Developing Undergraduate Mentorship Skills Through BEST

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Abstract – This paper discusses the use of undergraduate engineering students as mentors to junior-high and high school students competing in the Boosting Engineering, Science, and Technology (BEST) robotics competitions. BEST mentors are a key element in the competition, donating their time and effort to advise teams throughout the entire engineering process, from initial requirements definition, design and implementation, and into the competition itself. Mentors provide guidance, offer ideas and advice, act as sounding boards, teach specific engineering skills on an as needed basis, and act as construction supervisors overseeing the robot building process.

Keywords: BEST, Undergraduate Mentoring, Robotics Competition

OVERVIEW

As a volunteer organization, the BEST mission is to expose junior-high and high school students to the practice of engineering through annual robotics competitions. By providing teams with challenging, hands-on design and construction scenarios—and a competitive environment within which to demonstrate their efforts—students gain first-hand knowledge of the engineering process and how to apply it when solving complex technical problems.

Currently, over 8000 students participate in BEST competitions held each fall across the United States. Student teams design, construct, test, and field a robotic solution to a novel challenge problem constrained by a limited amount of material and time. Teams build and operate a radio-controlled robot to solve a particular set of problems within a time limit while competing against other robots. Only hardware provided by the contest organizers may be used in constructing the robot. These parts include a returnable radio transmitter and receiver, servos, pulleys, batteries, and switches. Additionally, each team receives a consumables kit of raw materials such as plywood, PVC piping, glue, screws, nuts, bolts, wire, connectors, etc. Their task is to turn these parts into a mobile robot capable of navigating within a playfield, carrying, moving and retrieving various items as dictated by the contest rules and scenario description, which changes annually.

Under the guidance and tutelage of technical mentors, the students participate in all aspects of the engineering process, from initial requirements gathering through design, production, test, and finally fielding a working system. The contest rules also require students to market their robot, present demonstrations to various groups in the community, and build a booth to display the robot and their documented development process on competition day. All requirements must be completed in a maximum of six weeks. Certainly this is a challenging activity for junior-high and high school students!

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BEST MENTORS

A key element in the BEST competition is the use of mentors. Mentors play the role of technical and organizational coaches by providing guidance, offering ideas and advice, and acting as sounding boards. They teach specific engineering skills on an as needed basis, act as project managers, and oversee the actual construction and testing of the robot. Note, however, that BEST is about student involvement and student-led activities. The students are placed in control of the project from the outset, making the key decisions and determining the direction of their efforts. Mentors offer suggestions and help to clarify the more challenging engineering concepts, but the team does the majority of the work.

Mentors are typically practicing engineers or other technical professionals; however this does not have to be the case as they often come from unique and diverse backgrounds. There are no formal qualifications or requirements for mentors.

THE 2006 DAVID LIPSCOMB CAMPUS SCHOOL BEST ROBOTICS TEAM

This paper is based on the authors' experiences as mentors for the 2006 David Lipscomb Campus School (DLCS) BEST team. DLCS is a K-12 college preparatory school located adjacent to the campus of Lipscomb University. As this was the first year for DLCS to field a BEST team, one of the DLCS team organizers contacted the Raymond B. Jones School of Engineering (RBJSE) at Lipscomb University about providing a mentor for the team, to which the RBJSE agreed.

The engineering curriculum at Lipscomb University has a strong hands-on component. The University believes that students need to be involved in laboratory and project work throughout their academic careers. However, due to the nature of undergraduate engineering, virtually all of the planning for laboratory and project work is done by the faculty (a notable exception to this is the senior design project). This places students in the role of learners instead of leaders or managers. In an effort to broaden the experiences of undergraduate engineering students, and given that BEST competitions are organized around university hubs, the RBJSE saw the BEST competition as a vehicle to provide it's students with engineering leadership and mentorship experiences in the form of a ready-made mentorship laboratory. This allowed Lipscomb University faculty to teach their students how to teach others, and they dubbed the experience "mentoring the mentors."

A multidisciplinary "mentorship team" was formed, consisting of one faculty member acting as senior mentor, and three undergraduate engineering students acting as assistant mentors. The remainder of this paper describes the experience of organizing and fielding this team.

MOTIVATION

The motivation for involving undergraduate engineering students was two-fold. As previously mentioned, engineering educators are always looking for new and exciting ways to connect the classroom experience with the real world of engineering. Mentoring a team in the BEST competition seemed like an ideal opportunity for such an experience. Students would be able to put into practice what they learned in the classroom while furthering their professional growth as engineers and technical leaders.

However, the motivation extended beyond merely taking advantage of an interesting technical setting within which students could practice engineering. Lipscomb University has a strong commitment to provide it's students with service-learning opportunities, blending academic development with community service. Such involvement helps create a life-long commitment within students to the service of others. By allowing them to apply their skills in a variety of ways—intellectually, socially, and physically—they make a real and positive difference in the world around them.

MENTORING THE MENTORS

To ensure RJBSE students success as BEST mentors, it was deemed necessary to first carefully select undergraduates for these positions and give them guidance and assistance as they prepared to take on the challenge of becoming technical consultants and advisors to the DLCS BEST team. The selection and preparation process are discussed below.

Mentor Selection

After becoming familiar with the BEST competition in general, and looking at past BEST competition results, it was decided that three student mentors would be needed to assist the DLCS BEST team. Two of the mentors would be from the Electrical and Computer Engineering program to provide guidance in controls, power distribution, electronic circuitry and radio control. The third student mentor would be from the Engineering Mechanics program, providing expertise in mechanical structures, component design, materials testing, and construction techniques.

Two weeks before the BEST competition began, the mentor positions were advertised by various RBJSE faculty in their classes. Several students expressed interest in joining the team. Three were selected as assistant mentors, based on personal interest, background, and programs of study.

Preparing the Assistant Mentors

While the students had the necessary engineering background and enthusiasm, they lacked some of the necessary people skills needed to form, nurture, and guide a team of junior-high and high school students. They were somewhat apprehensive at the thought of being responsible for the team's success. The mentors needed some mentoring!

To orient the new assistant mentors and develop a framework from which to operate, the faculty mentor held a meeting shortly before the competition began. In addition to encouraging them and sharing personal experiences with regards to teaching and mentoring others, several BEST documents were reviewed and discussed. These included a paper on the responsibilities and expectations of BEST mentors [BEST, 1], a booklet discussing how to lead and coach students throughout the competition [BEST, 2], and a technical presentation on the engineering and design process [BEST, 3]. This discussion and review went a long way toward clarifying the assistant mentor's roles, duties, and responsibilities within the team. Along with the clarification of the assistant mentor's position within the team came a reduction in their apprehension about the task before them. After studying the aforementioned documents, and discussing how each mentor fit into the overall strategy of the team, they were ready for their first meeting with the team.

The Pre-Kickoff Meeting

The DLCS BEST team's first meeting was held one week before the official start of the BEST competition. Because the competition had not yet begun, the actual game scenario was unavailable. However, the BEST website contains a substantial amount of information concerning past competitions. Using this information, the mentors gave the team a big picture view of the competition and helped them develop questions to ask of the BEST organizers at the official kickoff meeting the following week.

Several goals were identified for the first meeting, including introducing the team members to one another, conducting a team building exercise to assess skills and interests, and determining project goals and priorities. Also, as an introduction to the engineering process, the mentors led a discussion of the various activities and involvement needed over the course of the competition. The members of the DLCS team then divided into sub-teams, which would specialize on one aspect of the competition, and provided a tentative schedule for future meetings. In summary, our first meeting included the following activities:

1. Introductions of the team members and parents to each other, and to the mentors,
2. A review and discussion of the general BEST competition rules and previous competition scenarios,
3. An introductory presentation by the mentors of the engineering process, along with a guided discussion of how this process could be applied to the work the team was undertaking,
4. An assessment of each team members' skills, abilities, and interests,

5. A period of discussion about individual team member responsibilities, and
6. Creation of a meeting schedule.

While all of these activities were recognized as important to a successful BEST team experience, the assessment of each team member's skills and abilities was deemed the most critical. To help with that assessment, we devised an engineering exercise for the team. The exercise itself, along with our motivation and observed results, are discussed below.

The Team-Building and Skills Assessment Exercise

To integrate the mentors and team members, the students were divided into three groups and given one hour to solve an engineering problem. This provided an opportunity to determine team member's skills and interests, and gave the senior mentor an opportunity to observe the assistant mentor's technical and social leadership abilities.

An assistant mentor was assigned each team, and the teams were told to construct a tower capable of holding at least one full can of soda at a height of no less than 30" above the ground for a period of one minute without falling. The teams were provided a limited amount of materials with which to construct their towers—100 plastic straws, 10 clothes pins, and a few feet of duct tape.

Each team was advised to follow the engineering design process. First, they had to make sure they understood the problem completely. Next, they discussed and sketched alternative solutions to the problem. Once a design was chosen, they began constructing their towers. The assistant mentors were given limited guidance for this exercise. They were told only to advise their teams, not do the work themselves, and to use their engineering, planning and leadership skills to help the team achieve the best results.

At the end of the hour, each design was tested. After adding additional cans of soda, a winner was declared. Next, each team had to choose a spokesperson and explained their design strategy, including any alternative designs that were proposed but rejected. Finally, the team members had snacks and reviewed the evening's events.

While the team members were socializing, the mentors had a private follow-up meeting to discuss what they had observed and learned during the exercise. The results were somewhat surprising, at least to the student mentors. They discovered that the students needed much more help than they had originally anticipated, especially when analyzing and critiquing design ideas. The mentors also discussed the social aspects of the team—who were the leaders and who were the followers. These discussions would contribute later to actual team member assignments to the various working groups that were formed.

Additionally, feedback was provided to the assistant mentors on their performance. Each had displayed a natural and unique style of mentorship. One was very hands-on, leading his team into early prototype development—his team tried out several ideas before deciding on the final approach. Another was very analytical, guiding his team in the process of critical thinking and ideation. This group's only prototype became their final solution. The third was much more laissez-faire, allowing his team to work out many of the challenges on their own, only contributing when asked or invited in by the team. The mentoring styles employed in the assignment complemented each sub-team well For example, the hands-off approach was directed toward a team with several members who were comfortable taking the lead within the group, while the analytical mentor had students that were very good at visualizing and discussing their ideas.

This team building and skills assessment exercise was deemed a complete success by the mentor team and the students alike. It highlighted everyone's interests, skills, and abilities, while allowing the team to become comfortable working together to solve problems. It also created an initial bond between the team members and their mentors, forming a good foundation for future work and interaction. The skills assessment exercise was a key factor in the overall success the team.

Mentor Assignments

Once the BEST competition officially began, the team identified three areas on which to focus. For each area of the project a sub-team was formed. The first two sub-teams were concerned with the design and construction of the two

main pieces of hardware: the radio-controlled motion base and the reaching arm mechanism. The arm mechanism was used to place and retrieve contest items (the 2006 BEST contest scenario involved hanging wet laundry on clothes lines of various heights, as well as taking down dry laundry from the same lines). These two sub-teams worked somewhat independently. The third sub-team—the electrical team—focused on the transmitter, receiver, servos, and wiring. This team worked closely with the other sub-teams, as each needed electrical design and construction advice.

In a manner similar to the initial skills assessment exercise, each assistant mentor was assigned to one of the sub-teams. The senior mentor played the role of roving technical expert, becoming involved with each sub-team on an as-needed basis. This arrangement worked out very well, as it gave each sub-team the autonomy to focus on their particular problem domain and design a solution that would optimize their given set of constraints. With this arrangement of sub-teams, the team was ensured that the subcomponents would fit together and work in concert with each other during the all-important integration phase. The integration phase is a critical construction phase that must be carefully planned and coordinated, as six weeks doesn't allow much time for going back to the drawing board.

OUTCOMES

Competing in the BEST competition provided many opportunities for team members to experience growth, both socially and technically, while experiencing engineering in a real-world setting. The approach of involving student mentors extended this experience by giving the mentors a chance to develop new skills as well, particularly those involving technical mentorship. To experience first-hand what is involved in leading a diverse team of technical subordinates was another learning opportunity.

The assistant mentors were accepted by the DLCS team from the very beginning. This is attributed in large part to the skills-assessment exercise discussed previously. The junior high and high school students really liked the opportunity to work with university students. In addition to learning about engineering, the team members asked many questions about the college experience. They were interested in what engineering school was like, what made the mentors decide on engineering, how the mentors decided among the different types of engineering, and what they planned on doing after graduation. This close working relationship between the team members and the mentors allowed for conversations to take place that otherwise may never have happened. It brought the profession of engineering into focus for the students, and generated a level of excitement that cannot be matched by campus visits or engineering day events alone.

In summary, the experience of involving engineering students as BEST mentors was a resounding success, and we recommend this approach to others considering involvement in similar competitions.

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