A Strategy for Collaborative Outreach: Lessons from the CSbots Project

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ABSTRACT
Many efforts are being made to improve computer science education in order to address the retention and motivation of students. These efforts rely on the development of educational tools and environments, tools that, when successful, require many years to integrate into the computer science education community. We introduce a strategy that both speeds uptake in the community and improves the chances of the project creating an educationally successful tool. The strategy hinges on creating an initial community of educators before an educational tool is fully mature but at the point at which it becomes usable by teachers. While this is somewhat analogous to the beta-testing communities in software development, our aim is for the community to drive the underlying design in significant ways. Our context is CSbots, a project to develop a robot, software environment, and associated curricula for introductory computer science education. We detail our collaborative outreach effort, which resulted in the concurrent creation of a community of 30 invested educators and a well aligned educational tool ready for broad dissemination.

Categories and Subject Descriptors
K.3.2 [Computer and Information Science Education]: Computer Science Education and Curriculum.

General Terms
Documentation, Design, Experimentation, Human Factors

Keywords
Outreach, High School, Teacher Training, Robotics, Workshop, CSbots, Computer Programming, Participatory Design

1. INTRODUCTION
One of the most important problems confronting secondary education nationally is a declining interest in computer science among high school students, especially girls. Not surprisingly, this decline translates directly into a 50% decline in the number of Americans deciding to major in computer science since 2000 [2]. The solution to this problem lies in identifying methods for making computer science interesting to a broader and more diverse group of high school students, and in training high school teachers in these methods.

Several mature efforts are underway to tackle this problem; Alice [3] and Scratch [9] are visual programming languages that provide an environment for programming that allows students to create rich visualizations and animations within minutes. The Lego Mindstorms robotics kit coupled with powerful open source software environments for visual and textual programming allow students to program robots in addition to computers [8]. Finally, CS Unplugged introduces CS concepts through physical and paper based games, preparing students for the conceptual challenges of computer science [1]. All of these programs rely on mature, release versions of software, hardware, and/or curriculum and are supported by a network of trainers and training workshops. Though these efforts have had positive measurable impacts on students [5,7,8,10], the problem of low interest and motivation is by no means solved. We believe that many different approaches are necessary and that new efforts should be brought to the attention of educators as soon as possible.

This paper is about a strategy to create an initial community of secondary school educators before a project is fully mature but at the point at which it becomes usable by teachers. While this is somewhat analogous to the beta-testing communities in software development, our aim is for the community to drive the underlying design in significant ways. Although it may seem somewhat counterintuitive to try to build a community around something as it is still evolving, doing so makes it possible for the community itself to begin directing the evolution. As the community is a representative sample of the group of end users, this process can lead to a better alignment of the final release version of the software, hardware, and curricula. Furthermore, by creating an initial community of educators around the project, adoption of the final version of the project may be accelerated.

We introduce this strategy in the context of CSbots, a project to develop a robot, software environment, and associated curricula...
that are aligned with the learning goals of computer science education, specifically at the AP and introductory college level. Over the course of two years we engaged in a collaborative outreach experiment, working with a small community of teachers in the first year, holding a workshop at the end of this year, and then scaling the community to roughly 30 involved teachers. This outreach effort occurred while our system of educational tools was developing, and in many ways drove the evolution of that development. This paper is devoted to describing how we started the community in the initial project year, how we recruited and trained a larger community through a workshop, how we scaled the community during the second project year, and how the community affected our project’s development.

2. INITIAL PROJECT YEAR
At the start of our outreach effort, we had 1) an initial robot, dubbed ‘alpha’, 2) a set of potential assignments co-developed with a partner at a local community college, and 3) a Java API and environment. Though we were still making revisions to all three of these elements, we felt that the project had reached a sufficient level of maturity to introduce it to classrooms and teachers.

Over the 2007-2008 school year, we worked with five high school teachers in a participatory curriculum-development process. We were fortunate to be able to work with teachers from locations across the United States. Through this process the high school teachers gave us feedback on our curriculum and robot system; wrote additional assignments which utilized the robot; and tested the robot with students in the classroom, both as an extracurricular activity, and as a recruitment tool for their computer science programs.

2.1 Instructor Recruitment
Our goal was to recruit five teachers to actively participate during the initial year. We recruited teachers to work with us by offering a short, one and a half hour session at Carnegie Mellon’s CS4HS summer workshop for high school teachers [4]. During this workshop, we trained teachers on how to use the robot platform and associated software and tasked groups of teachers to write programs that responded to different colors of flash cards. We announced during this session that we were looking to partner with several teachers to develop curricula and inform hardware and software changes to the platform. Of the 35 teachers at the CS4HS session, 22 signed up for additional information about the partner program. We emailed these 22 several weeks later and asked them to complete a survey to help us determine their initial ability to work on the project; eight of the teachers responded to the survey and seven were able to partner with us. We sent robots to all seven, but two of the seven teachers dropped out during the year by mailing each teacher a robot and instructions on how to set up the robot at their school. Four teachers had no problems with setup, while the fifth had technical difficulties due to restrictive school policies on installing new software. These problems were resolved by calling the school’s technical support.

Once teachers had received their robots, we kept in touch using a wiki. In addition to phone calls, we also kept in touch using a wiki. Teachers were sent robots at the end of September and most began using the robots as soon as they arrived. In addition to the robots, we also sent twelve assignments targeting common high school computer science programs.

2.2 The Robot Platform
The alpha robot sent to our partner teachers was an intermediate design in the CSbots project. It was designed to be maximally instrumented, so as to allow us to discover which features appealed to teachers and students. The platform that we used in the alpha cycle was an iRobot Create\(^1\) and a Qwerk controller\(^2\). (Fig. 1). Together, these two off-the-shelf components provided a rich set of features:

- A wireless connection between computer and robot
- Programmability in standard Java through a Java API
- Bumpers for simple obstacle detection
- Position and velocity control
- Vision via a USB webcam
- Audio, including text to speech
- Response through RSS feeds to real-time internet data

\(^{1}\)http://www.irobot.com/sp.cfm?pageid=305

2.3 Communication and Instructor Support
At the beginning of the project we realized that frequent communication between the partner teachers and project team would be necessary. As our partners were distributed over the continental US face to face meetings could not occur. We began the year by mailing each teacher a robot and instructions on how to set up the robot at their school. Four teachers had no problems with setup, while the fifth had technical difficulties due to restrictive school policies on installing new software. These problems were resolved by calling the school’s technical support.

Once teachers had received their robots, we kept a schedule of monthly individual phone calls to get an idea of how each teacher was using the robot and to deal with any problems that might have arisen. These phone calls were crucial in maintaining the relationships between us and the teachers, as they created a series of monthly goals that drove both our group and the teachers to work on the curricula and software API.

In addition to phone calls, we also kept in touch using a wiki. Teachers used the wiki to provide information about their schools, upload pictures of themselves and their students, and later to share activities and assignments they had developed for the robot.

2.4 Structure of the First Year
Teachers were sent robots at the end of September and most began using the robots as soon as they arrived. In addition to the robots, we also sent twelve assignments targeting common high school computer science programs.

\(^{2}\)http://www.charmedlabs.com/
level concepts in the AP curriculum: control structures, arrays, variables, and classes. Our goals for the fall semester were to have the teachers set up the robot and attempt the assignments in order to become familiar with programming with the robot. Most teachers went beyond this, inviting their students to try out some of the assignments and providing feedback regarding the activities, software API, and robot hardware.

December marked the end of the training phase of the program, as by this time all had tried out a majority of the assignments and were becoming familiar with robot programming. The relationship between the teachers and us became less prescriptive and more cooperative. Teachers began creating additional activities and assignments for the robot. As their comfort with the robot grew, all the teachers involved their students to a great extent. Despite having only a single robot, they were able to integrate robot activities into their spring curricula, and were able to use the robot extensively in out-of-class settings. As part of the purpose of our study was to discover which hardware features were most useful to teachers and students, we sent supplementary kits of sensors and actuators and asked the teachers to try using them; these kits included light sensors, a distance sensor, and servos with which teachers could build robot arms. The teachers used these supplementary kits, and they, or in some cases their students, upgrated the robot hardware with them.

3. WORKSHOP AFTER YEAR ONE
The successes that our pilot teachers had with a single robot per classroom supported a belief that the program could be scaled, and we decided that a workshop after the initial project year was the best way to do so. We had support to host a summer 2008 workshop with up to twenty five teachers; as well as to subsidize the cost of alpha robots for all attendees. The workshop was centered on training teachers on the alpha robot used in the first year and on the curricular materials that were generated by the partner teachers and project team during that year.

3.1 Recruiting Participants
We recruited participants by emailing the SIGCSE and the Collegeboard’s AP Computer Science teacher mailing lists. We also worked with the CS4HS organizers to email their list of attending teachers. We co-located with CS4HS and held the workshop directly before CS4HS. This was essential to recruiting an adequate number of participants to a new and unknown workshop; as nearly all of our participants also attended CS4HS.

Twenty-four new teachers attended the workshop, and four of our existing partner teachers attended to share their experiences. Collectively, these teachers teach at least 1500 students per year. We were pleasantly surprised at the wide reach of the workshop which attracted teachers from 12 states and one foreign country (a teacher attended from the American Embassy School in India).

3.2 Workshop Composition
The workshop took place over one full and one half day near the end of July and was composed of a number of lectures, panel discussions, and directed and open ended robot activities.

3.2.1 Lectures
Two one-hour lectures were given during the first day. The first lecture was given at the start of the workshop and described the robot’s hardware, explained the wireless network configuration, and detailed the software API necessary to write programs. The second lecture concerned the curricular activities and assignments already created, and explained how certain high level CS1 concepts mapped well onto certain features of the robot’s hardware (for example, looping works well with reading in sensors).

3.2.2 Panel Discussions
Two 45 minute panel discussions were held on the first day. The panels consisted of the four teachers who took part in the pilot, allowing peer to peer discussion of common concerns related to teaching CS1 in high schools. The panel topics included:

- How the robot is used effectively at different schools.
- Challenges to setting up the robot in different contexts.
- Involving students out of class.
- How to maximize the limited resource of a single robot
- How the robot was used for community outreach.

3.2.3 Directed Robot Activities
Teachers worked on two directed robot activities during the workshop. These activities were relatively brief at 30 minutes each and allowed teachers to become familiar working with the hardware during the morning and early afternoon of the first day. The activities were based on some of the assignments created by our partner teachers during the pilot year.

3.2.4 Open-Ended Activities
The last hour and a half of the first day and the entire second day were devoted to allowing teachers to work in small groups to develop robot assignments and activities (and to write solutions to these with the robots present). This time was structured only in so much that a goal was presented to the participants: Create one or more potential assignments that involve the robot. These activities produced a long term beneficial result for the community, as all the participants shared their assignments with the group at the end of the workshop. The open-ended structure also allowed groups to focus on areas of personal interest (for example sensing or text-to-speech), to work at their own pace, and to receive individual assistance from us and the experienced teachers on an as-needed basis.

3.3 Evaluation
We evaluated the workshop through a post-workshop survey of participants. The goal of the post-workshop survey was to anonymously allow teachers to provide feedback about the workshop. The survey was conducted online, and 16 out of 24 teachers responded to our request to complete it. Our conclusion from the survey feedback was that the workshop effectively trained the teachers in use of the robot and accompanying materials. Twenty one out of 24 attendees purchased a robot at the end of the workshop, further confirming the workshop’s effectiveness.

3.3.1 Workshop Ratings
We asked teachers to rate a number of aspects of the workshop on a scale from 1 (Poor) to 5 (Excellent). Table 1 summarizes the mean ratings for each aspect.

Overall, teachers were very positive about the workshop in their ratings, and were fairly consistent as well -- almost all teachers rated every aspect of the workshop as either ‘good’ (a rating of 4) or ‘excellent’ (a rating of 5).
Table 1: Summary of Teacher Ratings of Workshop

<table>
<thead>
<tr>
<th>Workshop Aspect</th>
<th>Mean Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical lectures on robot, software, and curricula</td>
<td>4.6</td>
</tr>
<tr>
<td>Discussion panels</td>
<td>4.1</td>
</tr>
<tr>
<td>Guided hands-on activities</td>
<td>4.8</td>
</tr>
<tr>
<td>Open-ended activities/brainstorming</td>
<td>4.4</td>
</tr>
<tr>
<td>Overall workshop experience</td>
<td>4.8</td>
</tr>
</tbody>
</table>

We also asked teachers about our effectiveness at teaching them how to use the robot and curriculum developed for the workshop. Specifically we asked them to agree or disagree with the following statement: “The CSbots workshop gave me the appropriate information to effectively use the Create robot and associated curriculum at my school.” On a scale from strongly disagree to strongly agree, all teachers marked ‘agree’ or ‘strongly agree’.

4. SECOND PROJECT YEAR

Although in many outreach programs a training workshop is the culminating event, our project continued throughout the 2008-2009 school year. Our aims during the year were to build and support the community sparked by the summer workshop, gather feedback from the community about the design of a second generation robot, and evaluate the robot’s success in schools.

4.1 Building Community

Our group continued to support the community that developed during the summer workshop during the entire second year. Our motivation in maintaining communication with teachers after the workshop was two-fold. Firstly, we hoped to strengthen the young community by remaining available to participants for ongoing support. Secondly, continuing contact allowed us to monitor the effectiveness of the training received during the workshop, teachers’ use of the robot, and the robot platform’s robustness and performance during the year.

4.1.1 Community website

During the workshop we introduced teachers to a website where they could download software and sample assignments. We also encouraged them to use the site to share any assignments they developed which used the robot. The initial website, which was part of a larger robotics community site, was not well utilized by participants and received low ratings on participant surveys. This prompted us to develop a new community site targeted exclusively at the CSbots community. The new site, csbots.org, utilized wetpaint, an off the shelf community website building platform. Although we hoped this new site would elicit more assignment contributions from the community, teacher contributions remain relatively low though the new site is visited frequently to access documentation and posted assignments.

4.1.2 Documentation and Support

Over the course of the year, we continued to clarify documentation as questions arose and promulgated the new documentation through the website. We also added significant features to the software, notably standalone (“no robot required”) software packages for audio and Internet RSS feeds. We emailed teachers to alert them when significant new features became available via the website.

Though we expected to receive requests for technical support, most teachers were able to begin using the robots without additional help, and in the few cases where problems did arise, typically teachers resolved them independently.

4.2 Gathering Feedback

The teachers’ experiences during the initial project year with the robot and software, as well as on-going studies at a community college [6], provided us with insights into the next robot design. We began developing the hardware for this design after the summer workshop, and produced 100 robots in the spring of 2009. The community of teachers influenced the design of this second generation robot, known as the Finch (Fig. 2), in a number of ways:

- Teachers’ experiences adapting a single robot to a classroom of 30 students suggested that the Finch should be sufficiently low cost to enable schools to purchase one for every student.
- The Finch robot’s sensors and actuators were determined partially from the teacher’s experiences with the first generation robot and hardware kit during the first year.
- We sent teachers designs for the shell of the second generation robot and solicited feedback from teachers and their students to determine the aesthetics of the robot.
- In spring of 2009, ten teachers volunteered to receive Finch robots and tested these robots with their students in much the same spirit as the first year’s teachers. These experiences are informing the software API, documentation (especially with regards to instructionally supporting multiple operating systems and IDEs), and hardware modifications to the Finch.

4.3 Evaluating the Program

We asked teachers to complete two surveys during the course of the second year; one at the end of 2008 and one at the end of the academic year. These surveys were designed to gauge how the robots were being used and by whom.

4.3.1 Mid-year survey

Seventeen teachers responded to the mid-year survey. The two most common uses for the robot were as motivation for students and as a recruitment tool. Teachers reported that students used the
robot in class assignments and for extra credit. Students also used the robot as an extra-curricular activity. Gifted and advanced students who were no longer challenged by the traditional curriculum particularly enjoyed working with the robot.

We asked teachers how many students had used the robot in the past semester. The mean result was about 3.5 students per teacher, with a total of 55 students spread across 16 responding teachers. This is not too surprising, as there is only one robot at every school, and the way the robots were used appears to be to motivate small groups of students.

We asked teachers if they faced technical or logistical difficulties setting up their robots. Overwhelmingly teachers reported no problems, but two teachers did have trouble as their schools did not allow the creation of an independent wireless network, which is required to run the robot. The teachers eventually worked around this problem. No teachers reported broken robots.

4.3.2 End-of-year survey

Teachers participated in an end-of-year survey conducted in June 2009 to determine changes in the way they used the robot since our last survey at the end of 2008. Fifteen teachers participated in the survey. We also asked teachers who had been provided with a Finch to fill out a separate survey; 8 teachers responded.

As before, most teachers used the robot as a recruitment tool – 11 of the 15 teachers mentioned this as a use. Nine of the 15 teachers had students actively using the robots; in a few cases, these students were given full control of the robot for a few weeks or a month to do an extended project. Once again, it seems that gifted and advanced students were the main users of the robot. Teachers with a Finch also reported use primarily for recruitment and with small groups of students.

The total number of students using the alpha robot was 37, with most teachers who used the robot with students reporting groups of 4-6 using the robot. Among teachers who had also received a Finch, a total of 56 students used the Finch, with an average of roughly 10 students per teacher using the Finch in spring 2009. It appears that the Finch, perhaps because it is more portable, was used by a larger number of students for smaller, shorter projects.

Technical problems were somewhat rare and were typically resolved by the teacher. Problems were fairly idiosyncratic, with no teacher reporting the same problem as someone else. The problems reported were: Poor battery life, failed charger (a replacement was sent), setting up the software environment, compatibility problems with Mac OS, struggling to set up the hardware properly, bumpers that didn’t respond when hit, and getting wireless networking working. These problems, in all but one case were temporary and resolved by the teacher. Teachers who had a Finch generally reported fewer problems, and no hardware-related problems at all. Three of the eight responding teachers indicated some level of technical difficulty – one had trouble setting up the USB driver on their Mac, and two had trouble using software IDEs with the Finch. All three teachers resolved these problems on their own without contacting us.

4.3.3 Analysis

Of teachers completing the surveys, it seems that the training workshop was successful in achieving its goals; teachers were able to set up the robots at their school, integrate them into the school environment in a worthwhile and contextually appropriate manner, and when technical difficulties did appear, teachers mostly managed to solve these problems independently.

5. CONCLUSIONS

Though considerable effort was required to develop an alpha design that was usable in educational settings, involve teachers in a pilot program, and organize a workshop, the payoff was significant. The work done with our community of teachers has laid the foundation for a thriving program that has the potential to impact many students. This foundation includes all of the necessities for applicability to educational settings: Curriculum, software, a robust robot platform tailored to the needs of an introductory CS class, a community of educators, and a successful strategy for training teachers that could be scaled up in the future. Since this work was performed concurrently with the design of the robot and software API, the end result is a well-aligned educational tool developed in a relatively short period of time. After only three years the robot and accompanying software and curriculum are ready for mass production and distribution. We are pursuing plans to expand teacher training opportunities and look forward to a growing community of educators using this technology to teach and inspire their students.

6. ACKNOWLEDGMENTS

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7. REFERENCES