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Voices of Young Women in Engineering

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Overview

Over the past decade, researchers have identified a wide array of factors that hinder young women from pursuing fruitful careers or further studies in engineering and related technical fields. These factors include the lack of meaningful hands-on experiences with science and technology, lack of parental support, limited notions about career options, and little guidance or institutional support for taking advanced pre-requisite courses in mathematics and physics (Maple & Stage, 1991; Mcilwee & Robinson, 1992; Sadker & Sadker, 1984; 1986; 1989; 1991; Stage, Kreinberg, Eccles, and Becker, 1987; Syron, 1987).

Although this research has been helpful in pointing out many of the obstacles young women may encounter in pursuing technical fields, there have been few studies that have paid attention to the voices of young women at the secondary school level who are at the point of exploring their options and seriously considering engineering as a career. This is partly due to the fact that there are few pre-engineering and technical programs offered at the secondary school level.

Based on ethnographic studies at a specialized science high school in New York, this paper will discuss the experiences of five 17-year-old female pre-engineering students as they struggled to gain their own voices in an innovative, hands-on mechanical engineering program. The program itself is considered to be exemplary and includes many of the things that research contends is necessary to attract and prepare girls for the field of engineering: collaborative work, hands-on technical experience, and methods of instruction that encourage students to explore technology in relationship to society. Despite these curricular innovations, observations and interviews with the girls have revealed that there are a number of cultural and psychological pressures that they contend with on a regular basis in the classroom — pressures that have convinced many to opt out of pursuing engineering further. Based on these findings, alternative methods of intervention for educating young women in science and engineering will be discussed.

Background: *The School and the Young Women*

The high school in which this study has taken place is in many ways atypical. Being a specialized science high school, all students are exposed to engineering coursework and other technology-related work in their freshman and sophomore years. At the end of the sophomore year, students must enroll in a “major” that prepares them for college level work in science, engineering, liberal arts or the social sciences. Currently, the school offers 16 majors for students to choose from. Course coordinators select students for majors on the basis of grades in related freshman and sophomore courses, and on the basis of the students’ preferences.

Despite the unusual introduction to engineering that all students receive before selecting a major, the number of young women who elect to take any of the four engineering majors available (mechanical, civil, aeronautics, and electrical engineering) has been consistently low. At the end of 1992, only 6% of the junior and senior year girls were enrolled in engineering majors. Forty-six percent were enrolled in liberal arts majors, 38% enrolled in other biology, math, and chemistry-related majors, and 10% enrolled in architecture. For boys, course-taking patterns were more evenly distributed among the different majors, with the highest percentage of boys (36%) in engineering majors and the lowest percentage in the liberal arts (18%) and architecture (12%) majors.

Aware of the under representation of girls in the engineering classes, the course coordinator for the mechanical engineering program adopted the policy of accepting any girl that applies to the program regardless of grades in prerequisite courses offered in freshman and sophomore years. Of all the programs offered, many consider the mechanical engineering program to be exemplary for both male and female students because it integrates mathematics and science with hands-on tinkering, group work and critical thinking, all of which is essential for practicing engineers. Students work cooperatively in teams to design, build, and construct mechanical devices by using Fisher-Technik (Lego-like) materials in their junior year and real materials for full-scale projects in their senior year. In addition, students conduct research projects which explore the relationship of technology to society.

Despite the program's innovative approaches and the coordinator's efforts to actively recruit girls, the number of girls in the mechanical program also remains low. The mechanical engineering program has been one of the more successful engineering programs in the school to attract girls last year, yet there were only 17 girls out of 101 students who were enrolled in the program during 1992-93 year.

In collaboration with teachers of the mechanical engineering program, my colleagues and I at the Center for Children and Technology had the opportunity to explore more deeply some of the issues that engineering raises for young women by documenting closely five girls who were enrolled in the program over the course of two years. This exploratory work was an outgrowth of a larger research project we were conducting on alternative assessment which provided methods for uncovering some of the girls' experiences in the program as well as their academic accomplishments.

The young women who were part of this study had a variety of reasons for entering the mechanical engineering program: several indicated that

they enrolled because they performed well in their freshman year introductory engineering class, two were specifically interested in learning how to build things, and two had ended up in the mechanical engineering program because they could not get into their first program of choice. It should be noted that during the course of the junior year, nearly all the girls who were part of this study were performing at or above average in the mechanical engineering program. In fact, two of the girls were considered to be among the best students in their classes by the teacher. Despite their levels of achievement in the class and their initial curiosity about engineering in general, few are considering engineering as a career toward the end of the second year in the program. Out of the 9 girls who enrolled in the program in 1992, one has dropped out and only two are seriously considering studying engineering in college.*

Methods of Inquiry

As part of a research project on alternative assessment in science education, we have been collaborating with teachers within the mechanical engineering program to develop alternative methods for assessing what students know and can do in the context of the classroom. These methods have included interviewing students about the development of their projects, their problem-solving approaches, and their work habits as they progressed through their junior and senior year; videotaping students' project presentations; and collecting and analyzing students' reflections about their work captured in their daily journals. Through the process of scoring these records for achievement using candidate criteria developed by our Center, we gained insight into how students were performing in the class as well as how they were handling difficult issues that arose in their project work.

In addition, this work also involved ethnographic observations of the of the day-to-day life of the classroom in order to understand how new assessment methods were being integrated. This observational data helped us to establish relationships with the young women in the classes and to pinpoint some of the classroom issues that interfered with students' full participation in activities. These observations also led us to conduct in-depth clinical interviews with 6 girls who were in the junior year of the program at the time of this work. These interviews dealt more specifically with the girls' experiences in the program and their visions of what engineering entails, rather than their performances on projects.

Themes of Conflicts: *Introduction*

Analysis of the presentations and written reports we had collected from all students for the assessment project indicated that nearly all of the young women in the mechanical engineering program seemed competent and self-assured. However, when they voiced their concerns in the context

* The names of the students who appear throughout this report have been changed for confidentiality purposes.

of the process interviews, informal discussions, and journals, nearly all described a complex web of conflicts and pressures they encountered in the class and with engineering in general.

In these interviews, discussions, and writings, several themes of conflict emerged that pertain to the psycho-social issues that girls face when they participate in predominantly male classes in which they feel at the margin. These themes of conflict generally pertained to four different areas: conflicts that arise from their daily interactions with male peers; conflicts in acquiring the kind of knowledge and technical experience that is required to participate in the class; conflicts in applying their different approaches to design and technology, and conflicts over their need for validation. The conflicts these young women voiced can begin to explain the deeper psychological and socio-cultural barriers which may be at the core of what alienates girls from engineering.

Interpersonal Conflicts With Male Peers

Perhaps the most dominant theme to emerge in interviews and informal discussions with the girls in the program was the degree of isolation and marginalization they experienced being the only females in predominantly male classes. Girls often openly complained that they were disregarded as members of male groups and weren't taken seriously because of stereotyped beliefs about them. In an interview, one young women gave voice to the conflicts that such marginalization had caused for her: "The guys may not do it intentionally. Sometimes they're playing and it's a joke but sometimes it hits me. Even though they may be playing a joke, if they say time and time again that you can't do anything because you're a girl you start to believe it." Another revealed that she was tired of the boys commenting on her work as, "pretty good, for a girl that is."

This "playing around" would manifest itself in what girls were actually invited to do while working on projects with boys. One girl who grew up spending summers working on cars with her father at a mechanic shop expressed frustration when "people would say push the papers around and write notes and whatever." She went on to explain that it was horrible for her because she had nothing to do with most of the projects even though she felt she knew more than the boys. She added that if "I had input, the projects could have come out better." Others described how difficult it was to get a "word in" without the fear of setting the boys off. Still another complained how her male peers would often take over: "I worked on a project and John took over everything. He said that as somebody who wants to be an engineer you have to think more. And that pissed me off...because I was trying my hardest [to build] the defense system [for the project] and I had the idea. I kind of felt that he wasn't taking me seriously."

According to some of the girls, male peers were not the only ones who misjudged their abilities. When asked whether there was anything she would change about the major, one girl replied that she would get new teachers because sometimes "they think you can't do something when you can, like pick up something." Another girl mentioned that the teacher would ask her if she needed help when she was working on milling machines or with other heavy machinery. While the teacher often tried to offer help to students, this practice annoyed this young woman in particular because she felt that the teacher was assuming that she could not handle the work that the boys could in the class.

Strategies for Resolving Conflict

Along the way, the girls developed several strategies to deal with these conflicts usually at the cost of jeopardizing their own self-esteem, respect from their peers, or their own intellectual advancement. One girl who was often the leader in all-girl groups said that while working with boys, she took advantage of their special treatment of her. When possible, she would play on the boy's notions that she couldn't do anything by asking them to do some menial tasks for her. In her own words, "You let them be the chump while you get a perfectly cut nice piece of wood. And you continue working on your project."

Most of the girls were not as shrewd or self-assured. Nearly all reported at some time going along with the group in order to avoid conflict and to ensure that the projects got done. One girl described how she fell into the trap that another female student she worked with did: "Natalie thought that being the only two girls in the class we would always be carried along because you know all the guys would give you the answers if you needed them. I fell into the trap of acting exactly the same way."

For the most part, the young women learned fairly early on that they could only participate minimally when working with boys. As a result, nearly all of the girls chose to work with each other in groups whenever possible so that they would not have to feel like they were in competition with the boys as individuals. When working with other girls, many believed they could take the work seriously, have equal input and get the work done. For some, working with their female peers did not provide ideal situations. One young woman mentioned that although she preferred working with girls, she did not like being bossed around by them. She found it hard taking orders from other girls who were the same age as she was.

For the daughter of the mechanic, options were more limited because she was the only girl in her class by the second semester of the junior year. Tired of acting complacent and frustrated with the boys' inactivity in her group, this same girl decided to take action on her last project at the end of

the school year which involved designing a tank for a Boston University competition that was awarding a $10,000 scholarship to the winner. With encouragement from her father, she took the project home, worked on it and entered the competition on her own. The entire class was angry at her and would not speak to her when she returned. Furthermore, no one acknowledged that she had come in fifth place out of 100 students in the competitiion. Looking back, she feels it was still the most important accomplishment she had all year. While she realized this was not the desired approach to take, she felt she had no alternative. She wanted to prove "once and for all" what she was capable of doing on her own.

At different points in their interviews and in informal discussions, all of the girls spoke of this strong need to "prove themselves." For some, this meant studying twice as hard so that they could know all the answers in class to prove they deserved to be in it. It also meant rarely asking for help, since asking their peers and especially their teachers for help would make them appear like they did "not know what they were doing," one of the girls' most salient fears. This self-reliance was at times detrimental to their projects, since they would often undertake challenging projects and refuse to seek some minor assistance to keep them on track.

Dynamics of Acquiring Technical Knowledge

While many boys came to class with a rich knowledge-base about technology from years of childhood experiences tinkering with toy models, most of the girls in the program had little previous experience tinkering with technology. Instead, most entered the program because they did well in their theoretically-based freshman engineering class or had ended up in the mechanical engineering program because they could not get into their program of choice. Only two of the girls had expressed an explicit interest in building things before they came to the course. As a result, proving themselves meant that many of the girls had to play catch-up in learning about a lot of terms they never heard of as well as the tools that they were using. Girls did not appear to have a problem with keeping up, but they were acutely aware of the discrepancies between their technical experience and that of the boys. The girls dealt with these discrepancies in different ways. One explained that she realized she was going into an area "where all these people hung around their fathers and know what a monkey wrench is and all this other stuff. You have to teach yourself fast." Another girl however, was discouraged when she discovered that her male friend from another school was able to help her with her homework and "knew all the answers to this stuff when he wasn't even in the course." She later added, "It just made me look and say, why am I here? I hate that but it just seems true. They just seem to know about cars, how they run, and all the different parts that are associated with them."

Working in all-girl groups sometimes exacerbated the problem. Feeling unsafe to ask peers or teachers for help, they had to rely on each other to fill in the gaps of knowledge they did not have. This led to confusion on some projects where they could not find the information they needed in lay terms from a text-book. Only one of the girls mentioned how she would scout around for some help from the boys, but this was infrequent.

Despite their lack of experience, girls did take pride in what they were able to learn in a relatively short amount of time and enjoyed the special status newly-gained knowledge afforded them. Several mentioned how they were either excited that they could identify I-beams on the trips home on the subway, or how they became interested in learning different terms and finding out what was inside wind-up toys and other devices. For some of these girls, this knowledge provided a way for them to converse with their male peers and to gain their respect: "I like it when guys think I know what I'm talking about. Sometimes I don't think I know what I'm talking about but I do. I like to prove people wrong. I like to keep a conversation going with the guys. Yeah, let's talk about the engine. Sure. No problem. It's like yeah she does know something. There's a lot more to [her]." Others described how their increasing technical knowledge made them special because "at least they knew things their [girl] friends didn't know."

Different Work Styles and Ways of Knowing

While interpersonal and cultural conflicts permeated most of their work in the classroom, a more significant conflict had to do with the girls' own planful work style and their holistic approaches to design. Girls frequently spoke of the joy they derived from "mapping out a drawing and having all views of what you are doing." Another described her work process as looking at ideas from other projects and incorporating those ideas into her own. Having time to test devices and to make adjustments was considered crucial. For another, being able to fine tune her ideas and to fix her mistakes using the CADKEY technical drawing computer program made her feel proud.

Yet girls' planful approaches often caused conflicts when working with their male peers. One girl mentioned a fight she had with a boy in the class who refused to try her approach: "I would say we have to do a drawing because that's the only way we can see our idea and make [and cut] things easier. And he said, 'No! Let's do it off the tops of our heads." In my observations of groups working, it was not uncommon to see the boys building up and then ripping down several different designs while girls would carefully build up subsystems of their machines.

Their notions of teamwork also appeared to be quite different from those of the boys in the class. While boys frequently spoke of the importance of allocating jobs fairly in the group, girls frequently spoke of the necessity of getting everyone's ideas because "the group doesn't work based on one mind. You need everyone's ideas." While working in all female groups, the girls often described how easy it was to work together because one would pick up where the other left off. Several mentioned that the boys, on the other hand, often liked to keep it all to themselves. This frustrated them because, as one of the girls said, "How are we supposed to learn anything if you keep it in your head?" Another described how "girls are always open to new ideas while guys are not open."

Design Ideas and Technological Imagination

Aside from work styles and ways of knowing that caused conflict for the girls, the lack of opportunities for girls to implement their own design ideas and to have them valued in the classroom was also problematic. When we asked the girls what they would like to design in an ideal situation, they frequently mentioned technology that fostered communication or things that helped solve problems in everyday life: video phones where you can see a surprise party taking place on the other end of the phone, high speed magnet trains that would change the whole subway system from the inside out, or flying cars.

Unfortunately, few of the projects integral to the curriculum built upon these interests or tapped into girls' technological imaginations. Throughout the course of the junior year, the young women had few opportunities to design and create things that interested them because project assignments were often competitive and well-defined in advance. The projects they were asked to design included catapults that would shoot pellets at targets for points, a peak performance project which entailed designing a vehicle that could go up a ramp in the quickest time and defend itself against an opponent on the other side, and a crane that would lift a designated load to a specific point in a designated time period.

One exception was an open-ended problem which required students to design a two-motor device that had two simultaneous motions going in opposite directions. While the majority of the students designed vehicles and tanks, two all-girl groups designed projects of social utility: an oscillating fan and an elevator. They selected these devices because they were challenging, different and creative, but by the time the students presented their projects, one of the groups was convinced that they had failed miserably because others frequently made fun of them for going against the grain. Building an oscillating fan when everyone else was

building vehicles made them stand out as different and peculiar. Rather than relish this quality, many of the girls were more inclined to mask it or downplay their achievements.

The fact that such devices were also more intricate and more difficult to build than the more common vehicles, these devices often didn't run as efficiently as the model cars their male peers came up with. This also contributed to girls' feelings of inadequacy, even though the teachers often emphasized that they appreciated students taking risks rather than designing a functioning device that was easy to make.

Validation

The overriding issue that ties all of these experiences together is girls' need for validation and legitimacy in the classroom. Their feelings of isolation and their silent struggles were ignored or often went unnoticed by peers or teachers. Those who spoke up or shared the difficulties they were having in the class through personal journals or verbally were perceived as "complaining" or difficult to work with. Interestingly, when we asked girls to describe their favorite project, they often mentioned the project that earned them public recognition, either by attaining high grades or winning competitions.

In the in-depth interviews, several of the girls reported that when they did excel, they often were not acknowledged or their achievements were ignored by their peers. This was evident when one girl painfully recounted her return from the Boston University peak performance competition: "My tank came in fifth in the finals and no one said a word about it. The teacher didn't even congratulate me. It felt awful."

In the end, lacking support in this unfamiliar domain and opportunities to safely explore what truly interests them, in the middle of their senior year, 5 of the girls I interviewed mentioned that they did not plan to study engineering in college or at best were ambivalent about it. They explained that if they had female teachers who understood where they were coming from perhaps they would think differently. Others mentioned that they received little encouragement from their own parents to pursue engineering. Instead, their parents were more inclined to encourage them to go into medicine. They also questioned whether they had what it takes to become engineers. Surprisingly, one of the girls who was considered to be among the best in the class questioned her own abilities: "I just don't have what it takes. You either have the natural knack for it or you don't." And perhaps most importantly, many of the girls mentioned that there was nothing that intrinsically interested them about what they were doing. As one of the students aptly put it, " [I get] a lot more pleasure out of taking the liver out of a frog than screwing a nut into a bolt." Another student

who is planning to study physical therapy in college explained that "engineering has nothing to do with physical therapy...it doesn't have anything to do with helping people."

Another girl who was set on pursuing engineering from the beginning is now ambivalent after taking a summer course at a respected engineering college. This student explained how engineering was presented in a dry and boring manner: "We would go work on this joke of a robot and make it move and open it's hand or turn it's wrist. And I would look at it and say, "So what! It didn't have anything to do with what I was interested in." When asked what she was interested in doing, she quickly mentioned, "Trains. I love trains. [In the college program] we were working with gears and working with a motor. And I couldn't care less because I learned about gears in school already so that was boring me to death." She gave an elaborate explanation of the magnet trains she would like to design and how she would reform the whole subway system. Technology, in this case, was set in the context of what it could do to help people's lives. She described this process as "working from the inside and going out."

The one who has decided to pursue engineering in college had the traditional requirements that 7% of the women who make it in the field do: exemplary math skills and a fascination for the ways in which things work. This young woman was also particularly quiet and gave teachers the least problems in class. Teachers admitted that her personality made it easier to deal with her and as a result she had a good relationship with her teacher and received a lot of support. This support was lacking for the more vocal and resistant ones even though the support was something that they all said they needed most.

Discussion

Feeling that they have a legitimate voice within the culture of the classroom is very difficult for girls to achieve. Despite the fact that many of these girls were strong-willed and talented, at the end of the program many were left feeling "tired of fighting" to be recognized or disenchanted with engineering as a whole. Most present intervention programs designed to meet the educational needs of girls fail to address the legitimate concerns and difficulties that young women face in pursuing skills that have been traditionally masculine. We need to encourage a discourse and develop programs that give voice to the deeper psychological and psycho-social problems which often alienate girls from engineering.

A promising approach would be to acknowledge the interests and orientations of young women by developing teaching strategies and

curricula that have direct relevance to everyday life and to girls' socially-oriented perspectives. This would include incorporating open-ended design problems that have social relevance and most importantly, giving girls the opportunities to question, to voice their opinions, and to be creative. In such an environment, engineering, would be presented as a fluid, intellectual and hands-on process that enables them to safely explore and express their own technological imaginations through design projects that build on their own interests.

More importantly, strategies to provide girls with the support and validation that they need to sustain their interest are needed. A growing abundance of evidence at the undergraduate level indicates that women are more negatively affected by the absence of positive feedback from their teachers and lack of attention from their departments than male students (Matyas & Dix, 1992). Faced with this frequent lack of institutional support, those women who know how to take advantage of situational resources and have strategies for dealing with obstacles are the ones most likely to persist in technical fields (Seymour, 1992). When students are provided with access to both career and emotional support from mentors, studies indicate that young women find emotional support more valuable (Ragins, 1989; Association for Women in Science, 1993). In another study, mentees reported that they valued personal guidance as much as professional guidance (Reich, 1986).

With this in mind, linking young women with ongoing and sustained communication with appropriate female mentors could provide the emotional support that is often missing in the pre-engineering classroom. In addition, professional development programs that are designed to help teachers acquire skills for discussing and addressing the conflicts that girls experience with their male peers in mixed classrooms is necessary. Such training would involve helping teachers to impart explicit as well implicit messages about the kind of behavior and attitudes that are acceptable in the classroom. Such training would also involve developing skills in consciousness raising which would provide girls with opportunities to openly discuss when they are being pressured by the boys and would enable boys to learn strategies for working with and valuing the contributions of their female peers.

By making pre-engineering classes more responsive to the values, perspectives, and experiences that young women bring to the classroom, technology-based education as a whole would benefit. All students should be able to engage in engineering to understand how to solve society's problems with a critical, ethical perspective in a safe and legitimating environment. Curricula, like the mechanical engineering program in this study, that focus on developing students' hands-on experience and skill

development are vital for preparing girls to become active designers and engineers. Yet, few programs have taken more radical steps to truly invite young women's voices into engineering. These forgotten voices could be what revolutionizes engineering in the years to come.

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