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ABSTRACT

Females are underrepresented in courses in mathematics, science, and computer and other high technology applications. Research in the last decade has identified a variety of factors that contribute to females' lack of participation in math, science, and technology. These factors include, but are not limited to, the following: stereotypic images and expectations, lack of self-confidence, peer pressure, learning environment, teacher behavior, lack of female role models, failure to see relevance, attributional style or personal responsibility, and lack of incentives. The following strategies can address these issues: (1) parents', teachers', and counselors' efforts to dispel stereotypes; (2) improvement of self-confidence; (3) use of peer pressure by making success in math and science prestigious; (4) enhancement of the learning environment; (5) equalization of teacher behavior; (6) provision of female role models; (7) improvement of relevance by presentation of lessons with real-life applications; (8) adjustment of attributional style and instilling of personal responsibility; and (9) creation of incentives. (A bibliography lists 19 references. An annotated listing of 12 additional resources refers the reader to print and video resources available for loan to Ohio vocational educators from the Sex Equity Resource Library at the Center on Education and Training for Employment.) (YLB)

MONOGRAPH

MATH + SCIENCE + TECHNOLOGY = VOCATIONAL PREPARATION FOR GIRLS: A DIFFICULT EQUATION TO BALANCE

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- In 1989, fifty-six million women age sixteen and older were working or looking for work. Fifty-seven percent of all women sixteen years or older were labor force participants.
- Two out of three people who are earning minimum wage are women.
- Sixty percent of women in the labor force work out of economic need. They are single, divorced, widowed, or have spouses that earn less than fifteen thousand dollars per year.
- Sixteen percent of all families are maintained solely by women.
- By the year 2000, two out of three entrants to the labor force will be women.
- The average woman can expect to spend twenty-nine years of her life in the labor force.

INTRODUCTION

One in every six families is maintained by a woman, and more families than ever before are relying on women's earnings. For this reason, raising women's status in the labor market has been called **the family issue of the nineties** (Spalter-Roth and Hartmann, 1991). Although approximately half the American work force comprises females, most of those women are working in low-paying jobs. Many people attribute this situation to women's lack of preparation in math and science.

Females are underrepresented in courses in mathematics, science, and computer and other high tech applications (Sanders and Lubetkin, 1989). Females are also avoiding courses in industrial arts, trades, and other vocational-technical programs that provide training in applied technology. In one study, only four percent of female high school seniors, compared to twenty-three percent of male seniors, had taken at least two years of nontraditional courses, such as automotive mechanics, commercial art, drafting, or welding. Only three percent of female high school seniors, compared to seventeen percent of male seniors, had taken at least two years of technical courses, such as communications, transportation, or electronics technology (Strauss, 1988).

Mathematics and science are *critical filters* in the educational process for girls. That is, females reduce their future job opportunities by at least fifty percent when they choose not to take math and science courses. Female technicians with math and science training and a high school degree, a one-year postsecondary certificate, or a two-year associate degree are already in high demand (Stern, 1991). Because the level of technological sophistication required of workers is increasing so rapidly, and because the information required to deal with technological advances is learned through mathematical and scientific concepts, **girls who don't strengthen their math and science skills are destined for poverty.**

This paper will focus on the barriers that prevent females from participating in mathematics, science, and technology at the same rate as males. It will suggest ways to overcome these obstacles, and will supply a list of additional resources that are available to teachers and administrators to encourage girls' participation in math and science. Although the suggestions focus on female students, the proposed strategies can be used to recruit all students to take interest in math, science, and technology. By encouraging student interest in these disciplines, they will be better prepared to participate in an economy that requires technologically literate citizens.

REASONS WHY GIRLS DON'T PARTICIPATE IN MATH, SCIENCE, AND TECHNOLOGY

During the elementary school years, girls enjoy math and achieve in math as much as boys do, or even more. Yet when adolescence begins, girls become disinterested in math and science, and achievement and participation decline (Franklin, 1990). There has been a great deal of research conducted in the last decade that identifies a variety of factors that contribute to females' lack of participation in math, science, and technology. These factors include, but are not limited to

- Stereotypic images and expectations
- Lack of self-confidence
- Peer pressure
- Learning environment
- Teacher behavior
- Lack of female role models
- Failure to see relevance
- Attributional style or personal responsibility
- Lack of incentives

Stereotypic Images and Expectations

Society stereotypes math and science as male domains. Parents, teachers, counselors, and peers expect boys to do better in math than girls (Beane, 1988). Math is considered more valuable in the educational preparation of boys than it is for girls. Coupled with this are the stereotypic images that textbooks and the media project about women in math, science, and technology. If the women are successful, they are portrayed as uncaring, unpopular, and unattractive women. Most often though, they are portrayed as uninteresting and unsuccessful.

Female students internalize these messages. Because girls want to be viewed as attractive and feminine, some just choose to avoid, or to not achieve in, math and science courses. Some girls start to believe that they cannot do math, or they develop math anxiety stemming from an expectation of failure related to math.

Lack of Self-Confidence

Research regarding the success of boys and girls in math and science courses cites girls as having less confidence in their abilities regardless of any real difference in performance (Franklin, 1990). Sherman (cited in Chipman and Wilson, 1985) found that students' confidence as math learners was closely correlated to how much encouragement they received from their teacher. Equally important was the amount of encouragement that students received from their parents that built confidence in their academic abilities.

Peer Pressure

Related to stereotypic expectations and a lack of self-confidence is the influence that peer attitudes have toward female participation in these disciplines. In a survey of nontraditional career students at a joint vocational school in Ohio, a recurrent theme was the disapproval of female participation by male peers (Kapostasy, 1991a). Male students stated that female students should not be in particular classes because those classes were for males only. At a time when females seek approval and value relationships, these comments have a profound impact on girls (Gilligan, 1990). For many girls, it is easier to avoid the math, science, and technical courses that elicit these comments than to jeopardize their friendships and threaten their dignity.

Learning Environment

It is important to keep in mind that many females place a high value on relationships. They value cooperation over competition. When relationships are threatened by competition, or when circumstances are perceived by girls as unfair, girls tend to avoid or withdraw from the situation (Gilligan, 1990). Traditionally, math and science activities in the classroom have been driven by competition and not cooperation. When students are solving math problems or developing science projects, teamwork has not been emphasized as strongly as individual work has been.

Teacher Behavior

Teachers in general have been found to give boys more praise, more criticism, and more remedial help than they give girls. Teachers also respond more frequently to boys' requests for help and talk to boys more about ideas and concepts (Eccles, 1989). In math and science courses where girls need extra encouragement to counteract all the other barriers, more attention to girls is a necessity. However, giving attention and resources to boys is so much the norm that teachers who try to give equal attention to girls often feel uncomfortable because they think that the boys are being slighted (Whyte, 1984). This is usually not intentional; it more often results from socialization and can be corrected once teachers are aware of the situation, have practice responding fairly and equally, and receive feedback.

Lack of Female Role Models

Modeling behavior is a significant vehicle for learning. Without role models, female students have difficulty achieving in perceived *male* activities. Even though there have been significant contributions by women in the fields of math and science, these women are not often visible in textbooks or in the classroom. When girls have female role models they are more likely to participate and achieve in these fields. For example, girls having a high percentage of female math teachers more often pursue math-related careers (Franklin, 1990).

Failure to See Relevance

Students are often unable to see the relevance of mathematics in the *real* world. They have difficulty relating abstract concepts to concrete daily experiences, such as budgeting money, purchasing items, or balancing a checkbook. This inability on the part of the student to see the need for math or science skills causes a disinterest in the subjects that can be linked to low achievement. Additionally, many students do not believe that they will need math or science skills in their chosen career, even though virtually every profession requires math and science concepts and problem-solving abilities.

Attributional Style or Personal Responsibility

A not-so-familiar factor that prevents women from succeeding in these nontraditional areas is based on female's perceptions of personal responsibility. The concept is called *attributional style* and it refers to how one attributes success and failure. Boys typically attribute their success to skill, and attribute failure to their lack of effort or to the task's difficulty. In other words, they are personally responsible for success, but failure is not their fault. Girls attribute their success to luck, and attribute failure to their lack of ability. Therefore, success is not attained, it is merely chance; and failure results in self-blame. Attributing success to external factors and failure to a lack of ability has been linked to a pattern called *learned helplessness* (Franklin, 1990). Girls with this attitude are destined for failure because they expect failure and therefore **they don't even try.**

Lack of Incentives

Finally, there is little incentive for students *and schools* to achieve in mathematics, science, and technology. Although President Bush has identified math and science as areas in which American students need to excel, local school districts are not driven to meet this objective. At present, technology is not a subject in our schools. Similarly, science and technology are not areas included on Ohio's proficiency exam. Students find it difficult to enroll and persist in these courses because the studies tend to be rigorous and require much effort. For the vocational or general education student who does not plan to enter college, there is no reward related to the work force that encourages excellence in mathematics, science, or technology (Bishop, 1988). To these students, there appears to be no good reason for pursuing these subjects any more than is absolutely necessary.

IMPLICATIONS FOR EDUCATION

The reasons why female students do not pursue mathematics, science, and technology are diverse and yet connected. The strategies for addressing these issues are valuable not only to females but to all students about to enter the next century.

For students to function as tomorrow's work force, they must be prepared to meet the needs of a highly technical and ever-changing society (Fear-Fenn, 1986). Math and science are just the cornerstones of the technological literacy that will be needed to succeed in the next century. The following suggestions, which address the underrepresentation of women in mathematics, science, and technology, come from a variety of sources and a culmination of experience. However, two particularly influential sources are the *EQUALS* materials, published by Kaseberg, Kreinberg, and Downie (1990), and *Add-Ventures for Girls: Building Math Confidence* (Franklin, 1990).

Dispelling Stereotypes

In order to address the adverse affects of stereotypic attitudes, teachers can provide examples of females in story problems, on bulletin boards, and in discussions. For example, when presenting story problems, teachers can substitute a female name to identify the welder, builder, or technician. By avoiding stereotypic language, teachers can help females relate to being successful in these areas. Also, teachers can use girls' personal experiences to promote the idea that girls have been, and can be, successful in math and science. Girls have often measured ingredients when cooking or dimensions when sewing.

Counselors and parents must encourage females to take courses in mathematics, science, and technology. It is a misconception that an advanced degree is required to apply these concepts or to earn high wages in these areas. There are nearly twice as many technical jobs making use of math, science, and technological applications as there are professional jobs that do so. Females need a firm foundation at the secondary level in these areas.

Increasing Self-confidence

Students won't be successful if they believe they can't be successful. However, once success is experienced, it can be built upon. Females need a great deal of practice in nontraditional tasks in order to become confident in their abilities. Many computer software programs provide this opportunity as well as direct feedback, and avoid public correction.

It is important to structure activities that enable students to experience success. By understanding the need to know *how* to get to the answer rather than to simply *arrive* at the right answer, students will be more willing to take the risks necessary to internalize the mathematical or scientific concepts. Also, students' fear of getting the wrong answer lessens if the process, and not the result, is focused upon.

Utilizing Peer Pressure

Peer pressure can be a powerful influence on student decision making. Rather than allowing peer pressure to prevent females from participating in math and science, teachers can use it to help recruit students into these subjects. Teachers should try to make success in these subjects high status and to use peer pressure as a positive influence. This can be achieved by creating clubs or support groups for females that focus on their interests.

For example, *Girls Excited About Math and Science* (GEMS) is a club that meets weekly in order to make students aware of the importance of math and science (Kapostasy, 1991b). During these meetings students talk with role models, watch videotapes that show the relevance of mathematics, take field trips to interesting places, and participate in activities that are designed to increase skills and confidence in math and science. Because of the high interest level, students recruit peers into the club, after which relationships are formed and females are less likely to feel the need to avoid the areas of mathematics, science, and technology. Other programs that can involve parents, business or community groups, or teachers with students are *Operation SMART* and *Family Math*. These are further discussed in the list of additional resources.

Enhancing the Learning Environment

This country's educational system has traditionally focused on what is thought to be a male learning style, competitiveness (Franklin, 1990). This type of teaching strategy can be intimidating to female students and to some males. Cooperative activities

are now being suggested as more advantageous for the variety of students. Cooperative activities involve students working together in teams to solve problems. If all-male and all-female teams are avoided, both genders will learn valuable communication strategies that will be useful to them when they enter the work force. A round-robin technique is recommended for groups in order to prevent a high achiever from dominating the group. Some teachers have found the rotation of leadership roles to be effective in encouraging *all* students to participate.

Equalizing Teacher Behavior

It is hard to monitor or evaluate one's own teaching behavior while teaching. But teachers who videotape themselves and then code their interactions with students are often amazed to find *invisible* students—students who never talk and are never addressed. Studies have shown that another very effective means of equalizing teacher behavior is through *Gender/Ethnic Expectations and Student Achievement* (GESA) training. In GESA training, teachers team with other teachers and then observe and code one another's individual interactions with students. Ohio educational leaders have been promoting GESA training for several years. For more information, contact Connie Blair at the Ohio Department of Education, Division of Vocational and Career Education.

Providing Female Role Models

Linking with business and industry to provide female role models is an excellent strategy. Another is working with local unions or women's organizations to find female role models. Educators can invite female technicians into the classroom to talk about their experiences and their work. An excellent resource is *Exemplars*, published by the Ohio Academy of Science, which lists women in Ohio who are willing to serve as mentors for young female students interested in similar career pursuits. Teachers can also prepare bulletin boards, tests, and daily assignments with women pictured as the technicians.

Implanting Relevance

Rather than teaching skills in isolation, teachers can present lessons with real-life applications by using the names of students in the class, businesses in the area, other teachers in the school, and practical examples that students can appreciate. This will draw the students' interest to their lessons. In order to incorporate cooperative learning and to show mathematical relevance, ask students to work in groups to identify a number of ways in which math can be used in specific vocations or in their daily applications. Then ask students to create, share, and solve story problems related to each of the applications.

Adjusting Attributional Style and Instilling Personal Responsibility

Self comments that attribute success or failure to external forces can be devastating to a student. Students need to realize that they are personally responsible for their successes and failures. When a teacher hears a student demeaning his or her own ability or escaping personal responsibility, the teacher should address the comment to help the student see their responsibility. Another option is to seek opinions from other students who can exert peer pressure and encourage positive behaviors. Students need to be aware that they are in direct control of their behavior and that they are also responsible for facing the consequences of their behavior. Occasionally, they need to be reminded that with more effort they are capable of achieving success. It can also be helpful to provide specific praise for small accomplishments in order to avoid always praising students just for their efforts (Franklin, 1990).

Creating Incentives

Although teachers have little power over political decisions, teachers can provide incentives for students. Teachers can create an atmosphere of mutual respect and send all students the message that they are capable and valuable. This will provide a firm foundation on which to begin instruction. In order to provide drill and practice, teachers may find game-like formats more enjoyable. Finally, reinforcements such as pencils, erasers, paper, or even a point system designed to earn classroom activities or privileges can serve as powerful motivators for even the most mature audiences.

SUMMARY

The reasons for female disinterest and decline in achievement in mathematics, science, and technology are numerous yet related. As technology continues to explode at an ever increasing rate, it becomes more important than ever before for students, and particularly female students, to expand their skills and knowledge in the area of math and science in order to fully participate in a highly technical society. If teachers can make math and science courses interesting, inviting, relevant, and enjoyable for students, then students may enroll in these courses. The more mathematics and science courses that students take, the greater will be the number of options available to them in the future.

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ADDITIONAL RESOURCES

For additional information, consult the resources listed below. These resources are available for loan to Ohio vocational educators by contacting the Sex Equity Resource Library at the Center on Education and Training for Employment, 1900 Kenny Road, Columbus, Ohio, 43210, (614) 292-4353 or (800) 848-4815; Steve Chambers, Librarian.

Agency for Instructional Technology. *Women in Science*. Bloomington, IN: Agency for Instructional Technology, 1988. A series of seven 30-minute and one 40-minute video programs designed to encourage women to pursue careers in science. One video examines issues of sex equity for students and the adults who influence their career decisions. The other seven videos, for junior high, high school, and college students, feature careers in biomedical fields, chemistry, computer science, dentistry, engineering, geosciences, and astronomy. Some careers require technical training, some require an associate degree, and many require bachelor's degrees and beyond.

Consortium for Educational Equity. *Just Between Sisters: Futures Unlimited for Minority Women in Technology*. New Brunswick, NJ: Rutgers, 1988. A thirty-minute video, ten full-color posters, and a supplementary career guide feature young, determined, attractive black and Hispanic women working with pride in the exciting world of technology. The fast-paced video refutes stereotypes and fears that many students have concerning nontraditional careers and encourages students to stay in school and to take the necessary math and shop courses to prepare for high-paying jobs in the trades and technologies. Featured role models are an aircraft technician, an electrician, a laboratory technician, a plumber apprentice, a police officer, a radiologic technologist, a senior customer service engineer, a sheet metal worker apprentice, a train master, and a utilities and maintenance apprentice.

Conwell, C. R. *Science EQUALS Success*. Newton, MA: Women's Educational Equity Act Publishing Center, 1990. This book contains over thirty hands-on discovery-oriented science activities designed especially for girls and students of color (grades four through nine, and beyond). The activities focus on problem solving, cooperative learning, spatial skills, and career awareness. These activities build on the fun of science, increase competence in this area, and will motivate girls in the area of math and science. The activities are designed to supplement an existing program and can easily be integrated into the classroom.

Erickson, Tim. *Off and Running: The Computer Offline Activities Book*. Berkeley, CA: University of California, EQUALS program, 1986. This book is a collection of activities suitable for individuals, small groups, and classrooms. The activities illuminate important concepts having to do with computers. Computers are not needed to do the activities. Themes in the book include programming, cooperation, and equity. All the

book's activities are cooperative, and the activities provide career information, presentations by minority role models from technical professions, and opportunities for skill acquisition. Each activity has defined objectives, topics, methods, materials, preparation, procedures, and extensions.

Franklin, M., et al. *Add·Ventures for Girls: Building Math Confidence*. Newton, MA: Women's Educational Equity Act Publishing Center, 1990. An excellent, up-to-date, and valuable resource for math teachers to build math skills and positive math attitudes for female students (grades six through nine, and beyond). Fun, hands-on activities expose girls to the exciting world of math. Activities and information on teacher-student interaction patterns, girls' learning styles, and the importance of parent involvement help teachers create an environment that makes math work for girls. Strategies, tournaments, math problems, and activities are provided in areas such as encouraging cooperative learning; implementing an effort-persistence-mastery approach to problem solving; and encouraging independent thinking, intellectual risk taking, and creative problem solving.

Fraser, S., et al. S.P.A.C.E.S.: *Solving Problems of Access to Careers in Engineering and Science*. Palo Alto, CA: Dale Seymour Publications, 1982. Thirty-two classroom activities (grades four through ten, and beyond) help to stimulate students' thinking about scientific careers, develop problem-solving skills, promote positive attitudes toward the study of mathematics, increase interest and knowledge about scientific work, strengthen spatial-visualization skills, and introduce language and familiarity with mechanical tools. Organizational categories are design and construction, visualization, tool activities, attitudes and personal goals, job requirements and descriptions, and women in careers.

Genshaft, J., and J. Naglieri. *A Mindset for Math: Techniques for Working with Math-Anxious Girls*. Newton, MA: Women's Educational Equity Act Publishing Center, 1988. This book describes techniques for reducing math anxiety as a component of math instruction. It begins with a section on how to identify the math-anxious student, then focuses on helping girls recognize their feelings of anxiety and learn to reduce those feelings by using proven stress-reduction techniques. It introduces activities that make math relevant, intriguing, and stimulating.

Kaseberg, A., Kreinberg, N., and D. Downie. *Use EQUALS to Promote the Participation of Women in Mathematics*. Berkeley, CA: University of California, EQUALS program, 1990. The EQUALS program encourages teachers to be more creative when teaching mathematics. Manipulative and game-like activities inspire students and teach them how to identify patterns of logic and to learn problem-solving skills. This handbook is intended to help educators implement EQUALS activities in the classroom, conduct one or a series of inservice programs, and provide information to others. It is a practical resource for the classroom and a concise statement of the EQUALS philosophy and collective wisdom.

Los Angeles Foundation for Advancements in Science and Education. *Futures*. Alexandria, VA: Public Broadcasting Service, 1990. This is a twelve-part series on six videotapes. Careers are examined in the areas of agriculture, aircraft design, architecture, automotive design, cartography, fashion, water engineering, optics, space, sound engineering, statistics, and sports performance. *Futures* demonstrates the broad applications of mathematics while building a bridge between industry's needs for its future work force and the goals, desires, and plans of students. The host of, and motivating force behind, *Futures* is Jaime Escalante, a native of Bolivia, who received national acclaim for his extraordinary accomplishments with inner-city students in advanced-placement calculus.

Roman-Lazen, E. *Operation SMART*. New York: Girls Incorporated, 1990. Operation SMART is a program to encourage every girl in Science, Math, and Relevant Technology. A SMART girl might dismantle a computer, make a cloud, dig in the dirt with a construction worker, go on a worm hunt, or draft a blueprint. Hands-on, participatory, and experiential, SMART challenges girls (ages nine through fourteen, and beyond) to ask questions, make predictions, keep their options open, and plan for the future. It is appropriate for schools, business or community groups, parent organizations, science centers, or after-school programs. Guides explain how to establish the program, conduct the activities, evaluate the program's impact on girls, and promote linkages with community science resource organizations. An eight-minute video shows SMART girls in action.

Sanders, J. S., and A. Stone. *The Neuter Computer: Computers for Girls and Boys*. New York: Neal-Schuman Publishers, 1986. This book was written for everyone who wants to increase or improve computer use by children, especially girls. This includes educators at all levels, parents, students, teacher trainers, and educational policy makers. Among the fifty-six computer-equity strategies in this book are a good number that don't require a computer at all. The project that tested the strategies in this book increased girls computer use nearly one hundred and fifty percent in one term. That is, whereas girls made up one quarter of the optional-time computer users at the beginning of the term, girls accounted for half of this group at the term's end.

Stenmark, J. K., Thompson, V., and R. Cossey. *Family Math*. Berkeley, CA: University of California, EQUALS program, 1986. This activities book (kindergarten through eighth grade, and early secondary education) helps develop the ability to visualize spatial relationships (geometry), to approximate (estimation), to interpret data (probability and statistics), and to reason mathematically (logical thinking). The activities focus on problem-solving skills and build an understanding of mathematics by offering hands-on materials. The book describes a family math course of six to eight sessions for students in kindergarten through eighth grade; the course is designed to be taught by parents, but can be taught by teachers or community volunteers as well.