AC 2008-2001: AN EXTENDED ENGAGEMENT EFFORT

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An Extended Engagement Effort

Abstract

More than twenty years after the enactment of Title IX, women continue to be underrepresented in numerous career fields grounded in science, technology, engineering, and mathematics (STEM). Design competitions offer one approach to increasing interest in technology and engineering. Faculty, university students, industry supporters, and community representatives have joined together for several years to encourage student teams from a Midwestern middle school to participate in ToyChallenge™, a relatively low-cost, “girl-friendly” design competition organized by SallyRideScience™.

The paper discusses the motivating factors that led engineering technology faculty, university students, and middle school teachers to take on responsibility for coaching middle school design teams. The process for forming the teams, garnering industry support, and developing original working prototypes with sixth through eighth grade students is presented. Challenges encountered through the extended engagement collaboration are considered, and successes resulting from the ongoing effort are shared.

Background and Motivation:
Historically, children matured in a society where their future was predefined by factors beyond their control, particularly their parents’ place in society and their gender. Immigration offered one means for men to move toward self-determination; educational opportunity (such as the G.I Bill following World War II) established another. Within the United States, men have enjoyed relative freedom of choice throughout its existence, legally and in terms of cultural acceptance (assuming their choice is not a traditionally female role). Beginning in the mid-19th century, U.S. women and their male advocates have sought to legally mandate the same level of opportunity for self-determination for women. Major legislative successes in this arena include the right to vote, the Equal Pay Act, the Civil Rights Act, and the Education Amendments, including Title IX. Title IX requires schools to provide equivalent and/or equal educational opportunities for girls and boys, impacting admissions rules, availability of sports, and access to all classes. Girls were no longer barred from drafting and material processing classes, and boys were able to learn cooking, sewing, and clerical skills as part of the high school curriculum. Thirty years after Title IX was enacted, college enrollments of 2001-02 show male and female students admitted to medical and law schools nearly match their mix within the general population. Female engineering enrollments have grown by similar multiples, but unfortunately must overcome a much greater deficit to achieve gender equity[1].

For organizations, there is a participation level where underrepresented groups reach a point where their involvement is self-sustaining, or achieve critical mass. According to Professor Monique Frize, former Natural Sciences and Engineering Research Council (NSERC) Women in Engineering Chair, the point at which a population moves from underrepresented to reaching critical mass is approximately 33%[2]. Although some engineering disciplines are approaching critical mass within their majors at several institutions, the number of women in the more traditional fields of electrical, manufacturing, and mechanical engineering remains quite low. At Purdue University, the percentage of females in these engineering technology majors has rarely exceeded 5% in the past 20 years. Faculty have led workshops and hosted campus visits during that time to generate interest among high school girls, with no consistent corresponding increase in enrollment. A different approach to sharing the excitement of engineering applications was needed.

Beyond recruiting, retention of women students who enter one of the engineering technology majors at Purdue University is another concern. Program climate issues such as isolation may dissuade scholastically qualified female students from persisting in the institution's engineering technology majors. Although Women In Engineering Programs (WIEP) offer a well-known approach to improving the academic climate, they require significant ongoing staffing and funding to be effective[3]. This option was not available (initially). Additional relatively successful models include undergraduate research or other professional appointments and service learning experiences as a means of connecting students to the community where their expertise can positively impact others[4-7].

Fortunately, Ford Motor Company shares the concerns of the faculty at Purdue University regarding the low rate of participation of women in engineering technology. Ford especially wishes to address growth of a diverse manufacturing workforce. In 2001, Ford began supplying regular financial support to fund recruitment and retention activities through Purdue University's Mechanical Engineering Technology (MET) Department. Designated the Ford Female Recruiting Initiative (FFRI), funds were first used to hire female MET students to visit schools and lead other recruiting events such as one-day on-campus workshops. This "one-shot" approach brought engineering technology students and faculty together outside the classroom and showed promise as a retention tool. It has subsequently been expanded to include paid positions for developing several pre-college workshops. An open hiring policy is in place – all women in engineering technology who want to work for FFRI are employed on a limited hour basis. To date, no female engineering technology students hired through FFRI have changed majors or dropped out of the university. Several FFRI participants have graduated and subsequently completed their master of science in technology or other graduate degrees.

The success on the recruiting side of this effort has been much more difficult to assess. Overall percentage of women students in the engineering technology majors at Purdue University seems to oscillate slightly, but remains under ten percent for all three programs. In 2003, the institution expanded its college-level Diversity Office role to include women in its outreach effort. This change allowed the faculty and students to shift their FFRI attention away from coordination to focus on activities for and with potential students. Adding an ongoing activity that would allow FFRI recruiters to work with pre-college students over an extended time, where they could really get acquainted and potentially influence these girls was the next step. Leading a design team was determined to be the preferred path for FFRI.

Design competitions

The myriad of engineering design competitions provide tremendous opportunity for pre-college students to learn about engineering through personal experience. The website www.engineeringedu.com/competitions.html lists more than thirty STEM competitions. These competitions generally involve teams of students addressing a predefined technical problem in a specified field, such as bridge-building, solar car racing, or meeting a robotic challenge. Although some of the competitions are intended for elementary and middle school students, the majority focus on high school students with a strong interest in engineering, science, and/or technology.

Why ToyChallenge™?

Various studies indicate girls often begin to lose interest in mathematics and science as they reach middle school, for numerous reasons[1]. Social pressure and lack of adult encouragement to excel in the foundation disciplines of traditionally male-dominated STEM fields represent two of the major girl-discouragers ToyChallenge™ is intended to thwart[8]. Bringing more females into engineering and engineering technology in part means gaining their interest early, in an environment that encourages them to fit their own understanding of "acting like a girl". It also entails encouraging students who lack the economic and educational advantages that often lead students to choose resource-intensive college majors such as engineering (or even to pursue the more accelerated high school mathematics and science courses where things like home Internet access are assumed). The ToyChallenge™ design competition addresses aspects of these points well. It is for middle school students (grades 5-8), catching girls (and boys) as they begin to turn off mathematics and science, and hopefully regaining their interest.

ToyChallenge™ is set up to appeal to girls' desire to express their creativity in a way that integrates the engineering design process with social, and perhaps nurturing interested. Teams develop their own toy or game design within three very broad categories: Toys That Teach; Get Out and Play; and Games for the Family. Depending upon the category selected, the common propensity of girls to help others can be addressed. For example, one of 2007 teams designed a talking broncho to help teach young children to count to ten in up to six languages and two of the 2008 teams have opted to design a toy or game related to physical disabilities. The broncho and part of the team are shown in figure 1. One of the 2008 teams developed a game to teach Braille letters, numbers, and punctuation to its players. Each team's design must conform to a budget, and should demonstrate good practice regarding safety, market appeal, and function. Otherwise, the designs are left to the teams to develop. This diverges from the highly structured arrangement of many design competitions, where personal involvement with the design is limited to satisfying others' constraints and perhaps in packaging aesthetics. A related drawback of a subset of these competitions is an inherent bias toward things that interest nearly every boy (e.g., robots and racing), but appeal to a much smaller number of girls in their tweens and early teens.

There is a certain level of gender bias favoring girls built into the ToyChallenge™ design competition. Team makeup must be at least 50% girls, and can be 100% female. An all-girl team provides a setting where those girls who are uncomfortable speaking up regarding their ideas around boys or who otherwise struggle with the differing communication styles between genders feel free to fully participate in the engineering design process. Since middle school girls are often especially reticent about sharing their technical ideas (due to reduced self-confidence) and middle school boys tend to be extremely vocal in this same area (relying on bravado to perhaps mask a similar reduction in self-confidence), providing a girl-only design team option has definite merit[1].

Figure 1: Demonstrating the Blalando Broncho

Forming the ToyChallenge™ teams

The ToyChallenge™ (TC) competition was identified via an electronic search. The 2004 competition was tracked by FFRI volunteers to verify that it would really match FFRI needs. Next, appropriate sustainable leadership at Purdue University and a nearby middle school had to be established. Of the three school districts in the county surrounding Purdue University, the school district with the highest population of at-risk students has a middle school within a ten-minute drive. An interested science teacher at Sunnyside Middle School was identified and enlisted at the regional science fair the preceding year. An FFRI faculty co-advisor and one of the student recruiters made the weekly commitment to coaching a TC team throughout the initial year's competition, and several other recruiters were enlisted to help the team on a more sporadic basis. For year one, all leaders were female engineering technology students and faculty, with the science teacher providing assistance with facilities, student and parent communication, and ensuring compliance with school regulations while learning about the engineering design process.

Although FFRI activities focus on females, most of their outreach efforts are open to boys and girls, including ToyChallenge™. At the start of each design competition, a school-wide callout meeting is announced. This poses some risk, since each TC team must be at least 50% female and callouts are open to all Sunnyside students. To date, this has been resolved with a little extra recruiting of girls when necessary. At the callout, the students learn about ToyChallenge™ and go through some get-acquainted activities that prepare them for brainstorming about toy and game design ideas. Those who return for a second meeting are asked to group themselves into one of the three TC design categories (Toys that Teach, Get Out and Play, and Games for the Family) and begin brainstorming in earnest. The coaches write down all ideas and help the groups start focusing in on a practical idea. Some students will change categories as the ideas become more refined; some students may have to be moved to meet TC team requirements for number of participants and gender distribution. These constraints are necessary but have resulted in a few dropouts among the students who felt very strongly about one toy category or implementing their design idea without incorporating input from the rest of the team.

Designing and developing prototypes

Gaining an understanding of the engineering design process is a major part of the ToyChallenge™ experience. Teams must quickly progress from brainstorming to setting design criteria, then recognizing constraints on their idea. For a middle school student, many of the standard engineering design tools are not available, particularly for 5th and 6th graders. Available design development tools include sketching, modeling and testing of equivalent elements, measurement for sizing, and “market research”. In a few instances, simple algebraic expressions can serve as design aids if the team coach can provide the equations immediately. Creative identification of equivalent elements, access to rubber bands, duct tape, a variety of springs, magnets, electronic components, and cardboard all speed the design development process. If the first round design can be sectored into several prototypes, the students grasp the physical limitations on their ideas very quickly, and generally come up with several other ways to move forward with their toy or game design. For example, the 2005 team began with a self-supporting snowball launcher that went through several iterations before it evolved into a hand-held multi-purpose launcher, to be used with snowballs, water balloons, sponge balls, or any other fairly soft spherical item in its size range. Figure 2 shows most of the team with the initial mockup, with early launch mechanism details appearing in figure 3. Several variations on the energy source for the mechanism were tested; figure 4 presents data from one tested sample. Another key design aspect is cost. TC team members must track the cost of all materials used in their design. Even donated items are counted toward the Preliminary round $150 and the $200 Nationals budget limits.

Figure 2: The first TC team with an early version of the launcher

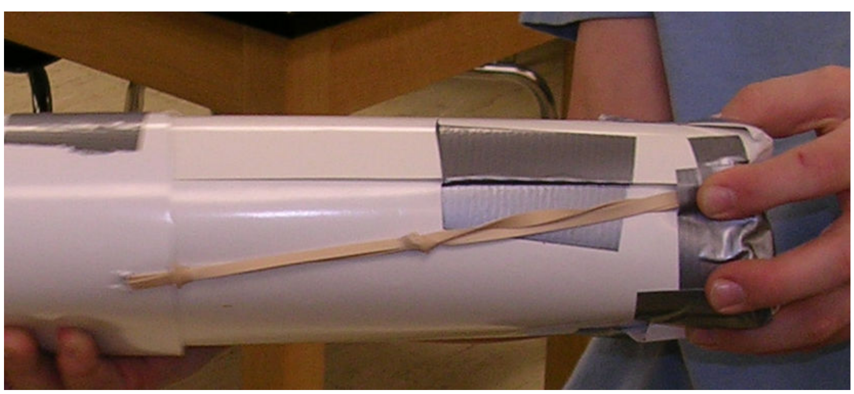

Figure 3: Initial attempt at providing energy to the launcher

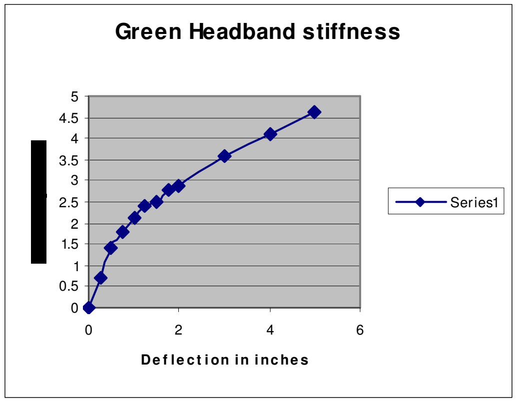

Figure 4: Student-generated graph of a possible launcher energy source

Garnering industry support

The engineering technology programs at Purdue University are fortunate to have strong industrial advisory committees with members who serve as program advocates at their respective companies. Ford Motor Company's MET representative worked with their vice-president for manufacturing and their Women in Manufacturing group to generate funding for the Purdue University recruiting initiative. As this effort matured, incorporating a school-based project was viewed as a natural progression. Ford is committed to a diverse manufacturing workforce. ToyChallenge™ emphasizes encouraging girls in STEM fields. The partner school population includes both a significant number of minority students and a substantial number of students who qualify for the federal reduced/free lunch program. These factors increase the likelihood that Ford's financial support would eventually result in a more diverse STEM workforce and added to its corporate appeal. Maintaining support at a level that allows team participation in ToyChallenge™ could probably be accomplished without industry support. Each team can spend up to approximately $225 for registration, preliminary design development, and documentation for the first round of judging. The low-budget aspect of the ToyChallenge™ design competition unfortunately disappears for those teams who are selected for the National Competition. A reasonable additional $200 can be invested in prototype development, but travel costs for a team can be quite high. The 2007 national competition was held in San Diego, California, for example. Time constraints coupled with TC rules meant most teams had to fly at least one girl and the team coach in for the weekend competition, pay for food and housing for a weekend, and so on. For the Sunnyside TC teams, the basic weekend cost was approximately $750 per person (and nearly every student wanted to attend). Industry support was essential for ensuring that family economics did not preclude participation at Nationals for any student. (Sponsorship from the Purdue University's college diversity office and a fundraising project also defrayed team member costs).

Challenges of extended engagement

At least three fairly divergent professional cultures and corresponding sets of expectations have to be met when a university, a middle school, and a private industrial corporation work together toward a common goal. In this case, the corporation is a longstanding supporter of engineering technology programs at the university and also has committed a portion of its resources to developing a more diverse manufacturing workforce. From the university perspective, the primary challenge for keeping this industrial partner engaged has been personnel-related. University development staff and industry personnel move to new positions and donor expectations change, introducing a level of uncertainty to the process that is a minor but ongoing concern.

Challenges of engagement between the university and the middle school exist at several levels. At the weekly team level, challenges begin with simple scheduling differences. Middle school students could only reliably meet right after school, from 3:15 p.m. to 4:10 p.m., when some students needed to catch a bus to the elementary school nearest their home. Their desire to have a little transition time between school and focusing on TC further limits the time available to move their design projects forward each week. College students in engineering technology often have classes until 5:20 p.m., so several FFRI recruiters interested in helping the TC teams have been shut out of direct interaction. Their participation has been limited to occasional shopping for supplies. Other potential challenges are preparing college students for mentoring middle school students who may come from very trying circumstances. TC team members have had to cope with parent difficulties ranging from language barriers and multiple sclerosis to prison, and with their own personal struggles such as learning disabilities, uncertain living conditions, and chronic illness. This wide range of external factors is common in a large public school, but represents significant challenge for the typical college student or faculty member. It also defines a large sector of the population that is often overlooked by the STEM fields, the sector which lacks the social, cultural, and in some circumstances, educational resources to be able to negotiate the unwritten success factors of these disciplines[9]. A final concern when working with middle school students is their wide range of social maturity. Some students are still very much children, while others have become teenagers. This can be a tricky matter whenever teams are made up of girls and boys. Sometimes the flirting prevents progress on the design; other times, the team becomes dysfunctional as the girls and boys act as if they cannot share adjacent space. Both problems can generally be circumvented if the team coach can plan what has to be accomplished at each team meeting, and proactively assigns tasks to team members.

At the management level, university and K-12 administrative policies and procedural differences represent major obstacles if middle school students are to leave their school, such as participate in the ToyChallenge™ National competition. Both parties must conform to strict regulations regarding finances and personnel. Determining exactly what these regulations mandate requires due diligence on the part of responsible faculty members each time the situation arises. For example, the middle school principal was determined to send 2007 team members on an educational field trip during free time at the National competition. Use of industry donations through the University must conform to donor restrictions and standard rules governing university funds, both of which precluded payment for the field trip. The final solution was to pay for the field trip with school fund-raising money. None of the administrative challenges have been insurmountable when thorough and clear communication is sought by all parties and all are dedicated to finding a solution.

An auxiliary challenge arose when the school district reorganized, making its two 6th through 8th grade middle schools into one 6th grade school (where ToyChallenge continues) and one 7th and 8th grade school. The team membership shifted from student ages ranging from 11to14 years, to nearly all 11 and 12 year olds, and their maturity and project experience was considerably reduced. The TC coach has to be alert to member capabilities and prepared to adjust her level of involvement in the design to keep the students engaged in the project and recognizing that they are making progress.

Successes

Participation in the middle school's TC teams has grown from a core of five students on one team who made it through the full first season to sufficient students for three or four teams each year (approximately twenty students). Each team has had to learn to communicate its ideas clearly through words and graphics. Three of the first seven teams were selected to participate in national competitions. For several of these students, the trip to Nationals was their first time to fly in an airplane. For all Nationals competitors, their oral communications skills were improved as they made a brief design presentation to two sets of judges and responded to their impromptu questions. University students have found potential employers to be very interested in their TC roles. Seven former TC team members are now in high school, and most are pursuing studies that will facilitate their success in a STEM field. A second science teacher has become a team coach, and several other teachers have helped out by chaperoning, assisting with fundraising, providing access to tools, and so on. Minority student participation increases slightly each year, and girls' involvement continues to grow.

Long-term

It is too early to gauge the long-term impact of ToyChallenge™ on recruiting of girls into engineering technology or any other STEM fields. In fall 2006, SallyRideScience began conducting annual surveys of participating students to determine if their views about the potential success of women in STEM fields are positively affected by ToyChallenge™. Survey results have not yet been published. It is reasonable to conclude, however, that large numbers of middle school students gain a better understanding of engineering design through their involvement on a TC team. They can be expected to know that engineering design draws from mathematical and scientific principles, and a good design requires creativity, communication, experimentation, materials and processes, and a market to be a success. Thus, as a minimum, these students are part of a technically literate population who are aware of product development, safety, and teamwork. They can choose to become engineers and technologists if they determine that this kind of work matches their career goals.

Acknowledgements

Too many people have contributed to the partnership that allows Purdue University and Sunnyside Middle School to participate in ToyChallenge to acknowledge all by name here. A few especially noteworthy contributors are listed. Garry Laymon (retired) and Roman Krygier of Ford Motor Company arranged most of the financial support; MET and Technology alumna Melissa Mladinic laid the initial groundwork and coached three teams; and Sunnyside teacher Kathleen O'Neal has facilitated, coached, chaperoned, and otherwise made this endeavor possible. Parents, administrators at Purdue and Lafayette School Corporation, FFRI students, and others have all provided encouragement and support over the past four years of TC teams.

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