Identifying and Cultivating Diverse STEM Talent through Creative Robotics

Jennifer Cross, Carnegie Mellon University

Jennifer Cross graduated from the F. W. Olin College of Engineering with a BS in Electrical and Computer Engineering and is now working toward her doctorate degree in Robotics at Carnegie Mellon University. A fellow of both the National Science Foundation's Graduate Research Program and the Institute of Education Sciences' Program for Interdisciplinary Educational Research at Carnegie Mellon, Jennifer's research focuses on the impacts of integrating creative robotics into cross-curricular learning environments and the development of the Arts & Bots program.

Emily Hamner, Carnegie Mellon University

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Introduction

In recent years, there has been increasing concern that the United States K-12 educational system is falling short in preparing the technology innovators of the future. Students who exhibit the intellectual curiosity and creative problem-solving talents crucial to the engineering process can slip through the cracks, going unrecognized by their teachers and therefore receive insufficient support as their education progresses.[1] We provide opportunities for teachers to better recognize and support these abilities through the integration of a creative robotics activity, called Arts & Bots, into standard required middle school courses, such as earth science and health classes. In this paper we describe the partnership we have formed to evaluate the impact of Arts & Bots on teachers' abilities to recognize and cultivate students' engineering interests and talents and the on-going work of this three year project.

Development of Arts & Bots

Arts & Bots, originally called Robot Diaries[2], is based on a robotics kit that combines standard robotics components such as servo motors and sensors, with a microcontroller, a custom-developed programming tool and commonly available craft materials (Figure 1). This kit was originally developed in 2006 at the Carnegie Mellon University CREATE Lab as an alternative path for engaging with engineering and developing technological fluency[3]. Whereas popular robotics programs, such as US First are built around high-intensity, task-oriented competitions[4], Arts & Bots is focused on using technology as a creative tool for self-expression in order to appeal to students otherwise intimidated or unexcited by task-based programs.

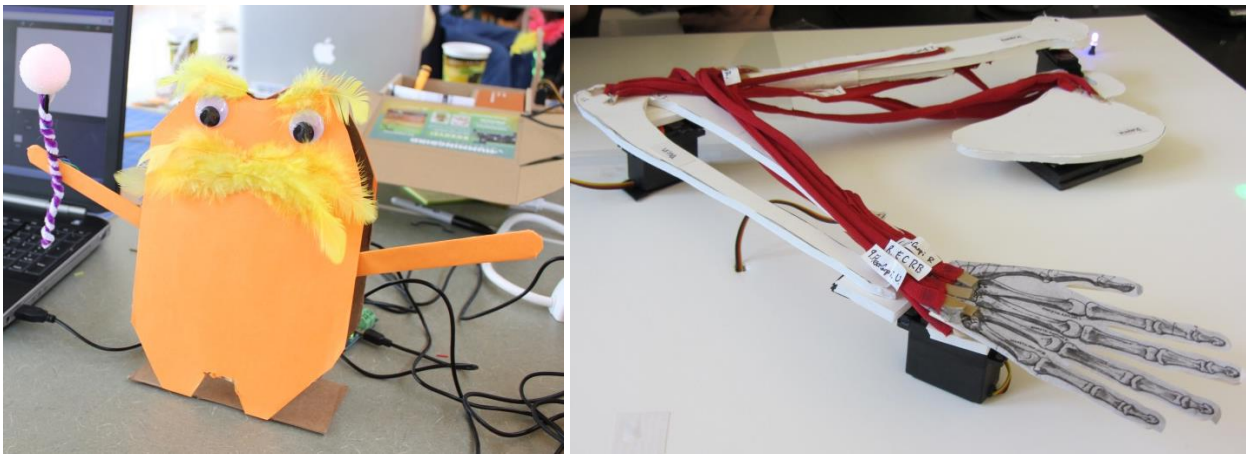

Figure 1. (Left) An Arts & Bots robot based on Dr. Seuss's poem *The Lorax* with servo motors to move the arms and an LED to light the "truffula tree". (Right) An Arts & Bots robot model of a human arm muscloskeletal system with servo motors to move the joints.

Early Arts & Bots pilot studies originally focused on developing a program to support these underserved students in gaining technological fluency. Technological fluency is the ability to manipulate technology creatively and for one's own use. In addition to creative expression, those

fluent with technology are able to reformulate knowledge and synthesize new information.[5] These pilot studies initially targeted female students in out-of-school activities. Unfortunately, due to the elective nature of these extracurricular activities, we found that our target audience self-selected away from participating.

In order to eliminate self-selection bias, we collaborated with partner teachers to adapt Arts & Bots for integration into required core classes, like social studies and science. These adaptations included revising the programming environment, to make it easier to include in classroom instruction.[6] Additionally, we developed a professional development workshop for teachers which covers the use of Arts & Bots and provides examples for integrating the program into various classrooms.[7] These efforts allowed the Arts & Bots program to be expanded to 40 schools in Pennsylvania and West Virginia.

An anecdotal observation that was made frequently by teachers using the program was that it allowed them to identify the skills and interests of their students that were otherwise not demonstrated in that core class. One teacher of seventh and eighth grade language arts remarked, "It was nice for me as a teacher to see a different side of them. Sometimes we get caught up in our content because of course that's our passion [...] It was nice to see their passions for something else and [see] them in a different light." This recurring trend by teachers to notice and informally note student talents, led to the formation of a partnership of organizations and schools to formally evaluate the utility of Arts & Bots as a tool for helping teachers and schools to identify and develop student talents and interests in engineering and computational thinking.

Partnership Overview

This partnership, started in fall 2013, is a joint collaboration combining the teacher training expertise of Marshall University's June Harless Center for Rural Educational Research and Development and West Liberty University's Center for Arts & Education, the engineering and technology development expertise of the Carnegie Mellon CREATE Lab, and school district-wide support from a suburban school district in Pennsylvania and a rural school district in West Virginia. The implementation of Arts & Bots in required courses, such that all 7th and 8th grade students of the two school districts will participate, eliminates the self-selection seen in elective technology courses and extracurricular activities. Through this elimination of self-selection and the contextualization of robotics in other disciplines, the partnership's in-progress Arts & Bots program aims to encourage students with diverse interests and skills to engage with the engineering process at their own level. In addition, by working with entire school districts we will be able to develop district-wide models for talent identification and support efforts across multiple classes and grade levels.

This program, which we are implementing over the next three years, focuses on three areas of work. We are creating and piloting professional development activities for teachers that incorporate training on the use of Arts & Bots, the creation of supporting curriculum and methods to identify and support students with latent STEM talents. We are collaboratively refining the existing Arts & Bots robotics kit to better reveal student abilities and create enrichment activities to allow teachers to cultivate these talents in their classes. Finally, we are refining and implementing tools to support the summative and formative evaluation of the

program including assessing teacher student-talent identification skills, teacher technology attitudes, student self-efficacy and student attitudes towards engineering and technology.

Talent Recognition and Training

This partnership's primary focus is the expansion and evaluation of Arts & Bots as a tool for helping to identify student talents and interests in engineering concepts. In particular, we are focusing on two primary talent areas: Engineering Design and Computational Thinking. The Engineering Design talent area includes skills and dispositions toward use of the engineering design process to solve ambiguous real-world problems. The Computational Thinking talent area includes skills and dispositions relevant to logical problem solving and the restructuring of problems to be solved with computational methods. Through the preparation of teachers to recognize students with talents in these areas, we hope to further disseminate engineering principles into core classes required for all students while guiding interested students to in-school pathways for further study.

In order to prepare the teachers from the two partnership school districts, we have designed a 2-day professional development series on integrating Arts & Bots into non-technology classes, observing students to identify engineering talents, and using the resource library (described below) to support the growth of these talents. It is important to train teachers of non-engineering classes to recognize these talents because they have broader access to students, thus maximizing the chances of recognizing student potential. Specifically targeted teachers in the partner school districts teach sixth through eighth grade health, science and art courses.

Arts & Bots will also be integrated into courses for pre-service teachers at West Liberty University and Marshall University. These pre-service teachers will be supported by the partnership in bringing Arts & Bots to the schools where they are student teaching. This integration into pre-service programs will serve as a route for dissemination to school districts beyond the core districts.

Resource Expansion

The existing Arts & Bots kit and program materials were initially developed for out-of-school activities as described above and are primarily focused on the development of student technological fluency. In the past three years, we have worked with K-12 teachers to integrate Arts & Bots into the classroom.[7] Through the work of the partnership, we plan to strengthen teacher preparation through our work with the districts and emphasize the use of Arts & Bots as a talent identification and cultivation tool. As part of this emphasis, we will be expanding on the existing Arts & Bots kit and materials with new components which will be specifically designed for the cultivation of student talents.

One such component we are developing is an expanded resource library of enrichment activities for teachers implementing Arts & Bots. This library is specifically aimed at providing teachers with activities with which they can tailor their Arts & Bots activities for the talents and interests of students in their classes. For instance, we are creating an online tutorial targeted at students ready to learn about using the kit sensors for more sophisticated robotic applications. Another

tutorial could guide an interested student in the use of the Scratch programming language for creating more elaborate programs for their Arts & Bots robot than can be made with the standard Arts & Bots software. Where the resource library requires modifications to the hardware and software components of the existing Arts & Bots program, we are refining and expanding on those components as needed. The creation and curation of these resources benefits both the students who are able to expand on their use of Arts & Bots at pace with their interests and talents, and the teachers who are able to provide these enrichment opportunities to their students by drawing on the robotics expertise of Carnegie Mellon University.

Evaluation Tools and Experimental Design

The third component of the current work is the formal evaluation of the Arts & Bots program. Building on evaluation tools from the earlier pilot studies, which focused on technological fluency, we are developing summative and formative evaluation tools aimed to answer two research questions: 1) how does contextualized creative technology allow students to engage with aspects of learning that would otherwise not appeal to them, and 2) how can a teacher use cross-disciplinary team projects, such as Arts & Bots, to identify different types of student talents and provide individually paced instruction for students at different levels within the same classroom?

Towards the completion of this evaluation, we are developing numerous new assessment tools. We will collect qualitative evidence via student interviews and classroom observations measuring student interest in technology topics and confidence in using and creating technology. We will collect quantitative evidence via student surveys measuring changes in student perceptions of engineering careers, technology and engineering skills, engagement with course materials, and attitudes towards technology. We are developing teacher interviews, classroom implementation logs, and surveys to collect qualitative and quantitative evidence of teachers' abilities to identify students with engineering design and computational thinking talents. School districts will provide enrollment information for elective STEM courses as a measure of district identification and engagement of talented students.

Expected Impacts

The new professional development workshops are scheduled to be held in spring and fall 2014 for fourteen middle school teachers from the partner school districts. These teachers in turn are expected to implement one-to-two week Arts & Bots interventions with approximately 400 students during the spring 2014 semester. In the following two years of the project we anticipate reaching approximately 900 students yearly.

In addition, the partnership institutions are each committed to structured change within their organization. The two partnership school districts are developing new procedures for identifying and recruiting talented students for elective engineering and technical courses. West Liberty University and Marshall University are integrating Arts & Bots content into the required coursework for students in their teacher training programs and will supply materials for pre-service teachers to implement Arts & Bots with students. Approximately 200 pre-service teachers will be exposed to Arts & Bots as part of their degree program at Marshall University in

spring 2014. In the two subsequent years approximately 260 pre-service teachers will participate in the program annually. Meanwhile, the Carnegie Mellon CREATE Lab is organizing and hosting an annual Creative Educational Technology Conference, beginning in 2015, to bring together organizations, school districts, and higher education institutions to create a community where best practices using Arts & Bots and similar programs can be shared. Through these organizational changes, along with the in-progress work to develop and evaluate the impact of Arts & Bots on teachers' abilities to identify and cultivate students' engineering interests and talents, we hope to provide a model partnership for school districts and universities.

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