How Different Parts Came Together: Building Underserved Student Self-Esteem, STEM Interest and Solidarity by Building a Robot

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Abstract - **The Metal Muscle Mentoring Program is an innovative pilot program at Kettering University to encourage underserved youths' interest in STEM higher education. This program involved two key elements: the combination of college student mentoring of high school students and the purposeful creation of a FIRST Robotics Competition (FRC) team made up of students from diverse backgrounds. Dean Kamen started FRC seventeen years ago to encourage high school interest in engineering and science. To further that interest, in 2008-09, the pilot program built on the five-year-old Metal Muscle FIRST Robotics team's exclusive use of former team members who became Kettering University students as mentors to the high school student team members. Additionally, with the support of a grant from the Mott Foundation, the Metal Muscle team consisted of both privileged and economically and socially disadvantaged youth. The theory behind the pilot program incorporated the importance of caring adult/peer mentors as well as intense team building among diverse peers. Results included an increase in (a) positive attitudes, (b) technical skills and knowledge, and (c) participation in STEM programs for all of the team's graduating high school seniors, with underserved youth showing significantly higher interest in higher education and STEM programs than underserved youth who did not participate on the team. Uniqueness of the team's operation and mentoring program is presented as a model for other universities and colleges to emulate and consequently increase interest in STEM programs, especially amongst underserved youth. Conference participants will be able to garner new ideas to develop K-12 partnerships and promote STEM learning.**

Index Terms – FIRST Robotics, pilot program, underserved, STEM, program evaluation.

BACKGROUND

This paper describes the Metal Muscle Mentoring pilot program to mentor underserved high school students in the FIRST Robotics Competition. FIRST, an acronym for "For Inspiration and Recognition of Science and Technology", was started twenty years ago by Dean Kamen to encourage youth interest in science and technology while promoting "gracious professionalism." Gracious professionalism "encourages high-quality work, emphasizes the value of others, and respects individuals and the community." The FIRST Robotics Competition (FRC) applies a competitive sports framework to youth mentoring, where engineers and other adult professionals work with high school youth on teams, building a robot that they then enter into competition with other FRC teams. Winning is not just a matter of having the most successful robot, but includes gaining knowledge and skills, self-respect, a sense of teamwork, and the positive valuation of others.

For the past five years, a Kettering University sponsored FIRST robotics team, Metal Muscle, has engaged youth from a wide range of Mid-Michigan high school districts. Typically team members must "pay to play" to participate which essentially limited the participation to "privileged" middle class or above. Mentors, who volunteer their time and talent, have come mainly from the Kettering University student body, alumni, and faculty. All of the mentors were once FRC youth team members themselves, many from Metal Muscle.

PROGRAM

In 2009 Kettering University extended its FIRST outreach with a Metal Muscle Mentoring Pilot Program (MMMPP). Targeted were economically and socially disadvantaged youth with the aim of increasing their interest in higher education; especially Science, Technology, Engineering and Mathematics (STEM) disciplines. A grant of $10,000 from the Mott Foundation allowed for five students at a Title I school with a free/reduced lunch rate of over 90% and a predominately African-American student population, to become sponsored team members. The scholarships covered the full cost of participation in Metal Muscle for the 2009 season. The five students from the Title 1 School plus one other "underserved" student are referred to as "sponsored" students or participants. Those who paid to participate are referred to as "nonsponsored" students or participants and the totality of sponsored and nonsponsored is simply referred to as "all team members."

The goals of the Metal Muscle Mentoring Pilot Program were in keeping with the FRC program philosophy and include:

- Increased awareness of, and interest in, STEM programs;
- Development of practical problem-solving and teamwork-related skills;
- Development of positive attitudes, including an increased sense of self-confidence and motivation to do well in school;
- The ability to work together within a team and to work cooperatively with those on other teams, including potential competitors; and
- An increased set of technical skills and knowledge.

PROGRAM EVALUATION METHODOLOGY

To assess the pilot program's ability to achieve the above goals, an evaluation utilizing an enhanced pre-post survey was designed. Sponsored team members (N=6) were surveyed at the beginning of their participation in MMMPP and then again at the conclusion of the FRC season. Surveys were completed on-line and incorporated both likert-scaled and open-ended questions Statements assessing the frequency of, or likelihood to, engage in certain behaviors or beliefs measured the following: interest in STEM education; capacity for leadership; sense of responsibility; respect for others; ability to communicate; familiarity with tools and technology; and overall experience on the team. Responses to open ended questions as well as copies of the survey instruments are presented in the reference listed in the Resources tabulation at the end of this paper.

Enhancing the comparison between measures taken before team participation ("pre-test") and measures taken after participation ("post-test") are comparisons between sponsored team members and all team members (N=13) on key variables. The overall post-participation level, changes between pre- and post-test levels, and differences between sponsored and all team members' scores are detailed in the findings listed below.

INTEREST IN STEM EDUCATION

Post-test responses shown in Figure 1 indicates that every team member intends to go to college, with the majority, 70%, of all team members "very likely" or "definitively" planning to go to obtain a professional degree, such as an MD or PhD. Although pre-test scores are not shown in Figure 1, before participating on the team, 71% of the sponsored team members' higher education plans included college and a professional degree. After participation, as shown in Figure 1, that percentage increased to 100%. Noting that in 2007, the graduation rate for economically disadvantaged students was a dismal 33%, we see the importance of the MMPP as a positive factor in increasing educational ambition among low-income students.

Team members' likelihood after participation to…	Not Sure %		Not Likely %		Somewhat Likely %		Very Likely %		Definitely %	
	Sponsored Team Members	All Team Members	Sponsored Team Members	All Team Members	Sponsored Team Members	All Team Members	Sponsored Team Members	All Team Members	Sponsored Team Members	All Team Members
Take an elective science class	0	15	0	0	20	8	40	43	20	31
Go to college	0	0	0	0	0	0	0	8	100	92
Obtain a professional degree	0	8	0	8	0	15	60	31	40	39
Major in science	0	8	0	8	0	8	20	31	80	46
Major in engineering	0	0	0	0	0	15	20	31	80	54
Major in mathematics	0	8	0	8	0	30	20	15	80	39
Major in computer science	20	15	0	8	0	39	20	23	40	15

FIGURE 1
TEAM MEMBERS' EDUCATIONAL INTENTIONS.

SENSE OF RESPONSIBILITY

Persistence and the willingness to take on responsibility are key factors in personal and professional success. As the data in Figure 2 show, all team members had improved scores in three main measures of sense of responsibility after their participation on the Metal Muscle team: their motivation and dedication; their tendency to keep the focus on fixing problems as opposed to assigning blame; and their ability to persist with a task despite pressure.

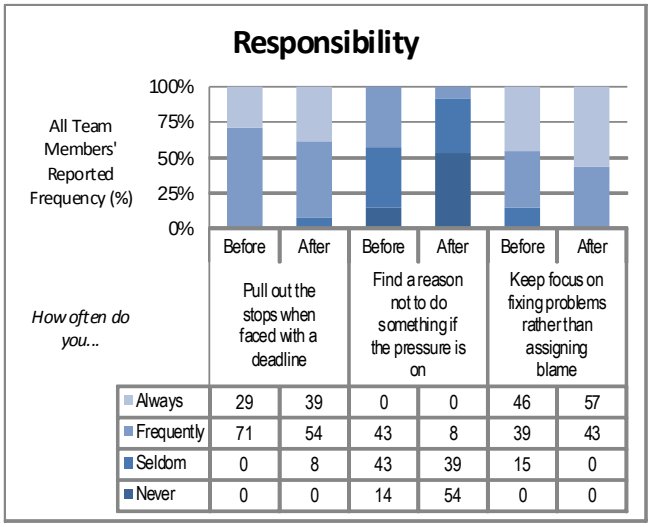

FIGURE 2
ALL TEAM MEMBERS SENSE OF RESPOSIBILITY.

LEADERSHIP CAPACITY

As Figure 3 shows, sponsored team members learned a great deal about the realities of shared leadership and teamwork. The ability to take on leadership roles was assessed through responses to three constructs: happiness working as the boss; happiness taking directions; and happiness making decision for the team. Although the percentage of team members reporting "always" being happy taking directions did not change, there was moderate change away from happiness

taking direction, 20% reported "seldom" being happy taking direction after, as opposed to none before participation. This may indicate a greater desire for self-direction, an important component of academic and professional success. Corresponding to this moderate change in answering to others was increased capacity in answering for others. The majority, 80%, moved from "frequently" to "always" being happy making decisions for the team. Prior to joining the team, sponsored team members were split in being happy working as the boss, with 40% reporting "always" being happy and 40% reporting "seldom" being happy working as the boss. After participation, the majority (60%) reported "frequently" being happy being the boss; the percent seldom feeling comfortable with this leadership position halved (from 40% down to 20%). This shows that team members are willing to assume leadership, even if they are not eager to be the boss *at all times*. Overall, it appears they are more confident in their decision-making within a team context, the most typical form of leadership in today's work environment.

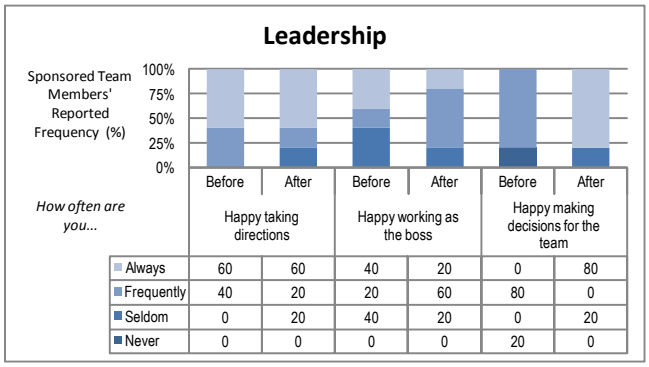

FIGURE 3
SPONSORED TEAM MEMBERS' LEADERSHIP CAPACITY – BEFORE AND AFTER TEAM PARTICIPATION.

RESPECT FOR OTHERS

Connected to the ability to thrive in a team environment is the quality of relationship an individual is able to cultivate. This ability to develop quality relationships derives from a person's concern for and support of others as well as the amount of respect they garner and confer. Team members improved significantly in their ability to develop connections with others, as measured by the constructs of seeking and offering input as shown in Figure 4. The percentage reporting "seldom" decreased to 8% (down from 29%) for seeking input or ideas from others and decreased to 15% (from 43%) for offering ideas to others.

The FIRST philosophy sees the importance of acting with sensitivity and empathy. Team members improved in their capacity for strong interpersonal connection, as measured by giving support when needed, complimenting others, and showing genuine concern for others. As Figure 4 shows, team participants increased in their abilities to give support when needed and to complement others. Those reporting "always" giving support nearly doubled, from 29 to 54%. Those reporting that they compliment others, as well as show genuine concern for them increased as well. In both cases, 62% of the team members indicated "always" doing so after joining the Metal Muscle team. "Always" showing genuine concern for others increased from 57 to 62%, while the percent reporting "always" complimenting others went up from 43 to 62%.

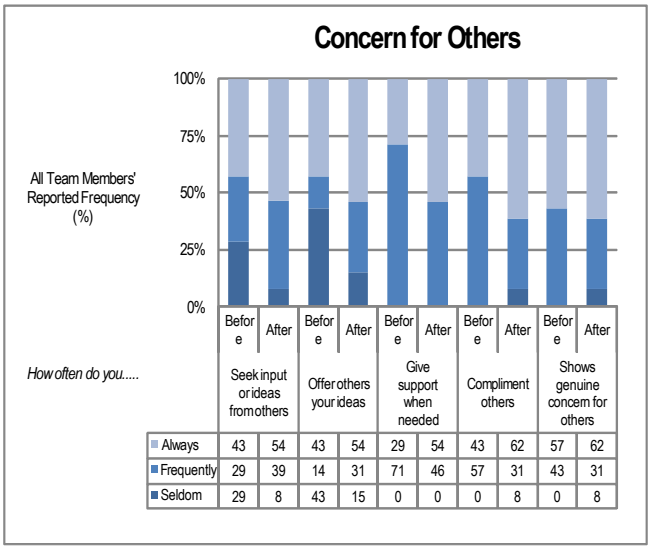

FIGURE 4
ALL TEAM MEMBERS' CONCERN FOR OTHERS – BEFORE AND AFTER TEAM PARTICIPATION.

TEAMWORK

Team members overall were least likely to get along "very well" with the mentors, 42%, as shown in Figure 5, but the majority reported getting along "very well" with the team as whole, 69% and other student team members, 77%.

How well YOU got along with....	Very Well	Well	Not Well	Poorly
The team as a whole	69%	31%	0%	0%
The mentors	42%	33%	25%	0%
Other student team members	77%	23%	0%	0%

FIGURE 5
ALL TEAM MEMBERS' ABILITY TO GET ALONG WITH OTHERS – AFTER TEAM PARTICIPATION.

When asked how other team members got along with the respondent and others, it is no surprise that the greatest percentage, 67%, of respondents thought others got along "very well" with them. The majority, 61.5%, also thought that other team members, got along "very well" with other team members, indicating a general high level of regard amongst the team members.

How well OTHER TEAM MEMBERS got along with....	Very Well	Well	Not Well	Poorly
The team as a whole	53.8%	30.8%	15.4%	0.0%
The mentors	15.4%	61.5%	15.4%	7.7%
Other student team members	61.5%	30.8%	7.7%	0.0%
You	66.7%	33.3%	0.0%	0.0%

FIGURE 6
ALL TEAM MEMBERS' ABILITY TO GET ALONG WITH OTHERS – AFTER TEAM PARTICIPATION.

COMMUNICATION

Communication involves understanding and being understood by others. At the basis of good communication is an individual's belief that both he/she and those he/she desires to connect with can learn and grow from the other, that each has something worthwhile to say. The ability to reach out to strangers and to feel comfortable meeting new people indicates a level of assertiveness and self-confidence; it suggests that the individual feels what he/she has to communicate will be worth the risk. Similarly, trying to find an area of agreement between friends who aren't getting along implies both concern for relationships experiencing discord and a sense of efficacy in one's ability to find middle ground.

For Metal Muscle team members, the ease with which they were able to talk to a group of people they really didn't know and their sense of comfort in meeting new people increased tremendously after team participation, as indicated in Figure 7. From the majority, 67%, reporting "seldom" talking to a group of people they really didn't know at the beginning of the FRC season, to only 15% reporting doing so after being on the team, there was a significant increase in the members' reported frequency of reaching out to others. Again, with feeling comfortable meeting new people, the majority, 57%, reported "seldom" doing so prior to being on the team, while only 23% reported doing so after. After participation, the majority, 62%, reported "always" being comfortable meeting new people.

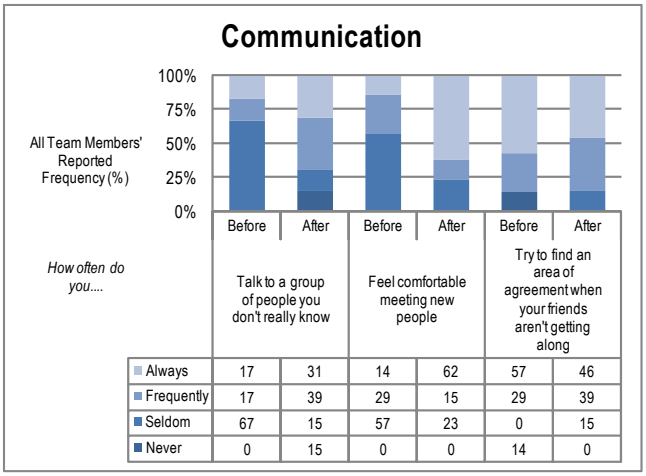

FIGURE 7
ALL MEMBERS EASE OF COMMUNICATION – BEFORE AND AFTER COMMUNICATION.

TECHNICAL SKILLS AND KNOWLEDGE

Team members were asked in the pre-and post-participation surveys to indicate their level of familiarity with a variety of tools and technical systems in order to assess changes in their technical skills and knowledge. From response categories of 1)not knowing what they were or 2) being afraid to use them, to 3) using the tools once or twice, and 4) finally being able to use them without problem, the level of the team members' technical skills and knowledge underwent a seismic shift during the FRC season. Being able to use tools designed by others is important, but identifying one's own distinct needs and being able to create tools by which to generate one's own solutions indicates more than skill; it is a sign of mastery.

As seen in Figure 8, team members' experience with hand tools increased moderately, in part attributable to the fact that none were unfamiliar with their use. In terms of power tools there was tremendous change in the percentage reporting facility from 14% before the FRC season, to 86% at the end. More remarkable yet was the fact no team members had used advanced tools such as a lathe, milling machine, band saw, or drill press even once or twice prior to joining the team, yet afterwards 98% indicated they had used them or were confident in their use..

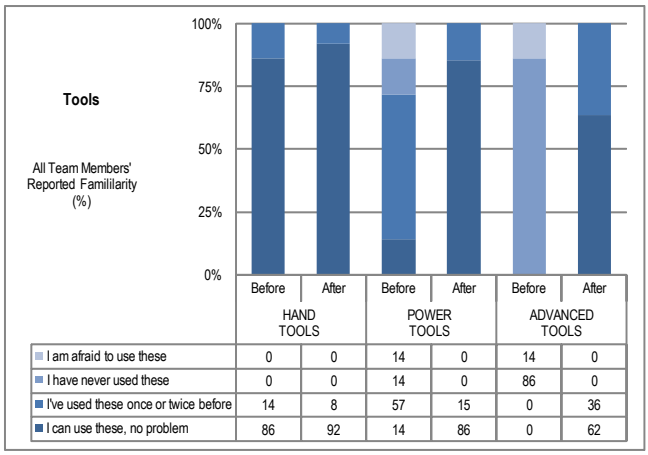

FIGURE 8
ALL MEMBERS' FACILITY WITH TOOLS – BEFORE AND AFTER PARTICIPATION.

COMPUTER TECHNOLOGY

Team members were asked about their familiarity with computer usage such as using windows or the internet as well as their familiarity with computer operations including basic programming or c^{++}. While 100% of the team members reported being able to use a computer prior to, during the course of their participation, they moved from being passive consumers of computer technology to active innovators. Sixty-two percent reported familiarity with programming, either doing this once or twice or programming with no problem, compared to 29% before joining the team.

DESIGN AND SPECIFICATION

Designing and specifying are crucial to moving beyond mere use of technological tools to arriving at innovation of technology. Being able to design things through drawing is

an important skill, but being able to design with advanced technology, such as CAD operations, shows mastery of today's most important tool, the computer. Similarly, specifying or ordering mechanical or electrical hardware implies not just understanding a problem, but understanding what is needed for its solution. As with the advanced and power tools in the previous section, 14% of the respondents reported being fearful of using these forms of design or ordering prior to joining Metal Muscle. After participation, 85% reported having used or being competent in CAD design and 77% reported having used or being competent in specifying hardware.

OVERALL EXPERIENCE

To gauge team members' overall experience, they were asked two key questions: 1) would they recommend that a friend join next year's team and 2) what is the likelihood of their becoming a FIRST Robotics Team mentor themselves, when the time came. To elicit qualitative comments, team members were asked what they enjoyed most about and what they felt could be improved with the Metal Muscle Team. Individual qualitative responses from the last two questions were analyzed and sorted into emergent categories.

Ninety two percent reported being likely to recommend that a friend join next year's Metal Muscle team. The majority, 54%, indicated they would highly likely become mentors when they entered college.

Nearly all of the qualitative comments about what the team members enjoyed most fit into one of three groups: Robotics, People & Relationships and Travel.

RESULTS

Evaluation shows the Metal Muscle Mentoring Pilot to be highly successful in its goals. Findings regarding team members' perceptions and skills after joining the Metal Muscle team include:

- 100% of sponsored team members intend to go college and obtain a professional degree, up from 71% prior to participation.
- 80% of sponsored team members report "definitely" intending to major in Science, Engineering, or Mathematics.
- The majority, 80%, report being happy working in a leadership position and are confident making decisions for the team.
- Only 8% report frequently finding a reason not to do something when under pressure, down from 43% prior to joining the team.
- Team members are significantly more willing to always solicit ideas, offer input, compliment others, give support, and show concern for others than prior to participation.
- 100% report showing peers respect frequently or always.
- 92% report showing adults respect frequently or always
- 85% report familiarity with CAD designing, compared to 29% before joining the team.
- Before joining the team, 100% reported never using or fearing use of advanced tools, such as a band saw or lathe. After participating, 100% reported familiarity or facility with use of advanced tools.
- The majority moved from never having used electrical, mechanical, or pneumatic systems before participation to having familiarity or facility in use after the team.

CONCLUSION

The Metal Muscle Mentoring Program was a positive factor in increasing educational ambitions, building leadership skills, instilling a sense of respect and producing a quantum leap in technical skills and knowledge for both sponsored and nonsponsored students, i.e., underserved and privileged students.

Through a minimal but committed investment of faculty, staff, students and facilities, nearly any institution of higher learning from community colleges to research universities can readily duplicate the Kettering University model of sponsoring a FIRST Robotics team, resulting in an increased interest in STEM programs and their own enrollments. Nearly 20% of all entering first year students at Kettering University have FIRST experience.

Government agencies and granting foundations can assist in promulgating the Kettering University model by partnering with colleges and universities. Financial support for appropriate proposals would have an exponential effect in propagating the Kettering University model. Visionary support, such as from the Mott Foundation, for unique and bold programs to avail the opportunities of the Kettering University model to underprivileged and socially disadvantaged high school students could produce astonishing results for the country; a highly educated and motivated citizenry.

REFERENCE

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