Teaching Creative Classroom Robotics through the Student Teacher Outreach Mentorship Program

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Abstract. The Student Teacher Outreach Mentorship Program (STOMP) aims to engage all students in engineering activities during the school day by partnering university students with classroom teachers. Traditional robotics competitions may not work well in this format, since the lessons occur weekly for only one hour. Additionally, STOMP operates in traditional classrooms and aims to engage students that may not sign up for robotics or engineering activities. Due to these facts, STOMP fellows strive to develop creative robotics activities to make engineering accessible for all students, regardless of interests or abilities.

Keywords. Educational Robotics, LEGO NXT, Creativity, Diversity of Solutions, Robotics for Children

1 Introduction

1.1 Program Structure

The Student Teacher Outreach Mentorship Program (STOMP) [1] was founded in 2001 as a response to the release of the Massachusetts educational standards in engineering. Students at the Center for Engineering Education and Outreach (CEEO) at Tufts University formed a partnership with two local teachers by going into their classroom for an hour a week to teach engineering. In the past twelve years, the program has grown to include twenty-nine K-8 classrooms. 57 undergraduate and graduate student teachers (STOMP fellows) are employed by the CEEO to bring innovative engineering projects into the K-8 classrooms on a weekly basis. A detailed breakdown of the ages and genders of employed Tufts students for the fall 2013 semester can be found in Figure 1. Participating classrooms have students ranging in age from kindergarten (age 5) to 8th grade (age 14) and include a broad population of students with a wide range of abilities and backgrounds. STOMP also serves a number of English-as-a-second-language classrooms.

Proceedings of 4th International Workshop Teaching Robotics, Teaching with Robotics &
5th International Conference Robotics in Education
Padova (Italy) July 18, 2014
ISBN 978-88-95872-06-3
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STOMP Statistics	
# of Classroom Teachers	28
# of Fellows (Total)	59
Fellow Stats	
# of Female Fellows	42
# of Male Fellows	17
# of Freshmen	7
# of Sophomores	16
# of Juniors	15
# of Seniors	12
# of Graduate Students	9
# of Engineering Majors	48

Fig. 1. STOMP statistics for the fall 2013 semester.

1.2 Curriculum Development

Every semester, the STOMP fellows collaborate with their classroom teacher to develop a curriculum for eight to ten weeks of hour-long lessons. We encourage STOMP fellows to work with the teacher as they design their unit. Often, units work to build upon a subject the teacher wants assistance teaching or to integrate engineering activities with other classroom topics such as literature or history. STOMP fellows also have access to an online database of activities done in past STOMP classrooms (stompnetwork.org). Fellows add to this database every semester in order to compile a comprehensive record of STOMP activity.

1.3 Goals of STOMP

The following goals describe the key motivation of the STOMP program. Fellows and teachers strive to:

1) Introduce all students to engineering and encourage them in STEM pursuits. Engineering is not typically introduced to K-8 students. When asked, they believe engineers fix cars and build bridges [2, 3]. STOMP helps students understand what engineers really do, as they begin to think like engineers by engaging them in problem solving activities. STOMP also makes science and engineering fun, creative, exploratory and accessible.

2) Provide students with a unique learning experience that helps them build creativity. Traditional classroom activities demand one correct answer (eg: 3+3=6, or the spelling of a word.) Conversely, STOMP activities are open-ended or ill-defined, requiring students

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to be creative and take risks. This allows students to learn that failure is not terminal, but a necessary step to finding a better solution.

3) Aid teachers in implementing engineering curricula in the classroom. STOMP strives to bring engineering into the typical classroom in an accessible way for teachers. While our first goal is the student learning experience, STOMP also partners with teachers to decrease the learning curve on new technologies and material.

1.4 A New Strategy

Over the twelve-year tenure of STOMP, we have observed that teaching robotics in our classrooms meets these three goals and also introduces students to new technology. Technological literacy is an underlying goal of STOMP: we hope that by encouraging students in engineering and bringing new technologies into the classroom in accessible ways for teachers and students, we increase technological literacy of everyone involved. LEGO NXT Robotics has proved to be an easy access point for students and teachers, and opened up the world of robotics in a nonthreatening way.

While robotics lessons have been generally well received by teachers and students, we noticed some challenges during observations of STOMP classrooms. Some robotics activities did not seem to meet learning goals defined above, in that they were not engaging or interesting all students. Specifically, building "robots" that were really just cars and then engaging in competitive challenges, was not attracting the attention and focus of female students. In one instance in a research project [4], a pair of 12-year-old girls spent two hours attempting to attach motors to their robotic brick (to build a car) with no success.

STOMP fellows observed certain activities were causing more frustration than learning. We challenged ourselves to create new and unique robotics activities that engage all students, hoping especially to reach female students. These activities were designed to allow for a wide diversity of solutions, and integrate content from other subjects. Over the last two years STOMP fellows have created new and unique robotics challenges. This paper presents the details of two of those challenges.

2 Case Studies: Sample Units

This paper highlights two creative robotics units that were implemented in STOMP classrooms during the fall 2013 or spring 2014 semester. All activities were developed and taught by undergraduate and graduate STOMP fellows. These activities were taught using the LEGO NXT Robotics kit and the MINDSTORMS NXT software program. The NXT Robotics kit is comprised of a brick, three motors, two touch sensors, one sound sensor, one motion sensor, 4 wheels, and various other beams, axles, pegs, and traditional

ISBN 978-88-95872-06-3
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LEGO pieces. The STOMP program teaches a wide variety of schools and ages. We encourage the STOMP fellows to respond to their students' learning and make curriculum decisions accordingly. Depending on a school's schedule and the class's fluency with technology, each unit is taught at a different pace. While some classrooms complete six activities in one semester, others only complete four.

2.1 Unit 1: Creative Robotics

The creative robotics unit was originally designed for a 5th grade classroom in an urban public school. This unit was created to introduce students to the basics of robotics and programming and allows for a huge range of solutions, with activities that are open ended enough to stimulate creativity, while still being accessible because there is no "best way" to respond to the challenges. Difficulty level of each activity was adjusted for students working at different paces.

Introduction to Building and Programming
Before jumping in to any activities, students had a short, energetic discussion about what robots do and how they work. Students were allowed play around with the LEGO NXT kits and get an introduction to how to build with the pieces. After, students learned how computers and robots "think" differently than humans by "programming" their STOMP fellows to perform tasks around the classroom. The purpose of this activity was to emphasize that robots need very specific instructions to act how you want them to act.

Silly Walks
This activity involved students building any vehicle that moves in a nontraditional way. This is often used as the first introductory activity to the NXT Robotics platform in STOMP classrooms. Students are not allowed to use wheels that roll to make their robot move forward. The sillier the motion they create, the better! Students attached 1-3 motors to the brick and had the whole robot move as a unit. The challenge asked students to combine the pieces in unique ways to mimic feet, legs, or other types of motion to push the robot along. At the end of the period, students lined up all the projects and hit start at the same time to share what they did with the class.

Freeze Dance
The freeze dance activity allowed students to learn about the sound sensor. Students built and programmed NXT Robots that "danced" when music was on, and stopped moving when music was off. The dancing robots were either extensions built off the "silly walkers," or totally new ones. This challenge also asked students to mimic their favorite dance moves using robotic motions. For an extra challenge, some students added other sensors to responsively dance to other robots in the room.

Perfect Puppy
Students made their "perfect puppy" which behaved exactly as they would want a pet puppy to behave. STOMP fellows introduced sensors by comparing them to animals' senses.

Fig. 2. Example of a puppy robot created for Dr. E's Robo-Zoo [7]

2.2 Unit 2: Animal Adaptations

The Animal Adaptations Unit was created to supplement a Massachusetts state science standard about animal behavior. This unit was adapted to fit the STOMP timeline from the product of a research project [5,6] that focused on creating engineering design activities integrated with science instruction. This unit asked students to remember what they had learned about animals and animal behavior and apply it to engineering design. In the communities surrounding Tufts University, animal behavior is typically taught to students in the fall of their 5th grade year.

Build an Animal Habitat
In this introductory activity, students familiarized themselves with the pieces in the NXT kit by constructing a physical representation of an animal's habitat. No motors or sensors were used in this activity. The students worked in teams, and each team chose its own animal. This activity asked students to start recalling what they had learned about animals before more complicated building and programming activities.

Fig. 3. An example of a model habitat: cacti in the desert.

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Representational Model of an Animal
To continue to gain familiarity with building, students next learned about representational models, or models that look like their animal but do not move like them. Again, no motors or sensors were used in this activity. Students used the LEGO NXT pieces to construct a physical representation of their chosen animal.

Motion Study
This is the last activity with no motors or sensors involved. Students conducted a "motion study" of their chosen animal. Students discussed joints and limbs, using humans as examples, and extended the concepts to their own animals. Students drew the joints and limbs of their chosen animals, and discussed their drawing with classmates. Students then figured out which pieces in the kit could be used to make joints and which could be used to make limbs. The final piece of the activity was for students to use the LEGO pieces to construct semi-functional models of their animal: models that move like the animal but do not necessarily look like it.

Introduce Programming and Sensors in Animal Context
STOMP fellows introduced the different sensors by comparing the sensors to the senses real animals have. For example, the sound sensor functions like ears, the light sensor and ultrasonic sensor like eyes, and the touch like paws. Human Robot (described in Unit 1:Introduction to Building and Programming) was done. The goal for this activity was to familiarize students with the concept of programming.

Functional Model of Animal Behaviors: "Translating" Animal Behaviors into Computer Language
The class brainstormed the behaviors animals need to survive (for example: find food, escape from predators, and protect their young.) They then "translated" those behaviors into sense-think-act programs for their robot. For example, escaping from predators was represented by the robot moving quickly in reverse whenever the sound sensor detected a noise above 80 decibels. Students then were introduced to the MINDSTORMS NXT software and the process of debugging a program as they collectively wrote a program, with the help of the STOMP fellows.

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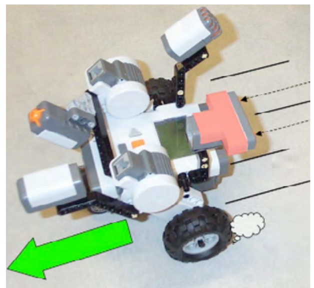

Fig. 4. A functional model of an animal, reacting to its surroundings.

Robo - Zoo

For their final projects, students built a robo-animal, which was different than the animal they focused on all semester. The animals both moved and looked like a real animal. STOMP fellows provided craft materials such as felt, paper, pipe cleaners, and more to help students be creative and get engaged in the challenge. Students often needed encouragement and help from the fellows to really think about how their animal moved and looked, and how they could mimic that. Looking at slow motion videos of animals walking, for example, was useful.

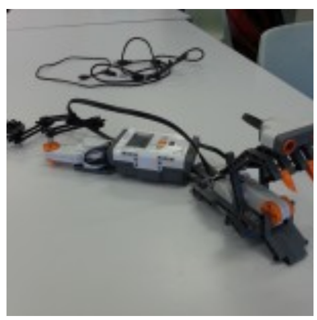

Fig. 5. A robotic snake created as part of Dr. E's Robo-Zoo [7]

3 Conclusion

3.1 Attitudes About Robotics and Engineering

Female students participating in these creative robotics activities through STOMP demonstrated positive attitudes about engineering, science, math, and robotics during interviews that took place after the units were completed. Many girls also expressed a

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strong understanding of what engineers do for their careers. While no formal statistical analysis was completed, two representative interviews are described below.

3.1.1 Interview 1: Divya, 5th Grade

Researcher: Do you know what an engineer does?
Divya: They help the world by designing… They design stuff, like machines, to help make the world better.
Researcher: How did you learn what an engineer is?
Divya: We had STOMPers in our classroom, so I learned from them.
Researcher: So you learned it in school, or did you learn it before then?
Divya: Yeah, I learned it in school, from the STOMPers.
Researcher: Do you have any science or engineering hobbies?
Divya: Sometimes, when there were STOMPers in my class, if I learned something, I go try it at home to see if I can do it better than I did it in the classroom.

3.1.2 Interview 2: Katie, 6th Grade

Researcher: Do you know what an engineer does?
Katie: I think that they build stuff to help people, and they use computers to program robots.
Researcher: If I said to you that girls can't be scientists or engineers, what would you say?
Katie: I would say that's not true, I would want to break that rule and want to become an engineer even more.

3.2 Future Work

We hope that future development and investigation of units such as those described here will aid in engaging students in problem solving activities and increase their technical literacy. We have observed a wide diversity of solutions we see being produced in STOMP classrooms implementing such curricula.

No quantitative data was obtained in this preliminary work. Future work must be done in STOMP classrooms involving pre and post-tests concerning robotics and engineering attitudes. By comparing student opinions and knowledge before and after participation in STOMP, we hope to clearly demonstrate the impact STOMP has on student engineering.

Additionally, comparison studies would be useful, comparing two similar STOMP classrooms doing different robotics units. One classroom will complete a traditional "cars and competition" robotics unit, while the other will engage in more unique challenges. Using a similar pre and post-test process as described above, we hope to compare student experiences and further understand student engagement in robotics activities.

In the future, we hope to collect quantitative data, additional interviews, and classroom video to understand more specifically the types of activities that engage all students in critical thinking, creativity, and technology. We hope to continue this work to better serve the students we teach as well as help more teachers integrate engineering into their classrooms.

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