



Using Sports to Attract Young Women into Engineering

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Abstract

Engineering, science and technology are used extensively in sports - from equipment design and increasing athletic performance, safety, health benefits and enjoyment, to preventing injury and assuring equity and longevity in sports. Yet for some individuals, sports and recreation may be associated with the word “fun”, while science, math and engineering may be equated with the words “hard” or “difficult”. Get SSET (Sport Science, Engineering and Technology) was first developed in 2003 as an innovative week-long summer residential sports science and engineering academy for girls entering grades 9 through 11. The academy has been conducted at the Massachusetts Institute of Technology (MIT), Stanford University and the University of San Diego.

The academy focuses on empowering female students with technical skills and success strategies through engaging sports STEM lectures and hands-on activities in a gender-neutral environment. A key component of the program is that instructors are female university faculty and/or professionals in sports science, engineering or math. The on-campus environment has been used as a stimulus to excite students about college/university education and an engineering, science, math or technology related career.

Our purpose has been to provide exposure and introduction to college-level Science, Technology, Engineering and Mathematics (STEM) materials and college life and female role models/exemplars in an informal framework. Discussed are best practices and content developed during the seven academies conducted from 2003-2012, including logistics (funding, student selection criteria, academy activities). Additionally, a brief summary of student evaluations and parent surveys (conducted 3-7 months after the academy) is provided. Over the past nine years students and parents have noted more “active learning”. Additionally, parents have noted more long term “self-confidence” in their daughters.

Introduction

While sport and recreation may be considered fun to watch or participate in, the science, engineering, mathematics and technology is often not recognized. Yet, the manufacturer’s (wholesale) sales of sporting goods equipment, fitness equipment, sports apparel, athletic footwear, and sports licensing merchandise in the U.S. totaled \$77.31 billion in 2011 (a 4.2% increase over 2010)¹.

As well, as professionals working in sports science and engineering we recognize the pattern of athletic development. While there are training regimes for a sport, there are hours and hours of individual practice, failure (or partial success), observing performance issues, resolution of these issues and perseverance. There is no one “right answer” in athletic development as there may be in a math problem. The young athlete who desires

to improve persists. These same characteristics can be key in becoming an engineer or scientist.

Get SSET was developed to introduce young women to engineering using sports as a theme. Our intent has always been to provide students an opportunity to experience college life and expose them to engineering while there still might be time to direct high school courses.

The academy was conducted at the Massachusetts Institute of Technology (MIT) from 2003-2005, Stanford University in 2005 and the University of San Diego in 2006-2007 and 2012. The programs hosted at MIT and the University of San Diego included campus residential components. The program hosted at Stanford University was a nonresidential daytime only program.

In sports engineering it is critical to understand and embrace physiological differences throughout the human life cycle (age), for both genders and for varying physical abilities and disabilities. This theme has been used throughout the academy to emphasize that understanding diversity is critical in obtaining good sports engineering solutions.

Program Logistics

Applicant Selection

From the onset of the Get SSET academy the intent has been to provide opportunities to underserved, underrepresented, minority, first generation college bound, rural, individuals with disabilities and at-risk high school women. The selection process only varied slightly for each of the three programs, which were located in three different areas of the United States. The program hosted at MIT was open to students from New England. Young women from the San Francisco Bay Area were eligible for the program hosted at Stanford University. The program hosted at the University of San Diego was open to students from San Diego County.

Criteria for selection included that applicants must be a rising 9th or 10th grader, have completed Algebra 1, must be registered for a math, science or technology course for the upcoming academic year, agree to academy policies and framework (including no controlled substances, alcohol, or tobacco products) and sign a behavior contract.

The application included a 1-page essay on the student's interest in science, engineering or technology AND sports and their desire to attend this academy. Two recommendations are required: one from a science, math or technology teacher and the second recommendation from a physical education teacher or coach. The coach/physical education teacher recommendation was important. This recommendation form asked if the student was "coachable", was the application a team player, worked well with others and was their behavior appropriate on the field? This information was deemed important in selection. While a student might be reserved in a classroom, their behavior might not be appropriate in the less structured environment of recreation.

A selection committee of at least four individuals was chosen. The committee was also permitted to use information within the application, which suggested that a specific candidate has not had financial advantages or the opportunity to attend other academies or programs.

Enthusiastic candidates with great desire to attend the academy may be ranked higher than those whose essays do not express this desire. Considerations are made for ESL (English Second Language) students so that their essay information and not the student's grammar are evaluated.

Funding

Funding to support the academy has come from various sources, which have included the Society of Women Engineers, the New England Women's Fund (New Fund) and the San Diego Science Alliance (SDSA). In turn each of these organizations received or coordinated funding through other corporations and donors. In particular the New Fund and SDSA (both advocacy organizations – New Fund for women in sports and SDSA for science education) partnered with our faculty team to organize and administrate Get SSET.

As the developers of the academy the intent was that each young woman be funded by a scholarship. This ensured that students were not discouraged from applying due to the cost. However, for the 2012 program the organization that the faculty collaborated with required a \$300 fee per student, although scholarships were easily provided on request.

Other Logistics

For the residential academies all female teaching assistants/resident advisors who are also STEM students and athletes were employed. In the last academy in San Diego (2012), some of the RA's were former graduates of our academy and now graduate students themselves. Since the academy instructors were not faculty at the hosting university, having student assistants who were students from that campus was critical for logistics. (They knew where buildings and facilities were, how to get last minute supplies, etc.)

Over the nine years since Get SSET's inception, we have encountered concerns and regulatory changes related to screening of program staff and faculty for criminal and sexual offenses, privacy of student information for longitudinal studies and gender-neutral program concerns. For example, when we first began the academy in 2003, there was a growing concern at universities regarding the support of programs where one gender is excluded (due to discrimination law suits). One university was happy to "host" the academy, but it was made clear by the university that it was not "sponsoring" the academy. Statements to the university were confirmed that only private (versus public) funds were being used. As the CAWMSET report discusses², girls may not have the opportunity to learn in lab situations when boys are in the class; yet concerns over discrimination can lead us back into the mixed gender labs even in an informal science

program. Additionally, in the state of Massachusetts, the faculty and staffed were screened for past and current criminal and sexual offenses.

Sample Activities

While the specific activities have varied and some have evolved, both the residential and daytime only programs have all included a sport aerodynamics activity, a design methodology activity, a biomechanics motion capture and analysis activity, local sport facility, science or other engineering facility tours and final presentations from the students to the sponsors, faculty, staff and their families. The activities can be found at the SWE Internet Activity Center ³. In addition, the residential programs hosted by MIT and the University of San Diego also included a CEO/Executive Breakfast and a Career Panel.

CEO/Executive Breakfast and Career Panel:

In addition to the engineering and science content, two other sessions that have been trademarks of our project have been the CEO/Executive Breakfast and Career Panel. CEOs or women executives from local technology firms are invited to breakfast with the Get SSET students. Students spend time with each executive and learn about their backgrounds, education, challenges and “how they got where they are today”.

The Career Panel is held during one evening. Participants are women who have successfully coupled sports and an aspect of STEM in their professional lives. Women from a variety of STEM backgrounds form our career panel. Over the years this has included: the manager of product design at an athletic footwear company with degrees in material science and mechanical engineering, the president of a computer technology firm with a degree in sport and leisure studies, an environmental engineer whose company creates recreational areas, a civil engineer whose company designs sports arenas, sports statisticians, biomechanists, a US Olympic Committee engineer, a sports physiologist and sport nutritionist from a US national sport governing body. During the Career Panel, one of the academy faculty or staff served as moderator and asked the panel several questions and then opened the floor for questions from the students. While we have generally attempted to only use women as role models, during the 2012 program the senior quantitative analyst (statistician) for the San Diego Padres baseball team participated on the Career Panel. The gentleman was an excellent participant and the students most interested in math resonated with him.

The general consensus among the young attendees for the CEO/Exec Breakfast and the Career Panel has been highly positive and a frequent evaluation comment has been “They were average people just like me, and if they could do it, I could do it.”

Design Of A Triathlete Running Shoe (Lecture and Hands-on Activity):

Students learn about the design and construction of athletic footwear and forces on the foot and leg in different sports. Students are provided a problem statement, led through a basic engineering design methodology, brainstorm and develop potential solutions as a team.

The class participants assume the role of sports engineers assigned to develop a new triathlete shoe for their company. Faculty members engage the students in a lecture and discussion on athletic footwear design and general design methodology, shoe components (upper, insole, midsole, outsole and lacing systems) and purpose, materials and construction, foot motion during athletic play (i.e., pivoting, starting and stopping, lateral and medial foot rolling), shoe and surface interaction, and about the magnitude and direction of forces on the foot and leg in different sports. The different types of triathlons are described as well as the order of the triathlon events (swim, cycle, run).

Students are told that the marketing department's current concerns with existing equipment include improving: speed of foot entry into the shoe, ease of lacing the shoe and durability. The last concern is actually a "false clue". Long-term durability has generally not been a key component of triathlete shoe design since most athletes utilize newer (less used) footwear in competition or their sponsor provides footwear.

Working in teams the students consider the following list of factors as they develop their design and determine whether a particular factor is important to the new shoe design: performance, environment, life in service, maintenance, cost, size, weight, aesthetic, appearance and finish, materials, quality and reliability. As expected the students have many questions. What factors are important in the design of a triathlete running shoe? How does this differ from a regular running shoe? Does a running shoe for a triathlete need to be durable? Students are given engineering worksheets to record information, their questions and answers and designs.

One of the key components of this activity is the design interview. Individuals working in athletic footwear design and/or triathletes are invited for interviews. Over the years of the program we have had industrial designers from athletic footwear companies, faculty working on athletic footwear innovation, triathlete coaches and elite or professional triathletes (both men and women) participate. The students interview the designers and/or athletes for an hour.

The teams use the design methodology, answers from the interviews and information on athletic footwear they have learned, the students develop and sketch their new footwear. Each team presents their solution and addresses how they met the design challenge. Class time has only permitted hand sketches of the designs by the student teams (Fig. 1). In the future we hope to utilize a computer-aided design program with this activity.



Figure 1 – Triathlete Shoe Design Sketch

Aerodynamics of Cycling Helmets (Tour, Lecture and Hands-on Activity): Students are introduced to basic concepts of aerodynamics, sources of aerodynamic drag and the techniques to reduce different types of drag. Working in teams, students redesigned and modified the shape of a cycling helmet to make it more aerodynamic and reduce its drag. Helmets are modified using simple materials (duct tape, Styrofoam, play dough, etc.) In a subsequent lab, students tested their modified helmets in an actual wind tunnel to determine the drag reduction.

Faculty members lecture on basic aerodynamic forces (lift and drag), the different types of drag typically encountered in sports (form, friction and induced drag), techniques to reduce each type of drag, how those aerodynamic forces affect cycling performance (speed), force calculations and the design of cycling helmets for optimum performance. An introduction to aerodynamics was given to students using examples in nature (bats, birds and gliding animals), bridges, vehicles and aerodynamics of sports equipment (balls, projectiles and vehicles), athletic-wear and athletes. Students learned how drag is a function of the shape of the body, smoothness and the velocity.

Student teams were given very inexpensive cycling helmets (approximately \$6 or less), which lacked good aerodynamic characteristics. They were asked to examine the helmet design and list and draw the helmet characteristics they would like to change. For each feature they proposed to change, students documented in their journal why they believed the change would improve the aerodynamics of the helmet. They were allowed to search the web for alternate designs and time trial helmets (although most did not chose to do this).

Students worked in teams, designed and modified the shape of their team's helmet to make it more aerodynamic. As a pretest, the students conducted a “tuft test”. Yarn strands were attached to each helmet and using a fan, and wire mesh as a flow straightener, students could determine overall aerodynamic characteristics. They subsequently tested their team's helmet out in the wind tunnel and calculate the drag.

After the tests were conducted the students discussed the characteristics of the best and least aerodynamic redesigned helmet (Fig. 2).

Each year of the program, we were fortunate to have access to a wind tunnel for either a tour or for actual usage. With the exception of 2012's program, the wind tunnel's test section was large enough to place a cycle with an athlete into the tunnel. The girls were allowed to stand inside the tunnel as well as observe a variety of flow visualization and audio (they could hear when the drag was reduced) techniques used to determine aerodynamic drag.

The athlete stationed in the wind tunnel on a cycle tested a baseline (unmodified helmet) and each student team's modified helmet. In 2012, a wind tunnel with a smaller test section was used. Each helmet was tested on a Styrofoam wig head holder.



Figure 2 a) Tuft Test and b) Modified Helmets

Biomechanics - Motion Capture and Analysis (Lecture, Hands-on Activity, Analysis with Software): Human movements involve dynamic interaction with the surrounding environment. For example in soccer, making a pass to a target from a standstill is significantly different from sprinting down the sidelines, dodging opponents, and crossing the ball in front of the goal. Still, when we learn skills we often simplify them in some way so that we can learn the parts before we put them all together as needed in competition. Likewise, moving quickly and changing direction are essential skills for competitive elite athletes. To figure out “how did they do that” biomechanical methods are often used to characterize how the performer simultaneously controls their center of mass (CM) path relative to the interactive reaction forces (RF) generated during contact with the environment (e.g. foot/ground interface, hand/rail interface). These motions can then be compared in relation to the structural and functional capacity of the individual's body.

In the activity students act as a sports biomechanist. They use a digital video camera and capture the motion of another student; use a software package to analyze the speed, displacement and time of the motion they capture or compare this motion pattern against a second similar motion pattern. The students then determine differences in the patterns and correlate to performance and/or skill.

Discussion and Conclusions

Written student evaluations were completed at the end of the program with almost 100% participation (approximately 160 surveys). Additionally, beginning in 2004, parents were sent 1-page surveys 3-7 months after the academy, which focused on any longer term changes in interest and learning style. A 20-33% return was the average parental response each year.

The student evaluation asked for comments and input on the application process, facilities (dorms, food, athletic facility usage), their goals in attending the academy, achievement of goals, what they learned, and ranking of each of the academy's activities/events.

The young women reported that they did like the all girl student enrollment. While they would not care for this in their regular school, they felt that they had more of an opportunity to participate. A few students reported that they felt isolated as a woman in sports and as a woman who enjoyed math and science. The academy gave them an opportunity to meet other women with the same interests.

Students reported that they became more active learners, versus independent or self-confident learners. However, parents who participated in the evaluation clearly reported that their daughters had become more self confident, independent and active learners. Of the 11 surveys submitted in 2006, 8 parents reported self-confidence increase, 7 reported more active learning and 6 reported more independent learning. 100% of the parents strongly agreed that their daughters were exposed to academic topics they would not receive elsewhere, 10 of the 11 surveys reported that using sports as the theme had made the learning more interesting to their daughters. There was agreement (2 agreed, 8 strongly agreed) that their daughters learned about college life. While the sample is small, the results have been consistent and similar year to year and "more self-confident learner" has been the top parental answer.

Based on the student evaluations, young women with a strong interest in both sports and engineering obtain the most benefit. The young women report having a connection with the other women in the program, since they feel isolation in school being unique in their interest in sports and in STEM.

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