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Family Influence on Engineering Students

Families of engineering students provide exceptional levels of support to their children. For women in engineering, this support is crucial from the pre-college level onward. In particular, female engineers' parents tend to raise their daughters with fewer gender stereotypes and place greater weight on education and learning. Characteristics of these families include:

- Girls in engineering perceive that they receive more parental support than their peers in any other discipline (Adelman, 1998; Hansen, 1995; Burgard, 1999; Ciccocioppo, 2002; Houser, 1985).
- Parents' expectations for their daughters' values, grades, and work ethics are higher when their daughters choose engineering (Eccles-Parsons, 1985; Mau, 2003; Wise, 1985; Stallings, 1985).
- Women engineers' parents, particularly their mothers, are more highly educated than male engineers' parents or parents of women professionals in other fields (Felder, 1995; Graham, 1997; McNeal Jr., 1999; Armstrong, 1985; Hansen, 1995 ; Ware, 1985 ; Jagacinski, 1987; Burgard, 1999).
- Girls from egalitarian families are more likely to maintain their science and math achievement as they age than girls whose families adhere more closely to traditional gender roles (Updegraff, 1996).

Using this information, WIE programs can design activities to support and inform family roles in encouraging educational achievement in their daughters, providing academic motivation, and promoting egalitarian roles and opportunities. Likewise, WIE programs can design and offer outreach activities to attract and support first-generation college students, students from high risk family situations, and students from families with fewer resources.

Family Influence on Engineering Students Sections

Parental Influence on Engineering Students

Compared to women in other professions, women who choose to study engineering experience different influences from their parents. Parents of women engineers tend to raise their daughters with fewer gender stereotypes, provide more support, and place greater weight on education and learning. Much of this support derives from pre-college experiences with mathematics and is integral to initial choice and success in engineering.

Research indicates that strong parental support can be critically important for female engineering majors because it correlates with high mathematics achievement (Hansen, 1995; Chipman, 1985) and positive attitudes toward math (Tocci, 1991; Hansen, 1995). These factors appear to be particularly important for female students who are immersed in a male-dominated environment and are coping with heavy stresses from school. Ware (1985) Hansen (1995) and Tocci's (1991) definitions of parental support rely on student perceived meaning gained through survey research, Chipman (1995) and Wilson (1992) emphasize parental encouragement as helping women achieve in math. In Stallings' (1985) study involving a student questionnaire, student ratings and test data, parental support and expectations were the most prominent factors that determining whether students continued in mathematics. Graham's (1997) study corroborates these results.

As role models, parents can expect their daughters to replicate parental attitudes and behaviors toward mathematics (Eccles-Parsons, 1985; Armstrong, 1985; Tocci, 1991). When parents enjoy, use, and feel comfortable with math, their daughters become interested in math and make a larger effort to pursue it. (Armstrong, 1985) Although fathers' educational expectations are one of the best predictors of math coursework *outcomes* (Armstrong, 1985) , mothers influence their daughters the most (Boswell, 1985; Armstrong, 1985; Stallings, 1985; Chipman, 1985; Wilson, 1992), especially when it comes to math attitudes (Boswell, 1985) and enrollment decisions (Chipman, 1985). Mothers, compared to fathers, are far more likely to display avoidance behaviors and dislike toward math, and, in turn, their daughters are apt to follow this example (Eccles-Parsons, 1985; Boswell, 1985).

Of all the parental involvement variables, discussion about school and career plans had the greatest influence on math test scores (Pong, 1997; McNeal Jr., 1999; Wise, 1985; Huang, Taddese, & Walter, 2000), making discussion a possible key to recruiting girls to engineering and for women persisting in engineering. Parents' expectations are vital for the recruitment of female engineering majors. One-half of the girls investigated by Gilroy would continue in math only if required to do so (Gilroy, 2002), demonstrating the importance of parental influence in making pre-college course selections. When making decisions, girls are likely to revisit their parents' attitudes, values and beliefs (Lucas, 1997).

Even though children receive the most pressure to conform to sex stereotypes during adolescence (Updegraff, 1996), children in elementary school already have formed the perception that math is a male domain (Boswell, 1985; Hansen, 1995), sometimes evident as soon as 3rd grade (Boswell, 1985). As role models, parents influence their daughters' beliefs about women's position in the world and what is expected of them in math course-taking and ability (Casserly, 1985; Hanson, 2000). Parents do this by unconsciously punishing and rewarding certain behaviors from their daughters, imposing their own attitudes about women's relationships with math (Metzler-Brennan, 1985). Many parents of women engineers hold the less conventional belief that math is not strictly a male domain, which accounts for much of women's math achievement (Boswell, 1985; Armstrong, 1985). In Boswell's 1985 study, two factors that influenced a female's underachievement in mathematics were the female's stereotyping

of mathematics and her father's stereotyping. Armstrong (1985) found similar results; when women didn't accept traditional sex-role stereotypes (i.e., not thinking of mathematics as a male domain or that man held negative attitudes toward women successful in mathematics), they had much higher math achievement scores than women who thought otherwise.

Parental expectations of daughters' math course-taking and performance can significantly affect their math achievement or whether they take math at all (Eccles-Parsons, 1985; Valian, 1998). Many parents consider math to be less important for girls than boys (Chipman, 1985; Valian, 1998), and therefore have higher expectations in math performance for their sons (Graham, 1997; Eccles-Parsons, 1985). Parents did not necessarily rate their daughters' math ability as being lower than that of boys; they simply felt their daughters had to work much harder to understand math (Eccles-Parsons, 1985; Chipman, 1985). Eccles (1985) found that daughters typically shared parental perceptions of their math ability. Whether this is because the parents have heard comments their daughters have made about their own ability or because the parents have influenced their daughters is uncertain. Regardless, this attitude allows parents to support their daughters in dropping out of math, especially if parents already think math is not important for their daughters. Parents are less tolerant of letting their sons drop out of math because they think it is more relevant to boys' futures (Eccles-Parsons, 1985). Some parents do not expect their daughters to excel in math at all, which may be a principal reason few girls do excel in math (Gavin, 2000).

Girls who perceive equal amounts of power between their parents are likelier to pursue male-dominated occupations. (Lavine, 1982), Updegraff (1996) did a revealing study concluding that egalitarian and traditional families seem to exert different influences on women's attitudes toward and performance in mathematics. They found that egalitarian parents were less conventional than traditional parents in their sex-role attitudes, which are then passed down to their daughters. Although there are no significant differences between math and science scores of girls from egalitarian and traditional families in the fifth and sixth grades, by the seventh grade girls from traditional families scored much lower in math and science than girls from egalitarian families. Significantly, girls from egalitarian families maintained their science and math achievement with age while girls from traditional families did not.

Parental Influence and Engineering

Girls in engineering think they receive more support from their parents than women or men in any other type of discipline (Adelman, 1998; Hansen, 1995; Burgard, 1999; Ciccocioppo, 2002; Houser, 1985). Unfortunately, there is not an explicit definition of support; data for these studies comes from student questionnaires, therefore relying on how subjects classify support. However, Graham (1997) draws from a survey that "supportive parents provided listening ears, empathetic understanding, unconditional love and acceptance, encouragement and career advice" (p. 83). Parental support can also be crucial to degree attainment. (Graham, 1997). In Lucas's study (1997), women scored lower than men on functional and emotional independence, suggesting that they depended more on parent assistance, approval, closeness and emotional support to achieve in engineering. Seymour and Hewitt (1997) found that women were about twice as likely as men to have chosen a science, math or engineering major because of the active influence of someone close to them. Fathers are usually the connection that females follow into engineering (Graham, 1997; Fox, 1985; Ciccocioppo, 2002).

Parental expectations for daughters' values, grades, and work ethic are higher for women who choose engineering (Eccles-Parsons, 1985; Mau, 2003; Wise, 1985; Stallings, 1985). Brown and Cross (1997) found that women engineers feel that their families emphasize achievement and competitiveness more than most families. Setting loftier family norms is particularly important for girls because parental influences are more prominent for women than men (Hanson, 2000; Xiaoxia, 2002; Seymour, 1997). This applies especially to norms relating to opinions and preferences (Seymour, 1997). Not only do parents encourage achievement through their expectations, but they influence what type of career their children choose (Houser, 1985; Graham, 1997). Eccles (1985) and Fan (2001) both found that children's future math plans were consistent with those of their parents.

Communication between parents and children is believed to be very powerful because of the kinship relationship that parents have with their children. If parents discuss the norms of the family, it is likely to move children to have higher expectations for themselves (McNeal Jr., 1999). Regular family discussions pertaining to school issues can indicate to children how important education is to the family (Wilson, 1992). Communication establishes values and acts as a method of support. In Graham's study (1997), female engineers reported their parents were supportive because they openly communicated with their daughters.

Family Demographics, Mathematics, and Science Achievement

Pong (1997) notes that eighth-graders from original two-parent families report more family discussion about school and involvement with school than children from single-parent and stepfamilies. Smith conducted a study in which girls from separated families experienced a quicker decline in science and math achievement than girls from biological families (Smith, 1992). The study noted that separation causes emotional distress, suggesting that this distress could be a contributing factor to lower science scores among girls in separated families. In Pong's (1997) study, eighth-grade math scores were lower among single-parent and stepfamilies, even after individual demographic characteristics and family background were controlled.

Socioeconomic status has been measured as higher for the parents of women engineers compared to the parents of daughters in other fields (Mau, 2003; Armstrong, 1985). In McNeal's (1999) study, students from families with higher socioeconomic status had better relationships with their parents. In addition, their parents maintained more dyadic, or working, relationships with other parents, teachers, and other people in general—magnifying parent influence on their children's attitudes and career choices (McNeal Jr., 1999).

Parents of women engineers have higher educational levels than parents with daughters in other fields (Felder, 1995; Graham, 1997; McNeal Jr., 1999; Armstrong, 1985; Hansen, 1995 ; Ware, 1985 ; Jagacinski, 1987; Burgard, 1999). Their educational level is higher, in fact, than the education level of the parents of male engineers (Felder, 1995). In 2000, NCES (the National Center for Education Statistics) found that parental education level positively affected engineering degree completion. A likely reason that parents of women engineers are more highly educated is that well-educated people tend to have higher expectations for their children (Ware et al. 1985; Hanson 1995; Felder, 1995; Wilson, 1992). Ware *et al* (1985) also mentioned that "highly educated parents will have less conventional ideas about what constitutes appropriate behavior for women and will consequently be more willing to encourage their daughters in nontraditional pursuits" (p. 77). Highly educated parents are likely to feel that high goals are attainable, desirable and perhaps expected (Ware, 1985). Interestingly, mothers of women engineers tend to have much higher educations compared to mothers of male engineers

(Burgard, 1999; Felder, 1995). Felder *et al* (1995) found that twice as many mothers of women engineers had advanced degrees (27%) than mothers of male engineers (13%). Burgard (1999) concludes that as role models, mothers are a factor for daughters.

The occupations of mothers of women engineers were not necessarily of higher status than the occupations of mothers of women in other fields, but the status of the occupations of the fathers was significantly higher (Hanson, 2000; Wise, 1985; Jagacinski, 1987). The math level of the father's occupation was correlated with the amount of math taken in school by the daughter (Wise, 1985; Jagacinski, 1987). In Hanson's study (2000), students whose fathers had higher-status occupations were more likely to gravitate toward science.

Family income has positive effects on math achievement (Pong, 1997; Dryler, 1998) and engineering degree completion (Huang, 2000). In 2003, NCES found that students eligible for free or reduced-price lunches scored 5.6% lower on math than students who were not eligible. Girls from families with higher incomes may do better in math because their parents can afford educational advantages such as summer enrichment programs and tutoring. They are also more likely to supply positive educational environments for their children (Ware, 1985; McNeal Jr., 1999; FItzpatrick, 1989; Wilson, 1992), which are related to growth in mathematics (Xiaoxia, 2002). Another possible factor in helping girls of parents with higher incomes attain engineering degrees is that their parents are likelier to pay for their daughters' educations (Seymour, 1997).

Interventions

Parents' attitudes and expectations have a substantial effect on the math and science achievement of their daughters (Mau, 2003; Armstrong, 1985; Valian, 1998), which in turn affects their vocational interests (Mau, 2003). It is important for parents to set a positive tone for their children regarding math, even if they have limited abilities themselves (Armstrong, 1985; Wilson, 1992). To make sure their daughters feel open to all career options, parents must assume responsibility for encouraging their daughters in math because society can send girls mixed messages about their roles and perceptions of mathematics (Gavin, 2000; Casserl, 1985; Houser, 1985). Encouraging daughters to take advanced math courses not only heightens their self-confidence but exposes them to more career options.[Stallings, 1985]

Seymour and Hewitt (1997) offer the following ways for parents to encourage (but not pressure) children to be open to science and math majors:

- Play at science, math, or technical problem-solving with children
- Discuss scientific and mathematical issues, and their applications, with their children as part of everyday family life
- Include their children in a hands-on way with technical domestic tasks, and in aspects of their own work
- Discuss what they do at work, what part their work plays in the world, and what they like about it
- Recognize and foster children's interests and abilities in school without bias or pressure towards particular subjects or careers
- Offer practical help with conceptual hurdles and emotional support through academic difficulties
- Encourage their children to develop realistic aspirations, and (for girls especially) not to underestimate their potential options

- Are active in ensuring that the quality and level of high school science and mathematics are adequate for college preparation
- Offer themselves as a source of information and advice, and give plenty of opportunities to talk out the options, clarifying the pros and cons of particular majors or career paths evenhandedly.

Sample of Interventions

The most abundant forms of interventions to help parents encourage their daughters in math and science come from family math and family science programs, which are targeted at children in elementary and middle school. These programs consist of parents participating in math or science-related activities with their children, which can be facilitated through a school or instigated by parents in their own homes. Some of these programs are aimed only at girls, but most include boys. The resources for finding curriculum for these activities are bountiful. Programs developed to increase awareness of the benefits from achievement in math and science and the opportunities open for girls to explore math and science are also important areas of intervention.

There are presenters who lead these kinds of activities at schools, but for parents doing the activities at home, there are several books that can serve as aids:

Family Math Books

Coates, G. D., Stenmark, J. K. & Craig, R. (1997). Family Math for Young Children: Comparing (Equals Series). Berkeley: Lawrence Hall of Science.

Coates, G. D., & Williams, A. H. (2003). Family Math II: Achieving Success in Mathematics. Berkeley, Equals/Lawrence Hall of Science, University of California.

Thompson, V. H., & Mayfield.-Ingram, K. (1998). Family Math, the Middle School Years: Algebraic Reasoning and Number Sense. Berkeley, Lawrence Hall of Science, University of California.

Kanter, P. F., & Dorfoman, C. H. (1994). Helping Your Child Learn Math: With Activities for Children Aged 5 Through 13. Washington D.C., U.S. Dept. of Education, Office of Educational Research and Improvement.

Family Science Books

Harlan, J. D., & Quattrocchi, C. G. (1994). Science As It Happens! Family Activities with Children Ages 4 to 8. New York, H. Holt.

Murphy, P., Klages, E., Shore, L. & Gorski, J. (1996). The Science Explorer: Family Experiments from the World's Favorite Hands-on Science Museum. New York, Henry Holt.

Murphy, P., Klages, E., Shore, L. & Gorski, J. (1997). The Science Explorer Out and About: Fantastic Science Experiments Your Family Can Do Anywhere! New York, Henry Holt.

Klages, E., & Rose, T. (1997). Exploratorium: A Year of Discoveries. Exciting Hands-on Activities for Every Month of the Year. San Francisco, Chronicle Books.

Murphy, P., Klages, E., & Shore, L. (1996). The Exploratorium Home Laboratory II: Hands-on Science Fun for Families. San Francisco, Exploratorium Magazine.

Websites

Valuable websites offering projects and experiments similar to those offered by the books and additional information are:

Figure This! Award-winning website that offers mathematical challenges for families. Includes hints, applications to the real world, fun facts, and questions to think about and complete solutions. The site also provides family support materials with suggestions on how to help with math homework and how to prepare children for continuing math education.

> ©1999 National Council of Teachers of Mathematics in association with Widmeyer Communications · National Action Committee for Minorities in Engineering
> http://www.figurethis.org

Family Science Offers different ideas about how to foster a family science night or take-home science project. The site gives an array of different experiments that can be conducted at home or at a school program. The site also provides models of successful programs and a step-by-step guide on how to start your own program, including tips on preparation and advertising.

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> http://www.sofweb.vic.edu.au/science/famsci/

Family Math at Rutgers University Family Math is an after school family involvement program that provides elementary school children and their parents opportunities to develop problem-solving and mathematical skills. Children and adults meet once a week for six weeks to do mathematics, then practice ideas they learn in class at home. The program uses inexpensive hands-on materials such as beans, toothpicks and coins. The main focus is learning the process of mathematics and developing a positive attitude toward mathematics. The curriculum represents areas from arithmetic, geometry, measurement, probability and statistics, calculators and computers, patterns, relations and functions and logical thinking. Note: this is a program developed by EQUALS at the University of California, Berkeley, and is presently being implemented in over 60 sites across the world.

> http://www.rci.rutgers.edu/~cfis/fm.html

Geometry Through Art: Family Math Day Geometry Through Art is a one-hour session for parents and first and second graders to learn the fundamental lessons of geometry. The sessions consist of drawing, visualization, and whole-group activities.

> http://www.mathforum.org/~sarah/shapiro/shapiro.family.math.html

Chevron Texaco Family Science Chevron Texaco launched a family science program in 1991 that tries to capture children's interest in math and science with projects and experiments. The bilingual program is currently established in 20 communities, but more are to participate in future. Textbooks are provided for all participants in either English or Spanish and contain hundreds of experiments that call for simple everyday items. Chevron Texaco employees volunteer to teach the Family Science workshops.

> http://www.chevrontexaco.com/social_responsibility/community/programs_family.asp

Family Science Adventures The Hands-on Science Center of the Lehigh Valley puts on Family Science Adventures, a program held one Saturday and one Thursday night each month at the center. It is for children 5 years and older and their families. An $8.00 dollar fee per person includes 4 hands-on science experiments and materials and supplies for two to three take-home projects.

http://www.wizardsofscience.com/family.htm

For more examples of family-oriented interventions, see New Formulas for America's Workforce: Girls in Science and Engineering. (2003). Washington, D.C.: National Science Foundation.

Conclusions

Over two decades of research indicate family support is crucial for women to excel in engineering. Parents of women engineers tend to raise their daughters with fewer gender stereotypes, provide more support, and place greater weight on education and learning. Skills, attitudes, and self-concepts about math and science (the core disciplines required for engineering) are formed before college when engineering courses are offered. In order for girls to consider engineering, families must provide early encouragement in math and science.

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