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This chapter provides a brief retrospective on the general topic and the empirical work presented in this volume, as well as a discussion of the practical implications of these findings for high schools, institutions of higher education, and the current workforce.

Twenty-Five Years of Research on Gender and Ethnic Differences in Math and Science Career Choices: What Have We Learned?

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The chapters in this volume address a fundamental question that I (and many others) have been asking for the past twenty-five years: Why are there significant gender differences in educational and career choices in the areas of math and science? Early in my graduate school career, Benbow and Stanley (1980) published a study in *Science* that made its way into many popular press outlets with headlines like, “Do Males Have a Math Gene?” (Williams & King, 1980) and “The Gender Factor in Math: A New Study Says Males May Be Naturally Abler Than Females” (1980). Although many did not agree with the inferences made by the original authors or with the conclusions drawn by the media (Jacobs and Eccles, 1985), there was irrefutable evidence that girls were less likely than boys to choose math and science courses and careers although their grades in math were as high as or higher than those of boys. Thus, the critical question became, If not a math gene, then what motivates one sex, but not the other, to go on in math and science?

The Eccles et al. Expectancy Value Model (Eccles (Parsons) and others, 1983), on which all of the chapters in this volume are based, allowed us to consider a variety of factors that might differentially motivate the educational and career choices of girls and boys, including, but not limited to, raw talent or ability. Based on this model and many others, over twenty years of research has been conducted, all of it pointing to a plethora of factors that

influence achievement choices, including individual expectancies and self-perceptions, task values, social and relational variables, and environmental factors (Eccles, 1984; Eccles, Midgley, and Adler, 1984; Eccles, Wigfield, Harold, and Blumenfeld, 1993; Jacobs and Eccles, 1992; Jacobs and others, 2002). Based on the research findings and many other social and environmental factors, many changes in school organization, teachers, and educational policies have occurred in the past twenty years. For example, middle schools have replaced junior high schools in most of the country, changing the timing of school transitions as well as the organizational structure of schools during early adolescence (Carnegie Council on Adolescent Development, 1989). In addition, most school systems require a greater number of mathematics courses than they did in the past, reducing the opportunity for girls to drop out of math early in high school (National Center for Education Statistics, 2000). The gender gap in math abilities and scores, never wide, has narrowed even more, and girls have continued to get higher grades than boys in math (Halpern, 2004; National Center for Education Statistics, 2001b).

If you had asked me when I was a graduate student, I would have predicted that the outcome of all of this research and all of these structural changes would be that girls would go into math-related careers at the same rate as boys. If my prediction had turned out to be right, we would not be writing about this topic now. Although the gender gap has narrowed in some fields like life sciences, women are still less likely than men to choose engineering, physics and other physical sciences, and some technology fields (National Science Foundation, 2004).

Although we might wring our collective hands in despair, the research presented in this volume does something far more useful: it digs deeper, honing in on new and more specific achievement domains, investigating the contributions of more than one factor at once, considering the role of specific prior experiences, and including social and environmental variables that affect gendered achievement choices. The findings from the set of studies considered together are far more powerful than they would have been if seen separately. The studies use the same theoretical framework to examine four data sets that use the same or very similar scales, and they include overlapping outcomes and predictors.

What Did We Learn?

Although each of the four studies in this volume offers a unique glimpse at how expectancies and values affect math and science achievement choices and each varies by domain, outcome variables, predictors, cohort, and even geography, a few strong patterns permeate the results. First, gender differences in both course choices and career aspirations in math, science, and information technology (IT) continue to exist, and they are not a function of objectively measured differences in math competence.

Second, individuals are generally more likely to select math and science courses and careers when they have high self-concepts of ability in math, science, and technology; however, the strength of these relations differed across groups and ages. Third, the values students place on the specific subjects (such as subjective task values) were important for educational and career plans in the domains in question, but the role of values depended more on the exact measures used for both perceived task value and the outcome being predicted. It was a good predictor of math and science course taking and career goals, but seemed to be more important for boys than girls in some domains. Fourth, these chapters demonstrate the importance of strong social support and perceptions of social support for achievement choices, whether in the form of parent expectations or perceived racial stereotyping or discrimination. Finally, the chapters individually and collectively support the Eccles et al. Expectancy Value Model and provide more precise and in-depth information about several components of the model within the math, science, and IT domains.

Each study contributed to one or more of these conclusions, often approaching the questions and providing answers in different ways. Helen Watt focused on explaining gender and individual differences in high school course mathematics enrollment patterns. She used the Eccles model to examine an Australian sample of secondary school students. She predicted the difficulty level of students' math curricular track, while controlling for actual achievement levels, allowing an examination of the unique contribution of ability self-concepts and interest values to course enrollment decisions. As has been found in other samples, despite the fact that the males and females scored equally well on standardized tests of math ability, the males held higher math ability self-concepts and interests in math than the females did, and the males selected more difficult math tracks than the females did. For both genders, tenth-grade interest in math was the strongest predictor of eleventh-grade math track, followed closely by ninth-grade math achievement. In both cases, those students with higher tenth-grade interest in math and higher ninth-grade achievement were most likely to be enrolled in the highest difficulty level math courses in the eleventh grade. Thus, Watt's study provides strong support for the Eccles et al. Expectancy Value Model and supports the gender differences reported in earlier studies with American samples.

Sandra Simpkins and Pamela Davis-Kean also found gender differences when they used an idiographic approach to investigate the joint predictive influence of ninth-grade ability self-concepts and subjective task value (defined in terms of both enjoyment and perceived importance) on high school math and science course enrollment decisions and career plans. As hypothesized in the Eccles et al. Expectancy Value Model, high math ability self-concepts and high subjective task values for math and science were related to more positive achievements in those domains (taking more advanced math and physical science courses and aspiring to careers in the

physical and biological sciences). This was true for both girls and boys. Interestingly, this chapter pointed to the importance of ability perception as students select high-level courses, as well as the role of gender.

Simpkins and Davis-Kean report gender differences in both self-concepts and career aspirations along traditional gender-typed lines. Girls were underrepresented in the high science ability self-concept cluster and in the high science ability self-concept and subjective task value cluster. They were also less likely than boys to aspire to careers in fields related to mathematics and physical science, but more likely than the boys to aspire to careers in health- and biology-related careers. However, no gender differences were found in the distribution of girls and boys across the math belief clusters, and girls were more likely than boys to take high school math courses. This suggests that some progress at narrowing the gender gap has been made in course taking and ability perceptions for course work, but that it has not yet had an impact on career decision making in some science-related areas.

Miriam Linver and Pamela Davis-Kean investigated the predictors of girls' and boys' math-related performance, interest, and ability self-concepts from middle school through the secondary school years, focusing on gender differences in the light of math ability curricular track. As has been found previously, they report a general downward trend for all indicators across the school years for both males and females in all ability tracks, even after actual math performance was controlled. As in earlier studies, girls had higher grades than boys in math, but their expectancies or self-concepts were lower than those of boys. In addition, interest in math was lower for girls than boys, but it varied by ability track. Surprisingly, girls in the college-honors group interest dropped the most over time, although their grades dropped the least. Meanwhile, their male counterparts' grades dropped more, but their interest in math dropped the least.

In addition to updating our understanding of gender, student grades, and interest, Linver and Davis-Kean shed light on the important role of socializers' expectations (in this case, mothers). Students whose mothers had high expectations for their performance showed the least decline in math grades, even after actual math performance was controlled. In addition, mothers' math performance expectations and earlier levels of interest in math were the strongest protective influences on the rate of decline in the students' interest in math. The findings presented in this chapter clearly support the Eccles et al. model, especially the inclusion of socializers (mothers) as important predictors of both expectancies (self-concept of math ability) and values (math interest level), as well as the changing trajectories of these constructs for boys and girls throughout adolescence.

Finally, Nicole Zarrett and Oksana Malanchuk extended the Eccles model to the new domain of IT and included race in addition to gender differences in young adults' career decisions. They used high school math

ability self-concepts and subjective task values, educational expectations, and perceptions related to likely future race and gender discrimination, as well as young adult computer ability self-concepts and enjoyment, support from others, and general attitudes toward computers to predict young adults' desires to pursue careers in IT. In general, their results provide strong support for the Eccles et al. model: individuals with both high math and computer ability self-concepts and high interest in computers were most likely to aspire to IT professions. In addition, the importance of students' perceptions of socializers' support for these choices was highlighted. Although few race differences emerged, gender was a large factor in IT career decisions. Females were less likely to aspire to computer careers than males, and when females did aspire to computer-related careers, they were more likely than males to aspire to lower-level computer-related careers. These differences were partially explained by gender differences in interest and ability self-concepts related to computers in particular. Thus, Zarrett and Malanchuk provide strong support for the importance of focusing on domain-specific concepts related to career choice.

Although the studies presented here contribute substantially to our knowledge, a number of things are still missing from the research. For example, we need to understand more about how expectancies, values, and other variables interact with each other when they are in the same model. The Eccles model clearly specifies the expected relations, but the topics have rarely been included in the same empirical models due to the complexity of analyses and interpretation. Similarly, we need to include a diverse set of achievement domains in the same models. Although it is easier for researchers to look only at math- or science-related choices, adolescents are never making decisions based on one domain; they are weighing their interest in sports against academics and their ability to fit chemistry, literature, or study hall into their course schedules. We also need to know more about the ways in which the relations between grades, values, expectancies, time use, and course choices unfold developmentally. Are the trends always linear, or do they include dramatic increases and decreases or curvilinear patterns? In future research, it will also be important to find outcome measures that are the best predictors of actual career decisions: Is intention to pursue a field the same as actually pursuing the career? Are the number of courses taken equivalent to course level and track? Finally, we need to use longitudinal data to look at actual career and job choices in relation to earlier expectancies and values rather than relying on intentions and plans to pursue particular paths.

Twenty-Five Years: What Has Changed?

I began this discussion by musing about the kinds of research questions that many of us were asking twenty-five years ago. What has changed since then? A number of things:

- The gender gap in math performance has closed or almost closed (National Center for Education Statistics, 2001b, 2003a).
- Gender differences in expectancies have narrowed in some domains, such as the biological sciences and in math (Bae and Smith, 1996; Eccles, Barber, and Jozefowicz, 1998).
- Women are almost as likely as men to receive advanced degrees across all subjects (National Center for Education Statistics, 2001a).
- We have begun to focus on new achievement domains, such as technology and computers (Kirkpatrick and Cuban, 1998; Margolis and Fisher, 2002).
- We have refined our focus in other domains, such as biological versus physical sciences (Jacobs, Finken, Griffin, and Wright, 1998; Bae and Smith, 1996).
- There is actually greater female versus male representation and minority versus nonminority representation in some science and technology fields (National Science Foundation, 2000).

These are all positive improvements for research and for equal access to math and science careers.

Despite progress in these areas, much has changed very little or not at all. Social psychological variables and social identity such as gender and race still play a large role in career choice. Data from several sources indicate that females continue to be less likely than males to go into particular math, science, and technology careers, including physical sciences, engineering, and “hard” IT such as computer programming (Camp, 1997; National Science Foundation, 2000). These choices appear to be related to gender differences in self-concept of ability and values or interest in the topics, manifesting themselves in courses taken and time spent on the topics. Finally, earlier studies pointed to the important role of parents in major life decisions, such as career selection, and they continue to play a pivotal role in adolescents’ educational and occupational choices (Bleeker and Jacobs, 2004; Chapter Five, this volume; Wintre, Hicks, McVey, and Fox, 1988).

Why Does the Leaky Pipeline Matter?

We often talk about the need to ensure that the pipeline of upcoming scientists and engineers is well supplied; however, the chapters presented in this volume make it clear that the pipeline has some nontrivial leaks and that those leaking out of the pipeline are more likely to be women and minorities. Having said that, it is important to point out that *all* students’ values and expectancies for math and science are dropping faster than their grades and that almost no one wants to go into occupations in these areas, especially careers at high levels. The trends described here and elsewhere appear to support a sequential sorting model, with more students being sorted out of the pipeline with age and those who remain being less diverse.

Do these patterns matter? Decisions not to enroll in math, science, and technology courses and to stay away from particular occupations clearly have an impact on the individuals involved. Women and minorities who believe that they do not have the skills or interests or are worried about barriers in certain fields limit their options and will miss out on some personally rewarding and high-paying jobs. In 2003–2004, engineering graduates had the highest average starting salaries of all bachelor's degree recipients (National Association of Colleges and Employers, 2004).

Even more important than individual satisfaction and reward is the ramification of the leaky pipeline for science and technology leadership in the future. This issue is especially critical in the United States. For more than half a century, the United States has enjoyed a dominant position intellectually and economically based on the strength of our research in basic sciences and technology. This position is changing. A dramatic example can be seen in the trends in a number of publications from American versus non-American scientists in the *Physical Review*, a key journal published by the American Physical Society (Broad, 2004). Until the 1990s, U.S. scientists led all others by a significant margin, but by 2003, our scientists had fallen decisively behind those from Europe and the rest of the world. One of the reasons for trends such as these is that rather than keeping American students in the pipeline for math and science careers, we have relied on international students who have come to the United States to receive graduate training in math, science, and technology and then stayed to become leaders in their fields. According to recent data (Stay, 1997), 47 percent of all foreign nationals who received doctorates in the 1990–91 academic year were working in the United States in 1995 and over 39 percent of those receiving doctorates in science and engineering stayed in the United States (National Science Foundation, 2000). In recent years, this pattern has changed. Fewer international students are choosing American universities for their graduate training; applications from foreign students were down nationally in 2003–04 (Pell, 2004). There has also been a steady decline of U.S. citizens receiving doctorates in the sciences (Hoffer and others, 2003; National Science Foundation, 2000), and undergraduates studying physical sciences, mathematics, and engineering declined 13, 19, and 21 percent, respectively, in the 1990s (National Science Foundation, 2000). If we add to these indicators the fact that fewer males than females are earning bachelor's, master's, and doctoral degrees (National Center for Education Statistics, 2003b) and we continue to rely on males to go into math and science fields, the future for science and technological leadership and innovation in this country does not look bright.

What can educators and employers do to encourage more students to go into math, science, and technology fields? To begin, educators may want to think about the students they prepare as part of a pipeline into future careers that are critical for science and technology fields rather than as required courses to be checked off. The data presented in this volume suggest that middle schools and high schools should be emphasizing both self-concepts

of ability and interest in these topics for males and females of all ethnicities. In addition, schools might do well to demonstrate to students, as well as to important socializers in their lives, the value of science and math education for future employment. Many students and parents do not know what skills and classes are required for careers in engineering or IT. As we noted at the start of this volume, once students make it to college in these fields, large numbers (disproportionately females) continue to drop out of the pipeline into more advanced degrees that are likely to be required for leadership roles as researchers, designers, and scientists. Institutions of higher education could also do more to help both genders understand what jobs are possible with advanced degrees and work harder to keep people in the pipeline rather than weeding out those who may not have the appropriate background or skills when they arrive. A number of universities are taking this approach to keep women and minorities in the science, technology, engineering, and math (STEM) disciplines (one is the Gateway Science Workshop at Northwestern University). Finally, future employers may need to partner with high schools and colleges to help attract budding scientists and engineers by providing internships and scholarships and promoting the disciplines that will train their future employees.

In short, all of us need to work together to stop the leaks in the pipeline, especially the systematic leaking of females and minorities. The chapters in this volume have provided some guidance about where to put our efforts, emphasizing the importance of feelings of competence and interest in science, math, and technology. Although more detailed research may be helpful, putting some of the current findings into practice may be the best way to ensure that the next generation makes it through the pipeline.

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