORK

This study added to the small but growing body of evidence that women who choose science careers do so for different reasons than men. It also added to the studies that concluded that ability was not the determining factor in career choice. However, the definitions of masculinity and femininity used in the study reflected an earlier time and current students have less stereotypical views of themselves and the appropriateness of careers. Using the Bem Sex Role Inventory as an instrument, although appropriate for the time, is probably not as appropriate an instrument to use today. This is good news and is an indication of the progress we have made toward increasing girls and women’s participation in science.

This study helped increase awareness of the problem of the low numbers of women in science and STEM fields more broadly and paved the way for programs to increase women’s participation in STEM fields. A quick look at the statistics will reveal how far we have come since 1987. Clearly, there are more women in STEM fields now than when this study was conducted with the exception of computer science. The average percentage of women holding a doctorate for the years surrounding this study (1986, 1987, 1988) was as follows: 12.4% computer science, 6.4% engineering, 35.8% life sciences, 16.5% mathematics, and 16.7% physical sciences (Burelli, 2008). In contrast, in 2012 the percentage of female doctorates in life science was 55.6%, physical sciences, 28.5% and engineering 22.3% (National Science Foundation, 2012b). The number of bachelor’s degrees in STEM fields awarded to women in the mid 1980s was: biological science 45%, chemistry 36%, mathematics 45.5% physical science 14.6% engineering 14%, and computer science 35% (Hill, Corbet, & Rose, 2010). The percentage of bachelor’s degrees awarded to women in 2012 (Digest of Educational Statistics, 2012) was computer science 2%, engineering 13.0%, physical science 30%, life sciences 50%, and mathematics 45%.
Despite the increases in women in some STEM fields, role-specific self-concept and the concept of self-efficacy which is closely related to role-specific self-concept still remain powerful predictors of career choice and may help us understand the decline in women’s interest in computer science.