The Use of Robotics to Promote Computing to Pre-College Students with Visual Impairments

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This article describes an outreach program to broaden participation in computing to include more students with visual impairments. The precollege workshops target students in grades 7–12 and engage students with robotics programming. The use of robotics at the precollege level has become popular in part due to the availability of Lego Mindstorm NXT kits. The robotics programming tools and materials used in the workshops are designed with an accessibility focus for participants with different degrees of vision. Through the use of available assistive technology and open source software, robotics is accessible to the visually impaired. The quantitative and qualitative results from three robotics workshops conducted during the past three years will be discussed, including some initial long-term results. Strategies, based on our experiences, will also be shared to promote accessible outreach. While many of the participants are in middle and early high school, findings indicate that participant interest in computing is high regardless of whether their schools offer computer science courses or not. Increased interest and confidence with robotics persists throughout follow-up activities.

Categories and Subject Descriptors: K.3.1 [**Computers and Education**]: Computer Uses in Education—*Collaborative learning*; K.3.2 [**Computers and Education**]: Computer and Information Science Education—*Computer science education*; K.4.2 [**Computers and Education**]: Social Issues—*Assistive technologies for persons with disabilities*

General Terms: Design, Experimentation, Human Factors

Additional Key Words and Phrases: Accessibility, broadening participation in computing, outreach, robotics, visually impaired

ACM Reference Format:
Ludi, S. and Reichlmayr, T. 2011. The use of robotics to promote computing to pre-college students with visual impairments. ACM Trans. Comput. Educ. 11, 3, Article 20 (October 2011), 20 pages.
DOI = 10.1145/2037276.2037284 http://doi.acm.org/10.1145/2037276.2037284

1. INTRODUCTION

Various approaches are used to reach out to the pre-college community when promoting Computer Science and related disciplines. Examples include day camps or camps that last for weeks at a time. These camps often consist of presentations about careers or skill building through activities in Alice [Kelleher et al. 2007], robotics [Cannon et al. 2007; Rodger et al. 2009], or CS Unplugged activities [Taub et al. 2009]. Students with disabilities are generally underrepresented in many such outreach activities. Consequently, students with disabilities do not have the same opportunity to learn about careers or acquire the precollege computing skills that will help them successfully pursue computing careers.

Project ACE is funded by the National Science Foundation (#0634319, 0837493).
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DOI 10.1145/2037276.2037284 http://doi.acm.org/10.1145/2037276.2037284

Even as computing courses are offered in many middle and high schools, students with disabilities (such as the visually impaired) are underrepresented. Visually impaired students can face barriers in terms of insufficient access to information that is often presented visually, including the use of graphical notations [Smith et al. 2000]. In addition to outreach programs, participation in mainstream computer courses and university programs is the gateway to a career in computing such as a software engineer, system administrator, database administrator.

The lack of statistics for participation in computing by visually impaired students causes a reliance on anecdotal evidence. Statistics are maintained for women and minorities, while at best all students with disabilities are grouped together. The potential for participation is great as approximately 1.5 million computer users are visually impaired [American Foundation for the Blind 2007].

The highly visual nature of software, such as Alice or Scratch, designed to draw young people into computing are examples of effective software that are also not accessible to the blind. Thus, young people who are visually impaired are less likely to participate in such outreach efforts as sighted students who use these popular programs. When paired with lower expectations by society and eventually themselves, young people who are visually impaired face additional challenges.

The goal of Project ACE (Accessible Computing Education) is to increase participation in computing by young people with visual impairments through accessible opportunities for exploration, skill, and confidence-building. The student outreach program is called ImagineIT and focuses on students in grades 7 through 12 who are visually impaired. Other components of Project ACE consist of teacher training and resource development.

Approximately 1.3 million Americans are considered legally blind, referring to "central visual acuity of 20/200 or less in the better eye with the best possible correction, as measured on a Snellen vision chart, or a visual field of 20 degrees or less" [American Foundation for the Blind 2006; Cannon et al. 2007].

The ImagineIT workshops are not entirely unique in the area of providing disabled students the opportunity to build their skills and explore technical careers. The University of Washington's DO-IT Center provides such opportunities for disabled students before college and after admission [University of Washington Do-It Center 2007]. The National Federation of the Blind held their second summer event to introduce blind high school students to STEM (Science, Technology, Engineering, and Mathematics) fields [National Federation of the Blind 2009]. In addition, one of the authors and two undergraduate student assistants conducted the robotics track at NFB's Youth Slam 2009 event. Many regional blind advocacy groups, such as ABVI/Goodwill, focus more on basic computer skills rather than college preparation skills and events. The ImagineIT student workshops seek to address this gap in terms of computing careers by introducing students to multiple areas of computing. As part of the workshop, students are encouraged to pursue their interests and follow up with in-school or after-school programs if present. The use of robotics programming as the primary technology leveraged in the workshops is the topic of focus in this article. To date nearly 50 participants in grades 7 through 12 have participated in the ImagineIT workshops during the last three years. The discussion of the design of accessible robotics programming using Lego Mindstorm NXT and the results of the workshops to date will be discussed based on our initial goals.

2. RESEARCH QUESTIONS

The population of focus for the ImagineIT student workshops is that of pre-college students with visual impairments in grades 7 through 12. The weeklong summer workshop introduces the students to robotics programming, computer hardware concepts, and general computing skills in an accessible environment that includes teamwork and problem-solving activities throughout. Follow-up, weekend workshops build on participants' robotics programming skills and continue an active discussion of computing careers and college.

The goal of ImagineIT is to increase participation in computing courses and activities by students with visual impairments. As such the research questions that are relevant to this goal are:

Q1: To what degree do the workshops' robotics activities engage the participants in computing in terms of interest and confidence?
Q2: Beyond the workshop, do participants remain engaged in computing?

In order to explore these questions, both quantitative and qualitative methods were used and shall be discussed in Section 8. Current results will be discussed in addition to strategies to help accommodate participants with visual impairments in other outreach efforts.

The outreach will be discussed in terms of the results to date in relation to the participants' interest level in computing, interest in pursuing computing, and subsequent participation in computing classes (e.g., computer science or related courses). The quantitative and qualitative results from three robotics workshops conducted during the past three years will be discussed, including some initial results from the follow-up workshops. The summer workshops are a week long in duration, supplemented with accessible CS Unplugged activities and discussions of college and careers. While many of the students are in middle and early high school, findings indicate that student interest in computing is high regardless of whether their schools offer computer science courses. Interest level and confidence with robotics is also higher after the activities and continues through the follow-up workshops. Following up with the students is critical especially for students less affluent schools. The results of a pilot set of follow-up workshops will be discussed in terms of tracking student interest over time and how such interest has manifested in and out of school.

3. RELATED WORK

During the past few years, many projects and initiatives have been undertaken to engage students in computing with the intent of increasing enrollment in Computer Science and related fields [National Center for Women in Technology 2010; National Science Foundation 2010]. The National Science Foundation alone has funded many such projects for students at the precollege level under its Broadening Participation in Computing program during the past four years. Some programs teach programming with Alice or Web site design. The use of robotics is also popular in summer camps, workshops, and similar activities. Robots are concrete, can be programmed, and often designed or customized. Kits such as the Lego Mindstorm NXT robots can also be purchased from online retailers or toy stores and come with software to program robots to interact with its environment.

Extracurricular efforts such as FIRST's Lego League, Tech Challenge and Robotics Challenge have engaged thousands of secondary school students since 1992. Brandeis University conducted research comparing students who have participated in FIRST with students who have not participated. Students who have participated in the high school-level Robotics Competition are slightly more than three times as likely to pursue a degree in engineering over students who did not participate—41% compared to

13%, respectively [FIRST 2010]. A 2009 Brandeis University [FIRST 2009] study on middle school-level FIRST Lego League participants noted that:

— 89% of FLL participants wanted to learn more about science and technology.
— 93% of FLL participants wanted to learn more about computers and robotics.
— 89% of FLL participants reported being more interested in doing well at school.

An earlier Brandeis study [FIRST 2006] undertaken to assess the impact of FLL on underserved populations found that:

— 90% of underserved FLL participants wanted to learn more about science and technology.
— 93.4% of underserved FLL participants wanted to learn more about computers and robotics.
— 88.5% of underserved FLL participants reported being more interested in doing well at school.

Note that the results, though a couple of years apart, are very similar. Because of the size and scale of FIRST is very large, with tens of thousands of participants in the United States alone, they have demonstrated a means for follow-up after students have graduated from other outreach activities.

On a smaller scale, robotics activities have been conducted as a means to broaden participation in computing. Examples include the University of Minnesota's Technology Day Camp for African-American and Hispanic students [Cannon et al. 2007], Georgia Tech's Technology Engineering and Computing Camp for middle school aged girls [Georgia Tech 2010], and Lamar University's INSPIRED Computing Academies for middle school students [Doerschuk et al. 2009].

Students with disabilities often do not feel included or welcomed in mainstream activities. While some outreach activities do target students with disabilities such as a camp offered at Auburn University [Marghitu 2008] and activities through University of Washington's DO-IT Center AccessComputing Alliance and the work of Richard Ladner [Ladner and VanDeGrift 2008; University of Washington Do-It Center 2007], mainstream activities do not gather statistics for participation by students with disabilities. Evidence is often anecdotal by students as many program do not keep track of disabilities as part of their demographic information for program assessment.

The ImagineIT student workshops intend to fill the gaps by offering challenging, yet accessible activities that also allow for visually impaired participants to connect with their peers throughout the school year. The latter is also important as students who attend mainstream schools are isolated from their peers who are also visually impaired. If ImagineIT is ultimately successful, students can move forward and ultimately follow up with enrollment in computer programming courses in their school or participate in an extracurricular activity such as those that FIRST conducts.

Other mechanisms exist to engage visually impaired students in programming such as programming chatbots [Bigham et al. 2008] or scripting audio routines for music using APL [Sánchez and Aguayo 2005]. The use of robots was selected for their tactile/physical quality, potential linkages to classes and clubs, and for the fun factor. The fact that robots are concrete objects and that robots have moved out of the factories and into many homes and other venues makes the interest factor potentially more appealing to participants. While visually impaired students have difficulty with vision, they are young people first. The authors want to engage them as young people who have similar interests as their sighted peers, but who need accommodations for their vision. The subsequent discussion of the accommodations needed explores these issues in more detail.

4. REQUIREMENTS

In order to design and develop an engaging, accessible workshop, a list of requirements was identified that must be consistently met. For the scope of this article, the requirements for the robotics activities are:

(1) The activities must be accessible to participants who represent a diversity of visual impairments. Regardless of whether a participant has no vision or low vision, the activities must be able to be accomplished by all.
(2) The software tools to be used must be compatible with screen reader and screen magnifier software, such as JAWS and Zoomtext. The user interface and the source code must be able to be heard/seen by participants. Since teams of students would be working together, the auditory and visual presentation must be able to be conducted simultaneously.
(3) The participants must be able to interact with their robot at a basic level in order to turn it on/off, plug in motors and sensors, and run the desired program.
(4) The tutorial materials must be available in digital form and in large print/Braille.
(5) The tutorials and design challenges must facilitate a progression of programming and software engineering skill building and exploration.
(6) The activities must be age-appropriate and fun.

The strategies for accomplishing these requirements are discussed in subsequent sections. It should be noted, that there is not a requirement for the participants to build their own robot. Due to the goals of the workshop, with a focus on programming skills, building the robot from scratch was explicitly part of the activities.

Note that requirements and subsequent discussion does not focus on the building of the robots themselves. The focus is on programming skills and related robotic concepts such as sensors and motors—not the assembly of the robots. While robot design is a useful skill with Lego Mindstorm NXT, the time needed for the students to assemble the robots is not practical for the current workshop schedule, especially given that the students use multiple robots during the course of the workshop. The need for tactile robot assembly instructions would also be needed for many students. The team is exploring the topic of tactile instructions, but a pilot set of such instructions was not available at the time. In order to provide the pilot some broader design skills and to observe how participants would accomplish basic tasks, the activities were designed to require participants to customize their robots with sensor modules and larger components during the activities throughout the week.

5. TECHNOLOGY OF BRICXCC AND NXC

Very early on in project planning, Lego Mindstorm robots were selected as the technology to use. Initially the older RCX robots were selected due to their larger brick sizes. Due to lack of RCX availability and technological shortcomings, the newer NXT platform was set as the standard for all outreach. The benefits outweigh the smaller size of the pieces, as the Mindstorm NXT robots are used in many K-12 classrooms for STEM activities and the robots are also used in many university classrooms for engineering and computing courses. The NXT robots are also used in most FIRST programs, thus making the transition to other follow-up programs easier for participants. The alternative of using a robot that does not require assembly was an option (e.g., iRobot Create or IPRE Scribbler robots). The potential use of the NXT robots in their subsequent class or extracurricular activities or even home use is seen as a large benefit. The flexibility of building various NXT robots from the same kits is also an advantage over preset robots. Lastly, the balance of cost, portability, and technical troubleshooting made the NXT robots the best choice for our program. NXT robots are easily mailed or packed in luggage for off-site workshops, where the Create robots would either be more costly to ship or take more space to pack. The Create robots are also more limited in their more basic form, and would require several upgrades to accomplish the similar tasks accomplished during the workshops. The IPRE Scribbler robots are small and have multiple sensors, but they can't be customized, the controller cards are bare (and susceptible to electrostatic discharges or other damage), and problems have arisen with Bluetooth conflicts in prior use. The Create and Scribbler robots are good products in their own right, and enable programming in various languages but they were not selected as appropriate for this project at this time.

Software is available from Lego for programming Lego Mindstorm robots. Robolab/NXT-G is developed from LabView, and is designed to be a simple language to learn especially given that icons are used to represent the commands. In order to meet our requirements, Robolab/NXT-G was not selected as it is not compatible with screen readers, thus making it impossible for blind students to use.

Research was conducted to find the best alternative programming software and language in terms of access and cost. The issue of cost is important in order to make it easier for students to continue programming. The finalists were between using BricxCC with the NXC (Not eXactly C) language and a text editor with Java (using lejOS or a similar firmware revision). Both languages are text-based and the development environments are free and compatible with screen readers. The ease of learning the language for both the participants and prospective mentors was a deciding factor as NXC is less complex than Java and was determined to be easier for students to learn given the duration of the workshops. The use of Java also required the Lego Mindstorm Brick firmware be replaced. Firmware adjustment was not desired in order to promote activity replication and technology adoption by parents and educators. Java will be considered for more advanced workshops. The BricxCC environment also includes features such as a virtual brick (as a brick interface aide) and a piano feature (to record sounds and add them to the program). Java environments currently do not facilitate such features.

While Java is commonly used as an introductory programming language, the NXC language was selected as an appropriate choice to provide a low learning curve and was accessible. The programs the students develop are relatively small—dozens of lines long. However, the programs created provide the desired design challenge for novice to intermediate students. The procedural NXC language has a simple, easy-to-learn syntax that is easily readable by screen reader software. A companion programming environment, BricxCC [Hansen 2007], was selected and found to be compatible with the JAWS and Zoomtext screen reader/magnification software. BricxCC is an open source environment that supports varying robotics technologies, including Lego Mindstorm NXT.

6. ASSESSMENT OF ACCESSIBILITY

Each element of the workshops is designed and tested so that all participants can complete the activities and contribute team effort. Other than the logistics of the workshop, the breakdown for assessment falls into the categories of: Software, Hardware, and Materials.

6.1 Software

In order to meet the requirements that the software tools are compatible with screen readers and magnifiers, careful assessment of BricxCC was conducted. Even after

Table I. BricxCC Feature Compatibility with JAWS and Zoomtext (M for Magnifier and S for Screen Reader)

BricxCC Feature	Compatibility		Comments
	JAWS	Zoomtext	
Accurate reading/display of source code	4	5 (M), 4 (S)	In order to read punctuation, a JAWS setting must be enabled. While line numbering is visible, they cannot be read on a screen reader.
Able to recognize the NXT brick, compile code and download programs to the brick with audio cues	4	4 (M), 3 (S)	No audio cue for finding the brick if it loses communication with it, but the brick beeps when the program is downloaded to it successfully.
Open and save source code files	5	5 (M, S)	
Able to read errors from the compiler	4	4 (M), 4 (S)	Since the window is at the bottom, the error and code cannot usually be seen at the same time on high magnification. Also, the error window changes the focus from the source code window.
Able to navigate to the line of code that the compiler error is referring to quickly	3	5 (M), 3 (S)	Due to the line numbers not being read, participants will need to count the line or embed line numbers as comments in order to work around the potential slowdown.
Creation of music files	1	5 (M), 1 (S)	Works with magnification, some buttons read for dialog box.
Direct control of NXT brick from the program	0	5 (M), 0 (S)	Works with magnification.

BricxCC was selected, the array of features to be used was tested as the activities were designed. The core concerns are the:

— Accurate reading of the source code.
— Ability to recognize the NXT brick, compile code, and download programs to the brick and indicate status of process with audio.
— Ability to open and save source code files.
— Ability to read errors from the compiler.
— Ability to navigate to the line of code that the compiler error is referring to quickly.

Desired features not required for the activities that BricxCC contained were also evaluated. These features were:

— Creation of music files (using a piano-like interface).
— Direct control of the NXT brick from the program.

Each feature was assessed with the JAWS screen reader and Zoomtext screen reader and magnifier. JAWS and Zoomtext were selected as they are popular screen reader and magnification products and virtually all of our participants regularly use one or both programs. Each feature was tested with the robot hardware and activity source code files (as relevant) and were deemed to be compatible on a scale of 0-5, where 0 is not at all compatible and 5 is entirely compatible. The assessment is shared in Table I.

Acceptable minimum ratings for either product for each required feature is three, as long as the activities can be conducted with minimal sighted support. The goal was for nearly all ratings to be four or five, especially where higher ratings in JAWS can complement slightly lower ratings in the Zoomtext screen reader features. It is currently possible to run both Zoomtext and JAWS at the same time. When both programs are run simultaneously, only JAWS reads the screen content.

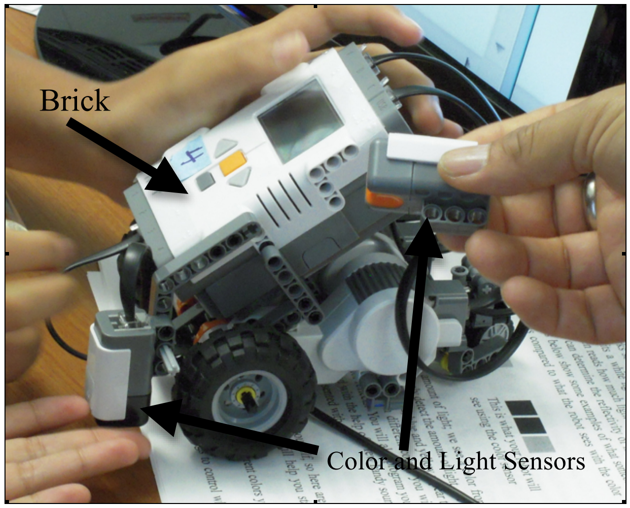

Fig. 1. Students attaching light sensor to Lego Mindstorm NXT robot. (Source: Project ACE).

6.2 Hardware

In addition to the accessibility of the software, the Mindstorm NXT hardware itself was assessed. Participants need to discern the robot's sensors; general layout of the robot model; and parts of the computer "brick" in terms of the ports, buttons, and user interface to navigate to downloaded programs. Each team has a mentor, who may or may not be sighted. A couple of sighted personnel are present at the workshops, and they float between teams to assist when needed. Though sighted personnel are present, the intent is for the participants to lead the work and the mentors/assistants to provide problem-solving guidance and teamwork facilitation. Participants cannot build confidence if they have to rely on a sighted person all the time.

The sensors used in the workshop robots are the touch sensor, light sensor, ultrasonic sensor, and sound sensor. One of the robots is shown in Figure 1.

While the sensors have the same general structure, they have visual and tactile differences, making them accessible to participants. The robot models vary from workshop to workshop in relation to the activities. Examples include the tribot model, whose building instructions come with the kit, and a forklift model that was designed by a research assistant. Each model is designed or modified to match the requirements of the activities and its orientation can be discerned through either visual or tactile means. The central part of the robot is the brick, which serves as the computer, controlling motors and accepting input from the sensors (as shown in Figure 1).

The brick contains ports for motors, sensors, and a USB port for downloading programs. The top ports are to connect to motors. The bottom ports connect to the sensors. The top and bottom orientation helps guide the students, but it is important to know which ports are connected to which motors/sensors for purposes of troubleshooting or modification. The ports are labeled with a Braille labeler. A participant who is blind can trace the connection to a specific motor/sensor by moving their finger from the labeled port via a cable that resembles a network cable.

The brick's user interface has some accessibility issues, but some workarounds exist. The brick has four buttons, with each having its own shape as seen in Figure 1. The buttons allow participants to turn the robot on, select programs, and run programs. The screen on the brick displays the choices to be made, and the output is only visual.

As such the initial selection of the program requires a sighted person or at least the use of a magnification aid for a low vision user. Once the program has been selected, it is easy for a blind user to select the same program and run it as it only requires the press of a single button—once to select the program and once to start it. Stopping a program is also straightforward, requiring the bottom button to be pressed once. While the brick has other features, these basic needs are taken care of for the purpose of the workshops and general use. Due to the self-contained nature of the brick's operating system, with its limited memory, the ideal solution for the access issue would be to rewrite the firmware to accommodate sound files or tones playing when menu items are selected.

The best accommodation derived thus far for participants with some sight is the use of the virtual brick feature in the BricxCC environment. The brick's interface and controls are displayed in a window and the user can select the brick's buttons and control the brick just as if the physical buttons were being pressed. The screen is displayed just as it is on the brick. The use of the virtual brick enabled the brick to be magnified using Zoomtext. Screen reader support does not exist for the virtual brick feature.

6.3 Materials

As critical as the computing tools are to the workshops, the materials must be accessible. As the participants have varying access needs regarding the printed word, various methods of presenting handouts are used. During the pre-registration process, participants are asked about their preferences for accessing printed materials. As a result of their input, the number of large print and Braille copies of the workshop materials are determined. In addition, the documents are also provided as documents that can be read via the screen reader or magnification software. Some students also prefer downloading the documents into a portable document reader that reads to them as they wear headphones.

Another form of activity is the code itself. The tutorial files are well commented in order to provide additional guidance to the students and help them with navigating through files as they become accustomed to the language syntax. The following tutorial example shows the careful placement of comments:

```
/**
 * This program uses the sound sensor
 * Once the sensor detects a sound louder than
 * the threshold, it will execute an action
 */

// sound THRESHOLD in decibels to trigger
movement
#define THRESHOLD 10
// name for SENSOR_2 (sound sensor)
#define SOUND SENSOR_2

task main()

{
   // sound sensor is connected to port #2
   SetSensorSound(IN_2);
```

```
   // loop forever
   while(true)
   {
          // keep sampling until threshold is
exceeded
     until(SOUND > THRESHOLD);
     // move forward
          OnFwd(OUT_AC, 75);
     // pause for .3 seconds
          Wait(300);
     // resume sampling for same threshold
     until(SOUND > THRESHOLD);
          // move backward
     OnRev(OUT_AC, 75);
     Wait(300);
   }
 }
```

In addition to the comment content is the access to the comments. When participants use magnification software, less screen real estate is accessible at a time. Thus comment statements need to be concise and limited in width so that more of the content is readable to the participants minimizing the need to scroll around the screen when compared to long, single-line comments.

7. ROBOTICS PROGRAMMING ACTIVITIES

The pace and format of the robotics activities consist of tutorials that focus on building programming skills, followed by design challenges that integrate programming and design skills with teamwork. During the initial workshop, the robotics portion was two days, while the current summer workshop has lengthened robotics programming to three days during the summer workshop and two weekend follow-up workshops.

The robotics activities for the first workshop have been described extensively in a previous article [Ludi and Reichlmayr 2008]. The difference with the pilot workshop was not only the length of the robotics unit and the addition of a new design challenge, but also the introduction of a new starter robot during the initial tutorial. The initial tutorial, called Activity 0, allows participants to focus on the sensors using an experiment-like approach. Activity 0 allows participants to experiment with sensor threshold values to better understand how their specific robot interacts with the world since each sensor can be a little different in temperament and sensitivity For example, the color sensors are inconsistent in how color values read. After Activity 0, each team of three students moves on to the same tutorials used in prior workshops, though with a more rugged robot model. Since several of the workshops are conducted away from the authors' home institution, the robots are either shipped or transported via checked luggage.

After the tutorials are completed, participants are given a design challenge that is broken down into incremental stages. At the end of each increment, each team demonstrates the robot doing something such as moving down a maze corridor or following a line. The most ambitious challenge used has been the forklift robot, which must follow a line to designated cargo, pick up the cargo, turn around, and deposit it on a box. The increments were broken down into stages, requiring each team to come up with a strategy and test their strategy with small programs before the larger (main) program is revised to accommodate the new step. The stages are:

(1) Robot moves and turns.
(2) Robot follows a black line.
(3) Robot then reads the colored swatch and stops when it sees the cargo.
(4) Robot then picks up the cargo.
(5) Robot then turns around and stops.
(6) Robot is able to follow the line back to another color swatch and sets the cargo down and backs up.

Based on the results of the experiments with the color sensors and the lighting in the room, adjustments have to be made as to which color swatches were used for each robot.

8. METHODOLOGY

The ImagineIT program has had a total of 46 students participate in the workshops. During the pilot workshop, 14 students participated from around the United States representing a wide range of socioeconomic groups. Of all participants, only five participants were female. The participants also represented a wide range of visual acuity and a small number of students have multiple disabilities.

During the current year of the program, two versions of the workshop were offered: one in Southern California and one in New York. Participants are self-selected, and heavy recruiting efforts are required due to the distributed nature of the prospective participants. Recruiting was successful through approaching individual school districts and working with the teachers who support students with visual impairments. Educators have been approached directly and through e-mail distribution lists and forums. In addition, community advocacy centers were also helpful in recruiting and sometimes transporting students, especially low-income students, to the workshop.

In order to support an off-site workshop and to start phasing in the educator portion of the project, the California workshops were supported by team facilitators—secondary school educators who support students with visual impairments. Some of the participants know at least one educator at the workshop.

Before the workshop, the participants were given a set of questions and asked to write a brief essay about their experience and interest in computing. This data was used to ascertain their skill level and assistive technology needs but also to serve as benchmark data to serve as comparison with data gathered later.

During the workshop several random observations and the final design showcase were collected using video. At the end of each workshop, participants were asked to complete a survey regarding their experiences, interest level, and plans for follow-up (e.g., course enrollment). Surveys were administered as either large print, on the computer with a screen reader (and headphones for privacy), and occasionally with a reader who was one of the educators. All quantitative and qualitative data was transcribed for analysis.

9. EVALUATION

The need for evaluation is twofold, to continuously evaluate the workshop program itself and to try and answer the research questions. The quantitative and qualitative data collected is presented in terms of Pre-Workshop Survey, Observations, Post-Summer Workshop Survey (including some parent feedback), and Follow-up Feedback and Sharing.

Table II. Pre-Survey Responses Regarding Pursuit of Computing Courses and Degree

Question	Yes	Maybe	No	One is/was not available
I have taken or have planned to take a computing course at my school, if one is available.	2	4	17	23
I have considered studying computing in college.	6	8	32	-

Table III. Aggregated Breakdown of Assistive Technology Use and Print Accommodation Preferences

Assistive Technology Use	
Magnification software (e.g., Zoomtext)	24 Participants
Screen Reader software (e.g., JAWS)	16 Participants
Other (e.g., Built-in Windows Adjustments)	6 Participants
Print Accommodations	
Large Print with or w/out magnifier	30 Participants
Braille	16 Participants
Digital	3 Participants (overlapped with Braille)

9.1 Pre-Workshop Survey

The purpose of the pre-workshop survey is to assess the participants' interest in pursuing a computing degree in college, assistive technology needs, the degree and focus of any interest in technology, and the types of experience with technology that they feel is important. These questions have remained constant through the different workshop offerings.

In addition to the general interests and technology needs, the need to understand the pre-workshop goals of the students was measured in the form of the two statements that were rated as Yes, Maybe, No. The statements are: “I have taken or have planned to take a computing course at my school, if one is available.” And “I have considered studying computing in college.” The results are presented in Table II.

Some students noted that there are either no computer courses available other than typing/computer literacy but that there may be in their (new) school.

As part of the registration process, parents were asked to describe how they thought the workshop would be helpful for their children in terms of student goals and interests. About a third of parents discussed their children as going to college, but only one noted that their child would study computing. Other professions/majors were noted such as English, theology, and education. However most parents noted that their children like to use computers and that the workshop could help their children learn more about computers. Two parents noted that their children already had some programming skills. One parent noted that their child liked fix computers.

In terms of assistive technologies, all of the attendees used at least one type of assistive technology on a daily basis. The breakdown of assistive technology and print accommodations is shown in Table III.

The need to ascertain the type of assistance technology used is critical in acquiring appropriate copies of the software, acquiring headsets/speakers for the screen reader users, and for considering other workshop logistics such as team formation and facilitator/mentor training in the appropriate technologies. The need to know the number of Braille readers is also particularly important in order to acquire the appropriate number of printouts as they cannot be printed by the authors. Braille printing was accomplished using online services and some school districts have provided assistance with low-volume jobs.

Table IV. Participant Use of Computers

Category of Use	Number of Participant Noted
Web Surfing	38
Communication	42
Social Networking	16
Programming	4
Other (e.g., Writing, Music)	8

More directly, student interest in and experience with computing is measured in terms of direct questions and the open-ended questions about what the participant likes to use computers for. The vast majority of participants are interested in using computers to help themselves (78.3%). In terms of experience, counts are taken for each participant questionnaire and are grouped into general categories of Web surfing, games, talking to friends using Instant Messenger/Skype, and programming. The counts are presented in Table IV. As the participants are free to list the areas of computing which they use, many participants mention multiple areas.

The participants' interests in computing mirror those of many of their sighted peers. The lower numbers of participants who mention social networking sites (e.g., Myspace, Facebook) are possibly due to the fact that that students with visual impairments may not know they can access these sites. In addition, many students note their use of computers to help them complete schoolwork in terms of reading course materials.

9.2 Observations

As useful as surveys are in gathering data, observations of the students as they work and during discussions is also valuable in understanding their interest in computing and the issues that can arise that impact their confidence with them. Even though students selected their preferences for assistive technology, some time was required to customize the technology settings for students. Thus, the collaborative nature of the programming activities requires a balance between tuning the assistive technology for the individual and allowing for all students in a team (who each have different needs) to have their needs met. For example, the use of analog assistive devices such as magnifier sheets or handheld magnifiers alongside the use of magnification software enable some low vision students to work together. During the course of the activities, students are also supportive of each other in terms of accessing information and to fill in gaps when assistive technology is inadequate. For example, BricxCC does not read line numbers, so a student with some sight helps another student find the line of code or helps diagnose a missing semicolon at the end of a line.

Other observations focus more on issues that affect how students see themselves using computers both before and after the workshop. During the initial 2007 workshop a student shared how she was actively discouraged from taking a programming class by the teacher, who didn't want to accommodate her use of magnification software. So she taught herself some Visual Basic.

During the final discussion about next steps in terms of classes and student clubs, students are encouraged to share what opportunities exist at their schools. All students are at least generally aware of what classes are offered at their schools. While many students are excited about possibilities, others state that their school clubs are focused on animation or that classes are limited to basic computer literacy to meet a graduation requirement. The computer literacy classes are reflected in the high number of students in the latest workshop. Clearer questions are needed to find out what types of classes are offered at schools.

Table V. Post-Workshop Student Survey Feedback

Survey Question	2007 Workshop (n = 13)	2009 Workshops (n = 32)
The workshop increased my understanding of the opportunities in a computing career. (1–5, with 5 being highest)	4 (σ = .96)	4.1 (σ = .98)
I will consider studying computing in college – No, Maybe, or Yes	100% said Maybe or Yes	
I will plan to take a computing course at my school, if one is available.	81.8% said Maybe or Yes	89.5% said Maybe or Yes
Degree of Interest: I thought the Robotics activity was *level of interest* (scale of 1 to 5)	4.1 (σ = 1.28)	4.2 (σ = 1.37)
Degree of Fun: I thought the Robotics activity was *level of fun* (scale 1 to 3)	1.6 (σ = .51)	2.8 (σ = 1.06)
Degree of Difficulty: I thought the Robotics activity was 1 Too Hard, 2 About Right 3 Too Easy	61.5% said it was About Right	72.7% said it was About Right

Note: In 2007, 1 student survey was incomplete and thus not included in analysis.

9.3 Post-Summer Workshop Survey, Including any Parent Feedback

The post-summer workshop survey focuses on each component of the workshop and asks students about their interest and plans in computing. While some of the questions have changed in later workshops, many remained the same. The relevant results are presented in Table V.

In the workshops nearly all students feel that the robotics activity difficulty is about right. Even with the increase in the duration of the robotics activity by one day in the 2009 summer workshop, the percentage of participants who feel the degree of difficulty is About Right increased. Along the same lines the average impression of the degree of fun, on a 3-point scale, is 2.8 with the much larger set of recent participants when compared to the initial group's rating of 1.6. Thus, the activities continue to be engaging, yet adequately challenging to the students. The link between the workshop and pursuit of computing courses and careers remains about the same, as shown in Table IV. While the students are self-selected, the result is still hopeful given that the student population is very diverse. In the most recent California workshop, the majority of the participants were Hispanic and several were low to middle income. The argument could be made that since the participants are already highly interested in computing, the workshop is not useful. When interest levels are compared before and after the summer workshop the level is maintained at 4.7 pre-survey and 4.8 post-survey. The skill level, which helps the students build confidence increased from 2.1 to a post-workshop level of 4.3 of self-reported skill level on a scale of 1 to 5, where 5 is highest.

More recent participants had comments about the robotics activities. A sample of their comments include:

— "I liked learning how computer programming worked and to the extend it could be used. I also liked the supportive and helpful staff."
— "This was an enjoyable and educational experience for me."
— "Very fun, I enjoyed the workshop very much! (smiley face)"
— "[I liked] that we programmed through code and not the included software [robolab]"
— "[I liked that] I got to mess around with the robot to see what it could do."

As discussed in earlier findings on the pilot (2007) workshop [Ludi and Reichlmayr 2008], parents in attendance who observed their children working with the robots had some comments to share. The following excerpts were taken from the parent survey from the initial workshop:

> "The workshop was geared specifically to visually impaired teens. This was important as many times in a "regular" classroom setting our kids have to fit in with non-VI kids + are constantly trying to play catch-up. This workshop allowed these teens many opportunities to let them see that a career in computers is very possible."

> "..The instructors pretty much let the kids do the work themselves as a group. I think it made the kids feel good about themselves, a sense of accomplishment."

> "The workshop gave the kids a lot of hands-on experience with computers that they might not have gotten otherwise (putting a computer together, working with robots, game design) plus they were able to share ideas and learn from other students." [Ludi and Reichlmayr 2008]

Note that parents focus not only on the educational aspects but also the need for their children to feel included. Thus, providing bridges to enable young people with visual impairments to work with sighted students in such activities is needed in order for them to succeed in the long term.

9.4 Follow-up Feedback and Sharing

The first full cycle of the summer workshop and the two weekend follow-up workshops (Fall and Spring) was recently completed. Initial feedback offers some long-term indications on student engagement. The weekend follow-up workshops include a brief review of material on the first day followed by some additional tutorials in areas such as creating functions and mathematical representations in algorithms. Approximately 60–70% of each follow-up workshop is dedicated to a new design challenge.

Due to scheduling conflicts and different school calendars between the districts some attrition occurred. However several students attended both follow-up workshops. Of the 22 students who participated in the follow-up workshops, 100% of the students felt that the follow-up activities were fun with 81.8% of the participants (18 out of 22) agreed that the follow-up activity was just right. The interest in definitely or possibly pursuing computing in college dipped to 77.3% (17 out of 22) participants, but the numbers remain strong. The drop-off may be attributed to several factors, such as the complexity of the new tasks, which are more challenging, and the fact that the new school year introduced new possibilities for students' futures. A detractor that has persisted is the lack of school-based courses for students and the anecdotal stories of students being actively dissuaded from enrolling in such courses.

The long-term feedback from our initial stand-alone workshops are noted in terms of after-workshop communication with parents. Parental feedback received has been qualitative in terms of how some of our participants have gone on to pursue their interest in computing. From our first (2007) workshop, one participant went on to learn about programming on his own to the delight of his parents. One of the youngest, and most introverted participants, is enrolled at a very selective technical high school. A couple of the 2009 participants noted their interest in pursuing computer programming though courses were not available at their schools.

Some of the educators who served as team facilitators, who are from the same district as some of the participants, expressed an interest in trying to follow up further with students in their district beyond the workshop in a venue such as a FIRST robotics team.

10. STRATEGIES FOR REPLICATION AND OUTREACH ACCOMMODATION

While some outreach may be directed to students with visual impairments or to disabled students in general, the wider impact is toward general outreach to students as a whole whereby students who are visually impaired are welcome and accommodated. Above all, students who are visually impaired or blind are just like sighted students in their interests, goals, and personalities. The differences come out in terms of accommodations for print or visual presentation of material and for related areas such as orientation and navigation if the area is unknown to the participant. Many of the accommodations follow universal design and best practices for instruction for al students. Some may require additional planning and consultation with your disabled student services department and the participant depending on the extent of the accommodations needed.

10.1 General Strategies

— Ask about accommodations in the registration form. Do not ask what the disability is as it is the accommodation that is of relevance.
— Don't be afraid to use vision words such as "let's take a look at. . . " when speaking to the group.
— Keep all participants active. Giving roles to each participant facilitates this and lessens the impact of a domineering personality. This is especially worth noting as many students with visual impairments are often ignored in mixed groups.
— Rotate roles to give students different perspectives on activity tasks.
— Present information using multiple means: such as orally and in writing on the board/handout. Beyond issues with participants who have multiple disabilities, a participant who is blind won't know what content is written on the board if it is never mentioned to the group.
— Providing handouts and reference cards is helpful, using large print or Braille (as appropriate), but so is encouraging participants to take ownership over their learning by taking their own notes as well. If your school does not have a Braille printer, you can mail order Braille printing with a 1–2 week turnaround. Be aware that Braille paper is often a different size than standard paper so the headings will likely fall off different pages. It is helpful to number section headers.
— Encourage participants to talk through the code to help locate and fix problems. Many sighted participants will starting typing silently thus leaving the student who is visually impaired out of the activity.
— Create a quick reference sheet for the symbols or commands. This is especially useful for students with visual impairments who have to learn many new commands and syntax.

10.2 General Strategies for Designing Robotics Activities

— Design activities that use multiple robot "senses" such as sight and sound or sound and touch. Use sound selectively as the work area is often noisy.
— Encourage participants to relate the robot's abilities and challenges to their own world. Many visually impaired and blind students can relate the sensors to their own navigation paradigms.
— Work with the participant a bit ahead of time in order to make sure any assistive technology is set up properly. You can also consult with their resource teacher or

your disabled student services office. Many issues are small but it is nice to identify them ahead of time.

— Be flexible. Don't get worked up when things don't go right as the participants will pick up on that anxiety.
— Place the maze or other area to run the robot at an accessible height for all participants. When the robot is moving some participants may need to keep a finger on the robot to know where it is.
— Have participants take turns programming the robot. The same goes for starting and stopping the program on the robot itself.
— Depending on the accommodations and cognitive development of your participants. You may need to either select a different programming language/environment or have more than one.
— As with any class, having support for participants is important. A single instructor with a full class is daunting. If parents are not available, computing or engineering students from your university can be helpful and offer "near peer" mentoring for participants.
— Spend a couple of minutes at the beginning of the activity to orient participants to the robot or parts to ensure that each participant becomes familiar with the robot parts, starting the robot, downloading programs, etc.

10.3 Suggested Accommodations for the Lego Mindstorm Kits and Required Software

For the robot:

— Label the brick and sensors with Braille for blind participants. A handheld Braille labeler costs approximately $10 online.
— Divide up pieces by type to make them easier for students to locate pieces.
— Robots can do multiple things at once such as move and play a sound so they don't need to stop the robot in order to play a sound or display a message on its screen. Several participants have found value in using sound (tones) as a debugging aid while the robot is running.

For the computer:

— Ask participants about their preferences for assistive technology and try out the accommodations before the activity.
— For some participants who are visually impaired, the accessibility settings within the computer's operating system may be satisfactory. Other students use assistive technology such as magnification software, screen readers and refreshable Braille displays. Your disabled student services office may be able to loan you such assistive technology. Alternatives to the magnification and screen reader software are evaluation copies that can be run and there are some open source options (quantity and quality vary by operating system). Facilitators and mentors should become familiar with the assistive technology selected, but complete fluency is generally not needed.
— If magnification software is needed, then try to connect the computer to a large LCD monitor in order to provide access to more of the software at a time.
— When using laptops, provide a mouse, track pad or other input devices in order to accommodate students who cannot use a track pad.
— Modifications to the keyboard are often not needed, though Braille and large print keyboard stickers can be purchased online at low cost. Special large print and Braille keyboards can also be purchased.
— Position the monitor so that multiple students can view it, if possible. Otherwise use a monitor splitter so that more students can see the screen clearly.

— When using a screen reader, provide headphones for each user. The headphones should have built-in volume control so that the participant can adjust to a level that is comfortable and allows for interaction with their peers during the activity.

11. CONCLUSIONS AND FUTURE WORK

In revisiting the research questions noted earlier, the degree to which the questions are answered with current data varies in terms of conclusions that can be drawn.

11.1 Questions 1: To What Degree Do the Workshop'S Robotics Activities Engage the Participants in Computing in Terms of Interest and Confidence?

Based on the post-workshop survey for the initial (summer) workshop, the participants felt that they learned a great deal in both the 2007 and 2009 cohorts. Before the workshop, very few of the students had any programming skills, and 6 out of the 46 participants reported that they would positively pursue computing in college. After the workshop, the participants' interest level remained high and their confidence level increased dramatically in programming. Also the desire to take computing courses in middle/high school increased but there are issues with dissuasion from others or course availability. In terms of the specific activities used over time, the participants generally felt that the activities were well balanced in terms of difficulty, while being enjoyable. After the follow-up activities for the 2009 cohorts, just over 77% of students still were highly interested in pursuing computing after the complexity of the content and topics increased.

While issues with pushback from counselors and instructors is a large and multifaceted, the expansion of extracurricular activities to include students with disabilities including those who are visually impaired can provide a path for continued participation in computing throughout high school. Whether the activities are university outreach or participation in FIRST or Robocup teams is not important as long as the participants feel welcomed and active in these activities.

11.2 Question 2: Beyond the Workshop, Do the Students Remain Engaged in Computing?

This question is more difficult to answer, and it is still being investigated as the project progresses. As mentioned earlier, initial results after the second follow-up workshop offer promising, positive results. As for interest beyond the workshops, there are confounding factors that can impact the active participation in school. Due to the mixture of course availability and parental resources, a wide variety of the means of engagement needs to be considered. At the end of the workshop, students are excited about computing, but some students stated that either courses were not available or the classes were at the literacy level (e.g., word processing, typing). A feasible and quantifiable means of collecting such measurements needs to be determined.

While some technical improvements need to be made to further increase the level of accessibility, the activity design and technology selection are appropriate and enjoyed by the participants. Most participants are not near graduation so the importance of providing a bridge for follow-up is critical to sustain interest in computing over time. The positive response to the workshop, including the robotics activities is promising, but integration into activities with sighted peers is also of value and may foster connections that sustain students over time.

In addition, the follow-up stories about how some students have been able to further pursue their interest in technology is also promising. Some students may have pursued classes anyway, but their confidence increased during the workshops, providing reinforcement for morale.

11.3 Next Steps

The ImagineIT workshops for students, and ultimately educators, will continue for some time. The goal is to not only offer such workshops ourselves but to also provide the framework where they can be replicated elsewhere. In order to have a solid framework for other workshops the lesson plans and student materials must be converted into more formalized workbooks. Some of the materials can currently be downloaded by educators or anyone else from the project Web site, and they are being revised to be in an “in a box” format that is more user friendly to educators.

Another facet of increasing accessibility for robotics programming is to create a more accessible version of BricxCC. Efforts are underway to create a Java-based version, called JBrick that increases accessibility for users who are visually impaired while also improving usability by sighted users. Examples include reading the line numbers, direct control of the NXT brick via an interface that supports screen readers, and improved navigation and legibility to the offending line of code when a compiler error appears. Eventually, features such as audio debugging will further help all users when working with larger programs. JBrick will be open source and will be tested during Summer 2010. While room exists to improve accessibility to the NXT brick itself, such an undertaking would be considerable due to the need to revise the firmware and to support sound with limited memory space.

However in order for students with visual impairments to be truly successful their interaction with robotics the interaction must be extended to include more participation in computing classes or in extra-curricular activities such as FIRST or Robocup. By introducing robotics programming to young people who are visually impaired by showing them that they can do it and what the possibilities are for applying themselves, the field of computing may benefit from their different perspectives on technology in the long run for the benefit of everyone.

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Received February 2010; revised July 2010, December 2010; accepted January 2011