e-NABLING Education: Curricula and Models for Teaching Students to Print Hands

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In January of 2013, a prop maker/puppeteer in US Pacific Northwest collaborated with a carpenter in South Africa to produce the world's first home-created, 3D printed hand. They spread the word of their effort via a video on YouTube and released the designs as open source. In May of 2013, an RIT professor, inspired by the video, created a simple Google Map mashup to link people who needed similar devices with people who'd be willing to print them. And so the e-NABLE project was born. By June of 2016 the e-NABLE Google Plus community had over 8,600 members and e-NABLE had delivered around 2,000 hands to children in 50 countries. Some "e-NABLErs" are students and faculty in middle schools, high schools and colleges around the world. One physical hub of this on-line volunteer effort is the e-NABLE Lab, part of the Center for Media, Art Games Interaction and Creativity (MAGIC) at the Rochester Institute of Technology. The Enable Community Foundation has compiled a collection of curricular models and materials to support the growth of e-NABLE efforts by students and their teachers. This work-in-progress paper will cover the current status of e-NABLE efforts in and out of the classroom. It will then detail the hardware and software needed to create hands and teach courses (a wide range of inexpensive 3D printers and low-cost or free software will suffice). Next it will provide an overview of the types of curricula and materials available for schools around the world to use with students of all ages. Lastly it will detail one particular program, a summer job-training program at the Vertus Charter School in Rochester, New York, in depth as an example of a school-based e-NABLE program that has been successful.

Index Terms - 2.a.iii 1a 3D modeling; 2.c.i. Human centered design; 2.c.iii. Product development; 4.d.iii. Middle school; 4.d.ii. High school; 4.f. Undergraduate; 11.f. STEM; 14.a. Interdisciplinary;

THE BIRTH OF E-NABLE

In 2011, Ivan Owen, created a functional, metal "puppet" hand as part of a costume for a Steampunk convention. He later posted a short video of it on YouTube. A carpenter from South Africa, who had lost fingers in a shop accident, saw the video and recognized that the mechanism could work as an inexpensive prosthetic. Over the course of almost a year, the two worked together; at first via the Internet and then together in South Africa. Although the first hand they created was made out of materials that could be found around the home they eventually developed a simple design that could be fabricated with a 3D printer. [1]

Having been contacted by a mother in South Africa, they came to realize that this device could potentially benefit children born missing fingers. In May of 2013, they released a YouTube video that described their work and included a clip of a South African child using their 3D printed hand. It went viral. [2]

FIGURE 1
FRAME FROM OWEN'S FIRST YOUTUBE VIDEO

Professor Jon Schull (now a research scientist with the RIT MAGIC Center) came across the video and noticed that a number of the comments on the video were enthusiastic and supportive, with people volunteering to print hands for others. Seeing an opportunity, he created a simple Google Map and left a comment inviting people with 3D printers, and people who needed prosthetics, to "put pins" on the map. Within six weeks seventy pins had been placed. Schull then created a Google Plus community to coordinate potential participants. [3], [4]

INTERNATIONAL IMPACT

The e-NABLE Google Plus community has grown continuously since it's inception, and by June of 2016 it has been joined by 8,600 people around the world. The community has delivered 2,000 devices in over fifty countries, and collaboratively developed over a dozen substantially improved hand and arm designs. A number of affiliated websites have sprung up, and the non-profit Enable Community Foundation [5] has been established to scale up the matching of makers with recipients and to advance the e-NABLE movement.

Because the prosthetic design files and guides distributed by the e-NABLE community are made available through the Internet free of charge or registration, it is currently difficult to track the dissemination of these devices with any precision. Nonetheless, it is clear from hundreds of news articles, awards, and requests for help setting up e-NABLE chapters around the world, that the devices and the emerging culture of "connected humanitarianism" they represent, have garnered considerable interest from policy makers and prosthetists, as well as educators.

So far, most e-NABLE devices have been given to children in the first world, where medical grade prosthetics for children are theoretically available. However, because they can cost thousands of dollars, and because children often find hooks or heavy cosmetic hands cumbersome or "creepy," and because children outgrow them, medical grade prosthetics for children are often impractical and unappealing. In contrast, the e-NABLE community soon discovered that brightly colored e-NABLE "superhero hands" were a big hit with many children and with the press. As word has spread, international interest has expanded as well. The non-profit Enable Community Foundation is working to bring inexpensive devices to underdeveloped regions around the world where upper-limb prosthetics are virtually unavailable.

GETTING SCHOOLED

A growing number of students, teachers, and youth groups have become part of the e-NABLE movement.

As early as 2013, teachers saw the educational potential of having students build 3D-printed hands for actual recipients and began making their first forays into this work. One such educator was Brookwood Science teacher Richard Lehrer who, after seeing the same YouTube video that inspired Schull, worked with his class to make a 3D-printed hand for his own son, Max.

Numerous other teachers have since discovered that this is a highly motivating, project-based and service-learning activity. A team at St. Margaret's Episcopal Upper School provides a well-documented case study of inspired children teachers and administrators who provided a brightly colored mechanical hand to a five-year old girl. [6]

Another interesting early case involves nine-year old Nathaniel, who lives in Dinwiddie, VA. He was paired up with a class at the Convent of the Sacred Heart, an all girls pre-school to High School institution in Manhattan, New York. The class documented their progress on-line. [7]

FIGURE 2
FRAME FROM ST. MARGARET'S EPISCOPAL UPPER SCHOOL E-NABLE TEAM.

Nathaniel was interviewed by a local television station six weeks *before* he received his student-built hand. Nathaniel tells the interviewer that until recently, he had bad dreams in which he was chased by monsters. "Now," he tells the interviewer, "I say, you don't scare me… because I have two hands!" [8]

Stories like Nathaniel's make it clear that the benefits of these devices go beyond their (still modest, but significant) mechanical functionality [9], [10]

In response to the significant interest in e-NABLE as a source of engaging learning opportunities, the Enable Community Foundation created the e3STEAM education initiative (e3STEAM stands for Enable Education Exchange, Science Technology Engineering, Arts and Math) in July 2015. The group is collecting and sharing best practices course plans, student-authored instructional videos, and other materials created by over 200 schools in North America. [11] Like the device designs, this material is typically open-sourced.

GETTING SCHOOLED AT VERTUS

In 2015, in its first year of operation, the Vertus Charter School in Rochester, NY, began planning for an ambitious summer program around e-NABLE and in partnership with the RIT FOSS@MAGIC LibreCorps program. Through this partnership they would develop a curriculum and summer job program for twelve 9th grade students.

A year-round, blended-learning, college and career high school, Vertus serves inner-city boys. Each student is part of a learning team of 12-16 students led by a full-time educator called a "Preceptor." The Preceptor, who is 100% responsible for the success of each of his student's, serves as a mentor, guide, and teacher. Each day, each Preceptor leads his team of young men as they rotate through personalized, mastery-based on-line coursework in learning labs, face-to-face instruction with teachers, and hands-on learning activities such as 3D printing, game design, machine design, art, chess, cooking, slam poetry, and improvisation. Preceptors also engage their teams in a daily character and career seminar.

Each student is assessed upon entry. Students who arrive below grade level (more than 70%) are placed in age-appropriate on-line and teacher-led reading and math courses that meet them where they are and build their skills as quickly as possible. As students become ready, they add higher-level subjects. Each student sets individual weekly goals for academics and character development. Teams and individual students compete on attendance, character, and academic progress and overall accomplishments for weekly and monthly for prizes and wristbands that have value in the school store.

In their first 1.5 years at Vertus, students averaged over 3 years growth in math and 4 years growth in reading as measured by the NWEA MAPS tests – moving from an average 5th grade level to on average 8th and 9th grade levels, respectively. [12] To date, of the twenty-five Vertus students to take a NY State Regents Exam, 100% have passed.

Through FOSS@MAGIC's LibreCorps program [13] (which places students in humanitarian, Open Source coops) RIT engineering student Elizabeth Jackson was hired for the Vertus Summer Job program. Elizabeth worked with Vertus Project Manager Jamaal Peavy and Vertus Curriculum Coordinator Naomi Geier, to create the curriculum and implement the program.

FIGURE 3
VERTUS STUDENTS AT WORK PRINTING PARTS OF AN E-NABLE HAND. [14]

Over six weeks, Vertus students learned about physiology, birth defects of the hand, 3D modeling, 3D printing, how to assemble e-NABLE hands and quality control testing. The Mayor of Rochester and her staff toured the program. At the end of the program the students met one of the clients they had built a hand for [15] and received tearful thanks from the child's father. For most of these students, this was a first job experience as well as an introduction to technology and service. Some of those students are now preparing to coach incoming students in a Summer 2016 replication.

FIGURE 4
A VERTUS STUDENT ADJUSTS THE TENSION ON AN E-NABLE HAND GRIPPING ACTUATOR [16]

FUTURE WORK

Education has become a significant focus of the Enable Community Foundation. Although the building of hands for actual recipients often provides the initial draw for schools, e-NABLE is seeing innovative educators create broad project based learning experiences for their students. These experiences include, but are not limited to, having students customize hands for recipients, design purpose-specific devices, conduct public speaking/tech presentations to educate communities in- and outside of schools about the work, engage in diversity/empathy training, and participate in collaborative e-NABLE projects with other schools (both in the U.S. and beyond).

Additionally, the e3STEAM initiative is developing a curated curriculum repository structured to help educators in different disciplines and educational settings find appropriate materials to adopt or modify for a variety of educational tracks, such as service learning, 3D design, 3D-printing, design thinking, etc. A first step is currently being undertaken by the RIT student leading the Summer 2016 e-NABLE program at Vertus: Akanksha Vishwakarma has created a guide to 12 different lesson plans and websites created by e-NABLE schools. These resources provide overviews and pointers to primary material at EnableCommunityFoundation.org and EnablingTheFuture.org, as well as instructional materials created for, or by, middle school and high school students. The guide will underpin the curated curriculum repository which will be offered under Creative Commons licenses at the Enable Community Foundation's e3STEAM website.

The curriculum created last year for Vertus will expand beyond the first year's focus, which was primarily on the skills and knowledge required to work on the production of the hands themselves. These changes are informed, in part, by the results of job interviews conducted to determine this year's cadre of student workers.

Andrea Bertucci, a Career Program Manager at Vertus, and Vishwakarma found an interesting split in motivations between students who would be participating for the first time and students who would be returning for a second year. Students who would be participating got the first time were interested in doing so because they wanted to learn 3D modeling and printing as well as a paid summer job on-site at the school. The potential returning veterans of the program, on the other hand, spoke more about the pleasure they got in helping others as an intrinsic motivation for reapplying. Bertucci will be working with Vishwakarma to add additional lesson plans to the overall curriculum to include writing assignments to build on these intrinsic motivators team, add team building activities and personality development programs. There will be additional emphasis on students iterating on existing designs and innovating around new ones.

Interest in e-NABLE from the education sector up to this point has centered around teachers' desires to involve students in the meaningful process of building and distributing devices. With more and more educators wanting to extend the students' e-NABLE experience beyond the building of hands, including many looking to address some of the NGSS engineering standards through this work, ECF welcomes input from the formal engineering Ed community.

The work described in this paper falls squarely within the emerging practice and traditions of project-based learning and service learning [16]. However, the design, fabrication, and delivery of prosthetics for children and underserved populations is arguably a uniquely multifaceted and inspirational arena for harnessing and integrating science, technology, engineering, art and medicine, as well as helping students experience, sometimes directly and profoundly, the rewards of applying learning and emerging technologies to the betterment of others.

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