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HS-STOMP: High School Student Teacher Outreach Mentorship Program*

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The High School Student Teacher Outreach Mentorship Program (HS-STOMP) is an outreach opportunity for high school students to flex their knowledge of science, engineering, and technology through a teaching experience. The program is designed as a learning opportunity to deepen and strengthen the high school students' understanding of science, while facilitating the learning of engineering and technology principles for K-8 students and teachers. This paper describes the concept of HS-STOMP, the development of the program, the program in action, and the challenges faced in the three-year evolution of HS-STOMP.

Keywords: outreach; student–teacher mentorship; engineering and technology

INTRODUCTION

INFUSING ENGINEERING AND TECHNOLOGY into an already crowded K-12 science curriculum is not an easy task. Unlike most subjects, teachers typically know less about engineering and technology than the students that they are teaching. Because of this, knowledgeable students have been used to mentor educators in engineering and technology as a solution rather than a drawback [1–11].

The Student Teacher Outreach Mentorship Program (STOMP) is a program that employs the concept of students as expert mentors for teachers. The original STOMP program, founded at Tufts University, uses undergraduate and graduate engineering students as the experts to assist K-12 teachers' implementation of engineering and technology [12]. The program has been successful in supporting local area schools, while also benefiting the mentees. STOMP participants, or fellows, benefit by expanding their sense of citizenship, improving their communication skills [13], and enhancing their engineering design understanding [14]. Unfortunately, such a program does not supply a solution for rural, remote communities that are distant from the university campus. To serve communities outside the immediate range of higher education institutions, the idea of High School STOMP (HS-STOMP) was developed.

To test the HS-STOMP model, one high school physics class in rural northern New Hampshire uses LEGO® robotics technology and stop action movie making to supplement project-based learning with student–teacher mentorship. As part of their physics class, students visit local K-8 classrooms to mentor teachers and teach K-8 students about physics, engineering, and technology concepts. High school physics students are provided with an additional opportunity to expand their own understanding of physics, engineering, and technology, while simultaneously educating both K-8 students and teachers. Thus, the outreach program serves the needs of the high school students as well as the local community.

The following paper elaborates on this unique concept being used to educate high school physics students, K-8 students, and K-8 teachers about engineering and technology. A description of the origins of the program, university support, and ongoing work to establish sustainability in a rural community will show that whereas most engineering and technology outreach revolves around a university location, the potential for impact in areas outside of university centers is plausible and worth exploring.

DEVELOPING HS-STOMP

Getting Started

The HS-STOMP model is a derivative of a university-level program supported by the Tufts University Center for Engineering Education & Outreach (CEEO). In 2005, the first high school program was established at the Littleton, New Hampshire High School by William Church, a physics teacher at the school. Church had become interested in STOMP while working with the Tufts CEEO to integrate their developed LEGO® robotics programming environment

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(ROBOLAB) and SAM Animation software (stop action movie making).

Church's interest in STOMP stemmed from prior monthly professional development workshops he orchestrated for local K-8 teachers who were interested in using engineering/technology curriculum and tools in their classrooms. Impressed and intrigued with the STOMP model, Church became interested in determining how the program could have a direct impact on the K-8 teachers he worked with 150 miles away from Tufts University. During a sabbatical year, Church worked closely with the Tufts CEEO and a core group of 13 New Hampshire teachers to adapt the university STOMP model for high school student mentors. Together they created a high school version of the program that incorporated aspects of effective professional development including support for collective participation of teachers within one school, focus on content-based and active learning, constant concern for sustainability, and situating the program within the classroom practice [15–22]. The following three sections describe the evolution of the program over its first three years.

Year 1: Establishing a framework for HS-STOMP

Over the course of the first year (2005–2006), 15 high school students from the coordinator's past physics classes were recruited to participate as fellows. The high school fellows utilized "free blocks" and field trip time in order to travel to local area schools. To support science, technology, engineering, and math (STEM) related curriculum, students used LEGO® Robotics, SAM Animation, and computer-based data-logging software learned in their physics class. Utilizing the 13 core K-8 teachers' classrooms, the first year supported 250 students in seven middle and elementary schools with an overwhelmingly positive reaction from all involved. An event that captured the enthusiasm for the program took place in May of 2006 when approximately 100 students, parents, and teachers gathered for an evening of learning with engineering and technology based activities held at a local theater.

Year 2: STOMP-Physics class

The second year of the program (2006–2007) presented a new challenge furthering the evolution of the program. Church, no longer on sabbatical, returned to his full-time teaching position with HS-STOMP management still solely his responsibility. To keep-HS STOMP operational, STOMP was incorporated into Church's physics class and reduced in size to help the coordinator balance his high school content teaching time and time spent on HS-STOMP. Church piloted this approach in two of his physics classes in an attempt to identify the degree to which students would gain physics related procedural and content skills through their mentor role. While Church retained the same level of teacher volunteerism as the previous year, he had to scale back the program due to student transportation constraints. At the end of the second year, 30 high school physics students supported 7 teachers and 150 students in three middle and elementary schools.

Year 3: STOMP as a stand alone class

After two successful years, local administrators deemed that HS-STOMP was worth permanently incorporating into the local school system, but not in its current form within an existing science course. Church worked with high school administrators to evolve the program, once again, establishing STOMP as a separate credit-bearing elective course in the high school science department. During 2007–2008, four students signed up for the independent STOMP course. Each student was an alumnus of Church's physics class and was proficient in the use of the technologies mentioned earlier. The STOMP class worked with seven teachers from three local schools. STOMP was also incorporated into one of Church's other classes focused on robotics. Additionally, through the Robotics class, four students helped two more teachers with robotics related projects.

The placement of STOMP in a separate class does not reflect poor results from the previous years' design. While conclusive data on student learning gains was not obtained, observations of student enthusiasm and "time on task" suggested that adding a STOMP component to a Physics class is worth further study; however for the time being, it was decided that the most sustainable approach to including STOMP in the high school curriculum was through a separate course. The evolution of this program makes it a compelling example in the literature on STEM outreach programs. The small rural community discussed in this paper sees the benefits of this program to all participants, but also recognizes the difficult sustainability issues it faces. As an example program in the literature on STEM outreach, it is important to note the challenges faced by novel programs. Consequently, more about the challenges of sustaining this outreach program will be discussed later in this paper.

HS-STOMP IN ACTION

For three years, HS-STOMP has provided a professional development opportunity for teachers, leadership opportunity for high school students, and an engineering, science, and technology-learning opportunity for all involved. The following section presents, with examples, what is being taught to the three different populations—teachers, high school students, and K-8 students—involved in STOMP, as well as a description of how it is being received in the K-8 school environment.

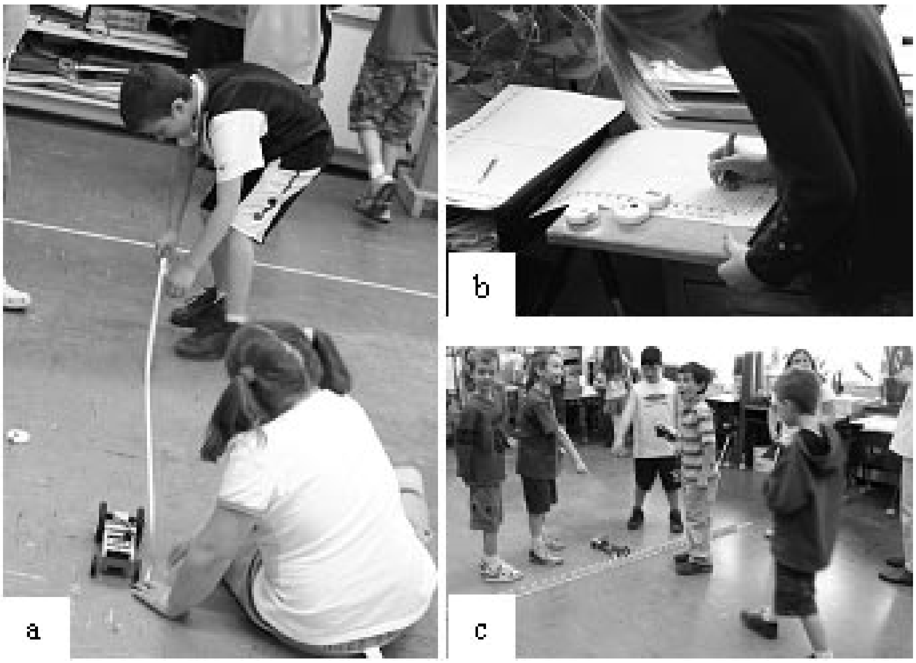

Fig. 1. (a) After designing a LEGO vehicle, the students measure how far it goes in certain periods of time. (b) Students record their measurements on a graph. (c) Students use the graph to predict the time it will take for their robot to travel an exact distance.

Example projects

HS-STOMP has helped teachers incorporate a multitude of technology-based engineering and science lessons into their curricula. Activities include an aerodynamics lesson using an animated model in third grade, a remote robotics project in a mixed third–fifth grade class, a robot design activity to study Newton's Laws of Motion in the sixth grade, and a space mission design project to study planetary science in the eighth grade.

For the purposes of examining what is being taught to the teacher in the classroom receiving the assistance, the HS-STOMP fellows, and the K-8 students, three specific activities will be detailed. The examples are named *Going the Distance*, *Newton's Laws through Robots*, and *Tractor Pull*.

Going the Distance is a Tufts CEEO designed activity used in third grade classrooms (Fig. 1). At the beginning of the activity, students are given the challenge of designing a robot car that can travel any distance that the teacher specifies. To complete the challenge, the students first design and build a LEGO® Mindstorms robot that is capable of traveling straight for at least three meters. During construction, students test the vehicle and redesign if necessary. Once the car is built, students proceed to program the car to travel for three different periods of time so that the student can collect and graph distance data for the different times. Finally, students interpret the data that they have collected to solve the main challenge of the project—figuring out how much time to program their own car so that it travels any distance that the teacher specifies.

Newton's Laws through Robots is an activity created by Littleton HS-STOMP in conjunction with Littleton sixth grade teachers. The activity requires students to design LEGO® robots to test Newton's three laws. To test the laws, students need to design and program a robot to travel straight at various speeds and be able to apply a force to a separate object. This activity is an open-ended design project that encourages students to create their own solutions to the problem. As depicted in Fig. 2, students use sensors (e.g. motion detector) with their LEGO® robots to perform data logging. Programmed robots collect the data, which is then downloaded to a computer for further analysis.

Tractor Pull is an activity used with a sixth–eighth grade after-school program. Students work in teams to design LEGO® robots that will engage in a game of tug-of-war. In this informal learning environment, students play while incorporating the use of gears to succeed in pulling their opponent out of position.

What is being taught

What follows is a dissection of these three activities to identify clearly what is being taught to HS-STOMP's target learners—the teachers, the high school fellows, and the K-8 students.

Teachers using the three examples with HS-STOMP fellow assistance were taught how to use specific technology tools to deliver engineering-based science and math lessons. In the *Going the Distance* and *Tractor Pull* activities, teachers learned how to program a LEGO®-based robot to travel a specified distance. Teacher education occurred throughout the lesson and during pre- or post-lesson discussions between the HS-STOMP fellows and the teachers (Fig. 3). While the

Fig. 2. (a) HS-STOMP fellow demonstrates to a sixth grade class how to use a motion detector to collect position vs. time data. (b) Students designed a LEGO® vehicle that could carry up to 2 kg of mass and (c) students tested the motion of the vehicle to determine whether there was any relationship between the mass of the vehicle and its motion.

teachers were not directly taught how to incorporate engineering into the curriculum, these projects allowed teachers to explore how their students responded to a design-based project. While further research is needed to document whether this approach helps a teacher meet their curricular needs, early anecdotal evidence indicates promise. One teacher reported that she was skeptical at first of using a LEGO® design challenge. The simple thought of dealing with LEGO® kits containing many small pieces was a bit too much of a hassle for her. After seeing the enthusiasm from her students, it motivated her to learn the technology so she could continue the lesson after the HS-STOMP students left the classroom.

During the *Newton's Laws through Robots* activity, teachers learned how to use three different technology tools—a motion detector , data-logging software, and LEGO® Robotics. Comparing the LEGO®-based Newton's Laws activity with previously used activities based on a set of "cookie cutter" labs, one sixth grade teacher expressed that her students spent much more time on the task during the LEGO®-based project. While the technology was simpler than the typical Newton's Laws labs, the level of engagement seen by the teacher in the LEGO®-based project motivated her to write a grant to fund the acquisition of LEGO® Mindstorms robot kits and Vernier® motion detectors. Involvement of HS-STOMP in this particular teacher's classroom changed the way she taught, ultimately advancing her to the point where she no longer needs the support.

Many of the teachers involved in HS-STOMP are also coming to the same conclusion. Of the fifteen teachers supported by HS-STOMP over the last three years, approximately a quarter of them have reached a point where they no longer require support. These teachers continue to utilize the technology tools to bring engineering-based science and math lessons into their curricula without the direct assistance of the HS-STOMP fellows.

As described in the literature on teacher professional development, HS-STOMP can be categorized as an effective program because it emphasizes collective participation of multiple teachers from the same school, utilizes active learning practices, is coherent and relevant to local needs, and emphasizes subject specific content [15, 16, 23, 24]. Because the technology instruction occurs in the classroom rather than in a pullout workshop, teachers are active learners as they work with their students utilizing the engineering and science technology supported by HS-STOMP.

HS-STOMP fellows who are awarded this teaching opportunity are generally observed to develop leadership skills and STEM related procedural and content skills. Leadership opportunities occur when the fellow, in collaboration with the teacher, decides how to pace a lesson and how to solve technology. One example of a HS-STOMP fellow

Fig. 3. (a) HS-STOMP fellows work with teachers during classroom activities and (b) in pre- or post-activity sessions.

capitalizing on a leadership opportunity occurred while doing the *Going the Distance* activity. In order to use the LEGO® hardware on several classroom computers, an administrative password was required. Not having this password and not wanting to shut down the activity, the fellow created a plan to re-allocate the available resources so that the students could continue with the project with minimal bottlenecking. Problem-solving occurrences like this example happen to some extent in all of the HS-STOMP classrooms.

Learning STEM related concepts through HS-STOMP begins with the high school physics class that most fellows enroll in before starting STOMP. The high school students first learn the concepts themselves through technology infused physics lessons. Knowing how to use the LEGO® robots at this juncture helps them make a direct connection between the concepts they learn in physics and the concepts the K-8 students are learning in the classrooms that they visit. When in the classroom, HS-STOMP fellows re-organize, describe (in terms that the K-8 students can understand), and answer novel questions about the engineering-based activities. By nature this teaching experience, like other teaching opportunities, helps the high school students gain a better understanding of the concepts [25, 26].

K-8 Students in HS-STOMP assisted classrooms are taught engineering and technology concepts in a design-based environment. Third graders in the *Going the Distance* activity design a LEGO® vehicle that stays together and travels straight. They then tackle the challenge of modeling motion data and programming their vehicle to travel exact distances. In the sixth grade *Newton's Laws through Robots* activity, students engaged in an open-ended project aimed at designing a robot system that exemplifies the laws of motion. While not a practical problem in an engineering sense, the students often picked a practical problem creating the connections to the laws of motion afterwards. For example, after being shown the sensors available to them, one student group wanted to build a robot that used a bumper switch to stop when it came into contact with an obstacle. This practical design challenge afforded the learners an excellent opportunity to observe Newton's FIRST Law. In their final presentation, this group of students simply placed several loose LEGO® pieces on top of their car and explained why the bricks flew forward when the robot stopped abruptly upon meeting an obstacle.

In the design-based environments, students learn specific grade level content through tackling complex design problems and the construction of artifacts. Such activities contextualize knowledge and provide students with opportunities to communicate ideas through direct discussions, pointing, and gesturing related to the artifacts [27]. These elements—environment, building artifacts, and communication through artifacts—make learning more meaningful [27].

Design-based learning environments also provide opportunities for students to experience the connections between STEM fields through the creation and manipulation of models [28]. For example, when students participate in an activity like *Going the Distance*, which requires them to build a robot, use measurements, create and interpret data, and program a robot with assorted values of time, students experience the connection between place value, graph interpretation, prediction, and experimentation.

CHALLENGES

To ensure that the HS-STOMP program is effective and efficient, there are a few challenges that must be addressed. These challenges include pedagogical knowledge, engineering and technology knowledge, and logistics.

Pedagogical knowledge

Unlike similar programs such as Generation YES [6], HS-STOMP does not explicitly teach pedagogy or content to students. It is believed that while K-8 teachers and students learn engineering and technology concepts, the HS-STOMP fellow is learning pedagogical knowledge from the teachers. The benefit of this approach is that HS-STOMP fellows can assist teachers in the classroom sooner and more often. Understanding and learning pedagogy also comes by the way of personal past experiences. Many fellows have past experiences as leaders in summer camps, recreation programs, coaching, and/or academic tutoring. While serving the Littleton HS-STOMP program very well, this reliance on other experiences might prohibit HS-STOMP from serving as an explicit model for other communities; this aspect needs to be further researched to identify the direct effects. For this instance, it has been shown that structured pedagogical training is not required in order for the program to succeed.

Engineering and technology knowledge

Content knowledge development for HS-STOMP fellows is reliant on both the high school curriculum and personal experiences to provide the fellows with the skills and knowledge necessary. Most HS-STOMP fellows gain their engineering technology skills through classes or experiences such as computer technology, *Project Lead the Way* [29], or physics. All three rely heavily on engineering and technology in their curricula. Each HS-STOMP fellow to date has taken, previously or concurrently, at least one of these courses. Much of the HS-STOMP knowledge comes from personal experiences using technology simply as a regular part of daily lives.

Logistics

In its current form, a single administrative director runs HS-STOMP handling logistical challenges. A director can deal with transportation and equipment issues as well as providing support through classroom visits throughout the project period (3–4 weeks, for example). The ability to visit the classrooms is particularly useful for dealing with the many logistical problems that can possibly occur. For example, when a fellow lacks a software installation disk or an administrative password for the computers that school systems allow only an adult to have, progress is hampered until someone can assist. Having a program director available also provides high school students with a technology resource.

In addressing the issue of transporting fellows to K-8 classrooms, the current program relies on the local taxi service to provide transportation for the students. This works exceptionally well in most instances because of the local relationships held between the school and the community. Problems occur when the taxi service is not available or when more students and equipment need to be moved than can be accommodated by the space available for transportation.

Equipment management is a responsibility shared between the administrative director and the K-8 classrooms. The initial inventory of the technology supplies was monitored and maintained by the high school. To alleviate the difficulty of delivering supplies, the inventory of supplies has been passed down to the individual schools allowing the high school to maintain separate inventories. This alleviates the difficulty of delivering supplies and allows the high schools to maintain separate inventories. In the last two years, the supported schools have acquired approximately \$15,000–20,000 through general budget requests, community/school support group requests, and state and national grants to purchase equipment for HS-STOMP supported programs. For a rural district, this is a substantial amount of money to commit to a young program giving early indications of how well received this program has been by the teachers, students, administrators, and parents.

CONCLUSIONS

In summary, the HS-STOMP program in its initial three years has been successful in integrating engineering and technology into the rural K-12 classrooms of Littleton, NH through outreach. High school students are benefiting from a teaching opportunity eliciting leadership and understanding of STEM content. K-8 teachers are benefiting by having "experts" in their classroom to assist them in not only teaching the content, but also in learning engineering and technology themselves. K-8 students are benefiting in that they are now receiving opportunities to learn engineering and technology. With support from teachers, students, administrators, and parents, the HS-STOMP program is prospering and evolving to fit itself into this rural town's education system.

Areas for further research include measuring the extent to which HS-STOMP helps high school students to gain domain specific and general skills and knowledge, the degree to which HS-STOMP affects change in teacher's practice, and the specific impact HS-STOMP has on learning in the K-8 classrooms. As HS-STOMP becomes more integrated into the town's culture, and research results are available, the opportunity may exist for reconsidering the reincorporation of HS-STOMP as a component of the regular high school physics class. For more information on STOMP, visit www.stompnetwork.org.

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