UNIVERSITY - PRE COLLEGE INTERACTION THROUGH FIRST ROBOTICS COMPETITION

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Abstract — *The FIRST Robotics competition offers an excellent opportunity for universities to excite high school students about careers in engineering while enhancing the engineering education of their own students. In this program Michigan Technological University engineering students handle tasks in design, manufacturing, and project management while mentoring local high school students. In the fall of 2001 Michigan Tech will adopt FIRST Robotics into its curriculum as part of its Engineering Enterprise Program. As part of the Enterprise Program, college students will learn skills important to engineering through courses aimed at leadership and teaming, but the heart of their learning will come from managing a significant engineering project, and communicating the results to campus and local communities. As a result, students will earn credit towards graduation via an alternative path. This paper elaborates on the FIRST Robotics team at Michigan Technological University. It explains how FIRST Robotics is organized, how it fits into the Enterprise Program, how it enhances the education of high school and college students, and plans for the future.*

Index Terms — *engineering projects, Enterprise Program, FIRST Robotics, pre-college interaction.*

WHAT IS FIRST ROBOTICS?

Imagine thousands of fans in a crowded arena cheering for their teams. Fans with painted faces and team uniforms dance in the aisles to music playing over loudspeakers. Excitement peaks as the competitors take the field and another match begins. This is a familiar scene to most American high school and college students. It describes almost any sporting event, but there is a difference here. The competitors on this playing field are made mostly of metal; they are battery powered and operate with several electric motors and some pneumatics. They are radio-controlled robots that have been designed and built to play a specific game. Another big difference between this and most sporting events is that the "fans" have been integral in the manufacture of their robot competitor. This just begins to describe a FIRST Robotics competition; you really have to see one to believe it.

The name FIRST is the acronym of, "For Inspiration and Recognition of Science and Technology." FIRST's mission is: "to excite young people about the fun, accessibility, and importance of science and engineering."

The following description of the FIRST Robotics competition is taken from their website.

"The FIRST Robotics Competition is a national engineering contest which immerses high school students in the exciting world of engineering. Teaming up with engineers from businesses and universities, students get a hands-on, inside look at the engineering profession. In six intense weeks, students and engineers work together to brainstorm, design, construct and test their "champion robot". With only six weeks, all jobs are critical path. The teams then compete in a spirited, no-holds-barred tournament complete with referees, cheerleaders and time clocks.

"The partnerships developed between schools, businesses, and universities provide an exchange of resources and talent, highlighting mutual needs, building cooperation, and exposing students to new career choices. The result is a fun, exciting and stimulating environment in which all participants discover the important connection between classroom lessons and real world applications.

"Each year, the competition is different, so returning teams always have a new challenge to look forward to. However, the details are kept secret until the unveiling at the Kick-Off workshop. This provides a high level of excitement as everyone sees the new challenge for the first time and ideas immediately begin forming in people's minds."[1]

Typically FIRST teams are joint ventures between corporations and one or more high schools. Hundreds of corporations across the U.S. sponsor FIRST teams. Government agencies are also significant FIRST supporters. NASA, for example, is a partial sponsor of 139 teams. Several universities, with financial help, also sponsor FIRST teams. (Approximately 30 of the 530 teams registered for the 2001 competition list a college or university as a partial sponsor.) The 2001 competition was the inaugural season for a FIRST team sponsored by Michigan Technological University (Michigan Tech).

A Typical FIRST Season

An outline of a typical FIRST season schedule is shown below. This skeleton outline shows only major task categories, while the text following the outline describes the season in more detail.

- September-October; organize team
- October-December; facilitate fundraising and teambuilding activities

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- January-February; obtain game rules, design, build, and ship robot
- March-April; attend competitions
- May-June; review season, prepare for next season

For a university FIRST team, the season begins with the new academic year. When students arrive on campus they need to organize the team and prepare for the season ahead. There are many tasks to be accomplished at this time, but the most important thing is to recruit high school teachers and students. This needs to be completed by around the end of October.

Once the team membership is decided, the process of team building can begin. Some action items that require teamwork during this phase of the season are making a team logo, public relations work, and fundraising.

In December, the entry fees for competition are due, and roles for all team members should be clearly defined. The size, makeup and organization of the team will determine how many work groups will exist and which jobs each is responsible for.

January brings the start of the official competition season and the Kick-Off workshop, which takes place in New Hampshire. This is where the rules of the new game are revealed to an expectant crowd. Each year the game is designed to test the abilities of the robot design/build team and the high-school student operators who must drive the robot in competition. In addition to the rules of the game, each team also receives its robot "kit" at the Kick-Off.

The word kit is a bit of a misnomer as used here because much more material is needed to make a robot than is included with the kit. Mainly the kit consists of the control system and a set of about 13 standard motors, which are the only ones that can be used on the robot. There is also a complete pneumatic system with actuators, conduit, and valves. Twelve-volt motorcycle-type batteries are also provided to power the robot. This kit is then taken back home to begin the building of the robot.

After Kick-Off, the next six weeks will reveal how well your team is structured. This is where prior planning will pay off, and lack of it will become very obvious to the students. There are only six weeks allowed to complete the robot and ship it to competition. The six-week time limit is strictly enforced and is a very significant factor in the design/build process. Once the robot is completed and shipped there is a welcome lull in activity as the team prepares to travel to competition.

March and April are the months of competition and teams can start to enjoy and appreciate what they have accomplished. Students are able to watch their robot perform and see how its performance compares to the design goals.

The end of the competition season corresponds with the winding down of the school year, but there is plenty to do before summer break. Listed below are several end-of-season tasks:

- Giving presentations to show the robot to school and community groups.
- Recruiting new students for the following year.
- Seeking funding sources.
- Reviewing the season to determining where and how to improve.

Because the FIRST schedule parallels a typical academic calendar it can be packaged to fit into the curriculum at most universities. FIRST Robotics also makes a perfect fit with the changing focus of engineering education towards a design-project oriented holistic approach.

FIRST at Michigan Tech

FIRST Robotics only exists at Michigan Tech because students who participated in FIRST while in high school wanted to continue the experience at college. Because it is truly student driven, students see the value in learning things like teamwork and communication skills and how they fit into an engineering career. Tapping into the motivation of these students results in a great learning opportunity.

FIRST Robotics at Michigan Tech began as an unofficial student group teamed up with one local high school. Funding came primarily from a distantly located company, which had sponsored one of the student's team the previous year. The only tie to Michigan Tech was the fact that the team leaders were students there.

The following season (2000-2001) saw more organization as well as significant support from the University and its administration. Several departments across campus gave money, materials and other resources to help support the team. Another funding source was through a National Science Foundation (NSF) program to facilitate interaction between engineering students and K-12 institutions.

Along with support from the University, the FIRST team also strengthened ties with local schools. The project became a collaborative one between the University and the Copper Country Intermediate School District (CCISD). The CCISD represents several high schools from the local area, and students from all of these high schools are eligible to be a part of FIRST Robotics. This relationship is critical to the success of our FIRST Robotics team.

In the upcoming year (2001-2002), FIRST Robotics will become officially integrated into the engineering curriculum at Michigan Tech. This will happen through the Enterprise Program, a new endeavor designed to get engineering students involved in "real life" projects.

MICHIGAN TECH ENTERPRISE PROGRAM

In 1998 Michigan Tech received funding from the National Science Foundation through the Action Agenda program to assist in a major overhaul of its engineering curricula. One of the key features of the successful grant application was

the implementation of a program called the Engineering Enterprise. The 2000-01 academic year marked the first year of operation for Enterprise. There were 11 enterprises in operation and there are several more planned for next year. One of these will be a Robotics Enterprise.

Students elect to join an Enterprise at the beginning of their sophomore year and continue to participate within the organization through graduation. As they work in the Enterprise, they take on increasing responsibility for its operation and management. When students are seniors, they will be the enterprise leaders; directing, managing, encouraging, and supervising the sophomores and juniors on the team. Students from outside of engineering, e.g., business, technical communication, computer science, can also participate in Enterprise. The Enterprise curriculum consists of several 1-credit modules of instruction as well as credit for design project work. It is expected that students will work on several real-life design projects over the course of their three-year involvement in an Enterprise. [2]

An enterprise may have an industrial sponsor to provide financial support, in return students help find solutions to engineering problems. The Michigan Tech Robotics Enterprise will be partially supported by at least two such sponsors, Shafi Inc., and Adept Robotics Inc.

When considering how to incorporate FIRST Robotics into the curriculum, making it part of the Enterprise Program was an ideal fit. Figure 1 shows how FIRST Robotics will be incorporated into the Enterprise Program and also its relationship with other major partners.

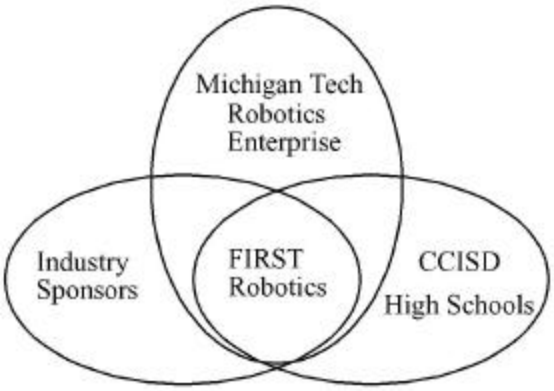

FIGURE. 1
RELATIONSHIP OF ORGANIZATIONS PARTICIPATING IN FIRST ROBOTICS

Within the Robotics Enterprise, FIRST will be just one part of the overall program. There will also be an autonomous robot project with its own design competition, as well as projects that come from the industrial partners. Students joining the enterprise will choose which projects they prefer to work on, but must make a significant contribution to earn project credit toward their degree. The Enterprise Program provides an avenue for evaluating this contribution and awarding credit.

EDUCATIONAL VALUE

The educational value of the Enterprise Program and specifically the FIRST Robotics project is manifold. For the college students, the educational aspect of the project is more formal because they are earning degree credit. For the high school students, FIRST serves primarily as a means to get them excited about careers in technology related fields. Hopefully (and this is often the case) the students become energized by the experience and want to learn more about engineering and technology in order to participate on the team to a greater extent. Educational benefits for both groups of students are outlined below.

College Students

Since these students are earning degree credit by their participation in FIRST, there needs to be a way to evaluate their work. Fortunately the Accreditation Board for Engineering and Technology (ABET) has a means of doing this. According to ABET, engineering programs must demonstrate that their graduates have:

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. [3]

These criteria provide benchmarks against which student work can be judged in order to evaluate their progress toward becoming an entry-level engineer. Most of these criteria are directly addressed by the FIRST Robotics project (two exceptions being h and j). As part of their enterprise experience, students themselves will help determine methods of assessment to evaluate the level to which these criteria are being met. Two major areas of assessment are project management and design/manufacture.

Functioning on a team is an important part of project management, and college students often need guidance in this area. FIRST Robotics offers a great opportunity for learning teaming skills. Employers desire these important skills and students who can demonstrate expertise in this area have an advantage over those who can not.

FIRST Robotics gives students an opportunity to take charge of at least one aspect of a project. For instance, at Michigan Tech the incoming Robotics Enterprise students have developed a plan for organizing the enterprise in a businesslike manner. They are also working to develop a mission statement and "corporate" logo. These will give the Robotics Enterprise its own identity and increase the commitment of the students involved by giving them ownership.

Even before officially being enrolled in the Robotics Enterprise, students have defined several items critical to the smooth operation of FIRST Robotics:

- Annual Operating Budget
- Project Timeline (to include entire academic year's activities – i.e. student recruiting, fundraising, robot design/build, etc.)
- Funding Plan
- Definition of roles/responsibilities of all team members (Michigan Tech students & faculty, CCISD students & faculty, parents of high school students)
- Recruiting Plan (for both high school and Michigan Tech students)

By identifying these items and then developing each one, students are gaining valuable experience in project development, and beginning to satisfy several of the ABET outcomes. Project management is an important engineering skill that is honed through participation in FIRST Robotics, in addition, valuable lessons are also learned from designing and building the robot.

It is during the design/build phase when students experience both the joy and heartbreak of turning ideas into operating systems. This is when they really learn about engineering, and the difference between being an engineer and being a technician.

New college students have a strong tendency to "just build it" which, if allowed to continue, takes away much of the learning from all students. Learning to plan and implement the entire design process can take a long time, but it is often the most valuable lesson that is learned in FIRST Robotics.

Integrating several different systems to function together is one of the most difficult tasks engineers encounter. FIRST Robotics is an excellent training ground for practicing this skill. For example, students must analyze the rules of the game and then agree on a realistic design concept to meet their goals. Then, several systems such as drive train, mechanical arm(s), and electrical wiring, have to be integrated into one package. To compound the problem, the results of the integration must be within stipulated size and weight limits. This is a challenge that can test even the most experienced engineering teams. For college students it is often a very painful, and thus meaningful, learning experience.

To insure that the enterprise is in fact adding to the value of its members' education, ongoing assessment is necessary. The framework for this is again provided by the ABET outcomes a-k and also may include placement data of graduates from the program along with industry surveys.

High School Students

Like the college students, high school students benefit in many ways from their experience in FIRST Robotics. They put math and science principles to work when conceiving the robot's design. When high school teachers are part of the team, their students benefit by being introduced to engineering fundamentals in the classroom. High school students may also get involved in the building of the robot.

Although the bulk of the robot manufacture is done by college students and outside shops, high school students have the opportunity to participate in the process. In the Michigan Tech program, local vocational educators have helped students make robot components in their shop facilities. The components are then assembled and tested in a facility provided by the CCISD, where students spend many hours outside of their regular school schedule.

At competitions there is a charged atmosphere where high school students learn many lessons. Some of these are specific to engineering, while others have much broader application. Winning is important in FIRST but it is far from the most important thing. The words "gracious professionalism" form the essence of all FIRST competitions, and being helpful and courteous to other teams is the expectation rather than the exception. This makes for a much more positive environment than most other competitive events.

High school students can also learn from helping with a myriad of activities that do not involve the robot directly. The following list presents several of these tasks:

- Making an animated video using sophisticated 3-D software.
- Raising funds for the team to travel to competitions.
- Making presentations to school and community groups.
- Constructing a mock-up or full size playing field so the robot can be tested in conditions similar to competition.
- Collecting or producing video, photographic and written documentation of the team's activities for a scrap book.
- Working on documentation for one of several awards, which are presented to FIRST teams at competitions.

All of these tasks, and many more, provide opportunities for interested high school students learn. Hopefully these students will enjoy their FIRST experience and go on to pursue a career in a technical field such as engineering. This is the ultimate goal of FIRST and one of the goals of the FIRST Robotics team at Michigan Tech.

BARRIERS TO SUCCESS

As with all new endeavors, there are many things about starting a FIRST program that need to be approached with open eyes. The following paragraphs describe several challenges that we, the Michigan Tech FIRST Robotics Team, have faced and some of the strategies being used to overcome them.

Often the biggest obstacle to supporting a FIRST team is the cost. The entry fees alone are $5000 for the first contest and $4000 for each successive event (2000-01 prices). The price of the first entry fee includes the robot kit. On top of this there are expenses for additional materials to build the robot, and for the team to travel to competitions.

Depending on the location of the team, travel costs can range from minimal, to prohibitive, as is the case at Michigan Tech. The nearest regional competition is 400 miles away and the cost of flying from our remote location is quite high. Our team consists of about 15-20 college students and a like number of high school students. Adding on faculty and chaperones means we might have to transport as many as 50 people to competitions. The 2001-02 targeted budget figure for our team is $53,000 with more than half of that amount earmarked for travel expenses. (This is to compete in three events; two regional competitions, and the National Championships in Orlando, Florida.) However, this is not a minimum figure needed to operate. This year our team spent around $27,000, which paid entry fees, built a robot, and sent a skeleton team to two competitions.

Getting supervisory personnel from high schools to participate in FIRST has proved more difficult than getting students. Teachers are generally very busy and often feel they don't have the time to give to yet another extracurricular activity. However, once involved, teachers often see the potential of the program and help to provide a support system at their school. At Michigan Tech we have met with groups of teachers to tell them about FIRST and its educational benefits. We hope that these teachers will become more interested and help spread FIRST in their respective schools. Without the support of high school teachers, a FIRST team is extremely handicapped, because college students and faculty are not generally equipped for supervision of high school students. Therefore, the amount of learning for all students is considerably reduced.

Community support is also very important to a FIRST program. Because of the high school involvement, many community and business leaders are willing to provide financial and other support to a FIRST team. There are many examples of this with established teams. Some local government bodies even sponsor teams. Getting support from the community is crucial but can also be difficult. Making presentations to local service clubs, chambers of commerce, and other organizations, is a good strategy to begin building community support. It should be recognized however that this is a long-term process; persistence and a willingness to succeed are mandatory.

FIRST is working its way into more and more universities as high school students want to continue their FIRST experience into their college years. This is a good thing, but can also be a liability, especially while starting a program. These students come to college with their only FIRST experience being from the high school student's "fun" perspective. Going from a "fun" centered environment to the engineering/mentoring centered environment is very difficult for some students. It is hard for them to realize they must now take on a different role, one that carries with it a great deal of responsibility. This is nothing new, as college professors often encounter students who come to college with a less-than-serious attitude. In FIRST, however, the effect is amplified due to tight deadlines, pressures of schoolwork, and mentoring high school students who are often close in age and maturity. Some university teams offer training in mentoring skills to help with this problem. Michigan Tech and Virginia Tech both offer such courses. As the FIRST program ages, however, older more mature students will make up a critical mass of the team. They can then help newcomers make the transition from fun-loving student to fundamentally-sound engineer.

To be sure, starting a FIRST program at the university level is fraught with challenges. If properly planned and executed, however, the experience can add much to an existing curriculum and give the graduating participants a significant advantage when seeking employment.

ADDITIONAL BENEFITS OF FIRST ROBOTICS

In addition to the educational benefits, there are many other benefits to organizations that are part of the program. Ties between university and industry are developed and strengthened which are mutually beneficial. Industry can, through the Enterprise Program, tap engineering students for solutions to engineering problems. Pipelines are established for corporations and colleges to recruit fresh engineering talent. The university benefits not only from the relationship with industry, but also through the pre-college interaction. FIRST is an ideal recruiting tool for the university because it enables high quality contact between high school students interested in engineering and university students, staff, and facilities.

The successful university FIRST team will be a partnership of several organizations such as these:

- student groups (high school and college)
- university and high school faculty
- local school districts
- local community and business groups
- industrial partners
- university administration.

Organizing these into a cohesive unit is no small task, but the result will be a partnership that benefits all and makes for a superior educational program.

The FIRST students and faculty at Michigan Tech are looking forward to many successful seasons. Beyond that, it is hoped that program participants will continue to support their former FIRST team, and continue a productive relationship with Michigan Tech.

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