Building Communities Through Role Models, Mentors, and Hands-on Science

Maria Ferreira

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Abstract

The use of community resources in science education, as a means to expand students' educational opportunities, is particularly important in urban areas serving mostly low-income students. This paper describes an after-school science program intended to provide a group of minority middle school girls with science experiences related to one of the largest industries in the area—the automobile industry. The program was implemented by a group of women engineers who served as role models and mentors and guided the girls through hands-on science activities related to automobile engineering. The program was successful in improving the students' attitudes toward science, engineering, and mathematics.

Introduction

When addressing the principle of equity and excellence in science education, the authors of the *National Science Education Standards* insist that, "All students, regardless of age, sex, cultural or ethnic background, disabilities, aspirations, or interest and motivation in science, should have the opportunity to attain high levels of scientific literacy" (National Research Council, 1996, p.20). Yet, as we enter the 21st century, our nation's efforts to provide an equitable science education for all children is still far from being realized. Today, as in the past, low-income, minority children continue to be clustered in inner-city schools where they are far less exposed to the type of educational opportunities experienced by those in more affluent areas (Thomas B. Fordham Foundation, 1998). Poorly maintained buildings, lack of science tools, materials, and technological resources, and lack of highly qualified science teachers often characterize the schools in these areas.

After-school science programs have the potential to provide disadvantaged children with educational experiences not traditionally available to them, particularly when combined with community resources. According to the *National Science Education Standards,* "The school science program must extend beyond the walls of the school to include resources of the community" (National Research Council, 1996, p.21). Local experts/specialists, businesses, industries, higher education and medical institutions, science centers and museums are some of the community resources that can increase students' opportunities to learn science. Developing partnerships between the school and others in the community at large can also be a strong force in developing a sense of community and belonging at the classroom and school levels (Battistich & Hom, 1997; Schaps, Battistich, & Solomon, 1997; Schaps, Watson, & Lewis, 1996).

This paper describes an after-school science program intended to provide a group of minority middle school girls with science experiences related to one of the largest industries in the area—the automobile industry. The program was implemented by a group of women engineers, who served as role models and mentors and guided the girls through hands-on science activities related to automobile engineering.

Review of the Literature

The rapid development and movement of sophisticated technologies into the workplace underscores the importance of educating all students to high levels of scientific and technological literacy. Yet the high dropout rates among minority children, along with the ethnic and gender gaps in science and engineering, reflect an educational system that continues to shortchange many of our youngsters. In 1997, the percentage of "status dropouts" (percentage of 16- to 24-year-olds who were not enrolled in school and who did not have a high school diploma) was 7.7 for whites, 13.4 for blacks, and 25.2 for Hispanics (National Center for Education Statistics, 2000).

Although females are less likely to drop out of school than their male counterparts, their presence in science, mathematics, and engineering continues to be largely unnoticed. In 1998 women of American citizenship earned only 6.2% of the doctoral degrees in engineering, 12.6% in the physical sciences, and 30.6% in the life sciences (National Research Council [NRC], 1999). Even though the NRC report did not provide data on the number of doctoral degrees in science and engineering awarded to minority females, the majority of women in science and engineering are Caucasian. According to a report of the National Science Foundation, although women of all ethnicities comprised 22% of the engineers and scientists in 1993, of these, only 1.5% were African American, 2.5% were Asian American, 1% were Hispanic, and less than 1% were Native American (National Science Foundation, 1996). In view of these figures, much talent is being lost that could contribute to the scientific and technological advancement of our country.

Research indicates that the ethnic and gender gaps in science and engineering are due, at least in part, to the discrepancies in the quantity and quality of students' science-related experiences (American Association of University Women [AAUW], 1992; Catsambis, 1995; Jovanovic & Dreves, 1998; Kahle & Rennie, 1993). Parents, teachers, and the media are powerful forces in the socialization of children into gender-specific roles. Parents tend to buy more toys that encourage manipulation and construction for boys, and are more likely to discourage girls from entering fields that have traditionally been the domain of males (Matyas, 1985; Oaks, 1990; Tracy, 1987). Studies of classroom interactions indicate that teachers tend to focus their attention on boys, asking them more challenging questions and allowing them to assume leadership roles in group activities (AAUW, 1992; Jovanovic & Dreves, 1998; Roth, 1996; Sadker & Sadker, 1994). As a result, boys consistently report more classroom and extra-curricular science activities than do girls (Jovanovic & Dreves, 1998; Kahle & Rennie, 1993).

These differential science experiences between boys and girls are in turn reflected in their attitudes toward science and science-related careers (AAUW, 1992; Catsambis, 1995; Jovanovic & Dreves, 1998; Kahle & Rennie, 1993). Investigators have found that until third grade an equal number of boys and girls show interest and feel confident in learning science; by fourth grade, 74% of the girls and 81% of the boys say they like science. Gender differences in attitude toward science continue to increase throughout middle school and by eighth grade 64% of the girls compared to 72% of the boys say they like science. By their senior year in high school, only 57% of the girls compared to 74% of the boys show interest in science (Jones, Mullis, Raizen, Weiss, & Weston, 1992).

The pattern of girls' decreasing attitudes toward science is mirrored by a similar pattern in their achievement in science. Using science proficiency data of 9-, 13-, and 17-year olds, Bruschi and Anderson (1994) found that gender differences increased over time. Although nine-year-old females showed similar performance to males in life and physical sciences, by age 13 boys out-performed girls, and that difference increased by age 17. The greatest differences were found in earth and space sciences. Furthermore, Caucasian students outperformed both Hispanic and African American students and that performance gap also increased by age.

Other researchers have reached similar conclusions regarding the relationship between students' attitudes toward science on their achievement in science (Cannon & Simpson, 1983; Schibeci & Riley, 1986; Weinburgh, 1995). In a meta-analysis of the research conducted between 1970 and 1991, Weinburgh (1995) concluded that "in all cases a positive attitude results in higher achievement" (p.387), and is greatest for low-performance female students. Attitudes toward science also predict student selection of future science courses (Farenga & Joyce, 1998) and affect students' aspirations to science careers (Catsambis, 1995). Males are three to four times more likely than females to pursue a degree in physical science, computer science, or engineering (The College Board, 1998).

In view of the extensive research linking students' attitudes toward science and achievement in science with the amount and quality of science-related experiences, educators are pressed to implement curricula and classroom strategies that positively influence students' attitudes toward science. The program described here utilized cooperative learning groups, hands-on/minds-on activities, and mentors who also served as role models.

Method

Program Description

The program was initiated by a member of the local chapter of the Society of Women Engineers (SWE) and was funded by a small grant from the ExxonMobil Education Foundation in collaboration with the SWE. The grant ($6,834.00) covered the cost of the curriculum development and a part-time program coordinator. One of the local automotive companies covered additional expenses related to supplies, food, and transportation associated with field trips.

Setting and Participants

The program was implemented in a small, urban middle school from September 1999 through April 2000. The biweekly sessions, from 4:30 to 6:00 p.m., took place in the classroom of the mathematics teacher who recruited the students and served as the liaison between the implementers of the program and the school's administrators and students' parents. The participants were 18 African American, middle school (7th and 8th grades), female students and a group of 7 volunteer, female engineers (5 of them African American) who implemented the program and served as mentors and role models.

Curriculum

Because all the mentors were engineers employed in local companies connected to the automotive industry, the curriculum focused on physical science topics related to the automotive industry. The curriculum covered the following topics: electricity, magnetism, gears, motors, freezing and antifreezing, friction, speed and acceleration, and center of mass and gravity. Each of these topics was explored through a variety of hands-on/minds-on activities.

During the activities in these topics, the students made observations, inferences, and predictions, tested their predictions through experimentation, collected data, and built and tested models of car parts. Research indicates that these types of activities increase student problem-solving skills, self-confidence, and improve their attitudes toward science and science-related careers (Bartsch, Snow, & Bell, 1998; Lee-Pearce, Plowman, & Touchstone, 1998; Tyler-Wood, Cass, & Potter, 1997).

In addition to the after-school sessions, the program included field trips to some of the local automotive engineering plants and museums connected to the automotive industry. During these trips the students had the opportunity to see how some of the concepts they had explored through the activities were applied in the design and manufacturing of automobiles.

Mentors

In general, mentoring is used to describe a relationship between two persons, the mentor and the protégé, at different stages of their career development (Fagenson, 1989). Mentors play a key role in the socialization of their protégés into a profession by serving as role models and by providing knowledge, advice, acceptance, and confirmation (Fagenson, 1989; Hall & Sandler, 1983; Healy & Welchert, 1990).

Some researchers contend that the lack of mentors and role models in science and engineering is a contributing factor to females' lack of interest in science and science-related careers (Marlow & Marlow, 1996; Matyas, 1985). In this program a group of women engineers was recruited through the local chapter of the Society of Women Engineers to serve as mentors and role models. Although some of these women had participated in previous mentoring activities such as sponsoring girls' activities or being shadowed by a girl during career day, none of them had ever participated in a program such as this one.

To facilitate the development of a trusting relationship between the mentors and the students, each mentor worked as a facilitator with a group of three girls. The role of the mentor was to foster discussion among the students, to ensure that all the students in the group participated, and guide them when they had difficulties with some aspect of the activities. In addition, each of the mentors did a demonstration related to their area of expertise. For example, one of the mentors did a demonstration on airbags. This approach helped students observe how a particular concept was applied in the automotive industry, and allowed them to see a female role model in the position of "expert" in her field. Research indicates that even though a mentor or role model does not necessarily need to be of the same race or sex as the protégé, seeing others of the same sex and/or race in positions of power and expertise helps affirm one's career aspirations (Astin & Astin, 1993; Janes, 1997; Kegel-Flom, 1995).

Evaluation of the Program

A pre- and post-test instrument (4-point Likert-type survey) was utilized to measure changes in: (1) students' attitudes towards math, science, and engineering; (2) their misconceptions concerning gender specific careers in science and engineering; and (3) their intentions to pursue a career in science or engineering. The participants were asked to rate each survey item from "strongly agree" (assigned value of 4) to "strongly disagree" (assigned value of 1).

Descriptive statistics were used to identify changes in students' attitudes in the aforementioned areas. Statistical significance was not computed due to the low (N), which made such analysis inadequate. Data were also collected through open-ended interviews with the students and mentors regarding various aspects of the program. These data were analyzed using qualitative methodologies (LeCompte & Preissle, 1993; Miles & Huberman, 1994).

Results and Discussion

According to the authors of the *National Science Education Standards,* "Working collaboratively with others not only enhances the understanding of science, it also fosters the practice of many of the skills, attitudes, and values that characterize science" (National Research Council, 1996, p. 50). In this program mentors worked with students in cooperative learning groups to build a "community of learners" (National Research Council, 1996). Cooperative learning groups are essential to the development of a sense of community in classrooms by fostering collaboration and interdependence among group members. Cooperative learning groups are particularly successful with females who tend to dislike the competitive aspects of science (Peltz, 1990). Such groups have also been shown to facilitate student learning and improve attitudes toward science (Bianchini, Holthuis, & Nielsen, 1995; Cannon & Scharmann, 1996; Chang & Mao, 1999; Kahle & Rennie, 1993).

As results in Table 1 indicate, the program had a positive influence on students' attitudes toward science, mathematics, and engineering. In addition, all the students agreed that they enjoyed the program, that they would participate again in a similar program, and that they would recommend the program to other girls. These results confirm previous ones in which increased experiences with science, such as performing experiments, lead to positive attitudes toward science classes and science related careers (Bartsch, et al., 1998; Lee-Pearce, et al., 1998; Travis, 1993).

Table 1. Mean and Percentage of Students Agreeing with Each Item on the Pre- and Post-test

Survey Statement	Average Pre	Average Post	% Agree (Pre)	% Agree (Post)
I like science	2.82	3.00	76.5	85.7
Science is easy for me	2.65	2.86	58.8	78.5
I think science is fun	3.12	3.21	76.5	85.7
Most scientists are men	1.71	1.54	16.8	11.4
Anyone can be a scientist	2.88	3.00	75.7	85.7
I would like to be an engineer some day	2.41	2.86	52.9	78.6
I would like to design the car of the future	2.90	3.00	76.5	85.6
I might study engineering in college	2.82	3.00	76.5	85.7
I like math	3.12	3.89	82.4	92.9
Math is very important for most jobs	3.89	3.93	96.7	100.0
Without good math skills one cannot become a scientist or engineer	2.94	3.29	76.5	78.6
Items on the Post-test Only				
I enjoyed the after school science program		3.50		100.0
I would recommend the program to other girls		3.57		100.0
Some day I would like to mentor young women		3.43		92.9

The curriculum for this program used inquiry to explore topics of physical science related to the automotive industry. Some of the topics included electricity, magnetism, gears, velocity, acceleration and others. Instructional approaches that focus on inquiry provide students with "hands-on, minds-on" activities, thus engaging students physically and mentally (National Research Council, 1996). During the activities in these topics, the students made observations, inferences, and predictions, tested their predictions through experimentation, collected data, and built and tested models of car parts.

Hands-on activities have also been shown to increase student problem-solving skills, self-confidence, and improve their attitudes toward science and science-related careers (Bartsch, et al., 1998; Lee-Pearce, et al., 1998; Tyler-Wood, et al., 1997). According to the students in the program the hands-on activities and the field trips were some of their favorite aspects of the program. Students commented that they enjoyed "building models, car parts, and paper works," "doing activities because they were very educational and fun," and that the field trips were "a lot of fun and we got to meet new people."

One of the strong aspects of the program was the involvement of women engineers from the local automobile industry who worked with the students and served as role models. In addition to guiding the girls through the activities, each of the mentors did at least one classroom presentation in an area of their expertise (e.g. airbags). In addition, some of the field trips took place at local engineering plants where the mentors explained various aspects of automobile engineering and design. The combination of science activities and women professionals connected to the automobile industry was key in helping the girls become aware of the accessibility of engineering as a career for women. As one of the girls put it, "it just goes to show you that girls can do the same as boys . . . ."

Feedback from the students' mathematics teacher also indicated that the program helped develop a sense a community among the students. According to the teacher, the attitude of some students had improved since the onset of the program. She mentioned particular students whose participation in math class has increased, saying, "they participate in class and encourage others to participate. They talk to me openly and freely about their problems with math, other students, and 'life'." She made reference to specific students whose past behavior in class had been disrupting. According to her, "they have stopped their rude outbursts in class."

Comments from the mentors also indicated that their relationship with the students helped develop a sense of community among them. According to one of them, the girls in her group looked up to her "as their big sister, as they often called [her]." In addition, the mentors played an important role in the socialization of the girls into the field of engineering (Fagenson, 1989; Turner & Thompson, 1993). When asked about the strengths of the program one of the mentors answered that, ". . . we really can make an impact on these girls' lives and possibly interest many of them in the sciences and engineering." Another one commented that the program "helped the girls learn the importance of team work to complete a task, especially on the final project. They seemed to stay interested in the various topics and experiments, asking a lot of good questions in our post-discussions."

Conclusion

The concept of "classroom" or "school as a community" has been proposed by some researchers as a means to achieve a sense of community and belonging among students (Battistich, Solomon, Kim, Watson, & Schaps, 1995; Peterson & Deal, 1998; Sergiovanni, 1994). A strong sense of community in schools has been shown to be positively related to students' pursuit of academic and social goals (Battistich, et al., 1995; Battistich & Hom, 1997; Wentzel, 1997) and negatively related to drug use, delinquency, and victimization (Battistich & Hom, 1997).

In the program reported here a sense of community was fostered through collaboration among a group of women engineers and a group of middle school girls, two groups brought together through the assistance of a mathematics teacher. While working together to solve problems related to automobile engineering, students realized the importance of mathematics in engineering (Lee-Pearce, et al., 1998; Rohrer & Welsch, 1998). Thus, the learning of mathematics was no longer decontextualized and the participants' new sense of community transferred into the math classroom. The program provided the math teacher and her students an opportunity to develop a relationship outside the constraints of the regular classroom. As a result, the students no longer viewed their math teacher as an "outsider"—a power figure who delivered mathematical knowledge. Girls who previously gave the math teacher a "hard time" started to build a community of learners in their math class by participating more and encouraging others to participate.

The results of this study illustrate the potential benefits that collaboration between schools and members of the community at large can bring to students in disadvantaged areas. Interestingly, urban areas have both the poorest schools and the most community resources. Yet partnerships between schools and local business, industry, and institutions are rare in these areas. Encouragement and support from school administrators combined with directories listing local resources would go a long way to help teachers utilize this untapped resource.

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Maria Ferreira is an assistant professor in science education at Wayne State University in Detroit, Michigan.