Robot Diaries Interim Project Report: Development of a Technology Program for Middle School Girls

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Abstract
Robot Diaries is a technology program for middle school girls. This report provides a summary of the first and second years of the Robot Diaries project and a description of how the lessons learned from these two years are guiding the third year of the project.

I. Introduction

As technological interaction and electronics artifacts integrate ever more tightly in our lives, it is disquieting to note that engineering enrollments continue to drop throughout the United States (Vegso 2006). Even more alarming is that women participate in dismally low number in fields such as computer science and engineering, whereas virtually all science and business fields show significant improvement in terms of female participation (Vegso 2005).

One popular movement to stem the current tide evolves out of a recognition that the pipeline is both the source of today's trends and the strategic place for leveraging real change: improve the technology literacy of students at the primary and secondary level, and the statistics of the subsequent decade may finally turn around (Adams 2007; Arsenault et al. 2005; Cannon et al. 2007; Doerschuk et al. 2007; Frost 2007; Hylton, Otoupal 2005; Morris, Lee 2004).

Robotics has served as a popular vehicle for such pipeline-based technology literacy programs because of its ability to attract and inspire the imagination of students who are often unmotivated by conventional classroom curricula (Druin, Hendler 2000). National contests include US First, BEST and Botball, programs that have jointly engaged more than 75,000 students (BEST Robotics 2008; Botball 2008; US First 2008). There is no doubt that some of the students have found the contest-driven problem-solving experience to be transformative. However these existing pipeline-focused technology literacy programs share a number of features that may limit participant diversity: they are short-term, high-intensity, competition-driven and technology focused.

In response, we propose a complementary class of activities (Buechley 2007, Kim et al 2007; Resnick 2006) that we believe can engage and retain the participation of secondary level students who will not be attracted to the currently available pipeline interventions. Our activities do not necessarily aim to expand the pipeline, but to increase the technological fluency of our audience. By *technological fluency*, we mean the ability to manipulate technology creatively and for one's own use. We believe that our focus on fluency-building activities, which encourage creativity and personal adaptation of technology, will engage a more *diverse* student population with technology and engineering. We additionally hope to demonstrate the characteristics of such a program that will allow it to be broadly disseminated.

Our point of departure therefore is to design a curriculum that is not driven by competitive and deadline-driven technical problem-solving but by strong social narrative along a thread that has extant value and meaning to diverse students. Technology is no longer the prime motivator, but an enabler for emotional and social communication in the program that we call Robot Diaries.

A *Robot Diary* is a customizable robot designed to serve as a means of expression for its creator. Using movement, light, and sound, users can choreograph their Robot Diaries to express emotions. They can then share these expressions with their friends in the Robot Diaries community. Ultimately, the Robot Diary provides a unique means of exploring, expressing, and sharing emotions, ideas and thoughts while promoting technological fluency.

II. Program Goals

The primary goal of the Robot Diaries program is to develop and disseminate a technology education experience that attracts students who are not interested in current technology education programs while still providing an experience which results in students who are both more interested in and more competent with technology. Our objective is to have students benefit from participating in Robot Diaries in three major ways; improved **technological fluency**, increased **motivation and confidence** to engage with technology, and a better grounding of **technical and design skills**.

A. Technological Fluency

Middle school girls are generally seen as avid technology *users*. Robot Diaries seeks to broaden this relationship with technology by providing middle school girls with the tools they need to become fluent *creators* and *adapters* of technology.

A number of different but largely overlapping definitions of technological fluency have been proposed. In *Being Fluent with Information Technology*, the National Research Council proposed that technological fluency is the ability to "express [oneself] creatively, to reformulate knowledge, and to synthesize new information" (NRC 1999, p. 2). As the report further states, fluent individuals "evaluate, distinguish, learn, and use new information technology as appropriate to their own personal and professional activities" (NRC 1999, p. 3). Similarly, Resnick and Rusk (Resnick and Rusk 1996) suggest that fluency involves the ability to be expressive, to explore, to experiment, and to create with technology. Such definitions imply that fluency goes beyond the basic ability to use technology as a passive consumer. Rather, fluent individuals are able to adapt or create new technology to serve their own goals. Technological fluency has become an issue of national importance, with many contending that enhancing the technological fluency of all citizens is critical to our nation's continued prosperity and economic success (AAUW 2000; NRC 1999; Schunn et al. 2006).

B. Motivation and Confidence

We believe that by giving girls an opportunity to participate in a creative technology-based community, we can impact girls' interest in technology, their motivation to engage with technology, and their confidence in their own ability to continue their technology explorations.

C. Technical and Design Skills

The Robot Diaries method revolves around girls participating in several design processes. Design steps are explicitly identified, and girls engage in both short and long design sessions. By necessity, girls will need to learn about a number of technical components like servos, motors, LEDs, and sensors and acquire skills in designing, fabricating, and programming.

Although not a primary program goal, in the longer term we see ample opportunities to use the Robot Diaries platform and related activities to support other educational objectives in numerous areas, including literacy, science, and technology education. For example, Robot Diaries activities could encourage students to experiment with different forms of writing, taking advantage of the robot as an expressive medium.

III. Approach

The approach we have taken to develop Robot Diaries can be characterized as feedback-driven refinement. In 2006, we began with some initial notions of what kinds of technology and activities would be appropriate and continually refined those notions based on feedback from girls participating in a series of workshops. In 2007, we deeply analyzed our experiences in those workshops with an eye towards improving the Robot Diaries activities and technology. Finally, in 2008, we redesigned the curricula and technology based on our analysis and on the assumption that we would be training outside teachers and mentors to teach the curriculum.

A. 2006 – Participatory Design Workshops

Our focus in all of the 2006 workshops was to encourage our participants to contribute their unique perspectives to our curricular and technology designs. As such, we elected to use participatory design (Druin 1999; Druin 2002; Druin and Fast 2002) methodology to run the workshops. Participatory design calls for deep involvement by end-users in the design process. It calls on the designer(s) to collaborate with end-users from the outset of and throughout the design process to form a design co-op, inviting the end-users to become co-designers. The benefits of participatory design for educational technology are clear: the designer receives immediate and constant feedback from a sample of the very same people who will eventually be using the technology and gains a greater understanding of their learning goals, while the involved end-users feel a sense of authorship over a design that directly applies to them. We held participatory design workshops with four groups of girls in 2006 (Figure 1).

Date	Participants	Program Hours
June – August	7	12
October	15	7
November	12	7
November – January	8	18
Total	42	44

Figure 1. 2006 Pilot Workshops

B. 2007 – Analysis and Planning
The second year of the project was dedicated to analysis of the prior pilots in order to inform the course of the following year. Specifically we:

1. Conducted an analysis of the evaluation data from our 2006 program pilots.
2. Determined detailed educational goals for the Robot Diaries program based on our analysis, lessons learned, and a review of existing standards.
3. Contacted representatives at community organizations to determine typical organizational capabilities.
4. Began development of a curriculum and technology kit aligned with the educational goals and sensitive to organization capabilities.
5. Continued refining the software that allows girls to easily program and communicate with their robots.
6. Finalized for dissemination a one day workshop based on Robot Diaries.

C. 2008 – Local Dissemination
Our emphasis for 2008 is on partnering with organizations and teachers who are unaffiliated with our research group to provide pilots of the Robot Diaries program *principally run by our partner organizations.* This represents a crucial first step to building a sustainable and disseminable program. Specifically, we aim to:

1. Build partnerships with 3 Pittsburgh area organizations to provide sites for Robot Diaries pilots.
2. Develop a teacher manual and training workshop.
3. Train teachers from our partner organizations to teach the Robot Diaries curriculum with minimal support from us.
4. Support and evaluate pilots of Robot Diaries in the summer and fall of 2008.

IV. Early Pilots

During the summer and fall of 2006, we conducted a series of 17 participatory design workshop sessions. Each session taught our team important lessons about working with middle school girls, markedly affected the evolution of our curriculum, and brought us closer to a final technology and curricular design that was appealing to the girls.

A. Curriculum Progression
We designed the Robot Diaries curriculum to follow an arc from simple to complex, familiar to new. We followed this guideline for the introduction of individual components, throughout the course of a workshop series, and for ourselves as we progressed from one series of workshops to another. We introduced new robotic components with a brief example followed by a free exploration time for the students. We then presented the students with a small design challenge, usually to use the component in an expressive manner. Later the students combined the parts to create whole robots that could express emotions and communicate.

We learned from the girls as well. In the early workshops, we focused on mechanical design and learned which design challenges worked as effective learning experiences and creative inspiration. We also learned what materials worked well for ease of building, expressive features, and fun robot designs. Then we were able to introduce more complex technology and more complex design challenges in later workshops as well as progress beyond mechanical design and introduce aspects of robot programming. Brief outlines of the curriculum are included with the relevant sections below.

B. Materials and Technology

We chose to use craft materials to construct the robot forms because these materials are familiar and approachable. We provided the students with cardboard and foam board to build the structure of their robots. They used markers, felt, beads, bells and other items from a local craft store to transform the plain cardboard and give the robots personality.

Figure 2. Girls created robots using craft materials.

Beneath the craft materials we used a variety of technical components to move and automate the robots. We began with simple circuits which the students assembled from AA battery packs, alligator clips, and switches. We taught them how to operate motors and light emitting diodes (LEDs) using this direct method. The students used radio transmitters designed for model airplanes to operate servo motors.

Once they understood how the various components functioned and how they could use them in expressive robots, we introduced the Qwerk controller board (Nourbakhsh et al. 2006). The Qwerk replaced the alligator clips and radio transmitters and enabled the students to write simple programs to control their robot creations.

C. Summer Workshop Series

During Summer 2006 we held a series of six two-hour long workshops at a local Public Library. Two to seven girls attended each workshop, with the same three girls attending almost every session. The primary purpose of the summer workshops was to engage a small group of girls in a series of participatory design activities that would lead toward the development of a working prototype of a "Robot Diary" for use in the more structured Fall 2006 study. The summer workshops allowed the research team to work closely with a group of representative girls over an extended period of time in direct, "hands-on" cooperative exploration of robotic technology. This, in turn, provided three important opportunities:

a) to experiment with a variety of participatory design activities and discover which were most effective and compelling for middle school girls.
b) to develop research themes and observational measures.
c) to progress the concept (both form and function) of a "Robot Diary".

See Figure 3 for a brief outline of the summer curriculum. A more in-depth description of the summer workshops can be found at (Nourbakhsh et al. 2007a, Nourbakhsh et al. 2007b).

Session 1: Introduction
- Introduction to the project and participatory design
- Brainstorm robot ideas

Session 2 – 3: Motion
- Stimulate thinking about expressive motion
- Introduce motors and servos and begin prototyping
- Explore the two primary robot concepts generated by students

Session 4: Sound
- Stimulate thinking about the relationship between sound, expression, and emotion
- Introduce mechanisms to produce sound and integrate sound into prototypes

Session 5: Light
- Stimulate thinking about the use of light for expression
- Introduce materials to produce or alter light and integrate light into prototypes

Session 6: Design
- Prototype "final" designs
- Present ideas to parents

Figure 3. Summer 2006 curriculum outline.

D. Single-Day Workshops

We distilled the activities developed during the summer for two one-day workshops in the early fall. We held these workshops in collaboration with C-MITES, a university-affiliated organization that provides educational programming for academically talented elementary and secondary school students. By advertising through C-MITES, we obtained significantly higher attendance numbers than over the summer – 15 girls attended the first workshop and 12 attended the second. These workshops served as a chance to observe a larger audience of girls using craft materials to create communicative robots.

E. Fall Workshop Series

Our most extensive workshop was held from early November 2006 to mid January 2007 with a group of 8 girls from a private, university-affiliated middle school. Sessions were two hours long and held immediately after school. We began the workshop in much the same way as our summer workshops, gradually introducing the students to important robotic technologies over the first four sessions (Figure 4). A major difference was the early introduction of the Qwerk, a controller which allows the girls to create programs which actuate motors, servos, and LEDs. In addition, we began to introduce the girls to chat software designed by our group that was later used to control the robots. The early introduction of the software was essential to easing the girls into eventually creating programs for their robots. The chat software also enabled the students and researchers to communicate as part of a private, informal, online community between workshop sessions.

Once students had the foundational robotics knowledge to make cogent design decisions, we began a series of participatory design exercises which yielded a final robot design in session six. This design was selected by the girls from a set of five after a group discussion. The girls then each constructed a variant on the design with the same underlying morphology but widely varying cosmetic touches. Once the final robots were constructed, the girls took their robots home each week to experiment with programming the robots in a novel software framework which was refined weekly based on the girls' feedback. At the conclusion of the workshop, we had successfully created a programming interface that was usable for the students, proved the robustness of the robot kit and its installation in the homes of eight middle school girls, and gathered extensive data on the effects of the workshop on the girls along several metrics. The results discussed in remainder of this paper will focus primarily on the outcomes of the fall workshop series.

Session 1 – 3: Introduction and Robot Prototyping

- Explore motors, servos, LEDs, and basic circuits.
- Prototype different forms of communicative robots.

Session 4: Transition from prototypes to personal communication robot

- Introduction to Qwerk microcontroller, programming software, and sensors.
- Choose a standard robot skeleton.

Session 5 – 7: Robot Construction & Messaging with Robots

- Build personal robots.
- Use and critique robot programming software and robot messaging software.

Session 8 – 9: Share and Document Experiences

- Create a web site to document girls' experiences.
- Demonstrate the various robots and software for the girls' parents.

Figure 4. Fall 2006 curriculum outline.

F. Evaluation Methodology

Our research utilized methods drawn from the learning sciences and interaction design. Collected data included interviews with participants and their parents, written surveys, workshop observations, home visits, and electronic activity logs. Participants were asked to sign consent forms in accordance with Institutional Review Board regulation.

Participants were interviewed individually at the beginning of the workshop (pre), and again at the end of the workshop (post). Interviews included questions about relevant declarative knowledge (e.g., identify and provide a definition for relevant parts, such as sensors and motors) and designed systems (e.g., examine an electronic toy and describe its components/how it works). Participants were also asked to imagine how they might build a new system (an alarm) using a fixed set of components (a battery pack, alligator clips, switch, LED, servo, and sensor). Pre-interviews ranged in length from 16 to 32 minutes. Post-interviews ranged in length from 21 to 45 minutes.

Parents were interviewed in their homes at the beginning of the workshop and again after the workshop was completed. In the pre-interview, parents were asked about their child's previous experience with robotics and related technologies and about the family's activities related to science and technology. Post-interviews mainly focused on parents' impressions of the workshop and what their child gained from participation.

V. Validation of Approach

Our evaluation and analysis of the 2006 pilots provided us with some preliminary data to validate our curricular approach. Specifically, we were able to document participants' engagement in the program, their knowledge gains, and their parents' viewpoints about how they had changed as a result of participating in the workshop. We also found that some of our curricular activities were scalable, as demonstrated by the fact that an outside organization has continued teaching one of our workshops without our support.

A. Participant Results

1. Capturing a New Audience

Parent interviews conducted at the start of the workshop revealed that children in the workshop group were generally interested in using and/or exploring technology. A subset had attempted to participate in other technology workshops, but these experiences were not always positive. One parent described her daughter's experience in the following way:

> She has been fascinated by robotics for a long time… every time we sign up for one of those [technology] camps… we'll get there on the first day and it's all obnoxious little boys and she just goes, 'never mind'

Another parent provided the following explanation for why she thought her daughter would enjoy Robot Diaries:

> The problem with some of those [technology workshops] was that there were often more boys there than girls, and so she didn't feel quite as comfortable. So that's why this [program] looked more interesting.

As comments from this small sample of parents suggest, existing resources may not be fully serving the needs of middle school girls interested in technology exploration. These parents point to the male-dominated culture of these activities as being particularly problematic for their daughters. One of the girls echoed this sentiment when she commented that her school's First LEGO League team, which she had joined briefly, was "more geared towards boys." However, three of the girls enjoyed their participation in other girls-only technology workshops run by the university community. This suggests that girls-only robotics programs, such as Robot Diaries, may serve an important role in bringing robotics and technology exploration to a new audience.

2. Engagement

In Robot Diaries, we tried to engage participants using a 'social narrative' approach, which enabled girls to engage with their robots in a narrative way. A quick look at the robots created during the workshop (Figure 5) suggests that this occurred for most participants. Six out of the eight participants named their robots. Nearly all of the participants personalized their robots through decoration, and a few created additional narrative elements such as accessories for the robot (for example, one student made an 'iPod' out of foam for her robot and another made a guitar). Another participant created a back-story to explain her robot's appearance:

> Dear old elderly professor Bob suffered from a head injury when he ran into an Eskimo… so now he has a band-aid on his head. And he's a professor so he has to dress up. The tie. And he has certain vision problems so he wears a 'monocule' [monocle].

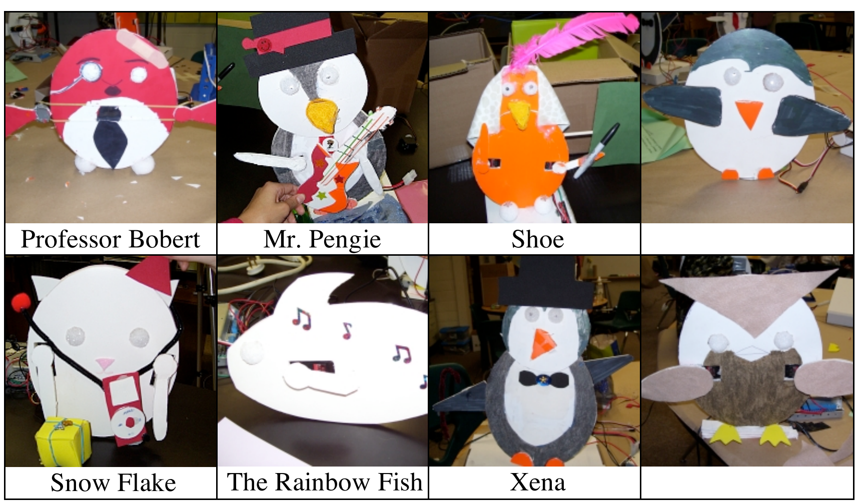

Figure 5. Robots created during the fall 2006 workshop.

An examination of the electronic activity logs showed that all eight students participated to some degree in the Robot Diaries online community from home. Each girl posted messages to the custom messaging program used during the workshop. Half of the students posted robot programs, or *Roboticons*, to share with the Robot Diaries community. An example of one such Roboticon was a program expressing sadness. The robot's eyes were lit by green LEDs as the robot's arms rose to cover the eyes and then slowly lowered. Network problems contributed to at least some of the remaining girls' inability to share Roboticons from home.

Lastly, informal observations of the girls' behavior at the workshops showed them to be engaged by the workshop content. Frequently one or more girls would not leave when the workshop ended. On one occasion one of the girls stayed a full hour after the two-hour session officially ended. It was not uncommon for girls to stay 15-30 minutes after the session to continue working on their robots.

3. Knowledge Gains

Knowledge gains were more formally measured through analysis of pre- and post-workshop interviews with participants. Analysis consisted of coding interview responses for correctness, comprehensiveness, and level of sophistication. In order to determine the reliability of our coding scheme, two raters coded three of the 16 transcripts. Inter rater reliability was calculated at over 83%. Coding disagreements were resolved through discussion.

Two main types of knowledge were assessed: declarative knowledge and knowledge of technical systems.

The majority of participants showed gains in declarative knowledge. On average, participants were able to identify and correctly label four (SD = 1.31) out of six robotic components at pre-test and 5.9 (SD = 0.35) at post-test. A paired t-test indicates this increase is statistically significant, $t(7) = -4.26$, $p < 0.05$. Additionally, there was a significant increase in the comprehensiveness and accuracy of participants' descriptions of a sensor and electric motor, as indicated by sign tests. Six out of eight participants showed improvement in their descriptions of a sensor at post-test (the other two participants were already knowledgeable at the start of the workshop), $p < 0.05$. Seven out of eight participants showed improvement in their descriptions of an electric motor, $p < 0.05$.

The American Association for the Advancement of Science (AAAS) recognizes knowledge of technical systems as an important component of scientific literacy for children in grades 6 through 8. The following benchmark is included in their Atlas of Scientific Literacy (AAAS 2007, p. 57):

> Analyze simple mechanical devices and describe what the various parts are for; estimate what the effect of making a change in one part of a device would have on the device as a whole.

We believe that this type of knowledge may be critically useful for engagement in the design process, and movement towards technological fluency. We assessed knowledge of technical systems in two ways. First, we presented participants with an electronic toy (a Furby, a Meowchi, or an iDog), and asked them to explain what parts were inside the toy, and how it worked[1]. At post-test, all seven children were able to identify parts from the workshop (e.g., servos or LED's) in the electronic toys. Additionally, six out of seven children were able to provide more sophisticated explanations of how the toy worked at post-test (one participant showed no change). The increase in sophistication of explanation was significant, $p < 0.05$ by sign test.

Participants were also presented with a set of components (battery pack, sensor, servo motor, switch, LED, alligator clips), and asked to describe how they could build an alarm system with these components[2]. Responses were coded for the number of connections (indicating the complexity of the system) and number of explanations (indicating an ability to describe the function of individual parts or groups of parts). The number of explanations provided for the alarm systems at post test increased for four of the participants, and decreased for two (one showed no change). The increase was not statistically significant. There was little change in the number of connections present in alarm systems at post-test.

In summary, Robot Diaries appeared to have a positive impact on its participants. The eight girls enrolled in the fall workshop were engaged by the social narrative approach to robotics and actively participated in the community formed by the workshop. Participants also gained valuable technical knowledge.

This evidence suggests that the Robot Diaries program is moving participants in a promising direction. However, given the pilot nature of the first phase of the program and the small number of participants, the findings are incomplete at this time. We will continue to evaluate the impact of the Robot Diaries curriculum in future iterations of the program, with the goal of consolidating the research into a rigorous and complete summative evaluation.

B. Parent Viewpoints[3]

One of the most important reasons to work on technical literacy in informal contexts is that we have an opportunity to change how parents see their children. This is crucial to long-term success of any technology enrichment program. We know from our prior work in museums that even the most educated parents often fall back on traditional stereotypes when they think about what girls might be interested in learning about (Crowley et al. 2001). Because parents play such a large role in orchestrating the educational enrichment experiences of middle school students, effective programs should change how parents

[1] Results for this question are out of 7; an electronic toy was not available during one post interview.

[2] One participant was not asked this question, so results are out of 7.

[3] Data presented in the 'Parent Viewpoints' section came from our analysis of the eight parent post-interviews. In order to assess the reliability of our coding scheme, two independent raters coded half of the interviews. Inter-rater reliability was 81.2%. Coding disagreements were resolved through discussion.

view their children's interests, competence, and potential for success in technology. Our preliminary evidence suggests that we did just that.

In interviews conducted after the conclusion of the workshop, a number of parents commented on changes they had observed in their daughters. Two parents commented that the workshop led to gains in interest and engagement in robotics and technology for their daughters. For example:

> I think [she] learned a lot from and just got much more adept and fluent at doing that kind of thing and um I think she just sort of just enjoyed the – the whole concept of doing it, and she got bitten by a bug, I mean she wants – she wants to do more and so now we're sort of trying to figure out how you do that – what else there is besides Lego Mindstorms.

Two parents commented that the workshop helped to broaden their daughter's perspective about technology. For example, when asked what he felt his daughter gained from the workshop, one parent responded, "I think she probably got an awareness that um computers and technology are in more parts of her life than she realized."

Additionally, three parents commented that the workshop helped to increase their daughters' comfort and confidence with technology.

> I would say there was a um – a pulling together of things that she probably already knew, but hadn't really combined all the skills in the way that she did, and um – just a higher comfort level. In some of the skills that she probably already had, I mean she'd downloaded things before, and she'd – you know, interacted with websites and whatever before, but she's just much, much faster at it now, and less afraid when she hits a glitch of her – that's – the big thing is that when she hits a glitch, she's like not afraid to kinda, fix it as opposed to 'eek!'

Finally, six parents commented that the workshop and associated activities led to knowledge gains for their daughters.

> Well I think she got a lot out of it. I know she really enjoyed it, and I know she learned, I mean I know before this she had no idea about, you know, all the things she would mention, words that I have no idea about. You know, like how to built the robot, how to pr- control it via the computer, how to enhance the robot. Like she was very excited, when she'd come home with the little – the little white and black [servo] boxes. And be like, I'm adding a new one to this, 'cause I want it to do that.

In summary, parents commented on changes in their daughters' knowledge, confidence, interest, and perspectives on technology. Each of these areas of change represents an important part of girls' movement towards fluent use of technology. As girls come to see technology as more relevant to their lives or think critically about technology more often, they take an important first step towards technology literacy and a deeper engagement with technology.

C. Scalability

Our approach was further validated by evidence of the scalability of the curriculum. The two pilot programs run with C-MITES consisted of a modified version of our Robot Diaries curriculum which was adjusted to run in a single day. The first run of the class, entitled '*Robots Are a Girl's Best Friend*,' filled to capacity and even generated a waiting list. Up until that point, our workshops had been fairly small (8 students or less), so the experience with C-MITES helped us realize that the Robot Diaries idea did in fact have broad appeal to our target audience.

Another thing we learned from working with C-MITES is that the curriculum could be self-sustaining. One of our first efforts this past year was to revise the single-day workshop curriculum that we piloted with C-MITES. Based on our experiences with the 2 single-day pilot workshops as well as direct feedback and input from the C-MITES staff, we adjusted the activities, timing, and teacher support materials to create a 'shrink-wrapped' curriculum suitable for dissemination (available online at (TeRK 2008)). While our research team ran the first '*Robots Are a Girl's Best Friend'* pilot, the second pilot was co-taught with C-MITES instructors, and subsequent iterations of the class have been taught exclusively by C-MITES staff. C-MITES is now using this curriculum to offer the course to their students on a regular basis. They have already held the workshop on their own twice and continue to include it in their offerings. The C-MITES instructors are also modifying the class to make a version for boys.

VI. 2008 Workshop Design Influences

Two major factors influenced our designs for the 2008 workshops: first, our previous experiences conducting the pilot workshops, the implications of which we discuss in detail in the curriculum and technology portions of this section; second, we are shifting the teaching responsibility from our research group to outside teachers associated with our community partners. This shift necessitates a basic change of approach: instead of utilizing participatory design, in which curricula are constantly in flux as new activities are tested, we need to create a detailed, written curriculum as well as explicitly identify the learning goals and explain how those goals are supported by the proposed activities. Further, we need to create a technology that is robust and easy to use, and which, while fallible, should be fixable by non-experts. As such, we approached the design of the 2008 curricula and technology with the design principle of *alignment*.

A. Alignment

Alignment is traditionally a guiding principle of curriculum design; essentially it advises the course designer to align the learning goals, instruction, and assessment, so that each supports the other. An example of an unaligned class is one in which a teacher has given an exam that assesses materials or concepts that were not covered by prior lectures or exercises. Although in some cases classes may be intuitively aligned by their designers, it is a practice that can be performed in a premeditated, explicit way (Wiggins 2005).

Generally this is done by first detailing the learning goals for the students because these goals will drive the required types of assessment and instruction. Once learning goals are determined, assessments are devised that can measure those outcomes. Finally, instructional tactics, exercises, and activities are devised to allow students to meet the desired outcomes. At each step, it is necessary to reconsider the already specified sections of the design - for example, when the instruction is designed, the assessment and goals are reconsidered to ensure that there will be no misalignment between the three major categories. With Robot Diaries, we are extending the principle of alignment to encompass technology design – that is, the features of our technological components are affected by and aligned with the instructional methods, assessments, and learning goals of the program.

B. Learning Goals

At the outset of our redesign of the curriculum and technology we identified the educational goals that we are aiming for in the Robot Diaries program. These goals are now being used to guide our design process.

The ultimate goal of Robot Diaries is to enable girls to engage with, change, customize or otherwise become fluent with the technology in their lives. In order to achieve this goal, we are engaging in a two-pronged strategy. First, we address girls' *dispositions towards technology.* Second, we provide girls with the *knowledge and skills* they need to engage fluently with technology.

The dispositional goals of the program are to help girls see technology as interesting and deeply relevant to their lives, to help motivate their continued engagement and exploration of technology, and to provide them with confidence in their own ability to create with, modify, or troubleshoot the technology in their lives.

The central knowledge and skills goals of Robot Diaries are focused on design and creation; although some of these goals are specific to the Robot Diaries technological context, many of them are in line with the ITEA Standards for Technological Literacy (ITEA 2002). With respect to design, girls will understand and be able to engage in an iterative design process, including prototyping, evaluating, troubleshooting, and documenting. They will understand the idea of trade-offs and constraints and be able to identify them for specific designs they create. In terms of creation, girls will receive a detailed understanding of the robotic and structural kit components to allow them to properly identify components which meet their needs. Girls will also learn to use a number of tools to construct their designs, as well as a graphical programming language to animate their creations.

C. Evaluation Approach

Our research and evaluation of the next Robot Diaries implementation will serve two goals. First, we want to ensure that the custom technology and curriculum developed for the project have met the goals laid out above. To this end, we are designing a series of embedded and explicit assessment tools to ensure alignment between the curriculum, the technology, and our educational objectives.

More broadly, we want to understand the extent to which participating in Robot Diaries will provide girls with the knowledge, dispositions, and other tools they will need to move towards technological fluency.

One way to measure movement towards technological fluency is by examining participant experiences for expressions of fluency, which we have called 'fluency moments.' These are moments in which participants' knowledge, motivation, interest, and confidence come together to support their exploration and development of new technological solutions to problems they have identified. Our analysis of the Robot Diaries pilot data led us to one such fluency moment, as described below.

The following excerpt was captured on a Robot Diaries participants' digital video camera. In the excerpt, a participant named Rosemary[4] explains how, during her winter break, she used a servo from the workshop to modify the robot she had created (a penguin):

> During break, I decided to do something with the extra servo I got. So, I added a servo to the nose. And it's kind of being difficult now, because I need a replacement nose. But, here, let me spin it *(penguin's nose moves back and forth on its own – she is controlling to from her computer)*. It basically goes back and forth. And what I did is, I unscrewed the inside part of the servo *(she removes the cardboard nose, and points to the motor shaft on the servo)*, and I broke a toothpick and stuck it in [the motor shaft], and I stuck my beak then into it *(demonstrates with the beak)*, and it was able to move for some time. But then as the hole got bigger it wouldn't move so much, so once I get the superglue, I'm going to superglue it together, so I can just put it in and out, and that will allow me to have maybe multiple beaks…which would be pretty neat.

By analyzing these types of examples, we can begin to examine the characteristics that move individuals and groups towards fluency. In this excerpt, Rosemary identified a problem on her robot: the lack of a movable beak. She then applied some of her knowledge of servos as well as other tools (toothpicks, superglue) to develop a feasible solution on her own. This is an example of a self-generated adaptation. Rosemary chose to add this component to her robot during her vacation, indicating a certain level of engagement with the technology. We might also assume a certain level of confidence on Rosemary's part, as she was able to undertake and successfully carry out the desired modification on her robot.

We can speculate that Rosemary's knowledge, engagement, motivation, and ability to carry out the task outside of the workshop setting all set her up well to engage in future fluency activities. We will continue to seek out examples of self-generated, creative technology use among workshop participants. In our future work, we will also engage participants in a series of tasks to measure whether they are able to transfer what they have gained in the workshop to new, less structured settings.

[4] Name has been changed.

D. Curriculum

The curriculum we used in our pilot workshops was designed to allow us and the participants to jointly explore and discover a compelling robotics experience for middle school girls. We focused on answering questions such as “What type of robot do middle school girls want to create?”, “What form should the robot take?”, and “What materials are the easiest to use and result in the most compelling robots?” This participatory design, discovery-based workshop curriculum was both labor- and materials-intensive, as well as being very open-ended and flexible. In order for the resulting robot concept and design to be taught with a broader audience it was necessary to develop a new curriculum based on both the concept and robot kit developed with the girls as well as other lessons we learned from designing technology with this age group.

A number of our lessons learned concern the timing and pacing of curriculum activities. For example, we learned that middle school students require significantly more time than adults to perform manual skills and have tried to pace our activities accordingly (e.g., attaching components to a microcontroller using a screwdriver took students roughly four times longer than adults). We have also aimed to make the overall timing of the curriculum flexible so it can meet the needs of as many groups as possible. Based on our conversations with several potential partner venues, we learned that the amount of time dedicated to any given program varied from site to site. Girl Scouts might spend roughly six hours working on a badge. Groups such as the People Always Learning Something (PALS) home school group and Sarah Heinz House Boys and Girls Club have ten- to twelve-week classes. In order to make our curriculum applicable to as many groups as possible, we decided to take a modular approach. We developed a core set of activities as well as optional activities. We intend to specify and study which learning goals are targeted by each activity so that teachers can see which learning goals they can accomplish given their own time requirements.

It also became apparent during our numerous design sessions that the materials provided can impact the students’ creativity. Both the specific variety of materials made available and the layout and arrangement of materials are very important. Students have a strong tendency to use the materials that are ‘at hand.’ Student creativity can be increased by providing a variety of arts and crafts materials and making the variety of materials readily apparent. Training materials will also be explicit about the choices we have made to include certain materials, particularly when the materials are meant to encourage creativity or creative expression (e.g., we suggest the use of multi-color LED’s because they are important for creating different emotions).

Our experiences working with students as designers also alerted us to some patterns in their design behavior. For example, while we hoped our students would iterate on their designs (i.e., go through multiple stages in order to improve their ideas), it sometimes seemed difficult for them to move beyond their initial ideas. Therefore one major curricular revision is a focus on the complete design cycle; in particular, specifically working iteration in to the curriculum and introducing programming as a means of testing and evaluating robot designs earlier in the curriculum than we had in previous pilots.

Figure 6 shows the outline of curriculum topics. Parts 1 and 2 (introduction and first design cycle) are relatively short compared to Part 3 (iterative design) in order to help students strengthen their iterative design skills.

Part 1: Introduction – *Introduction to robots as expressive devices, hardware components, and programming software.*

- Robots and Expression
- Motors, LEDs, and Basic Circuits
- Servos, Microcontrollers, and Program Building Blocks
- Sequential Programming and Communicating with Programs

Part 2: Building Basics – *Design, build, and program a simple robot.*

- The Design Process
- Build Your Own Robot
- Write and Share Expressive Robot Programs

Part 3: Advancing Your Design – *Iterative cycles of design, building, and structured use activities.*

- Expand Your Design
- Expand Your Robot
- Write and Share Longer Programs

Figure 6. Topics of the 2008 curriculum.

One important choice in shaping the Robot Diaries experience was how to guide and constrain the initial robot design task. How directed or open should the design task be in order to maximize student creativity, learning, engagement, and enjoyment? We chose to make the task fairly directed but allow room for flexibility. We are also broadening the number and diversity of prototype examples we show to students before beginning each design task to help them imagine the number of different possible designs available. The follow excerpt is from the initial design task instructions:

> Today you are going to build an expressive robot that has a body, 2 servos, and 2 LEDs. The servos can control arms, legs, ears, antennae, wings, fins, heads, tails, and so on. The LEDs can be used in the eyes, ears, nose, antennae, or some other part of your robot.

Terms like body, arms, and eyes set the tone for the robot to be modeled after living creatures. This is inline with the types of robots that the girls in our pilot programs found appealing. Students in our pilots also seemed to connect with the zoomorphic robots they created (they gave them names and background stories) (Hamner et al. 2008). A living creature is also a good model for making a robot that can express emotions and moods. We hope that these instructions along with sample robot pictures will help students think outside the often common robots-as-cars model.

Another advantage to this approach over a more open approach is that it gives direction to the first design and building task by narrowing the scope of possibilities. This should decrease the amount of time necessary to settle on and implement a design. By setting boundaries on the initial design task, we assert that students can more quickly reach a functioning robot which can be programmed. Thus we walk participants through the *complete* design cycle, including using and evaluating their designs, before having them iterate on the designs. Because we have tested the kit with these design parameters, it is more certain that the students' initial robots will function. Thus, the evaluation taking place after time spent using the robot should focus on how well the design meets the goal of a communicative, expressive robot, rather than simply answering the question, 'Does the robot work or not?' By asking the stronger question, we believe students will set higher goals for their robot designs and learn more fully the value of the complete design cycle, including testing, evaluation, and redesign, areas which did not appear to be natural strengths of this age range in this sort of design situation in our pilot work.

In our curriculum, we have allotted 1 hour and 15 minutes for designing and building the initial robot, although we know from experience that students could happily spend more time building and decorating their robots. We have made a conscious choice to limit the amount of personalization students are able to do to their early robot designs. While we value the sense of attachment students are able to gain from personalizing their robots, we do not want students to view their first robot design as a final product.

We then walk students through both a group and an individual task designed to make them program their robots and evaluate the robots' expressiveness. After testing the robots in this way, students are ready to revise and expand their designs and are given both a longer time to design and build (3 one-hour sessions) as well as more freedom in design direction.

E. Technology Development

Our experiences with Robot Diaries have made us thoughtful about the ways in which technology can enable fluency experiences or serve as a barrier. After the completion of the pilots, we set out to redesign the Robot Diaries technology. The central goals of the technology redesign were to maintain functionality and features useful to Robot Diaries, while drastically reducing cost and improving user-friendliness. To the extent that the technology is transparent and easy to use, it can greatly enhance a participant's experience in the program; non-functioning technology can frustrate students and lead to disengagement.

During the Fall 2006 workshop, the girls used the Qwerk as their central robot controller. A Qwerk is a powerful controller capable of controlling large robots, communicating over wireless networks, and sending video over a webcam. Although expensive, we used Qwerks in our initial pilots because it has a very large set of features, providing us with the flexibility to experiment with features and determine if they were valuable to retain. In our pilot iteration of Robot Diaries we relied on wireless networks in participants' homes to control the robots. While this approach worked well in some homes, others experienced connectivity problems that led to decreased robot use.

Our experimentation with the Qwerk's large feature set and the needs of our curriculum led us to determine a set of features for the next iteration of the Robot Diaries controller. Specifically, we needed to retain the ability to control servos, LEDs, motors, and a speaker, and our device would need to be directly connected to a computer over USB to simplify the setup process for home use. Furthermore, even though we had not found a direct use for them at the time that we were specifying our feature set, we felt it important to leave open the ability to use sensors.

Fortunately, none of the required features require the use of complex or expensive technology, and so we were able to design a new controller with the necessary capabilities. Whereas the Qwerk is $349 retail, the Robot Diaries controller, called the Hummingbird, could be sold for less than $50. By reducing the complexity of the controller and focusing only on useful features, we have incidentally created a more user-friendly experience; girls will no longer need to configure their home wireless network to connect to their robot, nor will they need to be instructed as to precisely where and how to connect their kit parts; we have greatly improved the labeling, placement, and connector type.

We have also worked hard to develop a set of software interfaces that middle school students can quickly master; RuR, Express-O-Matic, and Roboticon Messenger. The RuR, or Robot Universal Remote, allows girls to modify any port setting on the controller through a graphical interface; for example, a student can set the speed of a motor by simply moving a slider. It is also possible to save the RuR settings to create *expressions*. The Express-O-Matic takes expressions created through the RuR and provides an interface to chain them together, providing a simple iconic scripting method to make the robot move. Finally, the Roboticon Messenger allows girls to chat with one another while simultaneously sending *Roboticons*, which are the programs they have created with Express-O-Matic. When a Roboticon is sent, it is played on the receiving girl's robot, and so adds an emotional exclamation point to a conversation in a way similar to, but richer than, a simple emoticon. We are currently working on integrating these three interfaces into a single program to further simplify the robot programming process.

F. Community Partners

Our community partners provide a vital link between us and the students we are trying to reach; they take on the responsibilities of recruiting children, providing computers and a place for groups to meet, and providing instructors to lead the Robot Diaries sessions.

As we have been developing curriculum to be taught by community partners, we have also been considering what type of community partner is best suited to the Robot Diaries curriculum. In order to maintain the integrity of the program and to work with our community partners as effectively as possible, we have developed a set of suggested program guidelines. First, students in the workshop should be regular, committed participants in the program. We do not feel that casual, drop-in participation will provide enough continuity to make the program effective. Regarding facilities and staffing, we recommend that the workshop sites have at least one internet-connected computer per three participating students and one instructor for roughly every six girls. Although we will provide training in the curriculum, robot hardware, and software, instructors will need basic computer literacy skills, comfort using simple hand tools, and familiarity with fields such as art, design, or drama, to effectively lead the workshops. The creative building focus of Robot Diaries means that students will require ample space to explore materials and build their robots. The iterative nature of our core curriculum means that community partners should expect to spend approximately 15 – 18 hours with students to complete the Robot Diaries curriculum.

The Sarah Heinz House, People Always Learning Something (PALS) home school group, and YouthPlaces have all expressed interest in working with us in 2008. The Sarah Heinz House offers after-school programs much like a boys and girls club, however unlike most boys and girls clubs, students are required to attend several sessions a week in order to maintain their club member status. PALS offers 10-week classes to home school students on a wide variety of topics. Classes are often taught by parent volunteers. YouthPlaces offers after-school programs for at-risk youth. More specifically, their Girls Initiative program brings together girls from six different neighborhoods for team building and skills training activities.

These community groups have several characteristics in common which make them good testing grounds for Robot Diaries. They have committed students who attend programs on a regular basis; instructors who can lead workshops; workshop sites with ample space, computers and internet access; and they offer programs that extend over several months and include 15-20 hours of programming. This last characteristic is particularly noteworthy. While we hope to make the Robot Diaries curriculum flexible enough to work for groups with more or less time available, beginning with groups that have similar time constraints allows us to focus first on our core curriculum.

The choice of these community partners also allows us to engage a more diverse audience than our previous pilots. YouthPlaces and Sarah Heinz House serve at-risk youth. In addition, at YouthPlaces we will be working with high school students with little technical background. Although not our primary audience, this experience will help us understand the range of ages that can successfully be served by the Robot Diaries program.

VII. Disseminating Robot Diaries

Robot Diaries represents the hope that technology itself can be presented in a manner that significantly diversifies the technologically fluent. Our early successes encourage us to dedicate 2009 to attempting to make Robot Diaries a program that will live well beyond the confines of our research agenda: How can a curriculum such as Robot Diaries achieve broad adoption across informal-learning programs in a sustainable manner? Our strategy for answering this question relies on three topics: training, price, and commercialization. In the coming year we test the hypothesis that the Robot Diaries curriculum can be deployed effectively by training existing teachers in community centers, youth programs, and the home schooling environment. By tracking the ability of these teachers to make use of the Robot Diaries robot technology, software, and curricula, we plan to evaluate their use of the curriculum while also measuring the resulting learning taking place among their students.

In the case of price point, this year's Robot Diaries hardware represents a significant cost reduction from prior years, with a target price that can now drop below $100 for the controller and kit of parts in suitably large volume. We expect that, following the training experiments of this year, lessons learned may enable further simplification of the kit in terms of processor, motors, and sensors, resulting in a price point that enables more widespread adoption.

Finally, in order for large-scale dissemination to be possible, the distribution of Robot Diaries robotic hardware must be done commercially so that purchasing and repairs are all handled professionally. The CREATE Lab has a history of open-source releases combined with commercialization of necessary hardware in cases such as the CMUcam vision systems (CMUcam 2008) and the Telepresence Robot Kit Qwerk processor (Qwerk 2008). In the case of Robot Diaries, the ideal commercial partner is an educational technology or curriculum company that has an established brand in the learning community. Candidates that we plan to approach include Oregon Scientific and Scholastic.

VIII. Conclusion

Through the Robot Diaries project we set out to create a technology experience that is appealing to middle school girls not currently served by existing wide-spread programs. Through pilot participatory design workshops, we have developed an approach which we believe shows strong potential. Girls in our pilot programs were actively engaged by the workshop activities, showed evidence of improved technical skills and learning, and took steps towards greater technological fluency. We believe that Robot Diaries has the potential to appeal to a large audience of young girls. We plan to evaluate our new curriculum and robot technology kit in partnership with local community educators in 2008 with the hope of expanding the impact of Robot Diaries in the future.

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