ENGINEERING AS A CAREER CHOICE: STRENGTHENING THE WEAKEST LINK

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To increase the numbers of pre-college young women selecting engineering careers, there must be support for the preK-3 teachers and curricula. The existing math, science, and social studies curricula bolstered by the National Standards/Benchmarks of each discipline contain examples, illustrations and experiences directly related to engineering (13) (1).

This paper presents a prescription for pre-college engineering education and related programs. The primary research focus was to examine K-12 science, math and engineering programs. Then other important issues emerged and overshadowed the focus, gender and affective learning among them. However, equally important if not more so is the role of the teacher. She is the key. Providing teacher support is a crucial issue.

Just knowing about engineering fields is not enough to attract young women into thinking about them as potential career choices or even taking science and math courses. Students' early involvement, hands-on/brains-on activities, is what captures their interest. Elementary students' exposure to engineering concepts is weak with preK-3 involvement surfacing as the weakest link in the chain. The chain represents the trek through preK, elementary, middle and high school, college, graduate school to careers for girls. As the most critical link, preK-3 needs strengthening. Children form predominant attitudes before age nine. "Moving a mountain" is almost easier than changing a significant affective impression after this age. Therefore, it is crucial to make an impact on students in early grades about engineering themes through affective and cognitive learning approaches. This premise is based on an analysis from the findings of numerous studies.

GENDER, A KNOWN OBSTACLE

Affective Learning

It has been determined that attitudes developed in elementary school effect choices made in high school and as an adult. Beliefs, attitudes, and values may be seen as an integrated cognitive system. An opinion or expectation that a child believes to be true and is a major part of her learning is most resistant to change [4]. Further, an attitude can be defined as interrelated beliefs and is relatively stable. This concept of attitude is about what is true or false or what is desirable or undesirable to a child. "Attitudes have three components: an idea or thought, a feeling or emotion, and a readiness to respond or predisposition to action." To investigate a bit further, we see that beliefs come in complex sets that an individual holds about herself. This set makes up her self-concept that includes beliefs about achievement and abilities, character, physical attractiveness and self-allowed success [4]. It is generally accepted that students' positive attitudes toward science are prevalent until between 4th and 6th grade. This begins to wane and is in general decline before 8th grade. However, once a child is convinced that she cannot learn science, math, or other subjects, the tasks of teachers and other adults become almost impossible. "The notions that males excel in mathematics, science and technology and that females excel in the arts are two of many beliefs and cultural influences that are passed down through generations" [14]. It is even often incorrectly covered in the press where math and science are legitimized as in the male domain [5]. In Andre et al., [3] it is suggested that an affective dynamic is more powerful because teachers and parents may not realize they are holding such beliefs and acting on them. In this study [3] it was found that parents perceived: girls to have higher competence in reading and boys in science; math and reading to be more important for younger students; science more important for boys than girls. Where as both girls and boys liked science with girls liking reading more than boys, both girls and boys saw science related jobs as more male dominated. These perceptions held true for children across grades K-6. For three decades, Hofman has asked students (grades 2 through graduate school) to draw scientists. In each instance, the overwhelming majority drew white males. This has not changed in our country's collective mind since Margaret Mead investigated this topic in 1957 and obtained similar results.

Teacher educators need to take affective learning topics to heart and present them to pre-service teachers. These topics are covered in only about 11% of teacher preparation courses. We know that these types of gender biased attitudes become self fulfilling. Therefore, it is imperative that early childhood and primary educators perceive the often subtle but powerful cumulative impact of attitudes on the understanding of children about the world and their place in it.

Career Choices

Positive attitudes are reflected in our enjoyable and most passionate interests. Students are measured for career interests and exploration during middle and high school. The most frequently used instruments are interest inventories that are most likely invalid if girls have had their interests curbed for 12-13 years. Farmer reminds us that the data says girls typically choose careers from a very narrow set of options where boys perceive options from almost every career field [8]. Both learn early, with early being the operative word, which occupations are suitable to their gender and girls know which not to even have an interest in pursuing. In 1970 women represented less than 1% of engineers. The Educational Equity Act and Equal Employment Legislation was passed in 1972. Thirty years later there is some change [5]. Women now represent 17% of employed engineers, with employed being an issue and obstacle in this complex problem. However, there is a serious under-representation of women in the science, math and engineering fields as shown by Chinn [6]. Despite receiving over 55% of U.S. bachelors degrees in 1996, women earned only 19% of the engineering degrees. NSF data shows that the career options for women have not widened. For example, women in the field make up 50% of sociologists and psychologists, 9% of physicists, and only 8% of engineers. Also, at the graduate level, Ph.D.'s are 41% of the social sciences, 28% in Biology and only 4% in engineering. Chinn suggests that the K-12 educators, especially in elementary grades, need to challenge the practices that place students in stereotypical groups reflecting perceived ability and attitude. For over 50% of the population to have only increased from 1% to 17% of the engineers in three decades is neither progress nor a reflection of the claim of educational equity.

PROGRAMS

Among the hundreds of Science, Math and Engineering, SME, programs developed over the past ten years, some address the lack of women in engineering. However, there are precious few that look at the young child and address the early affective and cognitive needs of girls. As the saying goes, "We are only as strong as the weakest link." The first problem in strengthening the weakest link is in existing programs. Frequently, they propose SME interventions for middle school girls and/or women in high school instead of aiding preK-3. Other flaws in these programs include: (1) "blaming the young women" for not choosing SME when they have been educationally and culturally discouraged to do so; (2) being extracurricular in nature therefore sending the message "it is ok for girls to do science after school but not in school;" (3) overcompensating by producing materials for "girls and boys" when girls are not rapidly closing the gap in SME career choices; (4) designing supplementary materials/activities rather than complementary integrated curricular ones; (5) not including affective learning; (6) running short duration programs that do not produce lasting effects; (7 not gathering information longitudinally (ten to fifteen years) that follows young girls through to their careers; and (8) providing teacher development that is too content oriented without a balance of sessions about concepts and attitude. In view of these program shortcomings, it should be noted that in the few programs that address the issue of young women entering SME careers, most in fact do not contain all of the "flaws" and do contain positive components. However, the number of programs that have eliminated most "flaws" and target the early impressionable years of girls are only in single digits.

Program Criteria

Turning the above criteria into a positive description for funding preK-3 programs should improve the affective learning in SME for girls. A great potential for broadening their perceived career options could emerge. This is based on research results that suggest "part of the genesis of gender differences in science achievement and science-related careers, particularly in physical science, may lie in attitudinal reactions that begin to develop even at the earliest elementary school years [3]." The following areas are recommended for promoting change in preK-3.

Teacher Support

First and foremost, teacher support is fundamental. Hofman, in twenty years of designing, directing and evaluating teacher aerospace programs, provides substantial evidence of this [9]. The teacher is key and armed with an understanding of girls' attitudes and beliefs about SME, knowledge about the power of affective behavior in instruction, the importance of the affective environment, effective strategies, appropriate SME activities and on-going support, she/he can make an enormous impact. The best types of materials and activities should mimic those in the Physical Activities and Language for Science, PALS program, MEMCO, Bowling Green, Kentucky and those described by Crissman [7]. In these programs all activities were hands-on/brains-on and used the processes of problem solving. However, the most important aspect was the use of collaborative learning. These strategies and activities are ones that are generally accepted to benefit girls' learning.

Teacher development programs need to be of long duration and just not one or two weeks. That means follow-up for teachers. A program should give easy access to partners, peers and resources. The "partner" could be an engineer. The question then becomes "What can an individual engineer do to help turn the tide in this issue?" The response is " a good start would be to adopt a nearby elementary school. Volunteer to be the 'engineer in residence.' Be available, on-line, for questions from the students about your expertise and engineering in general. Partner with a preK-3 teacher. A true partnership involves assisting in plans for the SME program and sharing ideas. Begin with visits to the class and share informally stories about what you do on the job or have done in SME studies. Help children write stories about being a woman engineer and/or read books to them that have girls as the protagonist."

The teacher could also use a network (electronic, and/or personal) of educators and engineers from which to seek suggestions particularly about affective learning and appropriate resources. The author offers examples of teacher programs with excellent components in mentoring, networking and follow-up services. Each of the long term programs listed here serve preK-3 teachers: NASA's Education Workshops for elementary Science Teachers, NEWEST, Advancing Science Outreach Program and teacher workshops, Gettysburg College, Gettysburg, Pennsylvania, PALS, and the University of Alabama in Huntsville (UAH), Exploring Space Programs (three tiers of workshops held in Huntsville, Washington, D.C. and Russia). The UAH teachers claim that time to share with other professionals is important. Sharing with other teachers in a variety of settings, workshops, conferences, district meetings and with colleagues at school, is instrumental in creating change in teaching behavior. In-service programs aimed at changing teachers' practices should provide sessions on acquiring new teaching strategies in the affective domain [9].

Research should be funded for programs that track girls from classrooms where teachers are using such affective strategies. The tracking should continue through the ages when the girls make study and career choices. Hofman's [10] ten year study "SSIP Where Are They Now?" of participants from NASA's Student Space Science Involvement Program revealed important perceptions. The young women's responses suggested that "having the chance to interact with mentors, science and engineering role models, and to do real science" was memorable. These experiences figured in heavily when SSIP women chose career paths.

Interdisciplinary Approach

An interdisciplinary approach to teaching allows for holistic studies of SME themes. Students are able to note the interrelationships among math, science, reading, social studies, art, and music. With this approach, students come to realize that they often need to apply skills from more than one discipline to solve problems, study issues, and/or make decisions. Since in real life there are many perspectives to problem solving, students will become better prepared to make decisions [15]. Interdisciplinary methods expose children to a variety of resources, trade books, novels, prime documents, and a wealth of material through computers. It allows teachers to offer in an affective environment more rounded, less biased viewpoints. Children can be encouraged to develop higher level thinking skills long with the discovery that inquiries are often open-ended and continuing rather than discrete and complete.

Developmentally Appropriate Practice, DAP

The teacher who uses developmentally appropriate strategies reinforces attitudes that increase learning potential. This is according to Feinburg and Mindess in their 1994 edition of Eliciting Children's Full Potential. Such a teacher encourages children: to learn that it is all right at first not understand or know an answer; to understand that mistakes and errors are natural and important parts of the learning process; to see that they can make independent decisions; and to know that the learning process is important. It takes time for students to be investigative. If the number of topics studied in math and science is reduced to be more in line with the top scoring nations on the Third International Mathematics and Science Study, the time needed for DAP would be found. For example, in the U.S. depending on the grade, between 53 and 67 topics are covered in science where in Japan it is 8 to 17 topics and in Germany it averages 9 topics. In math, on average, the U.S. covers more topics than are covered in 75% of countries in the TTMSS [12]. The call is "less is more," less topics allow for more time and depth in the study of each.

Should we be empowering preK-3 children with time consuming scientific inquiries that will increase their interests in SME? According to the Standards/Benchmarks and the National Association for the Education of Young Children, NAEYC, yes. However, in reality the school curricula are a considerable distance from the ideal. To close that gap, Hofman with Kilmer in the NAEYC, Reaching Potentials: Transforming Early Childhood Curriculum and Assessment, Volume 2, offer the DAP for the young child doing science [11]. Investigations of the developmental needs of young children in science show that the curricula presently do not include DAP to an extent large enough to produce change.

This needs to be done immediately if we view as vital the 1999 data according to AAUW [3]. It shows: women are only 16% of the science and engineering workforce; in this year, 2000, two out of three new entrants into the labor force will be women; and girls are still systemically discouraged from courses of study essential to their future employability and economic well-being.

Curricula and Standards

The criteria related to curricula have several important attributes. However, the driver should be the National Standards and Benchmarks. According to the National Council of Mathematics, Principles and Standards for School Mathematics 2000, "Equity and excellence both must be the objectives of school mathematics programs. By enfranchising more students, while maintaining high standards, there will be a larger number available to pursue careers" in math, science and engineering. The standards supporting this premise are problem solving, communication, and connections. There are ten math standards and each has applications across preK-3 [13]. The American Association for the Advancement of Science, Project 2061 Benchmarks equally give sound basis to the appropriate learning needed. It comments on the importance of cooperative learning and exploration. "Children should have lots of time to talk about what they observe and compare their observations to others. From their very first day of school, students should be actively engaged in learning to view the world scientifically. By the end of 2nd grade, students should know that everybody can do science and event things and ideas [1]."

Guidelines for preK-3 Affective Learning Environments

- Teachers and other adults should be trained in use of affective learning strategies.
- DAP should be regularly employed.
- Teachers should be supported with appropriate technology and resources.
- SME programs should be an integral part of the regular curriculum not extra-curricular.
- SME activities should be interdisciplinary and interactive.
- National Standards and Benchmarks should provide the curricula framework.

CONCLUSION

We have not progressed enough over the past thirty years to allow engineering to be a viable choice for women. The educational reforms in SME do not address this problem in sufficient depth. Waiting for more research will no doubt result in another generation of girls being kept out in great numbers of the engineering fields. Instead, parallel with calling for more effective programs, we need to immediately start working with teachers and young girls to negate the job choice myths. Each of us can become a preK-3 partner and a mentor.

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