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Against the Odds: Self-Efficacy Beliefs of Women in Mathematical, Scientific, and Technological Careers

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The purpose of this study was to explore the personal stories of women who selected and continue to excel at careers in areas of mathematics, science, and technology to better understand the ways in which their self-efficacy beliefs influenced their academic and career choices. Analysis of 15 narratives revealed that verbal persuasions and vicarious experiences were critical sources of the women's self-efficacy beliefs. These findings suggest that the perceived importance of these sources of self-efficacy beliefs may be stronger for women in male-oriented domains than for individuals operating in traditional settings. Academic and relational self-efficacy perceptions resulted in the perseverance and resiliency required to overcome academic and career obstacles. Findings support and refine the theoretical tenets of A. Bandura's (1986) social cognitive theory, and they also suggest that critical tenets in this theory are consistent with the work of C. Gilligan (1982) and N. Noddings (1992).

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> I don't think all women should become scientists, but I hate to see people lost at such a young age just because they think they're incapable.
>
> —Martha
> Chemist and Study Participant

Although the number of women attending college during the last two decades has increased so that they are currently the majority, the participation of women in mathematical, scientific, and technological fields as well as advanced degrees earned are still disproportionate to those of men (Sadker & Sadker, 1994). Similarly, although girls are currently as likely as boys to take advanced mathematics and science courses while in high school, this parity disappears at the university level, where women earn fewer degrees in mathematics and science fields than do men (National Center for Education Statistics, 1995). Reasons for this continued underrepresentation of women in mathematics-related careers vary, but social cognitive researchers have suggested that the self-beliefs women hold about their capabilities may provide valuable insights (see Bandura, 1997; Hackett & Betz, 1989; Pajares, 1996a, 1996b).

Most theories of human motivation and behavior include self-beliefs as a key component. For example, the central construct in Bandura's (1986) social cognitive theory is *self-efficacy*, which Bandura defined as people's judgments of their capabilities to produce designated levels of performance. According to social cognitive theory, people are more likely to perform tasks they believe they are capable of accomplishing and are less likely to engage in tasks in which they feel less competent. Individuals' beliefs about their competencies in a given domain affect the choices they make, the effort they put forth, their inclinations to persist at certain tasks, and their resiliency in the face of failure.

People form their self-efficacy perceptions by interpreting information from four sources. Bandura (1986, 1997) has argued that the most important source of information comes from the interpreted results of one's past performance, which he called *mastery experiences*. Authentic mastery of a given task can create a strong sense of efficacy to accomplish similar tasks in the future. Alternatively, repeated failure can lower efficacy perceptions, especially when such failures occur early in the course of events and cannot be attributed to lack of effort or external circumstances. Continued success, on the other hand, can create hardy efficacy beliefs that occasional failures are unlikely to undermine.

The second source of self-efficacy information is the *vicarious experience* that individuals undergo when they observe others performing tasks. Observing the successes and failures of others perceived as similar in capability contributes to individuals' beliefs of their own capabilities. The behavior of models is particularly influential, and this is a prominent area of research in the study of self-efficacy. In situations in which individuals have had little experience with which to form a judgment of their competence in a particular area, models are especially informative.

Beliefs of personal competence are also influenced by the *verbal persuasions* one receives. Verbal messages and social encouragement help individuals to exert the extra effort and maintain the persistence required to succeed, resulting in the continued development of skills and of personal efficacy. However, verbally convincing people that they are indeed capable of accomplishing a particular task is hypothesized to have the greatest effect on those who already believe themselves capable (Bandura, 1997). Of course, messages can also work to undermine efficacy beliefs when used to convince people that they lack capabilities. For example, when women receive social messages that they do not belong in a male-dominated field such as mathematics, they may be especially vulnerable to believing that they are not, and cannot be, competent in that area. It is important to keep in mind Bandura's (1986, 1997) caution that verbal persuasions can more easily undermine efficacy beliefs than strengthen them.

Individuals look to their *physical and emotional states* as a fourth source of information about their capabilities. Stress and tension are often interpreted as indicators of susceptibility to failure, and one's mood can also have a pronounced effect on self-efficacy beliefs. Typically, optimism and a positive mood enhance efficacy beliefs, whereas depression, despair, or a sense of despondency diminish them.

Researchers who have investigated the sources of self-efficacy perceptions have focused on Bandura's (1986) hypothesized sources. Lent, Lopez, Brown, and Gore (1996) factor analyzed a source scale and reported that a four-factor model of the latent structure of the efficacy sources underlay the instrument. In general, mastery experience consistently makes the strongest contribution to mathematics self-efficacy (see Lopez & Lent, 1992). Lent, Lopez, and Bieschke (1991) found that each of the four sources correlated with mathematics self-efficacy but that, after controlling for mastery experience, the other three sources did not explain significant additional variance. Matsui, Matsui, and Ohnishi (1990) found that verbal persuasion was the only source that did not make a significant contribution to mathematics self-efficacy beliefs. Although these findings support Bandura's (1986) contention that mastery experience is the most important source of efficacy information, researchers have reported some interesting gender differences. For example, whereas male students report more mathematics-related performance accomplishments than do women, women report more vicarious learning and persuasive experiences than do men (Lent, Lopez, et al., 1996). Lent, Brown, Gover, and Nijjer (1996) found that mastery experience was the most mentioned source of efficacy that college students believed accounted for their mathematics-related efficacy perceptions, but women tended to cite physiological reactions and teaching quality considerations much more often than did men.

The more prominent contribution of mastery experience to individuals' self-efficacy perceptions may be due to several reasons. The forced-choice structure of survey scales typically used to assess self-efficacy sources does not allow for elaboration or for examples of instances in which the source

variables worked independently or together. Also, it is possible that past performance accomplishments may be the most relevant to students at the time surveys are administered. As Hackett (1995) noted, "memories tapped in retrospective research of this type are heavily influenced by current attitudes. Individuals are far more likely to recall their own successes and failures than to remember comments of others or observational experiences" (p. 246). Although this line of research has demonstrated how much of each source of self-efficacy has contributed to the overall efficacy perception, it has not painted a holistic picture. Intricacies of self-efficacy development, as well as the importance of each source to different stages in academic and career paths, still remain largely unexplored.

The self-efficacy beliefs that people hold influence the choices they make, the amount of effort they expend, their resilience to encountered hardships, their persistence in the face of adversity, the anxiety they experience, and the level of success they ultimately achieve. Individuals with strong self-efficacy beliefs work harder and persist longer when they encounter difficulties than those who doubt their capabilities. Results from research on self-efficacy beliefs indicate that these judgments of personal competence are often stronger predictors of behavior than are prior accomplishments, skill, or knowledge (Multon, Brown, & Lent, 1991; and see Pajares, 1996b; Schunk, 1991).

The mathematics self-beliefs of college students pursuing mathematics and science-related majors and careers have by now received extensive study. Researchers have demonstrated that college women's perceptions of their capabilities to succeed in mathematics and related areas are significantly lower than those of men in the same areas (Hackett, 1985; Pajares & Miller, 1994). Findings have also revealed that students' confidence in their mathematics capabilities influence their career choice and direction as potently as their performance (see Bandura, 1997; Hackett, 1995; Lent & Hackett, 1987, for reviews). In fact, researchers have observed that women aptly competent in mathematics often fail to pursue mathematics-related careers because they have low self-efficacy perceptions about their competence (Hackett, 1985; Lent, Lopez, & Bieschke, 1991, 1993; and see Phillips & Zimmerman, 1990). This is consistent with Bandura's (1997) observation that "girls have a lower opinion of their capabilities for mathematical activities than do boys, even though they perform equally well in this subject" (p. 430). When college women come to believe that they are not as capable as they really are or that they will be unable to compete in a male domain, they may shy away from mathematics courses, avoid mathematics-related majors, and select academic paths for which they may be less prepared or interested but more confident (Hackett & Betz, 1989).

Mathematics educators who have examined the factors that influence students in university mathematics classes have also noted differences between women and men in terms of their confidence (e.g., Mura, 1987). When students are asked to identify factors influencing them to pursue a graduate degree in mathematics, men and women express similar reasons

for liking mathematics, and they report having developed an interest in mathematics as early as elementary school. Women, however, seem to need more persuasion from at least one person, usually a teacher, to attend graduate school, and their career aspirations are set at a lower level than are men's (Becker, 1984). Women report being both encouraged and discouraged in their educational histories to a far greater degree than do men. They also express lower confidence in their abilities in their fields and are less likely to aspire to pursue a doctoral degree (Becker, 1990). Interestingly, these findings suggest that the perceived importance of verbal persuasions as a source for confidence beliefs may be stronger for women in male-oriented domains than is hypothesized by social cognitive theory. .

It may be that women are taught to view mathematics through socialization practices that place mathematics-relevant tasks in a male domain, contributing to their feelings that they may not be as capable of continued success in this area as their male colleagues (Bandura, 1997; Eisenberg, Martin, & Fabes, 1996). It is also likely that men and women have different sex-typed experiences in childhood that limit women's exposure to the sources of information necessary to develop strong self-efficacy perceptions in traditionally male arenas. For example, women have been found to possess higher self-efficacy for tasks associated with working with people than for tasks associated with working with things (Whiston, 1993). In traditionally male domains, women may lack opportunities to engage in mastery experiences, to learn vicariously from vocational role models, and to be encouraged by significant others to pursue nonstereotypical career paths (Eccles, 1989; Betz & Hackett, 1981).

And yet there are women who are undeterred by these obstacles and go on to pursue mathematics- and science-related careers. Despite educational and social systems that begin to undermine the mathematics confidence of girls as early as middle school (Eccles, 1989; Midgley, Feldlaufer, & Eccles, 1989; Pajares, 1996a), some women maintain the high level of effort, persistence, and confidence in their mathematics skills required to succeed in this area. Self-efficacy theorists would argue that these women have selected mathematics-related majors and pursue mathematics-related careers in large part because their high attainments were accompanied by the corresponding confidence in their capabilities (Bandura, 1986, 1997; Schunk, 1991). But how were they able to accomplish this in environments similar to those in which most other female students develop lower expectations about what they can achieve?

Traditionally, self-efficacy research has been overwhelmingly quantitative. Studies have provided important findings and have demonstrated the existence of the confidence gap. However, quantitative methods do not provide the opportunity for rich description available through narrative. Self-efficacy theorists have argued that deeper insights must come from qualitative research (Pajares, 1996b, 1997; Schunk, 1991). A notable exception to the quantitative studies that have examined the career development and self-beliefs of women in mathematics was a recent study by Stage and Maple

(1996). Using a narrative approach, they explored the educational and career paths of seven women who had successfully completed a bachelor's or master's degree in mathematics and chose to leave the mathematics/science pipeline to pursue a doctorate in education. They found that these women had an interest and aptitude in mathematics at an early age and most had individual mentors who were instrumental in helping them develop their interest. Although all women had negative experiences as undergraduate mathematics majors, they reported at least one memorable negative incident as graduate students that stood out as a primary reason for them to leave mathematics.

Stage and Maple (1996) demonstrated that women who were deterred from their goals to have a career in a mathematics-related area were hindered, in part, by the conflict of their beliefs about themselves and their beliefs about the discipline of mathematics. Similarly, self-efficacy research has shown that women are not likely to persevere in traditionally male domains such as mathematics when their judgments of personal competence are low (see Hackett, 1995). In such cases, self-efficacy beliefs are maladaptive but instrumental in women avoiding mathematics-related courses and careers.

The purpose of this study was to discover the role played by self-efficacy beliefs in the success of women who selected mathematics-related majors and pursued mathematics-related careers. Specifically, we explored the personal stories of women who have selected and continue to excel at careers in the area of mathematics, science, and technology to better understand the ways in which their self-efficacy beliefs influenced their academic and career choices as well as the manner in which their self-efficacy beliefs were developed. Although prior research results suggest that self-efficacy beliefs are influential arbiters in the development of human competence and that past performance accomplishments are generally the strongest source of self-efficacy development, the population of women who have pursued mathematics-related careers and encountered success in mathematics-related domains has not been the target of inquiry. Consequently, we sought to better understand the contribution made by the four sources of self-efficacy information to the development of self-efficacy beliefs and to gauge the subsequent contribution made by these beliefs to the development of mathematics-related competence.

Methods and Procedures

According to Merriam, "Qualitative research assumes that there are multiple realities—that the world is not an objective thing out there but a function of personal interaction and perception. It is a highly subjective phenomenon in need of interpreting rather than measuring" (p. 17). Consequently, we selected qualitative methodology to obtain the rich description, narrative, and self-efficacy stories that emerge when individuals explore their natural history. Our choice in this regard is in concert with Jerome Bruner's (1990, 1996) call for a greater use of narrative in studies of psychological constructs

to better understand the meanings with which individuals imbue their experiences (see Lieblich & Josselson, 1994). And recall that various researchers have suggested that quantitative efforts in the study of self-efficacy should be complemented by qualitative studies aimed at exploring how efficacy beliefs are developed, how students perceive that these beliefs influence their academic attainments and the academic paths they follow, and how the beliefs influence choices, effort, persistence, perseverance, and resiliency (e.g., Pajares, 1996b; Schunk, 1991).

Case study methodology is especially appropriate when prior theoretical propositions guide data collection and analysis and the researcher wishes to account for and describe contextual conditions (Yin, 1994). Self-efficacy theory has by now specified a clear set of propositions as well as circumstances within which the propositions are believed to be true. A single critical case meeting all the conditions necessary for testing the theory is used to extend, confirm, or challenge the existing propositions. In the present study, the case of women who have succeeded in mathematics-related careers is critical because in meeting the theoretical suppositions of social cognition, the women must have held the corresponding belief in their capabilities to have that career. Consequently, we selected case study methodology as the method to best extend social cognitive theory by exploring how women's self-efficacy beliefs were developed and maintained.

Participants

Participants were 15 women who currently have a career in mathematics, science, or technology. Because we were primarily interested in studying the development of self-efficacy beliefs related to mathematics, we required that the careers of our participants should rely on an extensive use of mathematics or have had mathematics as a prerequisite. There are several careers that fulfilled the criteria for this study: mathematics professors, teachers, and researchers in mathematics-related fields at the university level; chemists, physicists, and computer software developers; and engineers (see Table 1). Because our aim was to explore the self-efficacy beliefs of women who made the choice to pursue mathematics-related careers that have less representation of women, we did not include those women in the medical or health professions. To bound the sample and to provide insights relevant to America's educational system, we selected participants who were schooled in the United States.

Because of the underrepresentation of women in mathematics-related fields, the proportion of women in these careers is small, making them a difficult sample to find. Participants in the study were selected by a combination of network selection and primary contacts. We gained access to a large northwestern software company through a personal contact who recommended women who might be interested in participating in the present investigation. We also contacted professors in the mathematics department through the faculty directory at the university level. Women who

Table 1
Background of Participants

Name	Age	Ethnicity	Educational background	Occupation
Lynn	40	Caucasian	BA, MD, PhD Candidate, genetics	Epidemiologist, geneticist
Suzanne	53	Caucasian	BA, MS, PhD chemistry	Research chemist, epidemiologist
Anne	26	Caucasian	BA sociology and communications	Software test engineer
Patty	42	Caucasian	BA chemistry, MA mathematics PhD Candidate, measurement	Statistics professor
Katy	41	Caucasian	BS, MA nuclear engineering	Nuclear engineer, radiation studies
Dinah	32	Caucasian	BS, PhD computer science	Computer science professor
Eve	38	Caucasian	BS, PhD mathematics	Mathematics professor
Laura	30	Japanese American	BS electrical engineering	Software engineer, project manager
Cindy	27	Caucasian	BS mathematics	Software programmer, technical editor
Tammy	44	Caucasian	On-the-job technical training	Software development, project manager
Jean	32	Caucasian	BS chemical engineering MBA business administration	Chemical engineer High-Tech organizational consultant
Martha	34	Caucasian	BS chemistry MS experimental polymer chemistry PhD theoretical chemistry	University-Based research chemist Chemistry software developer and business owner
Mary	34	Caucasian	BS mathematics	Program manager for technical exam, development, and certification
Julie	30	Caucasian	BS computer science	Software design engineer
Lily	31	Latin American	BS nuclear engineering MA metallurgical engineering	Technical engineer, applications engineer

agreed to participate in the study were asked to recommend other women who might also be interested in participating, and we asked personal acquaintances to recommend others with mathematics-related careers.

Instrumentation

According to Merriam (1988), the purpose of interviewing is to "enter into the other person's perspective" (p. 72). Interviewing also allows for direct focus on the case study topic and provides insight into perceived developmental inferences, especially important to this study because women were asked to reflect on the reasons for making their academic choices and selecting specific careers (Yin, 1994).

Previous research in the area of self-efficacy has examined the development of self-beliefs predominantly from the results of structured surveys. To allow for the unique narratives that emerge when individuals reflect on their own development, we designed an open-ended interview protocol (see appendix). The interview protocol was semistructured, allowing for both the standardization needed to acquire similar information from each participant as well as the flexibility required during individual administration. We also structured the protocol so that the same questions were asked of each participant in a similar order to remain focused on the participants' self-efficacy beliefs. Furthermore, the structure of protocol ensured that we asked each participant the same questions, thus minimizing the effect of the protocol itself on the patterns in the findings.

We designed the protocol questions using several strategies. The first author administered two sample open-ended interviews to ensure that the wording of the refined questions on the protocol were clear and appropriate. Protocol questions were designed in keeping with an understanding of the sources of self-efficacy that was consistent with previous theoretical notions (see Yin, 1994). We accomplished this by examining sources of self-efficacy surveys that assessed the four hypothesized sources of efficacy and consulting with a researcher with expertise in the area of self-beliefs and self-efficacy (see Lent et al., 1996; Lopez & Lent, 1992). To get a holistic description of each participant and her story, we included questions designed to elicit a variety of information covering the totality of the phenomenon under investigation (Patton, 1980). Questions covered different time dimensions as well as content types. These questions provided the most complete picture of the participants' academic and career history and self-beliefs, as well as maximizing response consistency. We want to emphasize at this point that we took some pains to design the protocol such that participants would not be led toward a discussion that would have them emphasize their self-efficacy beliefs in the context of their rich and personal academic and career histories. If themes related to confidence were to emerge from the study, we wanted them to emerge from the participants' own narratives rather than as prompted responses to leading questions.

We began the protocol with a question designed to gather demographic information, family background, academic background, and career history.

This information served as a springboard for continued discussion and also helped to establish a comfortable rapport. The second question asked the participant to describe her current occupation. It served to help the researchers more fully understand the participants' career and to provide a foundation on which to ground other responses that might be particular to that career.

The four hypothesized sources of self-efficacy were then systematically explored. Question 3 asked participants to recall experiences that influenced their choices and decisions to pursue their career. Our aim was to explore past performance attainments, theoretically the most influential source of self-efficacy. Because participants were free to discuss their past in their own words, they had an opportunity to explore the varied experiences that they perceived to have guided them along this career path. Question 4 was designed to discover whether, and how, the women in our study observed and learned from others and whether they used these vicarious experiences to help develop their own self-efficacy beliefs. Question 5 explored the verbal persuasion source of self-efficacy. This source is typically operationalized with survey questions that assess whether or not individuals were discouraged or encouraged by those around them. Consistent with our efforts not to lead our participants, we explored the content of those types of messages but without a prompt explicitly eliciting encouragement or discouragement. The fourth hypothesized source of self-efficacy, physiological indexes, was explored with Question 6. So that participants would address their emotional reactions to mathematics-related courses, we included probes such as, "How did pursuing mathematics (science or technology) make you feel?"

We explored in additional detail the career development of women by asking for a memorable story that would aid in understanding how participants selected their careers. This question guided respondents to tell their own stories and allowed them to provide their own interpretations of what they perceived to be meaningful events to their academic and career success. Because women who currently have careers in mathematics-related fields may provide unique insights into the problem of less representation by women, we asked them to express their own opinions about why so few women pursue such careers as well as what they thought should be done to alter the situation. Finally, to enhance the participants' analysis of their own personal histories, the last question asked them to comment on whether they would have liked to have done anything differently in their academic and career histories.

Data Collection

The first author contacted the recommended participant by telephone to ensure that she fulfilled the criteria. At that time, the researcher briefly explained the purpose of the study to be an investigation of women in mathematics-related fields. Participants were told that they would be asked to take part in an in-person interview that would ask them to discuss their

academic and career personal histories. The researcher also informed them that the information they shared—their names, the names of their companies, and the names of the people they might discuss—would be kept confidential.

All efforts were made to conduct the interview at the participants' place of work. There were two reasons for this: It was our hope that the participants would be more comfortable in their own familiar surroundings and that the work place locale would inspire them to focus on career-related beliefs. The first author spent the first few minutes establishing a rapport with each woman.

All interviews were conducted by the first author and recorded by an audiocassette recorder. The researcher took notes during the interview to pace the interview and to write down a statement or idea that required further probing so as to not interrupt the respondent at an inappropriate time. Also, the researcher noted any observations or summary points that came to mind immediately after the interview in a researcher's notebook. To provide the most complete database for analysis, recordings were transcribed verbatim. Interview length averaged 60 minutes. We proofread all transcriptions by listening to the recorded interview and reading the transcription. So that participants could clarify or add to the transcript any meaning they thought was necessary, a complete copy of the interview transcription was sent to each participant and changes were made accordingly.

Data Analysis

Transcriptions were coded by the guidelines set forth by Miles and Huberman (1994). We developed a list of start codes according to the conceptual framework of the study. Codes were generated from each question on the protocol. Start codes were initially descriptive in nature for the purpose of "chunking" information into smaller units for analysis. So that coders did not have to translate the code into the concept, codes were named close to the content that they were describing. We revised the start list during initial coding to add codes that were needed to describe more specific instances or subjects that were not included in the beginning list.

Ideas about and reactions to the meaning of the information while coding were written on the margin of the document. These interpretations of the descriptive coding were then used to design pattern-based themes. According to Miles and Huberman (1994), whose procedures we followed, first level coding is a device for summarizing segments of data, and pattern coding is a way of grouping those summaries into a smaller number of sets, themes, or constructs. Data were check-coded by a colleague both at the stage where start codes were beginning to be applied and when pattern codes were developed. Because the present case study is bounded by participants in the same area, reoccurring phrases and common threads in the participants' academic and career histories were sought. To understand how the self-efficacy beliefs of women influenced their academic paths and

career choices, we examined *commonalities* in the development of their self-efficacy beliefs; to understand the factors that enhanced or inhibited self-efficacy, we explored the *patterns of relationships* between the beliefs described by the participants and the resulting decisions that they made regarding their career and academic paths.

Reliability and Validity

One of the assumptions underlying qualitative research is that reality is holistic, multidimensional, and ever-changing; it is not a single, fixed, objective phenomenon waiting to be discovered, observed, and measured. Assessing the isomorphism between data collected and the reality from which they were derived is thus an inappropriate determinant of validity (Merriam, 1988, p. 167). Threats to the internal validity of this investigation were addressed by trying to represent an honest rendition of how the participants see themselves and how their beliefs functioned in their academic and career development. We sought to maximize internal validity by peer examination and by exposing our own biases (Merriam, 1988). Because we approached the case study from the perspective of self-efficacy theory, and because one of our primary aims was to shed light on theoretical concerns, we interpreted responses and made inferences within the understandings which that perspective provided. Colleagues well versed in case study methodology were asked to comment on the patterns of the data and the findings as they emerged. Two colleagues familiar with educational issues but not with self-efficacy theory were asked to read transcriptions and resulting findings to ensure that alternative theoretical explanations were not ignored.

Reliability in case study methodology is best ensured by standards of qualitative inquiry. "That is, rather than demanding that outsiders get the same results, one wishes outsiders to concur that, given the data collected, the results make sense—they are consistent and dependable" (Merriam, 1988, p. 172). The main strategies we used in this case study to address threats to reliability were documentation and development of an audit trail. We kept a detailed record of how data was collected, how decisions were made regarding the case, as well as how many times and under what circumstances participants were contacted. Our objective, of course, was to maximize the likelihood that subsequent investigators following our procedures in similar domains would obtain similar data and arrive at similar conclusions.

External validity, focusing on the generalizability of the findings, is an important concern in qualitative research. Because we did not use random sampling, the analogy to statistical generalization should be avoided. We addressed validity concerns in keeping with guidelines set out by Merriam (1988). First, we attempted to assess and report in a detailed manner the ways in which the participants' self-efficacy beliefs played a role in their academic and career development. In this way, the appropriateness of the transferability of the case can be determined by the readers or practitioners

who might apply the study's findings to similar situations and contexts. Second, we tried to establish the typicality of the case, so that others can make comparisons with similar situations. By setting definitive sample criteria and providing a report that will emphasize the uniqueness of the academic and career histories of the women in this case, users should have a strong foundation for comparison. Third, though not designed to be part of the present study, future research could use a cross-case analysis design. Findings from this study could be compared with those of other types of cases, men in mathematics-related careers or women in careers that are not mathematics-related.

Results and Discussion

Two themes emerged from our analysis of our participants' responses. The first was that vicarious experiences and verbal persuasions were instrumental sources for the development and maintenance of self-efficacy beliefs for women in mathematics-related careers. Our participants recalled vicarious experiences and verbal persuasions to a greater extent than they did performance attainments. Experiences involving significant others in the women's lives were pervasive in their perceptions of why and how they arrived at their career decisions. This leads us to suggest that the perceived importance of these sources of self-efficacy beliefs may be stronger for women in male-oriented domains than for individuals operating in traditional settings. The second theme was that the self-efficacy beliefs of women in these male-oriented domains, although nourished by sources theoretically posited to be modest sources of confidence, functioned in the way suggested by Bandura's (1986, 1997) social cognitive theory and supported by previous research (e.g., Hackett, Lent, and their colleagues). These self-beliefs helped the women in our sample to be resilient to both academic and social obstacles. The women also demonstrated a great amount of persistence and effort while they continued along their academic and career paths.

Vicarious Experiences and Verbal Persuasions as Critical Sources of Self-Efficacy

Family. Women recalled critical episodes in which the interactions they had with a family member led to efficacy-building experiences. Typically, the vicarious experiences as well as the verbal persuasions dealt directly with a mathematics-related content area. Ten of the women provided examples of individuals in their family who had mathematics-related careers or modeled mathematics-related skills on a regular basis. Suzanne, a chemist for about 30 years, spoke of her father's tenacity in pursuing an education in engineering:

> My dad was very, very good [at mathematics]. He was gifted at it, but he never had much of a formal education. But he studied math at home by correspondence school, and then he was actually given a degree in what would amount to electrical engineering. He was very

> good at math and always encouraged me in math and science, and I thought I could do anything the boys could do, so it was never a problem.

Mary ascribed her perseverence with mathematics work to her father's encouragement, and she credited him as a primary influence in her career selection—program manager for exam development.

> [My] pursuit of mathematics is definitely due to my dad. He was very supportive, and I never got the impression that I couldn't do math from my dad. I never got that math anxiety, and, in fact, when I would not understand something, he would just get up with me in the morning, and he would explain it to me, and we would work through the problems together, and he really emphasized that it just takes practice. You just practice, and pretty soon you start to see a pattern.

A software design engineer, Cindy explained how familial influences in the form of relatives who used mathematics-related skills and worked in mathematics-related fields influenced her in a similar direction:

> All my male relatives are engineers. And it seems to me that along the way . . . a lot of the women should have been. My mother is a nurse, but she's better then she gives herself credit for. She rewired her entire house the other summer. I believe she taught herself out of a work book . She said, "You just do a simple circuit, and then you do a more complicated circuit, and then you do your whole house." Being fairly sufficiently rural, we were always doing something like building a barn or running insulated pipe out to the chicken house or something, so that it took a fair amount of people using numerical or analytical or just practical working area stuff, and, while I was growing up, that seemed like a normal thing to do. And if your whole family does this, you might as well.

Early exposure to mathematics-related content areas by various members of the women's families made these areas accessible ("I had my first exposure to computers when I was a little older than 6. We've always had a computer in the house; my father was always sort of involved with it. He likes little problems—little math problems. And he would teach me tricks about numbers."). Their experiences with certain skills were part of their dealings with family members with whom they interacted or whom they frequently observed in mathematics-related areas ("My family's totally encouraging about math because a lot of them are in math and from that kind of background."). They learned that mathematics-related areas were those in which they were capable of participating and in which they could compete. Tammy, who went on to become a software project manager, spoke about how she was influenced by her older brothers to participate in activities that she felt contributed to her later interest in mathematics-related academic subjects as well as her comfort with analyzing objects.

> Both my brothers had automobiles, and they always took them apart, and I was always interested in the fact that they had all these things that they could tear apart and put back together, and I wanted to do that. Usually, I had the ear to listen to their carburetor, their engine when it was running, and they would have me come out and listen to tell them what was wrong with their car. Which was kind of interesting. So it was a good training ground.

It was both normal and comfortable for the participants to have an interest and a competence in mathematics, since members of their families shared those qualities ("My father has actually been working in computers for most of my life. I have a 5-years-younger brother who has been a computer genius since about 7; my sister was an electrical engineer before me. So I thought, 'Well, you know, I'll just do that.'").

For some women, the social persuasions they received from members of their family regarding the idea of women going into male-dominated areas and of women doing what they wanted to do were critical and integral to their later paths ("I did have a family who would tell me I was smart; people who affected me, I think, were my father and my brother who thought it was great that a female could do math; I just had a knack for math. You know, my parents were ecstatic that I liked it so much and I did so well with it. And that encouragement, you know, made me keep working hard at it."). These experiences, either via modeling or via attending to verbal persuasive messages, did not have to be mathematics-related in order to become self-efficacy enhancing ("I think I'm fairly confident in my abilities. Probably a lot of it has to do with my upbringing, the way that my mother always let us know that we were doing good jobs, and, you know, 'You can do it, just try and keep trying.'"). For example, Martha discussed the powerful message she received from her mother during her early school years.

> My mother always engendered in me the attitude that I could do absolutely anything I ever want to do. So she really gave me a confidence that is a big part of success in academics and maybe in other things—sometimes you get to a point where you don't have that much either skill or knowledge, and you have to just go on your guts or your confidence. You have to just kind of push your way through something until you have the time to accumulate the knowledge. And I think that that's something she engendered in me just by always being herself so confident of my abilities, rightly or wrongly. And my father certainly never detracted from that. He always portrayed her as being the smarter of the two. So I was raised in an environment where women were not only capable but were even potentially very well and highly regarded.

Katy, who became a nuclear engineer, did not have a member of her family in a mathematics-related career, but she credited her parents both with the formation of her self-efficacy beliefs and with a mental toughness that surely helped her resiliency to overcome obstacles.

> I was just born to be who I was. I then had other kinds of things that, you know, gave me the gumption and the drive and the will to do something different than what was traditional for a woman to do. And that came from my parents. Both of my parents, really. My father never expected his girls to be soft and female. We were raised to be tough.

A 30-year-old program manager, named Laura, who had majored in electrical engineering spoke about her grandmother as a critical influence.

> [Since I was] as a small child, [my grandmother] told me and my sister, this was my mother's mother, "You really have to study hard and have your career and your own life." Because my grandfather passed away when she was 32, . . . She . . . had to raise my mom by herself. And she gave us money to go to college and said, "Here's money—go to college—don't spend it on a guy. Don't get married and give it to your husband." It was like, "You do it for yourself, you have your own career, be able to take care of yourself."

Tammy credited her grandfather in a similar way.

> My mother's father would tell us stories when we were younger, and even as we got older. He died when I was 17. He came to America on the boat, all by himself, when he was 17 years old, and he was very influential in saying things like, "Take risks. Try something new. It just means another chapter in your life." He would say, "A lot of people will say, 'Don't do this.' But think about it for yourself. Make your own decisions."

Teachers. Women were especially responsive to the vicarious experiences and verbal persuasions from their teachers. All women spoke about teachers whom they believed to be highly influential in the development of their competence and confidence. A 40-year-old geneticist noted that she "had an excellent mathematics teacher. I got encouragement from this one teacher, and he was a former military man. He was very strict, but everybody liked him. I really wanted to work through problems and stuff." Jean, a 32-year-old chemical engineer, observed that she had been

> brainwashed by a high school physics teacher. I found that, if you were a female who was good at math and science, this particular teacher really believed in getting women into scientific degrees. So every year for 2 years that I was in his physics class, he said, "Marry a doctor, be an engineer." When I came to college and I was pre-med, I hated physics, though that is what I had planned to major in. Well, somewhere at this point, this saying kept going through my head. . . just marry a doctor and be a chemical engineer, and I went into chemical engineering.

The teachers whom the women described arrived at various points throughout their academic and career paths. Some spoke of significant

middle school teachers ("I think when I was younger, like in junior high, I had a math teacher that I really liked. He was a really good math teacher, and I think that influenced me a lot."). Cindy vividly described her experience with a middle school mathematics teacher.

> One of our teachers, being most stereotypically weird, nerdy, coke-bottom-glasses, extremely shy math teacher, we had was really quite nice. He walked up to me once some time early in class when I was studying and said one of the nicest things anyone has ever said to me, which was, "You slipped beautifully into the disjunctive." Which was referring to a specific step in a math problem we were doing . . . which is right up there for emotional support.

Martha, one of the chemists in our sample, found that critical influence in one of her university professors.

> As a junior I took a quantum mechanics course, which is actually my field, with a faculty member, another man, and he was just excellent at taking the romance out of the science and laying it out in everyday terms. And it really, really, enthused me and made me want to follow that area.

We want to emphasize that both male and female teachers were represented in the participants' recollections ("I think my experience was different from other women, that I did have a [male] mathematics teacher who seemed to be nongender biased and encouraged women, the women in the class, or girls at that point, as much as the boys."). Although the instructor's gender did not seem to play a role as far as the intensity of the influence, it was important that women perceived their instructors as supportive of them in their specific area. One of our chemists found inspiration in a male university chemistry instructor.

> One [important influence] was this first general chemistry instructor who was not only very, very enthused about the material himself but was able to articulate it, and his view of the student was almost genderless. It didn't matter to him if you were a male or female. He treated everyone the same. He was a bit of a nebish, but he was a very nice guy. That would have been the person who kind of kept me in the chemistry program.

In fact, Mary even suggested that she found her male professors superior to her female professors.

> I had more male professors, and to be honest, the male professors were better—they were a lot better. They were clearer, there was a point. I cannot think of any female professor that I look back and think, "Wow, she was outstanding." But I can think of many male professors that I had like that.

As had been the case in their experiences with their families, women felt that teachers' influences were effective because of the teachers' enthusiasm for the subject matter and because of their passion regarding the success of women in the male domains.

> My calculus teacher—she was excellent—she really made it make sense. She went through it really slowly and explained all the reasons behind everything. She loved her subject matter so much that it kind of came through, and you couldn't not be interested when she was talking about it. You know, when the teacher loves their subject, I guess it's more easy for you to be infected.

Patty, a 42-year-old professor of statistics, found this passion and enthusiasm in her high school algebra teacher.

> It was the first time I had algebra, and I loved it. And then, all of a sudden, I excelled in it. And the teacher said, "Oh no, you should be in the honors course," or something like that. So, there's somebody who definitely influenced me because I don't think I ever even noticed. I mean, I didn't care one way or the other about mathematics. It was just something you had to do. I remember she used to run up and down the aisle. She was real excited. She was just this little, tiny, skinny nun who was just full of energy. She said, "Oh, you gotta go in this other class. You gotta." And she kind of pushed a little bit, and I was willing to be pushed, and so that was nice.

Peers. Several of the women described peers as important influences in their development of confidence and competence, although peers and friends as positive influences or models for pursuing a mathematics-related area were mentioned less often than were family members and teachers. Typically, the influence of peers was described in terms of support once the women had made their decision to pursue a mathematics-related major or career and had entered that academic area. Take the following illustrative highlight of friends providing, in essence, a support structure.

> Well, in high school, my friends were a little bit more the high achiever types, and we all went through the math classes together. And, so it wasn't like I was different. In fact, there was a math club. Some of my good friends were in math. And it wasn't considered to be nerdy or anything like that.

Often, women found themselves in peer communities with a shared interest in mathematics-related areas ("It's kind of a weird thing because the people who were my immediate group of friends are very proud about this. But I mean, it's like they all excelled in school also, so they don't consider anything I'm doing good or bad or anything. It's like that's just the way it is."). These groups helped with the maintenance of the confidence needed to stay involved in the area. A future engineer described the need for having other women around to feel comfortable.

> I think I've always noticed when I'm the only one. And, when there are one or two others, it matters more whether they happen to be like you or not. But once there are three or four other people, you become sort of almost every other group you can divide, like outgoing people versus introverted, or east coasters versus west coasters, as long as there are enough women that almost any other division has some women on both sides. I think it is much easier for women to fit in or be accepted because at all moments, when people are thinking in some other divisive way, they have to enlist more women on their side.

Group membership afforded women relational experiences in areas such as chemistry clubs, computer hacker communities, or friends that were described as "academic achievers."

> I remember I was in this chemistry club, and it was interesting because at the time it was a very small club—there were maybe six or seven people. And I'd say, including myself, four of them were women. And it was pretty much the women who were the leaders. I can remember this woman saying, "Well, everyone has always told me that women don't do well in math and science, so I'm just going to push forward with that." And I remember thinking that it was such a good feeling that she had kind of confronted this whole image but wasn't going to allow it to detract from the way she really felt about herself. I think this actual group of women also not only cemented my love of science and knowing this is what I wanted to do . . . as a job or a career, but it made science *social* to me.

Supervisors. Several women discussed the influence of bosses or managers in their career history as important motivators. Reflections about managers involved both male and female supervisors, and memories included strong persuasive messages and encouragement ("I had a boss there that just started leading me, and he encouraged me, and he sent me to classes, took me on a lot of business trips with him."). A 26-year-old engineer, Anne, credited her manager with affording her the confidence to pursue her current career.

> My manager was a really good influence. He was very encouraging in taking classes. You know, didn't make me feel that because I didn't have a computer science degree like I didn't have a chance. He would say things like, "Well, you know, a lot of other people don't too, and you can learn how." So he was very encouraging. I definitely wouldn't have done it, if I wouldn't have had him as a manager.

Resiliency to Obstacles

Self-efficacy built on relational experiences resulted in a pattern of resiliency to perceived obstacles as women continued along their academic and career paths. The women we spoke with described themselves as "persistent" and

"resilient." Clearly, they had not let perceived failure deter them from their paths. Instead, they had, as Bandura (1997) suggested, turned difficult situations into temporary setbacks, rather than into insurmountable hurdles.

Academic resiliency. Tammy spoke about the difficulties she encountered in certain engineering classes and how she overcame these academic impediments.

> I knew how to work hard. And so I would study. A couple of times—I remember one or two classes—in which I just said, "I'm going to try this later," and dropped out of it before the halfway mark, and then came back a year or two later and took it, and it was no big deal. It was just the first time I had seen stuff like that, and it scared me. More scared than anything, you know. And so when I came back, then it was okay.

Dinah, a computer science professor, demonstrated her persistency as well as the strategies she used to achieve in a challenging doctoral level seminar.

> I was invited to join a really advanced seminar group in our department. Absolutely no idea what was going on 99% of the time. I understood some of it, but, after the first 15 or 20 minutes, it got so esoteric that I just couldn't handle it. So I said, "All right, what can I do to make sure that I can keep a handle on what's going on?" All right, well, maybe read papers aloud. Let me be the person who does the reading. That way, at least, I'd know where they are, and I could follow what's going on. That helped. A lot. And, I don't know, finding the smart people to study with was always very helpful. I know I'm good. I know I'm not brilliant. I'm more of a bang my head against the wall until the problem is solved or until my head breaks. So far my head hasn't broken.

Suzanne, a 53-year-old research chemist and epidemiologist, described how this sense of resilience and persistence was necessary to surmount financial obstacles.

> About the time that I was graduating from high school, I told [my father] I was going to college. Well, [the family] didn't have any money at all. He said, "Only rich men's children go to college. You can't go to college." And I was really shocked that he would say that. I said, "I will." And that's it. I got a scholarship and went. Never a doubt in my mind that I was going to college. It wasn't that I wasn't capable of doing it, he thought. We had no money. Our family had never gone to college, so he didn't see how I would.

Because their confidence was developed through the caring of others at the same time that their competencies were taking shape, the women in our sample developed strong beliefs that carried them through the tough times in their academic and career histories that otherwise could have been potentially devastating ("I've always felt like, if you try hard, you can do just

about anything. And I think that comes more than anything from my upbringing. And the fact that I was surrounded by a lot of women that did really well in whatever they did."). Lynn, the epidemiologist in our group, spoke on this issue directly.

> I always knew I was smart. And I guess you get some confidence from just knowing. We always had some sort of struggle going on, and I had a lot of uncertainties in life, and, when you deal with those as a young child, it helps you to deal with situations that aren't so comfortable when you're older. It wasn't just one thing that made me know that I could keep on going. I guess it was just watching the people around me. They just didn't believe in ever giving up, I mean not unrealistically, but they wouldn't give up just because adversity came, and so I think I picked that up from them.

Without the efficacy-building relationships that infused them with a desire to succeed, women could have been easily discouraged in their pursuit of mathematics-related majors and careers. Mary described her experience in college as a mathematics major at a time when academic material started to become very difficult for her.

> I never thought, "Well, I just can't get this." When I went to college, I did experience that more—where I didn't understand as much as I used to. But never, ever, did I think, "I'm just not good at this." I always thought, "I just don't get this right now. I haven't figured out the right way to look at this to get it." And I had no qualms about going to professors, and they never intimidated me. They never scared me. It's like, "I just don't get this, and you need to find a better way to explain this to me."

It is noteworthy, but certainly not unusual, that all of the women spoke of encountering obstacles along their particular paths. For example, two of the women in our sample—Tammy and Julie—dropped out of their undergraduate institutions but returned to finish their degrees. Others recalled people in their lives whom they felt had been extremely negative influences, but they found ways in which to counteract potential harm. This resiliency was evident in Suzanne's recollection of high school chemistry.

> My high school chemistry class was terrible. It was so bad. The teacher who was teaching it didn't really understand anything, and she was not a good teacher. So when thinking about going to college, thinking about what I would major in, I decided then and there it would be chemistry because I wanted to know. I will never forget that woman; she was just such a bad teacher that she drove me to chemistry.

Lynn overcame poor guidance and had to pursue her own scholarship sources to enable her to go to college.

> I had a very, very poor guidance counselor, who, even though I was valedictorian, . . . told me I really ought to find something easier to do

> and never helped me with trying to get scholarships or things like that. I had to do that on my own.

Social resiliency. It is safe to say that the women in our sample found that their self-efficacy beliefs were resistant to negative verbal persuasions. Although all could speak to instances in which they received negative sociocultural messages about women in their field, they either ignored them or did not let such messages deter them from their goals. Lily, an applications engineer, and Dinah, the computer science professor, voiced this most eloquently.

> It was hard . . . because I'd never experienced that before. I mean, I had always been looked upon as a peer. And I'd always been more than anything for what I could do, not what I looked like. But you got a lot of comments— "Make sure you dress nice," and "Stand next to this equipment at the show," and, "Do you come with the machine?" You don't like to deal with that when it just brings out the ugly in me. You feel like saying, "Look, I have a master's degree, and I can run circles around you mentally, so lay off." But that's an ugly feeling to have to feel that way. And, in a business setting, that's not funny. When the manager of our division makes jokes like that, it's pretty unprofessional. It's beyond words. So you just deal with it, and keep on going.

> I never got those kind of messages. On the other hand, if I had, I probably would have ignored them. I'm very good at ignoring things that I don't want to hear. I'm very stubborn and pigheaded in that regard, but, if somebody is ignoring me, I tend to kick and scream until I get paid attention to.

Although women sometimes considered peers with similar academic interests and careers to be positive influences, many described instances in which they received negative messages from peers. ("None of the boys wanted to be my lab partner; some guys would make digs about you're really smart or something that was not a compliment at all."). Another participant spoke about the negativity she felt from her peers. "I think that what you got mostly from male peers was either they thought that you'd never make it or they thought, "I don't want to do anything socially with this person. I don't want to have to do that. She's okay to go to class with, but that's about it.'"

Unable to alter their social environment, women selected appropriate and often elaborate coping strategies, but they remained persistent in pursuit of their goals. These two passages illustrate the pain and pathos these messages created for Jean, a chemical engineer and organizational consultant, and for Lily, the applications engineer.

> The messages were pretty negative. But not so much about being technical as about being smart. Being too smart in many ways. I hated

> that. I went out of my way not to let anyone know. It's interesting. I felt a really strong drive to succeed and get good grades, but I also tried to very hard to hide my grades from people. And from parents and relatives the good grades were really wanted. But whenever you get in a high school or peer type situation, where you're succeeding at a higher grade level, people look down on you. I think that's fairly common. That it's not considered to be feminine, or you must not care about other things, or that must be all you do.

> I think amongst your peers, it's kind of boring. It wasn't the greatest party thing. If they asked you, "Well, what are you studying?" And you said, "Nuclear engineering." Boy, they make a beeline for the door. It just didn't work. So after a while you start saying, "Oh yeah, I'm a stewardess."

In general, it was evident that the perseverance and resiliency of the women in our sample had been primarily strengthened by the verbal persuasions and vicarious experiences with people who had played a critical role in their lives and whom we described earlier. Without a belief in their own capabilities to succeed that was grounded in their relationships with significant others, the perceived obstacles they encountered might have easily deterred them from their goals. The women in this investigation did not consider giving up or giving in as options.

> If my dad wasn't there telling me, "Yeah, you can get this," I would have been influenced by some teachers that, if they explained it to me one way and I didn't get it, that would be it. Everybody growing up has somebody telling them that you can't do something. It's having the resilience to come back and say, "I don't care what you say. I'm going to try it anyway."

We want also to note that women expressed the belief that providing female role models in mathematics-related areas—models who would provide encouragement and mentoring—would encourage other women to pursue mathematics-related careers ("There's got to be a way to make it sexy for girls to do this. I think a lot of it has to do with role modeling, and a lot of it has to do with making it okay to be smart and okay to be in technology; I think highlighting the women in the field to just realize that there's a lot to be said for being self-sufficient and making your way in the world; I think role models that are women who are successful, doing well in these fields, that other women can identify with."). In fact, several of them were currently participating in mentoring programs, and it was their hope to inspire a future generation of young women to enter mathematics- and science-related careers.

Summary

In summary, the mathematics self-efficacy beliefs of the women in our sample were nurtured by familial, academic, peer, and work-related influ-

ences, and these influences were recalled primarily in terms of the encouragement received or through the vicarious experience that they provided. The self-beliefs, in turn, nurtured the effort, persistence, and resilience required to overcome personal, social, and academic obstacles. The women consistently recalled experiences that involved an influential person, often during a critical time, who helped them develop their beliefs about their capabilities while they also honed their own mathematics or scientific talents. The vicarious experiences—watching and learning from others—influenced them both on their ideas regarding mathematics-related areas and on their philosophies about women in these male domains. Social messages and verbal persuasions proved influential during the selection and retention of career and academic behaviors. Women experienced obstacles in the form of negative social messages about themselves and about their career or academic pursuits.

Recall that one prominent theme to emerge from the narratives was that, just as important as it was for the women to believe in themselves, it was also important that *others* believed in *them*. Bandura (1997) has suggested that the "self-affirming beliefs of others promote development of skills and a sense of personal efficacy" (p. 101). This is reminiscent of Cooley's (1902) metaphor of the *looking-glass self*, the idea that individuals' self-conceptions are, in part, formed as a result of their perceptions of how other people perceive them (see Mead, 1982). That is, the perceptions and judgments of others act as mirrors through which individuals view and define their own self-beliefs. This conception of self brought to the forefront of psychological thought an emphasis on social interactions in the development of self-beliefs. All of which is to suggest that, as folk psychology maintains, other people have a powerful hand in the mental habits that individuals create and develop.

Bandura (1997) has observed that parents, teachers, and peers play key roles in the development of self-efficacy beliefs and are enabling influences in helping one develop resilience to adversity. In part, this is because such individuals serve to validate one's own self-beliefs. The modeling provided by parents and teachers can be especially critical in this regard because "self-appraisals are partly based on the opinions of others who presumably possess diagnostic competence gained through years of experience with aspirants in a given field" (p. 104). The influence of models and persuaders is especially pronounced when they are knowledgeable about the nature of the activity at hand. Finally, we found that women were especially attentive and susceptible to the encouragement of those about whom they cared and with whom they felt a relational bond. This is consistent with Bandura's (1997) insight that the impact of verbal persuasions on one's own self-beliefs is likely to be only as strong as one's confidence in the person who issues them.

Conclusion and Implications

As is evident at this point, by listening to the women in our study we

discovered that the most important factor in the enhancement of self-efficacy beliefs of women in mathematics-related careers was the confidence that significant others expressed in the women's capabilities. That is to say, it was critical that others have confidence *in them* and express that confidence *to them* so that women developed confidence in themselves and developed resiliency to the obstacles they were sure to encounter. Exploring the self-efficacy stories of women in this particular context demonstrated that they relied heavily on the vicarious experiences and the verbal persuasions of people around them. Their sensitivities to these messages and observations were, in a sense, used as motivational fuel to persevere along their paths.

The fact that the women in our study spoke with greater frequency of the vicarious experiences and verbal persuasions they received rather than of their mastery experiences provides insights related to the sources of self-efficacy information. Recall that Bandura (1986, 1997) posited that, although vicarious experiences and verbal persuasions can influence self-efficacy appraisals, authentic mastery experiences provide the most influential source of efficacy information. Certainly, perceived mastery of a given task is critical in developing efficacy perceptions, but the women in this study provided evidence that the influence of particular self-efficacy sources may differ for women in male-dominated domains. Women seemed to rely extensively on the accompanying confidence development from the relationships in their lives while they were honing their mathematics-related skills. Relational episodes gave birth to a relational confidence developed from others, and this *relational efficacy* informed their judgments of their own abilities profoundly.

If we may be allowed the pleasure of engaging in some intertheoretical cross talk, Gilligan (1982) wrote about women using the significant relationships in their lives as a foundation on which to ground their behavior. In fact, "the elusive mystery of women's development lies in its recognition of the continuing importance of attachment in the human life cycle" (p. 23). She adds a critical insight.

> Among the most pressing items on the agenda for research on adult development is the need to delineate in women's own terms the experience of their adult life. My own work in that direction indicates that the inclusion of women's experience brings to developmental understanding a new perspective on relationships that changes the basic constructs of interpretation. The concept of identity expands to include the experience of interconnection. (p. 173)

The idea that self-efficacy beliefs can primarily be moored on experiences that are nonrelational may not be appropriate for understanding women, who perceive themselves as the center of an intricate relational web (Gilligan, 1982). If it is true that women function from an ethic built on care and on social responsibility, then they may be more likely than men to permit others to play an especially critical influence on their developing

confidence. In fact, we feel safe in suggesting that women may feel a special responsibility to let significant others help define their achievements. The women in this study demonstrated through their experiences with their families, teachers, and peers that insights related to their academic competence and career decisions can be provided by understanding the role played by the beliefs of significant people in their lives. When women struggled with obstacles, they were naturally inclined to remember episodes involving people about whom they came to care or who came to care about them. These memories act much like episodic images that infuse them with the necessary resilience to succeed (see Calderhead & Robson, 1991).

Interestingly, women did not recall or require exclusively female role models. In fact, they found critical male influences along the way, and these male influences had pronounced effects on their academic and relational efficacy. Naturally, there are more men to be found in mathematics and science than women, and so they were exposed to more men in teaching and mentoring situations. Yet it is important to note that the influences had less to do with gender and more to do with the quality of the message women received about their capabilities. Men who demonstrated confidence in women's abilities were perceived to be just as positive and self-efficacy enhancing as were influential women. Although the women suggested that they would like to see more female role models, they continued to rely on men as important sources of vicarious experiences and social persuasions. Gilligan (1982) and Noddings (1986, 1988, 1992) have suggested that women's beliefs are founded on an ethic of care. We want to emphasize that caring can be provided and received from men or from women in equal measure. We are all able to provide a therapeutic influence on the lives of the children in our care.

We found that self-efficacy beliefs were an important factor in helping women to select a career in mathematics, science, or technology. It is evident that educational programs should be geared to helping girls develop stronger self-efficacy beliefs during critical periods in their lives (Brown & Lent, 1996). Guidance counselors could use this information to help students pursue careers for which they have the capability but lack the corresponding confidence (Betz, 1992). Teachers would also benefit from these programs through increased understanding of the development of their students' self-efficacy perceptions. By knowing how students come to underestimate their performance, teachers could work to increase the accuracy of their students' self-perceptions so that they will be better equipped to fulfill their academic and career potential (Ashton & Webb, 1986; Pajares, 1996b, 1997).

Some self-efficacy researchers have suggested that teachers should pay as much attention to students' perceptions of competence as to actual competence, for it is the perceptions that may more accurately predict students' motivation and future academic choices (Hackett & Betz, 1989). Assessing students' self-efficacy can provide teachers with important insights. As noted earlier, researchers have demonstrated that self-efficacy beliefs strongly influence the choice of majors and career decisions of

college students. In some cases, unrealistically low mathematics self-efficacy perceptions, not lack of capability or skill, may in part be responsible for avoidance of mathematics-related courses and careers, and this is more likely to be the case with women than with men (Hackett & Betz, 1989). If this is so, in addition to skill improvement, researchers should acquaint schools with ways to identify these inaccurate judgments and aid in designing and implementing interventions to alter them. School and teaching practices that foster both competence and the necessary accompanying confidence should be identified, as well as practices that "convert instructional experiences into education in inefficacy" (Bandura, 1997).

Individuals are not well served when their efficacy perceptions underestimate what they are capable of achieving. Lower self-efficacy perceptions result in decreased effort, low persistence, and defeat in the face of obstacles (Bandura, 1986, 1997). To women pursuing careers in mathematics-related areas, low self-efficacy may be particularly detrimental because it can result in lower enrollment in advanced college mathematics and science courses, lack of participation in mathematics-related college majors, and failure to pursue mathematics-related careers. When women do not pursue the potentially lucrative mathematics-related careers for which they are capable, they also decrease their chances for a financially stable career future and cannot take advantage of the personal challenge and fulfillment that these types of opportunities represent (Hackett, 1995). Moreover, a society unable to correct its inequities cheats itself out of important and meaningful contributions from a significant portion of its citizens. This is especially critical at a time when there is a proportional decline of male students in college populations and a proportional increase of female students. If this trend holds, it seems evident that American society will have to increasingly rely on the mathematical talents of women to maintain its scientific, technological, and economic viability (see Bandura, 1997; Hackett, 1995).

What our findings suggest with some clarity is that these practices should include the types of verbal persuasions and vicarious experiences likely to nourish the self-efficacy beliefs of girls and women as they set out to meet the challenges required to succeed in male-dominated academic domains. Girls will develop higher mathematics self-efficacy in homes and classrooms in which parents and teachers stress the importance and value of mathematical skills; encourage girls to persist and persevere in the face of academic and social obstacles, and break down stereotypical conceptions regarding academic domains. Parents and teachers also have the responsibility to convey a message that success in an academic area is a matter of desire, effort, and commitment rather than of gender or established social structure. They should also provide models that validate that message. The women in our study observed that these models need not be exclusively female, although they suggested that female models could provide an important vicarious experience for young women considering careers in mathematics and science. It seems especially critical to emphasize that parents, teachers, and those who would seek to be caring agents in the lives

of young women be especially reflective and *proactive* in this regard, especially given the fact that individuals often convey stereotypical and maladaptive messages to girls in unintentional but subtle ways (Bandura, 1997; Eccles, 1989).

Some cautions are in order. First, issues of sampling, representativeness, and generalizability are important in qualitative research, particularly when there exist implications for educational practices for people other than the actual study participants (Maxwell, 1992). Although we took safeguards to maximize reliability and validity of findings, caution should be exercised when making inferences about other women in similar situations. Second, because the qualitative design of the study required the researchers to be the primary instrument for gathering and analyzing data (Merriam, 1988), it is always important to note possible researcher bias. We created and designed the present study and protocol from a social cognitive lens, and we searched for patterns in the results with a marked theoretical orientation.

Principles derived from theory should not be expected to operate uniformly across dissimilar contexts. Rather, if we may paraphrase the cautions expressed by Lee Cronbach (1975) and William James (1885/1975), when researchers give proper weight to local conditions, to *situating* their theoretical understandings, formal principles become hypotheses to be investigated rather than conclusions on which they can rest their search. Such a process can either invalidate, support, or refine theoretical tenets. We believe that our finding regarding how the sources of self-efficacy may operate for women who pursue male-dominated careers refines the contentions of social cognitive theory. This added understanding broadens this principle to include the local conditions that exist when individuals strive in nontraditional pursuits. As Bandura (1986, 1997) has pointed out, the challenge is to identify which aspects of the multifaceted influences on self-efficacy beliefs contribute to different types of developmental change in varying contexts. We believe that our study identifies relevant aspects in one such context.

Finally, ours was primarily a theoretical enterprise. We sought to test the tenets of social cognitive theory as regards the sources and effects of self-efficacy beliefs in women who pursue nontraditional life paths. As such, we grounded our understandings and interpreted data from the perspective that our theoretical framework provided us. We did not engage in alternative explanations, although we certainly believe that such explanations are not only possible but likely. We are nonetheless confident that alternative understandings would not invalidate our own understandings nor weaken our theoretical inferences.

We close by observing that, as Noddings (1986) has suggested, *fidelity* to persons and to relations is a concept that may be particularly useful for those wishing to influence the self-efficacy beliefs of women in male-dominated areas. Fidelity from an ethic of caring is "a direct response to individuals with whom one is in relation" (p. 497). From this perspective, development of the whole person is necessarily a concern. Of course, self-

efficacy beliefs should be developed in concert with the corresponding competence. As Noddings stated,

> fidelity to persons does not imply that academic excellence, the acquisition of skills, or the needs of contemporary society should be of no concern. To suppose, for example, that attention to affective needs necessarily implies less time for arithmetic is simply a mistake. (p. 499)

The women in our study cultivated the necessary competence to succeed. In essence, they developed the skill and the will (see Pintrich & De Groot, 1990) to make it in a man's world. What encouraged them to persevere and ultimately succeed in this world, however, was more than their skill. It seems evident to us that academic and relational self-efficacy beliefs enable women in male-dominated domains to develop and maintain their will. It seems equally evident that these beliefs are themselves created and nourished by the caring relationships in women's lives as well as by the confidence that significant others express in their abilities.

Appendix

Interview Protocol

1. Background information—age, schools attended, family, previous occupations, and how many years at current occupation?
2. Please describe your current occupation?
3. What experiences contributed to your decision to pursue your occupation?
4. How were you influenced by others?
5. What did people (family/teachers/peers/and culture) say to you as you were pursuing mathematics (science or technology)? What sort of sociocultural messages did you get?
6. How would you describe your feelings and beliefs about mathematics (science or technology) as you were pursuing it?
7. Tell me one memorable story that would really help me understand how you came to do what you do.
8. Why do you think that so few women pursue mathematical-related careers? What could be or should be done to alter that?
9. Considering your academic and career history, if you could have done anything differently, what would that be?

References

Ashton, P. T., & Webb, R. B. (1986). *Making a difference: Teacher's sense of efficacy and student achievement.* New York: Longman.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory.* Englewood Cliffs, NJ: Prentice-Hall.

Bandura, A. (1997). *Self-efficacy: The exercise of control.* New York: Freeman.

Becker, J. R. (1984). The pursuit of graduate education in mathematics: Factors that influence women and men. *Journal of Educational Equity and Leadership, 4* (1), 39–53.

Becker, J. R. (1990). Graduate education in the mathematical sciences: Factors influencing women and men. In L. Burton (Ed.), *Gender and mathematics: An international perspective* (pp. 119–130). London: Cassell.

Betz, N. E. (1992). Counseling uses of career self-efficacy. *The Career Development Quarterly, 41*, 22–26.

Betz, N. E., & Hackett, G. (1981). The relationship of career-related self-efficacy expectations to perceived career options in college women and men. *Journal of Counseling Psychology, 28*, 399–410.

Brown, S. D., & Lent, R. W. (1996). A social cognitive framework for career choice counseling. *The Career Development Quarterly, 44*, 354–366.

Bruner, J. (1990). *Acts of meaning*. Cambridge, MA: Harvard University Press.

Bruner, J. (1996). *The culture of education*. Cambridge, MA: Harvard University Press.

Calderhead, J., & Robson, M. (1991). Images of teaching: Student teachers' early conceptions of classroom practice. *Teaching & Teacher Education, 7*, 1–8.

Cooley, C. H. (1902). *Human nature and the social order*. New York: Scribner.

Cronbach, L. J. (1975). Beyond the two disciplines of psychology. *American Psychologist, 30*, 116–127.

Eccles, J. S. (1989). Bringing young women to math and science. In M. Crawford & M. Gentry (Eds.), *Gender and thought* (pp. 36–58). New York: Springer-Verlag.

Eisenberg, N., Martin, C. L., & Fabes, R. A. (1996). Gender development and gender effects. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp. 358–396). New York: Simon & Schuster, Macmillan.

Gilligan, C. (1982). *In a different voice: Psychological theory and women's development*. Cambridge, MA: Harvard University Press.

Hackett, G. (1985). Role of mathematics self-efficacy in the choice of math-related majors of college women and men: A path analysis. *Journal of Counseling Psychology, 32*, 47–56.

Hackett, G. (1995). Self-efficacy in career choice and development. In A. Bandura (Ed.), *Self-efficacy and changing societies* (pp. 232–258). New York: Cambridge University Press.

Hackett, G., & Betz, N. E. (1989). An exploration of the mathematics self-efficacy/mathematics performance correspondence. *Journal for Research in Mathematics Education, 20,* 261–273.

James, W. (1975). *Pragmatism*. Cambridge, MA: Harvard University Press. (Original work published 1885)

Lent, R. W., Brown, S. D., Gover, M. R., & Nijjer, S. K. (1996). Cognitive assessment of the sources of mathematics self-efficacy: A thought-listing analysis. *Journal of Career Assessment, 4* (1), 33–46.

Lent, R. W., & Hackett, G. (1987). Career self-efficacy: Empirical status and future directions. *Journal of Vocational Behavior, 30*, 347–382.

Lent, R. W., Lopez, F. G., & Bieschke, K. J. (1991). Mathematics self-efficacy: Sources and relation to science-based career choice. *Journal of Counseling Psychology, 38*, 424–430.

Lent, R. W., Lopez, F. G., & Bieschke, K. J. (1993). Predicting mathematics-related choice and success behaviors: Test of an expanded social cognitive model. *Journal of Vocational Behavior, 42*, 223–236.

Lent, R. W., Lopez, F. G., Brown, S. D., & Gore, P. A. (1996). Latent structure of the sources of mathematics self-efficacy. *Journal of Vocational Behavior, 49,* 292–308.

Lieblich, A., & Josselson, R. (Eds.). (1994). *The narrative study of lives*. Thousand Oaks, CA: Sage.

Lopez, F. G., & Lent, R. W. (1992). Sources of mathematics self-efficacy in high school students. *The Career Development Quarterly, 41*, 3–12.

Matsui, T., Matsui, K., & Ohnishi, R. (1990). Mechanisms underlying math self-

efficacy learning of college students. *Journal of Vocational Behavior, 37*, 223–238.
Maxwell, J. A. (1992). Understanding and validity in qualitative research. *Harvard Educational Review, 62*, 279–297.
Mead, G. H. (1982). *The individual and the social self*. Chicago: University of Chicago Press.
Merriam, S. B. (1988). *Case study research in education: A qualitative approach*. San Francisco: Jossey-Bass.
Midgley, C., Feldlaufer, H., & Eccles, J. S. (1989). Change in teacher efficacy and student and self- and task-related beliefs in mathematics during transition to junior high school. *Journal of Educational Psychology, 81*, 247–258.
Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis* (2nd ed.). Beverly Hills, CA: Sage.
Multon, K. D., Brown, S. D., & Lent, R. W. (1991). Relation of self-efficacy beliefs to academic outcomes: A meta-analytic investigation. *Journal of Counseling Psychology, 38*, 30–38.
Mura, R. (1987). Sex-related differences in expectations of success in undergraduate mathematics. *Journal for Research in Mathematics Education 18* (1), 15–24.
National Center for Education Statistics. (1995). *Findings from the condition of education. No. 5: The educational progress of women* (NC 96-768). Washington, DC: United States Department of Education, Office of Educational Research and Improvement.
Noddings, N. (1986). Fidelity in teaching, teacher education, and research for teaching. *Harvard Educational Review, 56*, 496–510.
Noddings, N. (1988). An ethic of caring and its implications for instructional arrangements. *American Journal of Education, 96*, 215–230.
Noddings, N. (1992). *The challenge to care in schools: An alternative approach to education*. New York: Teachers College Press.
Pajares, F. (1996a). Self-efficacy beliefs and mathematical problem solving of gifted students. *Contemporary Educational Psychology, 21*, 325–344.
Pajares, F. (1996b). Self-efficacy beliefs in academic settings. *Review of Educational Research, 66*, 543–578.
Pajares, F. (1997). Current directions in self-efficacy research. In M. Maehr & P. R. Pintrich (Eds.), *Advances in motivation and achievement* (Vol. 10, pp. 1–49). Greenwich, CT: JAI Press.
Pajares, F., & Miller, M. D. (1994). The role of self-efficacy and self-concept beliefs in mathematical problem solving: A path analysis. *Journal of Educational Psychology, 86*, 193–203.
Patton, M. Q. (1980). *Qualitative evaluation methods*. Newbury Park, CA: Sage.
Phillips, D. A., & Zimmerman, M. (1990). The developmental course of perceived competence and incompetence among competent children. In R. J. Sternberg & J. Koligian, Jr. (Eds.), *Competence considered* (pp. 41–66). New Haven, CT: Yale University Press.
Pintrich, P. R., & De Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology, 82*, 33–40.
Sadker, M., & Sadker, D. (1994). *Failing at fairness: How our school's cheat girls*. New York: Touchstone.
Schunk, D. H. (1991). Self-efficacy and academic motivation. *Educational Psychologist, 26*, 207–231.
Stage, F. K., & Maple, S. A. (1996). Incompatible goals: Narratives of graduate women in the mathematics pipeline. *American Educational Research Journal, 33*, 23–51.
Whiston, S. C. (1993). Self-efficacy of women in traditional and nontraditional occupations: Differences in working with people and things. *Journal of Career*

Development, 49 (3), 175–185.
Yin, R. K. (1994). *Case study research: Design and methods.* Newbury Park, CA: Sage.

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