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TechSTEP: Connecting High School Teachers and Students to Integrated Engineering and Science

Abstract

TechSTEP is an NSF-funded program developed by the mathematics, science and engineering faculty of our College. The primary goal is to motivate students to consider mathematics, science, and engineering majors in college. Faculty members from the College of Engineering and Science have teamed up with area high school teachers to develop engaging projects aimed at high school juniors and seniors. These projects utilize techniques that have proven successful in our Integrated Engineering and Science Curricula, including team building, collaborative learning, and hands-on activities. Close collaboration between college faculty and high school teachers maximizes the benefit to students by having both their regular teachers and university faculty directly involved in their projects. This team approach involving both high school and university teachers and the integration of topics sets our project apart from the more traditional high school weekend science camps. TechSTEP also serves as a model for the students by effectively demonstrating how diverse teams can often provide better solutions to problems. Moreover, the relationships that are built between the high school and university faculty will have a long-term impact on all students influenced by these high school teachers.

TechSTEP consists of three distinct projects which are delivered on a three-year cycle. These projects are each centered on a common theme which connects high school level math and science to engineering. Each year’s theme showcases a topic that encompasses engineering concepts, as well as team skills, creative problem solving, and career exploration. These themes serve as good applications of algebra and trigonometry, are very hands-on and intuitive, give an excellent introduction to engineering design, and easily lead to a design competition. The projects pique student interest and show the importance and relevance of both mathematics and science.

Introduction and Background

According to the National Science Board’s Science and Engineering Indicators 2004, enrollment in undergraduate engineering and science programs decreased sharply during the 1980s, followed by slower declines in the 1990s. Since 2000, enrollment numbers have begun to increase again; but the report also indicates that, of those students who do enroll in engineering and science programs, fewer than 50% earn an engineering or science degree within six years. Clearly, there is a continued need for increased enrollment and retention in science and engineering. In The Science and Engineering Workforce: Realizing America’s Potential, the Board strongly recommends national-level action to provide an adequate number of science and engineering graduates to ensure competitiveness in the ever changing global economy (NSB 2003).

Louisiana Tech University’s STEM Talent Expansion Program (LaTechSTEP), funded by the National Science Foundation, has two major components that will yield increased numbers of graduates in STEM disciplines. One component focuses on recruitment of new students, while the second component increases retention of enrolled students. The Recruiting Component, hereafter referred to as TechSTEP, described in this paper stimulates interest in STEM topics at
the high school level by partnering with area and regional math and science teachers in Discovery Weekends for high school students. Our overall goal is an annual increase in STEM graduation rates from 220 students per year to a sustainable 300 students per year.

**High School Partnerships and Discovery Weekends**

The goal of TechSTEP is the development of partnerships with key feeder high schools in our area. These partnerships are formed through a series of three Teacher Workshops, each leading to a Discovery Weekend for students. They are held on Saturdays from 9:00 am to 4:00pm and are designed around a common engineering or science theme for the year. The Teacher Workshops, led by engineering, mathematics, and science faculty at Louisiana Tech University, illustrate practical applications of high school mathematics and science topics. The Discovery Weekends include project-oriented, hands-on engineering and science activities following the same theme as the Teacher Workshops. The culminating Challenge Weekend includes a design competition in which students apply knowledge gained throughout the year. Students who participate in this program will have a broader exposure to applications of mathematics and science and will be more likely to choose careers in one of the STEM areas. Improved preparation and motivation will also increase the success of these students in completing an engineering or science degree.

**Teacher Workshops**

The goals of the Teacher Workshops are to demonstrate applications of fundamental mathematics and science topics that can be integrated into high school math and science classes as well as to develop meaningful and engaging relationships between the university faculty and the high school teachers. During these workshops, the teachers form teams with a college student mentor and together work through the same projects that their high school students will complete the following week. This preview ensures that the teachers are comfortable with the Discovery Weekend material. These workshops also provide the opportunity to explore related topics at a deeper level with the teachers.

**Discovery Weekends**

The primary goal of the Discovery Weekends is to motivate high school students to consider mathematics, science, and engineering majors in college. Discovery Weekends are held one to two weeks after each Teacher Workshop. The interdisciplinary teams of high school teachers, college student mentors, and university faculty formed during the Teacher Workshops conduct the Discovery Weekends. This collaborative team approach, the integration and depth of STEM topics covered, and the inclusion of a global and societal context set these projects apart from many traditional high school weekend science camps.

**TechSTEP Projects**

TechSTEP includes three distinct themes: *Bridges to Engineering, The Fuel Cell Future, and Catapult to Success*. These projects are rotated on a three-year cycle so that students who participate as juniors and again as seniors experience different content. In addition to basic
design concepts, each project includes in-depth engineering analysis and other topics such as global, environmental, and communication issues.

TechSTEP began as a pilot project with an area high school, during which it became apparent that interaction with a small group of teachers was necessary in order to adequately tailor the engineering material for high school students. This pilot significantly impacted the structure of TechSTEP. As a result, we determined that each of the three TechSTEP projects should be piloted prior to full-scale implementation.

**Bridges to Engineering** – The goal of *Bridges to Engineering* is for students to work in groups to design and build bridges made of manila folder material. The students learn the mathematics behind bridge design and ultimately compete with the bridges they design. This project was modified from Dr. Stephen J. Ressler’s *Designing and Building File-Folder Bridges: A Problem-Based Introduction to Engineering.* Discovery Weekend 1 begins with the teams building a bridge out of manila folder material, following a template provided by the TechSTEP team. The students are introduced to engineering fundamentals such as the Method of Joints. Discovery Weekend 2 continues with the analysis of the bridges built during Discovery Weekend 1. Using the Method of Joints, each team predicts the force their truss bridge will carry before failing and the member at which it will fail; then they test their bridges using a materials testing machine and compare their predictions with the tests. In preparation for the Challenge Weekend, each team designs and analyzes their own bridge and prepares a presentation about their design. During the Challenge Weekend, the teams construct and test their bridges; awards are given for the strongest bridge, most accurate predictions, best presentation, and quality of construction. The students also tour Louisiana Tech University’s structural research facilities. Future plans for this project include developing “smart” bridges by incorporating student-built strain gages.

**The Fuel Cell Future** – The ultimate goal of *The Fuel Cell Future* project is for each team to build a small model car powered by a fuel cell. To place this project in context, we discuss and mathematically model global population growth and world-wide energy sources. A preliminary design competition is used to introduce creative problem solving and teamwork. This preliminary competition is to build and race a small battery-powered car from a box of assorted items (similar to a scene in the movie *Apollo 13*.) The students are then introduced to fuel cell technology, gear trains, solids modeling, and prototyping methods leading to a final design challenge. Based on the topics from the first two Discovery Weekends, students create a computer model of a chassis for their fuel cell cars. This model is used to print a plastic version of the team’s chassis using a rapid prototyping machine. The Challenge Weekend includes several competitions ranging from tug-of-war to a race; therefore, students must consider multiple design constraints. The students also tour the Center for BioMedical Engineering and Rehabilitation Science to gain a broader perspective on careers in engineering and science. *Figure 1* shows in more detail the relationships between the Teacher Workshops and the Discovery Weekends, as well as the flow throughout the entire project.
Figure 1. Teacher Workshops and Discovery Weekend Plan for *The Fuel Cell Future* TechSTEP Project.
Catapult to Success – The goal of Catapult to Success is to design and build an automated catapult capable of receiving a ball from one team and delivering it to the next until the ball has completed a circuit through all teams’ catapults. Many of the interactions regarding the design of the teams’ catapults occur via electronic communication – modeling the global work environment. Discovery Weekend 1 begins with teams constructing catapults from foamcore, wood, and general hardware. After constructing their catapult, the students develop a mathematical model based on the principle of Conservation of Energy to predict the range of their catapults. The groups also watch a thought-provoking video and discuss the social and ethical implications of rapid changes in technology. To conclude Discovery Weekend 1, the catapults are tested to see if predictions match actual performance. Between Discovery Weekends 1 and 2, students are challenged with an e-Hunt (similar to National Treasure) designed to build community among schools. Discovery Weekend 2 includes an exercise to improve the students’ ability to effectively communicate the details of a design project. To further increase students’ ability to function in a global environment, a panel comprising international faculty and students discuss cultural awareness issues. An automatic release mechanism is designed for the catapults. The catch mechanism and final designs are done via email prior to the Challenge Weekend. The Challenge Weekend begins with the “Catch and Release” activity, followed by more traditional catapult competitions (longest range, most accurate trajectory …) The students also tour our High Energy Physics Research Center to gain a broader perspective on career possibilities in engineering and science.

Program Impact

During the first full year of NSF support (2007-08 academic year), we began the Teacher Workshops and Discovery Weekends with seven key feeder schools in our region impacting 53 students, 18 teachers, 8 college student mentors, and 6 university faculty. Two students from the first year TechSTEP pilot program have enrolled at Louisiana Tech and are now TechSTEP student mentors. By the fourth year of TechSTEP (2010-11), we will have expanded to at least twelve schools impacting 120 students, 48 teachers, 12 college student mentors, and 6 university faculty. The long-term relationships established with area high school teachers will have as much impact on increasing engineering and science enrollments as other aspects of the project.

The schools participating in this project represent a diverse student population. Three of the schools are located approximately 70 miles away from the university; one is located approximately 35 miles away; one is in a rural area; and one is local; and one is in a neighboring state. One of the schools is a magnet high school and most have a high proportion of minority students ranging from 27% to 60%. TechSTEP targets students who have shown an aptitude for math and science but need additional encouragement to consider a STEM discipline as a career choice. Participating teachers select these students based on their personal experiences with them.
Quotes from TechSTEP Teachers:

“I’ve participated in a lot of programs like this and this is the best one I have been to.”

“. . . we would like to thank you for hosting us this past weekend. We had a great time and we found your plans for the upcoming engineering competition to be awesome. The TechSTEP Team was extremely well organized and did a great job of implementing their vision for the program. We were made to feel incredibly welcome, were definitely challenged intellectually, and are very excited about the upcoming competition.”

“. . . Please make sure you thank the students as well. They were great! When you are ready, let’s get together and talk about future ways we can build the relationship. I am thinking video conferencing between classes, cross-mentoring engineering students with high school students, internships for engineering students thinking about teaching as a career, summer camps, and having your professors teach on our campus.”

TechSTEP Student Quotes:

“TechSTEP allowed me to glimpse the style of teaching and the material of a college class while not having to worry about passing the program . . . One of the challenges of first attending college is you discover how few people you know. Since I had participated in TechSTEP, I had gotten to know these individuals.”

“TechSTEP allowed me to know what Louisiana Tech offered and how they presented it to their students. I had talked to Dr. Nelson prior to orientation about choosing engineering as a major and he had explained that Louisiana Tech University offered integrated engineering. If I had not participated in TechSTEP I would not have had experience in such a style of teaching.”

“The fact that we all learned so much and were able to work together on an original project was very enlightening and beneficial to me.”

Lessons Learned

We have encountered several challenges in implementing the TechSTEP program. One challenge is finding the right level of difficulty for the content presented during the Workshops and Weekends. Both TechSTEP students and teachers come to the program with varying backgrounds and confidence. We believe it is important to set high standards to improve the preparation of students entering STEM disciplines. However, this approach will be successful only if we can build a truly collaborative relationship with high school teachers. We plan to continue developing these close interactions.
A second challenge is finding the balance between open-ended creativity and a guided learning process. During an earlier pilot program we used a more open-ended design process and found that the student teams did not converge on a solution in a reasonable time frame. In order to remedy this problem, we now use a guided process where we provide the teams with plans for a workable solution and ask them to build a device from these plans. Once this knowledge foundation is built, the students are encouraged to design and build their own version for the final Challenge Weekend, thus providing an opportunity for them to employ their creativity.

We believe that the relationships built between our faculty and the high school teachers are crucial to accomplishing the goals of this program. Our initial plan for the Teacher Workshops was to develop the Discovery Weekend activities alongside the teachers. We found that the teachers preferred to have more detail presented to them during their workshops so they would be better prepared for the Discovery Weekends. This change meant that we needed to work through most of the details before the workshops. Currently, during the Teacher Workshops the teachers perform all of the activities for the upcoming weekend and provide valuable feedback on the level of difficulty and their students’ abilities. Also, the teachers are grouped with a college student serving as a mentor for their school’s students. This grouping creates a teamwork environment where the teachers feel comfortable asking questions either to or through the student mentors.

Another challenge is to continue drawing students and teachers to participate in TechSTEP. Since all of the TechSTEP activities are held on Saturdays, it takes a significant commitment for the teachers and students to participate. Though it is difficult to work around everyone’s weekend schedules (soccer games, ACT/SAT, homecoming . . .), we ask that all participants commit to attending all of the workshops and weekends. We provide stipends for the teachers, as well as recommending them for Continuing Learning Units. In order to keep the students enthusiastic about TechSTEP throughout the year, we use several strategies. First, there is no cost to the students. Second, the student mentors provide continuity by keeping in contact with the students between Discovery Weekends and act as a resource for both the teachers and students. Also, the weekends always begin with community building and hands-on activities and then alternate between segments of hands-on, active learning and presentations of fundamental STEM concepts. The weekends also include a variety of other experiences including “field trips” to research areas on campus, discussion panels, and guest speakers. The Challenge Weekends provide the “competition factor” where students from different schools compete and display their work from the TechSTEP year. Finally, faculty, teachers, and students all receive TechSTEP t-shirts that serve both as advertisement and as a symbol of belonging to the group.

Summary

TechSTEP aims to recruit and retain students to STEM majors. The students targeted by TechSTEP have shown potential for STEM disciplines, and it is our goal to recruit these students through hands-on, real-world applications of engineering while they are juniors and seniors in high school. Additional material concerning this program is available through the TechSTEP website (www.LaTechSTEP.org).
Bibliography