the Invention Factory

Student inventions aid individuals with disabilities

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The Invention Factory is a nontraditional youth-based, after-school program in Honolulu that teaches information technology and mechanics to teenagers through interactive, hands-on projects that improve human computer interaction for individuals with disabilities. The content area students study is electronics with embedded microcomputers, and the targeted population is students in grades 8 through 12. All teacher and student participation is voluntary.

One objective of the program is to stimulate interest in science and engineering careers among students currently underrepresented in those fields: women, native Hawaiians, students with disabilities, and at-risk students. Another objective is for students to learn enough electronics, mechanics, mathematics, and computer programming to conduct needs analysis, design, fabrication, and evaluation of devices that meet the needs of people who are disabled. The program intends to demonstrate that students who create technology-based solutions that impact people have increased motivation to pursue careers in engineering and science. The results are not in yet because the students are halfway through their three-year program.

An idea for a program

The idea for the Invention Factory program began with a single two-hour career-week workshop for high school girls. The organizers asked Sandy Gabrielli, a female engineer, to share her experiences in assistive technology (AT) engineering with the girls. Instead of just talking about engineering, she provided a short engineering experience by teaching students some elementary electrical theory and hands-on skills so that they could properly build a large switch and modify electronic toys to make them usable by children with motor disabilities.

The students, none of whom had used hand tools or soldering irons before, glowed with satisfaction when they successfully tested their switch and toy. This practical activity provided a perfect introduction for a short discussion about the engineering knowledge involved in the creation of more advanced human interfaces to information technologies. At the end of the workshop several students said they wanted to become engineers and all of them wanted to sign up for another workshop.

Later student and teacher interviews revealed several different driving forces at work: The students were fascinated by the technologies, learned new information, mastered new skills, related to the intended user and recognized the need, understood how the proposed solution matched the need, and experienced a great sense of achievement when their small project was successful. These activities provided a way to get young people interested in science, technology, engineering, and mathematics (STEM). Word of this workshop spread quickly among teachers and within a few weeks there were requests from schools all around the island of Oahu for similar workshops to be held in schools. So from a small start, the Invention Factory grew.

Community partners

This program consists of quite a few collaborating partners. Invention Factory staff are University of Hawaii employees from the colleges of education and engineering, including faculty, instructors, technicians, graduate students, and undergraduate students. A dozen undergraduates volunteer their time to help with the project. The Native Hawaiian Science and Engineering Mentoring program has provided the project with workshop instructional aides. Participating middle and high school teachers collaborate, providing school and curricular connections, supervision, and space. Women in Technology, a nonprofit organization that encourages girls to enter the STEM fields, facilitates recruitment of participating schools. Gender equity objectives are addressed by attempting to have an equal number of boys and girls in each workshop, and mentoring opportunities are ensured for girls who participate in the program. Currently 34% of workshop students are girls and 19% of workshop students are native Hawaiians.

Community collaborations and projects for special-needs clients are initiated through staff contact with individual teachers, AT utilization specialists, and service providers. Outreach and publicity activities include presentations to teacher groups and project exhibits and workshops at local conferences for disability-related organizations. The program has grown in the community through word of mouth and successful experiences by end users, which generate additional requests.

Students have contributed over 100 modified toys and switches to the community in the first year of the project. The AT Resource Center of Hawaii maintains a lending library of toys that students have modified and provides students tours of their AT lab. Students have modified toys and donated them to Shriners Hos-

FIGURE 1

Examples of Modules.

Module 1: Introduction to Electronics
Students modify a toy and make a remote switch for children with motor impairments.

Module 2: Attention-Getting Devices
Students develop alternative alerts (attention-getting circuits) for people with sensory deficits. Students work with light (hearing impairments), sound (visual impairments) and vibration (hearing and visual impairments).

Module 3: Magnetism
Students build a Morse code communication device.

Module 4: Electrical Machines
Students invent a moving display to entertain and amaze.

Module 5: Audio
Students build an audio amplification system and voice-operated relay switch for people with speech disorders.

Module 6: Accessible User Interaction
Students develop a single switch scanner for operating a toy or a communication device for persons with limited movement.

Module 7: Introduction to Microprocessors
Students develop light and temperature sensor systems.

Module 8: Electronic Dice
Students build electronic dice to be used as a recreation tool for elderly individuals.

Module 9: Remote Control Applications
Students work with infrared and radio frecuency to develop ways to control fans, lamps, televisions, etc.

Module 10: Digital Recorder Applications
Students develop digital recorders to be used as simple sound- or speech-based games and communication devices.

FIGURE 2

Knowledge and Skills Self-Inventory.

Scoring

0 = Don't know or can't do it

1 = Know how to or have done it

2 = Can teach it to another student or teacher

I. Ability to recognize the following

Passive components

[ ] conductors [ ] protoboards
[ ] insulators [ ] connectors
[ ] lamps [ ] resistors
[ ] batteries [ ] capacitors
[ ] switches [ ] inductors

Electromechanical components

[ ] motors [ ] relays [ ] microphones [ ] speakers

Sensors

[ ] light-dependent resistors [ ] optointerrupters
[ ] temperature-integrated circuits [ ] pressure
[ ] infrared detectors

Active devices

[ ] diodes [ ] transistors
[ ] light-emitting diodes (LEDs) [ ] optoisolators
[ ] integrated circuits

II. Can explain the function of

Passive components

[ ] conductors [ ] protoboards
[ ] insulators [ ] connectors
[ ] lamps [ ] resistors
[ ] batteries [ ] capacitors
[ ] switches [ ] inductors

Electromechanical components

[ ] motors [ ] relays [ ] microphones [ ] speakers

Sensors

[ ] light-dependent resistors [ ] optointerrupters
[ ] temperature-integrated circuits [ ] pressure
[ ] infrared detectors

Active devices

[ ] diodes [ ] transistors
[ ] LEDs [ ] optoisolators
[ ] integrated circuits

III. Skills

Using hand tools

[ ] sidecutter [ ] solder sucker [ ] hand punch
[ ] longnose pliers [ ] wire stripper [ ] metal press
[ ] wrench [ ] hammer [ ] hot-glue gun
[ ] screwdriver [ ] hack saw [ ] needle and thread
[ ] hand drill [ ] ruler [ ] scalpel
[ ] electric drill [ ] scribe [ ] heat shrink gun
[ ] soldering iron [ ] center punch [ ] other ____

[ ] Reading an electrical circuit schematic

[ ] Using a digital multimeter to measure resistance, voltage, and current

Following a circuit diagram and assembly instructions to construct a hand-wired electrical device including

[ ] disability access switch [ ] flashlight
[ ] modified electronic toy [ ] other ____
[ ] Morse code key switch and buzzer

Following a circuit diagram and assembly instructions to assemble and test electrical circuits on a prototyping board

Audio circuits

[ ] microphone [ ] amplifier
[ ] speaker [ ] tone generator

Digital circuits

[ ] logic [ ] timer [ ] counter [ ] other

Programming a microprocessor to perform a variety of tasks

[ ] flashing LEDs [ ] controlling a motor
[ ] producing sounds [ ] electronic die
[ ] other ____

IV. Invention

Describing an invention

[ ] name [ ] microprocessor programming
[ ] general description [ ] mechanical specification
[ ] electrical specification [ ] sketches

Prototyping an invention

[ ] simulation [ ] working model
[ ] trial test [ ] user instructions
[ ] usability test

pital and participated in recreational therapy with the hospital clients. Hawaii Department of Education special-education teachers, speech teachers, and teachers of the visually impaired have presented lectures about disability at workshop sessions and made specific device requests. Students then built those projects (predominantly toy modifications in early workshops) and gave them to teachers to use with students with special needs. Kapiolani Children's Hospital's Speech and Hearing Clinic provided students with project ideas that are being implemented in student design exercises. The Hawaii Department of Health's Early Intervention Program has requested specific devices. In some schools, students are given design projects that involve students enrolled in the special-education classes at their own school. These projects are carefully defined to include the client student as an equal partner in the design and invention process.

Other community collaborators include the Engineering Information Foundation, the University of Hawaii's Institute of Electrical and Electronics Engineers student branch, the Special Parents Information Network, and parents, including homeschooling parents.

Promoting inquiry

Invention Factory activities address numerous National Science Education Standards. As a result of their participation, students develop abilities in technological design and understandings about science and technology (NRC 1996, p. 190). Creativity, imagination, and a good knowledge base are all required for this work, and students respond positively to the concrete, practical outcome orientation of design problems. Students also see science in a social perspective, developing understanding of personal and community health and environmental quality (NRC 1996, p. 193).

Invention Factory personnel work closely with AT professionals to develop curricula that inform students as well as provide real-world applications and working public-service projects for student participation. The program curricula consist of individual modules that cover a basic concept in electronics; activities, exercises, demonstrations, and projects to support that concept; and an activity that directly relates to AT.

Instructors travel to schools with raw materials organized as kit sets designed and produced by Invention Factory staff. These sets and accompanying activity booklets help the instructors guide students through the modules (see Figure 1, p. 43, for examples of modules). Experience has shown that traditional lecture/lab format does not work with after-school program youth. After some trial and error, the modules have evolved into sequences of short periods of hands-on activities, each preceded and followed by a short period of explanation or discussion. A typical class period may contain about six activities and demonstrations that teach basic principles that collectively lead to a functioning electronic device. Many of the activities are designed to evoke the question, "How could a disabled person use this, or use a variation of this?" Toy modifications are introduced during the first module as a lead in to teaching practical skills and applying what students have just learned.

The first module consists of an introduction to electricity and simple circuits during which students construct a circuit consisting of a battery, lamp, and switch. After students complete wiring we ask them, "How could you modify this to enable it to be used by a person with a disability?" After students have figured this out and modified the lamp circuit so that it can be controlled by a remote switch, they then assemble an accessible switch and test it with the lamp circuit. Then students select a toy, study how it works, decide which switch or switches need to be made remote, make drawings of what they propose doing, dismantle the toy, insert additional wires and sockets, reassemble the toy, and test it with the switch they made earlier. If the toy does not work, students backtrack to find the problem, fix it, and then reassemble the toy. All of these activities introduce and reinforce a wide range of hand, analytical, and invention skills. Both the toys and the switches are donated to disabled children.

FIGURE 3

Radio-Controlled Car.

Student invention to encourage a child with autism to participate in speech-therapy activities.

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Disability awareness lessons are included in each module. For example, in Module 1 (Figure 1), students are given additional reading about inclusion of students with disabilities in classrooms and have a class discussion about issues of accessibility.

Assessment and self-inventory

Much of the student assessment is informal. Because our primary goals are to develop positive attitudes toward STEM subjects and to stimulate inventiveness, any specific skills and knowledge students acquire are seen as a bonus. Later modules do include deliberate information gaps to be bridged by students, and at key points in any project's construction students must have devices checked by an instructor who will point out problems, opportunities, and related concepts. Most of the activities can be considered a success if the project is assembled correctly and neatly and the circuit or device works in the intended manner.

Students keep a record of their acquired skills, knowledge, and invention ideas and development in an engineering notebook. We are just starting to implement a concept-and-skill student self assessment that can be corroborated by an instructor. The prototype is shown in Figure 2 (p. 44). Important statements include invention of an accessible device, ability to recognize and give the function of electrical components, ability to solder, ability to design a circuit board, and ability to program a microprocessor. We are also developing a resume-writing computer program tied into the concept-and-skill student self assessment that will help students communicate the wide array of skills, knowledge, and experiences that they have garnered in and out of the Invention Factory program. The authors believe that students will graduate from the program with the confidence and knowledge, as exemplified in the resume, to further pursue STEM careers.

Examples of inventions

One example of the types of inventions developed through the Invention Factory program originated during a class presentation—a speech therapist described how a young boy with autism had refused to intentionally blow air. The child's parent had specifically requested in the individual education plan that the student be able to blow out his birthday candles; his teachers and the speech therapist had tried everything from bubbles to a silk scarf but nothing was working. Invention Factory students knew that radio-controlled cars are very motivating to many young boys, so they designed and built a working pinwheel interface made out of a small microprocessor, the guts of a computer mouse, a very cool off-the-shelf car, and a pinwheel. As the pinwheel is blown, the car drives forward or backward (Figure 3, p. 45).

Another group of students designed an "Incredibles Mobile" after hearing a class presentation from a family member of a five-year-old boy with autism. Students were told that the child loved things that are heavy, circular, and have repetitive motion. The child needed functional-skills development in understanding cause and effect and how to turn knobs. Students designed and created a mobile out of a motorized musical baby-crib mobile, accessible switches, and action figures from the movie *The Incredibles*.

Impacts of the Invention Factory

The Invention Factory shows students that they can invent and produce practical solutions to real problems and makes them aware of entrepreneurial opportunities. By focusing on inventing solutions to problems facing disabled and aging people, students fulfill their community-service responsibilities and increase their awareness of how technology can be used to help people. Techniques developed to assist individuals with disabilities naturally fit the needs of elderly people with mental or physical limitations brought on by aging. Some students have made a trip to a nursing facility and met with elderly people. The project is just reaching the stage of increasing these activities. Applications for elderly people include turning on appliances instead of a toy, answering the phone, and electronic dice for playing board games. Students are taught the processes involved in taking an idea through to the product stage. They are shown the difference between a handmade prototype and the same thing assembled on a printed circuit. Students have the experience during the summer of designing and making a microprocessor unit on a printed circuit. They also begin to understand the value of intellectual property and are taught about the patent system and what it does to protect inventors.

The Invention Factory has five levels of impact: (1) students attending the Invention Factory; (2) the products they generate; (3) the disabled and elderly populations affected by students; (4) community awareness (parents, regular school teachers, and the general public) of the need for STEM education and the needs of people with disabilities by press coverage and word of mouth about the impact of student outreach; and (5) the reproducibility and extension of the program to other communities. One goal for next year is to increase the number of opportunities for students to meet directly with the consumers of AT.

Creating a device that empowers a disabled child to do something they have never been able to do before, or enabling an elderly person to regain the ability to do things they thought they would never be able to do again, is an extremely moving, exciting, and motivating experience. There is a natural feeling of wanting to come up with an even better solution that strengthens the incentive to learn how to do so. Seemingly irrelevant physics or mathematics activities suddenly become relevant to meeting real needs. Once the link to real people with real needs is established, the ability and skills to actually make a working device become just as important as knowing how to design the software and electronic circuits. ■

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Reference

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academy Press.