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Richer Connections to Robotics through Project Personalization

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ABSTRACT

In this work, we describe youth outreach activities carried out under the Chair for Women in Science and Engineering for Ontario (CWSE-ON) program. Specifically, we outline our design and implementation of robotics workshops to introduce and engage middle and secondary school students in engineering and computer science. Toward the goal of increasing the participation of women in science and engineering, our workshop design incorporates strategies presented in work by Rusk *et al*. (2008) on broadening participation in robotics:

1. focusing on themes, not just challenges;
2. combining art and engineering;
3. encouraging story-telling; and
4. organizing exhibitions, rather than competitions (Rusk *et al*., 2008, page 1)

We discuss three workshop themes designed to highlight creativity and provide choices to participants. Our "Wild in the Rainforest" workshops make use of the PicoCrickets robotics kits and software used and described by Rusk *et al*. (2008). We also present Lego Mindstorms workshops themed "So You Think Your Robot Can Dance" and "A Day at the Park". Our workshops are presented by female role models with academic backgrounds in science and engineering. Although workshop periods are fairly short (60-90 minutes), participants learn that robots have perception, cognition, and action – and are tasked with designing and programming to highlight these abilities. We present the results of our workshops through images and videos of the teams' creations. Workshop evaluation data provided by participants demonstrate that our approach results in rich connections to engineering and technology for participants of both genders.

Keywords: Robotics, workshops, pre-college outreach

INTRODUCTION

The CWSE-ON[1] program was established at the University of Guelph in 2003 with a broad mandate to encourage girls and women into science and engineering careers, and to retain women as valuable contributors to science and engineering. One important area of activity within the CWSE-ON program was to provide workshops for students to engage with electronics and computer technology, areas where the under-representation of women is a significant issue. As societies become increasingly dependent on advanced technologies, it is essential to have more females working as developers and designers of products and software. We also agree with Weber and Custer (2005) that "*[a]ll students of both genders need to acquire the skills necessary to become consumers capable of critically assessing the technologies they use*".

In the following sections, we describe the implementation of workshops designed to increase the interest of young women in robotics and associated areas such as computer science and engineering. The workshop environments were designed to allow participants to problem-find and personalize their projects in ways that fostered engagement, creativity and collaboration. In 2010 and 2011, 12 workshops were offered: 8 workshops for female-only and 4 workshops for co-ed audiences. To demonstrate participant engagement and enthusiasm we showcase a number of student projects from the workshops through images and video demonstrations. We also present participants' feedback based on workshop evaluation surveys and observations documented by the workshop leaders.

LITERATURE BACKGROUND

Robotics workshops can be used to engage youth with technology in a non-threatening manner and aid in the development of skills in critical thinking, problem solving, math, science, computer programming, and engineering (Beer, 1999; Bers et al., 2002; Goldman, Eguchi, and Sklar, 2004; Beisser, 2005; Resnick, 2006; Yanco, 2006; Weinberg, 2007). A wealth of literature on constructivism and constructionism demonstrates that through the use of robotics, children are able to engage by doing, and that their interactions reinforce learning (Papert, 1980, 1992; Resnick, Ocko, and Papert, 1988; Bers et al. 2002; Goldman, Eguchi, and Sklar, 2004).

Hartmann, Wiesner, and Wiesner-Steiner (2007) suggest that biases which limit access to technology learning can be mitigated by combining robotics technology with a constructivist approach that allows for open learning scenarios and the use of 'gender-neutral' project themes. Goldman, Eguchi,

[1]The CWSE-ON program was one of five regional initiatives supported by the NSERC Chairs for Women in Science and Engineering (CWSE). Professor Valerie Davidson was the Chair-holder for the region of Ontario from 2003–2011.

and Sklar (2004), for example, report on their Lego Mindstorms workshops for inner-city students, a group in which the majority are visible minorities and/or female. Weber and Custer (2005), in their work assessing gender preferences for technology learning, assert that "developing engaging construction-related activities for females remains a significant challenge".

Rusk et al. (2008) present four strategies which have been successful in engaging different types of learners in robotics workshops:

1. focusing on themes, not just challenges
2. combining art and engineering
3. encouraging story telling
4. organizing exhibitions, rather than competitions

By providing a theme rather than defining an explicit problem that is common to all, participants are free to make decisions about what they wish to learn and explore in the workshop. Rusk et al. (2008) found that when participants work on projects that are of personal interest to them, they form deeper connections to the underlying workshop lessons. Resnick (2006) similarly observes that the intrinsic motivation provided by self-guided projects is crucial to engagement. Hartmann, Wiesner, and Wiesner-Steiner (2007) also recommend promoting open learning scenarios and believe that providing freedom, balanced with sufficient guidance, is the key to achieving success in robotics workshops designed to appeal to females.

On combining art and engineering, Rusk et al. (2008) point out that participants are more likely to engage, enjoy, and express themselves with familiar workshop supplies. They suggest that many girls are more comfortable with art and craft supplies than they are with Lego and robotics kits, and that combining the two mediums can inspire both genders to express themselves more creatively. With a similar goal of broadening participation in computing, Yanco et al. (2006) propose that the "(u)se of art as a project medium will garner interest of students who might be reluctant to try a course that focuses solely on mobile robots." In her TED talk on teaching the arts and sciences together[2], Mae Jemison - an American astronaut, physician, and art collector – discusses the need to incorporate art, science and engineering into learning experiences, criticizing the popular notion that the sciences and the arts are two separate and distinct entities. She suggests that as long as art and science are divided into two separate camps, people perceive that they are faced with the decision of being either illogical or uncreative - and who really wants to be either of these? (Jemison, 2002).

Rusk et al. (2008) encourage storytelling in order to extend the appeal of the workshops to children described as 'dramatists' – those who prefer to focus their play on social interaction rather than structures and puzzles. They also suggest that encouraging students to express a narrative

[2] http://www.ted.com/talks/lang/eng/mae_jemison_on_teaching_arts_and_sciences_together.html

or journal about their design process can engage dramatist students who might otherwise not be interested in traditional robotics activities. Bers et al. (2002) discuss the role of self-reflective practice as one of the four basic tenets of constructionism, and similarly suggest design journaling and open exhibitions to serve as a basis for sharing experiences.

Finally, Rusk et al. (2008) propose that workshops that incorporate an exhibition component are more effective than competition style activities in broadening participation in robotics. They suggest that the goal of exhibiting designs provides motivation to teams while accommodating a wider range of talents and creativity. In the same way that tinkering with electronics and computer hardware appeals to some, competition appeals to some, and not to others. In particular, collaborative tasks have been found to be strongly favored by females compared to competitive tasks. In her book on the gender gap in technology, Pinker (2008) discusses research findings that boys' performance is enhanced by the knowledge that they are taking part in a competition – whereas girls tend to shy away from competition. "When given the choice, nine- and ten-year old boys compete overtly 50% of their play time, while girls choose to compete only 1% of theirs. Boys choose games with winners and losers most often; girls prefer turn-taking games, with pauses built in for social interaction."(Pinker, 2008).

CWSE-ON ROBOTICS WORKSHOPS

Overview

In 2010 and 2011, the CWSE-ON program offered 12 robotics workshops to students at elementary and high school levels. All of the workshops incorporated the four strategies suggested by Rusk et al. (2008) but there were differences in terms of the creative themes, robot platform and participant demographics as summarized in Table 1. The workshops were offered at no cost to the participants. In some cases, participants registered for a larger program and chose a robotics workshop from a number of alternatives. In other cases, participants attended the workshop based on recommendations from their teachers and parents. All workshops were held on the University of Guelph campus. As indicated in Table 1, most were held on weekdays but two were held on Saturdays.

Workshop leaders were females who had recently graduated from university programs related to science and technology. The role of the workshop leaders was important at many levels. First of all, in the context of technology education, youth engagement and effective learning have been shown to be increased by teachers who demonstrate success and a positive attitude toward technology (Beisser, 2005). By talking about their personal experiences and successes in science and

Workshop Theme	*Dates*	Participant Demographics	Size of design groups
Lego Mindstorms NXT platform:			
"So You Think Your Robot Can Dance"	2 workshops in July 2010 (weekdays)	20 females aged 12–17 (grades 7–12)	2–4
"Day in the Park"	2 workshops in October 2010 and November 2010 (Saturdays)	17 females aged 12–15 years (grades 7–10)	2–4
PicoCrickets platform:			
"Wild in the Rainforest"			
Female-only workshops	2 workshops in April 2010 (weekdays)	37 females aged 12–13 years (grade 8)	4–5
	2 workshops in March 2011 (weekdays)	16 females aged 12–13 years (grade 8)	2–3
Co-ed workshops	2 workshops in April 2010 (weekdays)	13 males and 17 females aged 14-16 years (grades 9–11)	3–5
	2 workshops in April 2011 (weekdays)	11 males and 25 females aged 14–16 years (grades 9–11)	3–5

Table 1: Workshop Themes and Participant Details.

engineering fields, the workshop leaders provided examples to counter gendered notions about engaging in engineering and technology. Even for female students with a well-developed interest in science and engineering, external encouragement and interaction with role models plays an important role in developing and nurturing an interest in exploring career paths in engineering (Fleischer et al., 2010)**.** In addition to providing encouragement as the teams worked through their designs, leaders also facilitated design presentations at the end of the workshops, and posed questions to the teams to provide opportunities for reflection on their designs. Hartmann, Wiesner, and Wiesner-Steiner (2007) suggest that providing performance-related feedback is especially important for girls participating in robotics workshops.

As indicated in Table 1, we used two platforms: Lego Mindstorms NXT (The Lego Group, Billund, Denmark) and PicoCrickets (The Playful Invention Company, Montreal, Canada). Since this influenced the teaching elements required to explain the hardware and software components, workshop descriptions are presented for each platform. All of the workshops were offered in relatively short blocks of time (between 60 and 90 minutes) so some components were pre-built. In addition to an outline of workshop steps, we include some observations from the workshop leaders.

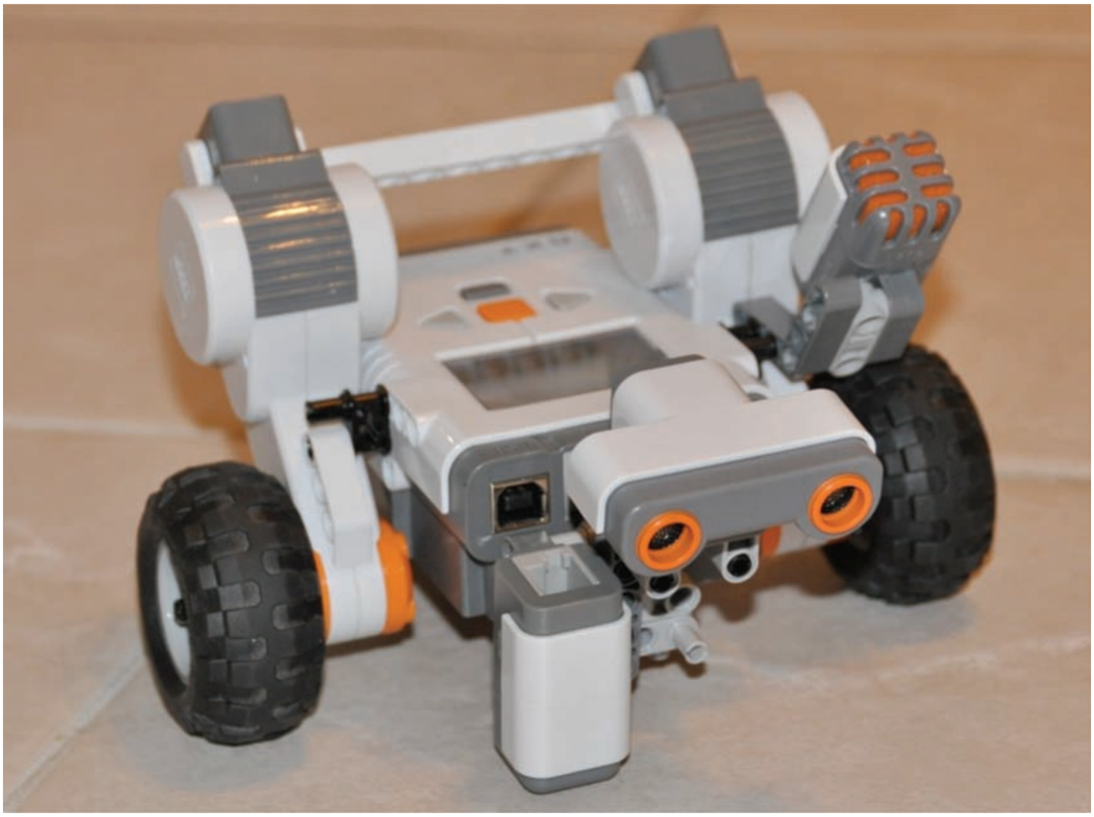

Figure 1. Configuration for Lego Mindstorms workshops: the NXT brick is mounted on a two-motor car structure (with rear swivel wheel not shown), with the following sensor modules attached: Ultrasonic Sensor, Light Sensor, Sound Sensor, Touch Sensor, Rotation sensors in two servo motors. Connector cables not shown.

Lego Mindstorms NXT workshops

Workshop Outline

To begin the workshops, participants were introduced to a Mindstorms NXT robot which was built as illustrated in Figure 1 above and which had a few simple programs pre-loaded to demonstrate sensing and action functions. To explain the hardware and software components, each workshop leader followed a similar overall approach but used slightly different examples. The following details outline the "So You Think Your Robot Can Dance" workshop.

The workshop leader gathered the students around a table to observe a robot as it moved within a defined environment. Participants made guesses about how the robot was able to move to the edge of the table without falling off - they conjectured about what types of sensors the robot could be using and how it used the information received from them. At first, as the robot moved closer to the edge of the table, participants physically blocked it from falling off. However they quickly recognized that the robot had a touch sensor and it retreated in response to bumping into something. A line following program was used to demonstrate a light sensor – running this program, participants learned that they didn't need to provide a physical barrier, but rather that the robot could sense the electrical tape that had been fashioned around the edge of the table top. An ultrasonic sensor was demonstrated using participants as a "human" wall around the table and participants were able to make the connection that this sensor was similar to the ultrasonic sense of bats. Finally, participants were asked to yell "STOP!" as the robot approached an edge, and they deduced that it was responding to a sound sensor.

In this way, participants were introduced to the notion that robots can sense the environment around them (using input sensors), make decisions (using the NXT Brick/robot brain), and respond by changing their behavior (using motors, and other outputs like lights and sound). An analogy was made to sensory perceptions in animals and humans and to their brains, nervous systems and muscles which guide and effect actions.

The next step was a synchronized dance with the girls working in teams with a robot (configured as in Figure 1). A workshop leader showed the participants how to program their robot via the NXT brick interface to do the following in a loop:

- move forward
- turn in response to noise
- move forward in response to noise

With their robots programmed, the girls were asked to bring them to the front of the room and line them up in a row parallel to the leader's robot. One girl from each team started her robot's program in sync with the others. With Michael Jackson's song 'Thriller' playing, the leaders and the girls clapped their hands on the beat. After a question and answer session designed to help the girls explore and understand the robots' behavior, the teams returned to their stations and the leader walked them through creating the same program using the NXT-G 2.0 software on the computer workstations and uploading the program to the brick via USB connection.

The teams were then presented with their challenge, which was to design, build and program the most awesome dancing robot. Each workstation was also equipped with a set of headphones and a directory with 10 pop songs (including songs from the television show Glee, and hits by Justin Beiber, Katy Perry, and Lady Gaga), and the instructions for their task were as follows:

- You choose the music
- Your robot needs to be able to dance for at least 20 seconds

- Your robot's program needs to have at least 6 blocks (visual components in the programming interface which represent functionality, e.g., loops, switches and waits for sensors, outputs including move, audio)
- Your robot needs to make use of at least 1 sensor
- Your robot needs to make use of at least 3 outputs

Five workshop leaders circulated among the teams, asking and answering questions and making some suggestions. At the end of the allotted build-and-test time, the teams were asked to bring their robots to the "dance" floor - which was fully equipped with a spinning disco ball and a light reflecting off of it. Each robot had a turn dancing - with the song the team had chosen playing throughout the room on stereo quality speakers - so that the 'judges' (workshop leaders) and the 'audience' (workshop participants) could watch and applaud. Judges provided positive feedback in the style of reality-show competitions, with comments like "Wow, folks, this robot really surprised me with its unique use of a light sensor to control its motion!" and "Yes, those streamers really highlighted the robots' motions with the spinning action!" The judges also asked probing, open-ended questions about the girls' designs, e.g., what sort of sensors did they incorporate in their robot? and did their

Figure 2. Video 'Robots, Disco Balls, and Streamers' available online:
http://www.youtube.com/user/girls4science#p/a/u/2/ZI5PEkGD8aw

teams face any challenges? Girls voluntarily shared their experiences in designing, programming, testing and re-designing their robot. This gave the teams the opportunity to think about and share their success and any challenges they faced, and provided a chance for all of the girls to learn from each other's experiences.

Video footage was taken during the workshop and can be seen via the link in Figure 2.

The second workshop theme "A Day in the Park" allowed teams to design a robot to function in a park setting. At the end of their build time the team designs were presented on a stage measuring approximately 2.5m by 2m, illustrated in Figure 3, with a path and other design elements (e.g. soccer field, band shell). The "Day in the Park" theme provided teams with a number of design choices, including:

- Walk a dog around the park, using the light sensor or other method to follow the track
- Play soccer in the soccer field, having the robot "kick" the ball into the net
- Dance at the bandshell
- Remove a (heavy) fallen log that is obstructing the path of the robot
- Navigate through the park by recognizing colored elements (like the blue pond) or using a touch sensor through the treed area.

Figure 3. The park setting provided context for the "Day in the Park" workshops.

How the teams and robots interacted with the park platform can be seen in the videos shown in Figure 4 and Figure 5.

Observations

The girls were interested and engaged in the robots in all of the Lego Mindstorms workshops. The teams exhibited confidence in starting their task, and seemed to enjoy selecting first the song and then the right moves to accompany it. Although most of the teams chose to program their robots' behavior in response to the sound sensor, one team programmed their robot to respond to a light sensor and exhibited extensive troubleshooting to achieve their goal. Three teams added a third motor to their pre-constructed robot and were successful in having their robot spin streamers as part of its dance.

Many teams who participated in the "Day at the Park" workshops chose to design their robot to dance, building upon a line-following program that was demonstrated during the workshop introduction. A few teams added Lego structures to their robots, with one team adding the third motor and a mechanical structure to implement goal-scoring functionality (to have their robot interact with the soccer net).

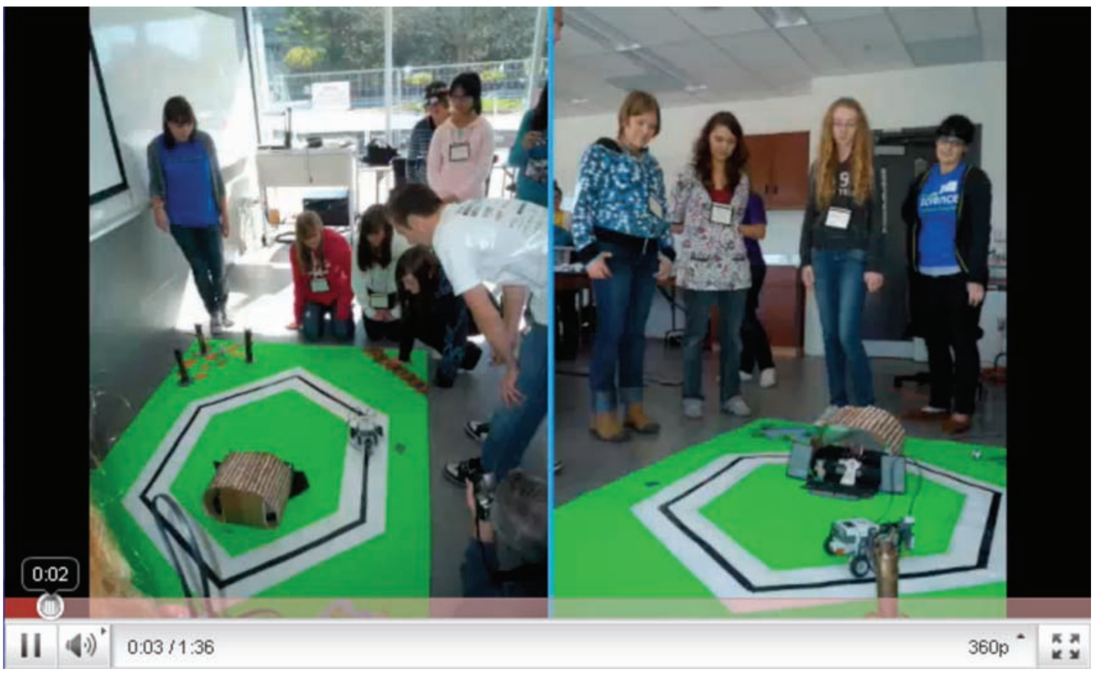

Figure 4. A Day in the Park setting and team projects are depicted in in the video 'Robot Day at the Park' available online:
http://www.youtube.com/user/girls4science#p/u/7/fumnCIQadII

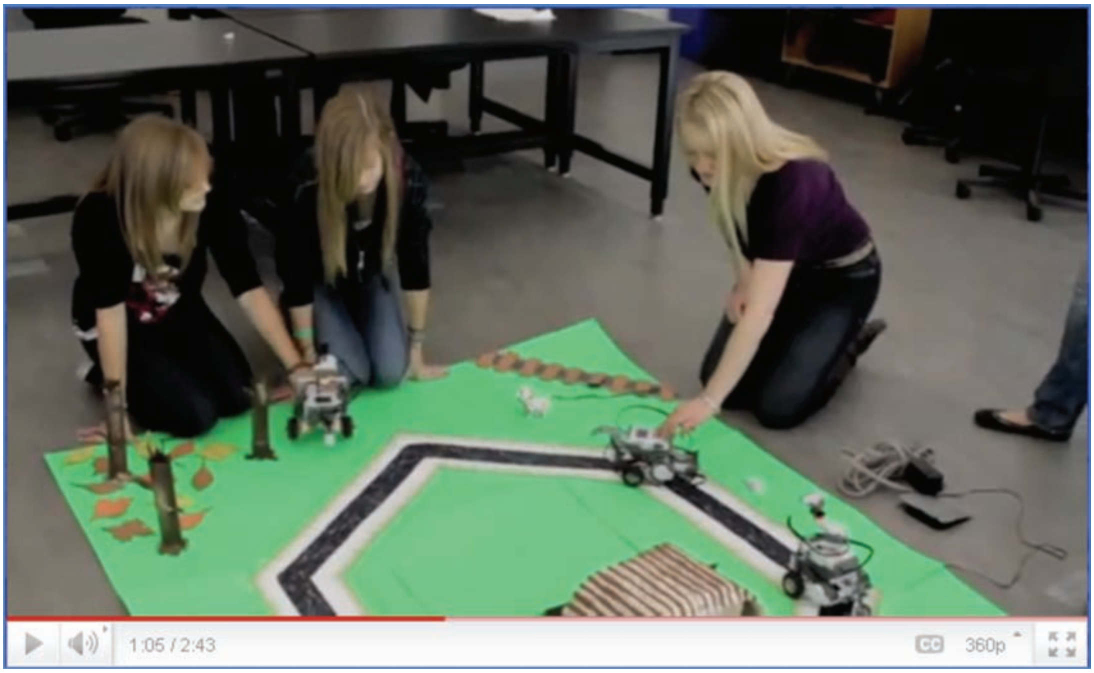

Figure 5. Footage of Day at the Park workshops can be seen in the video 'What We Do: Robotics Workshops' available online:
http://www.youtube.com/user/Girls4Science#p/u/0/zIbB0lTKngU

PicoCricket Workshops

The PicoCricket kits (The Playful Invention Company, Montreal, Canada)[3] offer an alternative platform for robotics workshops. Each kit includes Lego elements (blocks, gears, motors) that can be used to create simple mechanical devices which can be integrated with sensors and output devices to produce a robot. Additionally, the kit contains pipe cleaners, fabric, pom-poms, and other craft material. Readers can find images of the kits and their components in Appendix A1. The software interface is intuitive and easily grasped by participants who have no programming experience. Finally the cost per kit is significantly lower than the Lego Mindstorms NXT.

The common theme for the PicoCricket workshops was "Wild in the Rainforest" as explained in this outline which was used to promote the workshop:

> *This workshop brings art, engineering and computer science together to craft an interactive story of wildlife in the rainforest. Students will learn how to create art that responds in*

[3] http://www.picocricket.com

different ways to light and sound through connections to tiny programmable computers and sensors. Build origami dragonflies that dance when the sun comes out or exotic flowers that sing when the wind blows! Your design will become part of an interactive story set in an enchanting rainforest.

The rainforest theme is further conveyed through workshop materials (see Figures in Appendix A2), and the 3D rainforest setting for the design presentations illustrated in Figure 6.

Workshop Outline

Each workshop began with a very short introduction to what is possible in the world of robotics. Through video resources, participants were introduced to the notion that autonomous robots – aside from coming in all shapes and sizes – are able to sense their world, and make decisions and behave according to how they perceive their environment. Each team workstation was equipped with the following:

- a PicoCricket robotics kit with a cricket (robot); sound sensor, light sensor, and button press sensor; outputs: music box, 2 lights,

Figure 6. The 3D rainforest setting for the Wild in the Rainforest workshops.

- a laptop running the PicoBlocks software with the beamer connected via USB, and
- a worksheet that explained key steps in building the robot and the design task (Appendix A2).

The workshop leader began by demonstrating the PicoCricket kit components and emphasizing the connection between inputs and actions. Some simple Lego devices were pre-built around the motor components: one included rotating elements and the other included components that moved up and down asynchronously. Participants were shown how to use mini USB-like cables to connect

Figure 7. The Wild in the Rainforest setting and team projects are depicted in the video 'Wild In The Rainforest with PicoCrickets' available online: http://www.youtube.com/watch?v=JCbHYya8eb8

Project	Design Goal	Input(s)	Output(s)	Team Gender Mix
Franklin the Monkey (Figure 8a)	To have Franklin run through the rainforest and bark	• Touch sensor • Light sensor	• Soundbox • Motor (modified up-and-down)	2M ,2F
Rock + Rain (Figure 8b)	To have spinning rocker playing a light up guitar.	• Light sensor	• Light • Motor (spinning)	4F
B.H.R.B. (Black Headed Rainbow Bird) (Figure 8c)	To have a squawking bird with flapping wings	• Light sensor	• Light • Soundbox • Motor (modified up-and-down)	2M, 2F
The singing and dancing bird and bear (Figure 8d)	To have the bird and bear sing and dance simultaneously	• Light sensor • Sound sensor	• Soundbox • Motor (up-and-down)	1M, 3F
Diablo the king of birds and all types of feathered mammals, reptiles, beasts, worms and cats (Figure 8e)	To have Diablo honk like a goose, spin, and meow	• Sound sensor	• Soundbox • Motor (spinning)	3M
Fifi the Firefly (Figure 8f)	To have Fifi 'jump' up and down atop a flashing blue light	• Light sensor	• Light • Motor (up-and-down)	1M, 3F
Horse (Figure 8g)	To have the horse run and light up	• Touch sensor	• Light • Motor (up-and-down)	1M, 3F
Bunny vs. Fox Magical Chase (Figure 8h)	To have the bunny and the fox chase each other through the forest and play a magical sound	• Touch sensor	• Soundbox • Motor (up-and-down)	4F
Bloops the Alien (Figure 8i)	To have Bloops spin and make an alien sound	• Sound sensor	• Soundbox • Motor (spinning)	1M, 4F

Table 2: Details of 2011 projects.

inputs and outputs to the cricket itself. One or two different sample projects were presented – a set of flowers that rotated in response to a light sensor, and a caterpillar that jumped and 'ran' when it heard a noise. Finally, the software elements were introduced using the sample projects. Students were shown how to build a simple program by dragging and clicking together functionality components (puzzle pieces), and transmit the instructions to their cricket using a beamer.

The design task was simply to create a rainforest creature, plant, or animal that used (at least) one input and produced (at least) one output behavior. Teams were shown a variety of craft materials (including fabric ends, origami paper, Popsicle sticks, etc.) and were instructed to think through their design and complete a design worksheet (illustrated in Figure A2.2) before getting started. The worksheet asked each team to define what type of creature they would create, which input sensor(s) it would respond to, and which output device(s) would be used in expressing its behavior. Once a team completed the worksheet, they were allowed to ask a leader for one of the pre-built mechanical devices (if they chose to include one of the motor actions in their design). At the end

Figure 8. 2011 workshop creations, details of each project explained in Table 2.

of the design and build time, teams were asked to name their creations (Figure A2.4) and exhibit their designs in the 3D rainforest setting.

Observations

A variety of team projects from the 2010 and 2011 workshops are depicted in images in Appendix A3; some of the creatures and actions can be seen in the short video in Figure 7. For the team projects created in our most recent workshops (the co-ed workshops held in 2011), we provide details in Table 2 as well as images in Figure 8. It is clear that the workshops provided the teams with ample opportunities to make choices and express their creativity in their designs and programming. During these workshops, the leaders formally documented observations of the teams, specifically focusing on team dynamics, design goals, and the components they used in their projects.

Although many participants in the Wild in the Rainforest workshops were entirely new to the idea of robotics, most exhibited enthusiasm and confidence right from the start in their building and programming. The crafting materials seemed to motivate creative ideas – pipe cleaners made very good spider legs, sparkly foam could be fashioned into showy top-hats for pom-pom penguins (see Figures A3.2 and A3.5) – and students let their imaginations lead them to their results. Problem-solving was a big part of their designs and students were heard laughing at their mistakes and collectively making changes to complete their creations. Most teams made use of the art and craft supplies in the workshop kits. However a male-only team chose to focus their efforts on designing and building a car out of the Lego components and did not use any of the craft supplies.

In the co-ed workshops, we observed that team members took on individualized roles. For example, the team who created Franklin the Monkey (Figure 8a) divided themselves by task: one male group member dedicated his time to creating the body for the monkey out of Lego, while one female worked on creating the head out of craft materials, and the other female team member worked on creating and testing the program on the laptop. Most of the programming was done by one member, while the other team members worked on constructing the physical aspects of the design. This is not surprising, as once one person has control of the keyboard, they essentially become the expert with the interface. There were some teams in which a pair of friends worked together on the programming. We observed that in all of the co-ed teams, it was a female or a pair of females who took control of the keyboard and dominated the programming component.

In the female-only workshops, teams were smaller with 2 or 3 members on each team. These smaller teams and pairs demonstrated different dynamics, in which there was more collaboration on programming and design. It was quite common that two members would work together to troubleshoot the software (pairs can more easily share access to the laptop), and similarly the physical components of their design. The entire group interacted with the exhibition at the end of the workshops, trying out each other's designs and nearly all of the girls pulled out digital cameras or cell phones to capture pictures and video. We feel this demonstrated their enthusiasm for the workshop.

Some teams faced challenges because the integration of the creature design with the Lego mechanism was the last step in their design sequence and they realized that some of their concepts were flawed. For example, the body of Franklin quickly fell apart when the team connected it to a motor with an up and down mechanism. Many teams who worked on a winged creature experienced similar results but some creative solutions were developed. Beer, Chiel, and Drushel (1999) explain how this phenomenon is common among their undergraduate teams, asserting that

> "*A tacit assumption … is that if each piece of a complex project works in isolation, the complete system will work as a unified whole. Unexpected problems emerge unless one takes into account the special properties of each piece of the system, and their interactions*".

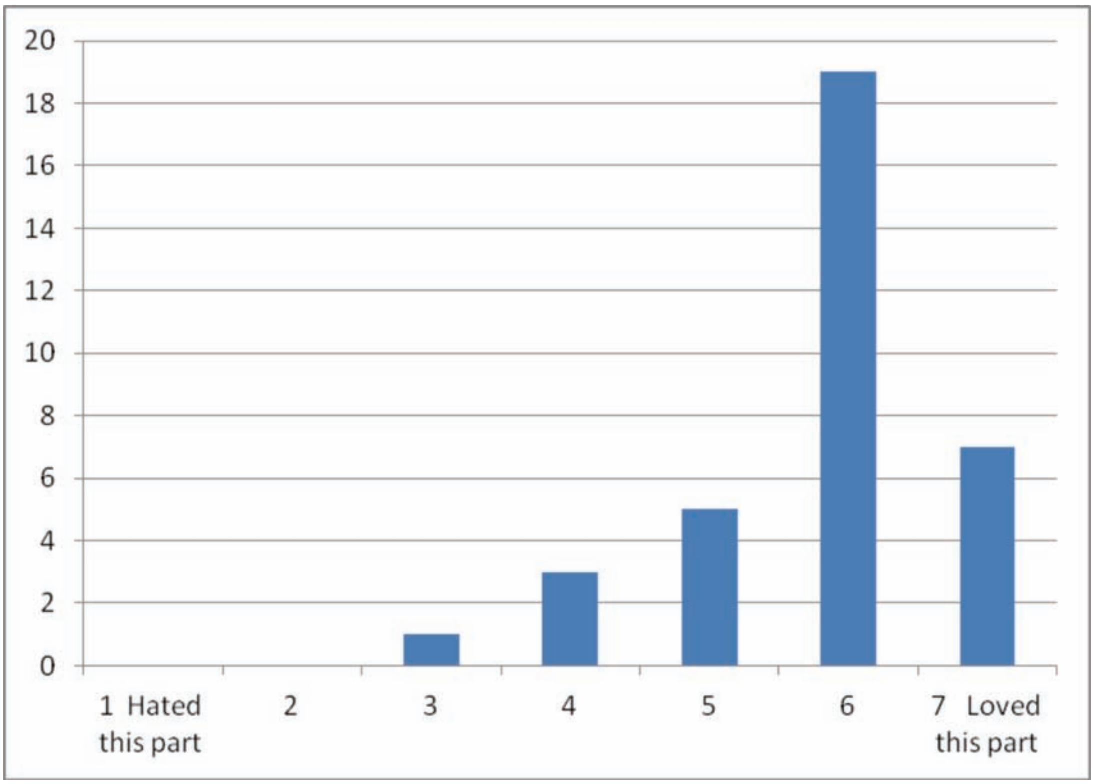

Figure 9. Ratings for "Wild in the Rainforest" activity in 2010 program for Grade 8 girls.

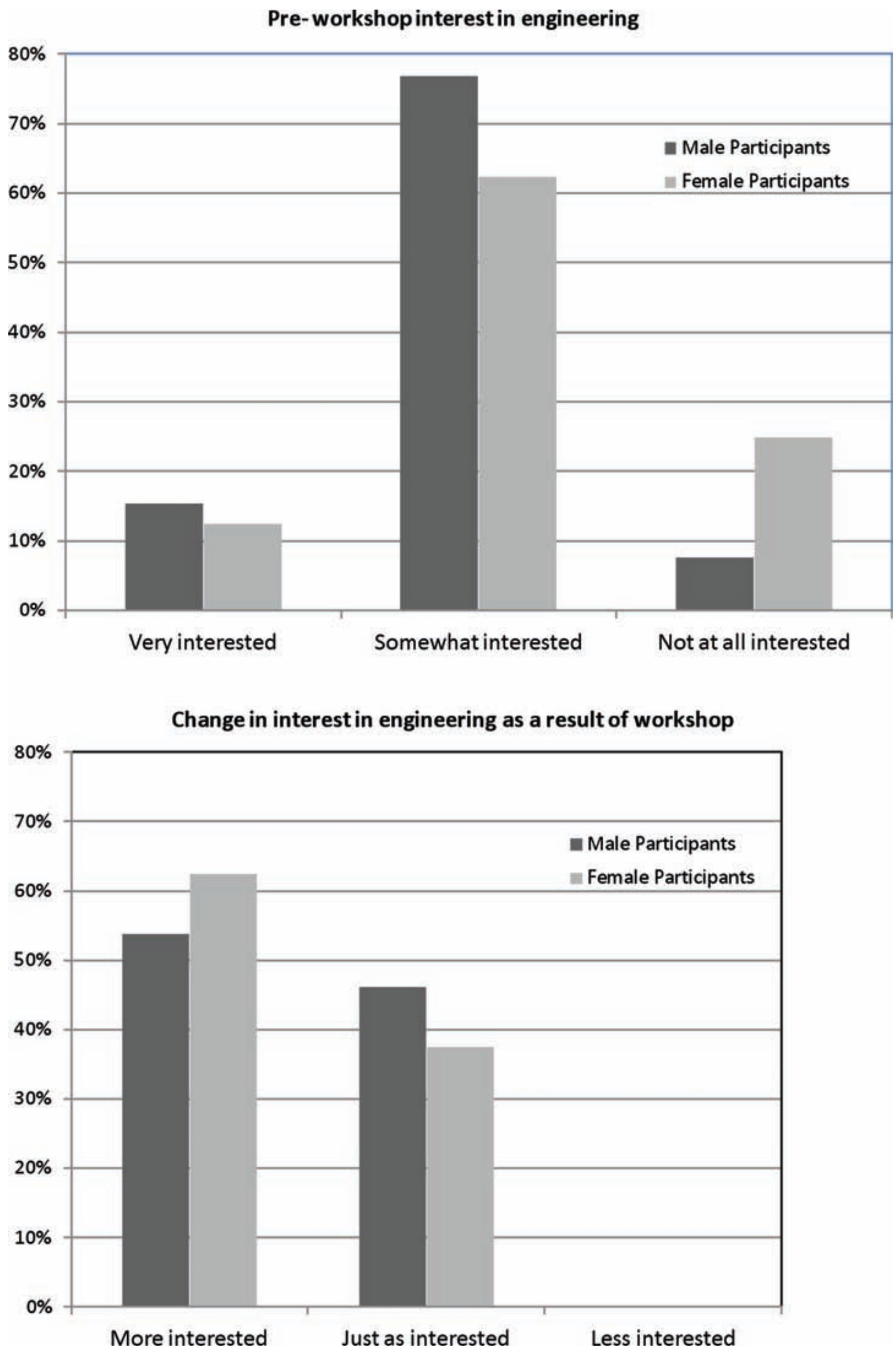

Figure 10. Survey responses after 2010 "Wild in the Rainforest Workshop".

One female-only team stands out as integrating the robotics components into their design from the very start. “Rock n Rain”, illustrated in Figure 8b includes a guitar player and a pink glitter guitar built around the light. The girls on the team were testing the response of the light output very early in the activity.

ASSESSMENT BY PARTICIPANTS

We asked participants to complete short surveys at the end of most workshops. In some cases the assessment of the robotics workshop was part of a survey for a larger program so questions did not follow a standardized format for all workshops. However the surveys did allow us to assess

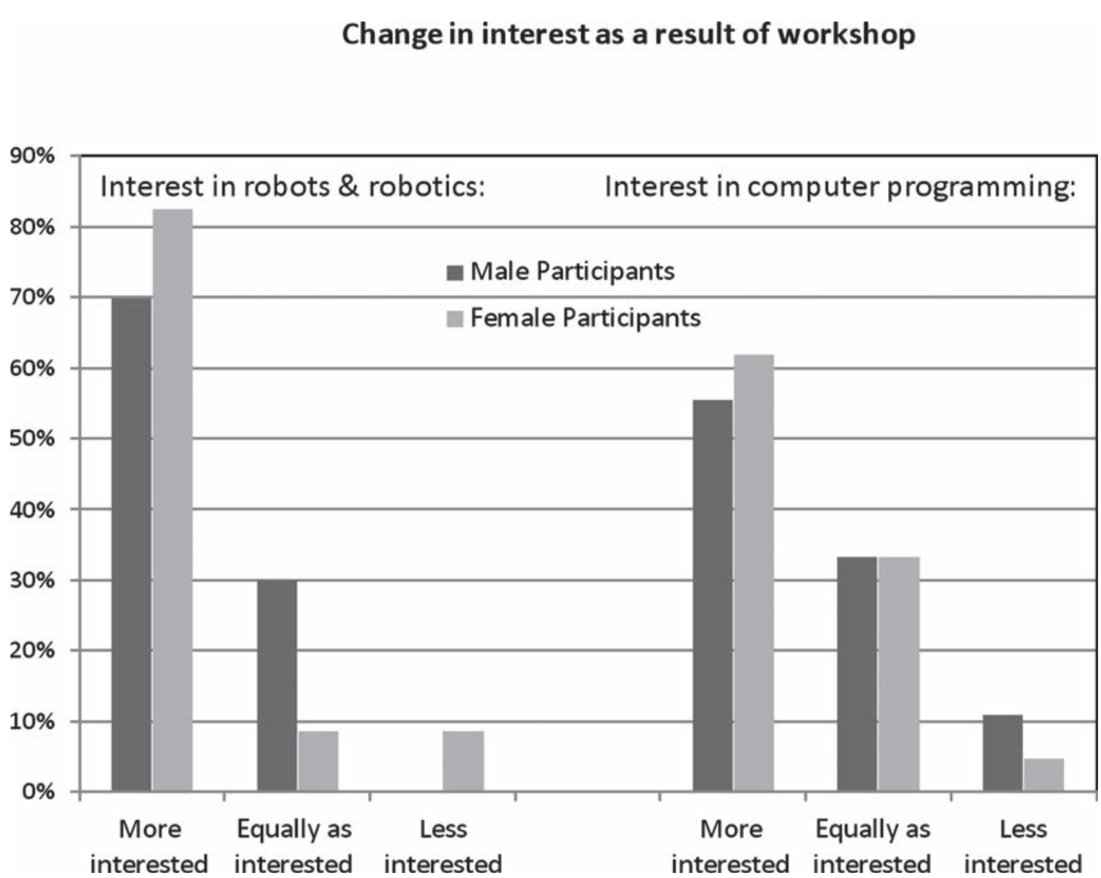

Figure 11. Survey responses after 2011 “Wild in the Rainforest Workshop.

the impact of the workshop on participants' interest in engineering, robotics and/or programming and to obtain feedback comments.

Participants in 2010 workshops for Grade 8 girls provided feedback on the "Wild in the Rainforest" activity using a 7-point Likert scale ('Hated this part' = 1; 'Loved this part'=7). Thirty-six participants responded as shown in Figure 9. The mode of the distribution is 6 and the mean is 5.8.

Thirteen male and sixteen female participants (Grades 9-11) at the 2010 "Wild in the Rainforest" workshop completed workshop evaluations. As shown in Figure 10, the majority of participants indicated that they had limited or a complete lack of interest in engineering prior to the workshop. However 62.5% of the females and 53.8% of the males indicated that the workshop activities had made them more interested in engineering and no one indicated a decrease in interest (Figure 10). Furthermore 25% the females and 38.5% of the males indicated that they were "very interested" in learning more about careers in engineering after participating in the workshop. For both genders, this was about double the proportion who indicated that they were "very interested" in engineering prior to the workshop.

The surveys completed by participants of the 2011 workshops (10 male respondents, 23 female respondents) focused on participants' interests in robotics and computer programming. The response rate was 100% for the robotics question and 91% for the computer programming question and responses are compared by gender in Figure 11. A majority of the participants and a higher proportion of female participants reported increased interest in both robotics and computer programming as a result of the workshop.

All 2011 respondents indicated that they would recommend the workshop to at least a few friends or classmates. More females (82.6%) than males (70%) responded that they would recommend it to all of their friends or classmates. An open-ended question asked participants to write down three words they would use to describe their experience in the workshop to their friends. The most common words provided by respondents were:

- *fun* (80% of males and 65.2% of females)
- *creative* (40% of males and 47.8% of females)
- *interesting* (39.1% of males and 30% of females)

Other positive descriptors provided by the students included *unexpected*, *glittery*, *legendary*, and *computer-tastic*.

In their feedback about how to improve the workshop, many commented that the workshop was good or fun the way it was but some wanted more time to work on their project and others wanted more Lego pieces and parts to build more complex robots. Specifically, 13% of male respondents commented that they wanted more complex parts or actions (compared with 7.4% of females). Some more encouraging comments include the following:

- *I had a blast! I really liked using all the craft supplies! I would definitely do it again! I only wish I had more time to do it!* (female comment)
- *I had alot of fun in this workshop and I'm glad I chose it! maybe just more time for creating robots! I would definitely do that again.* (female comment)
- *I think this workshop was Amazing! It was much more than what I thought and I loved it. I'm going to definitely try this again!* (male comment)
- *Encourage people to design their own motor systems.* (male comment)
- *More computers and more diverse pieces*. (female comment)

DISCUSSION

We consider that all of the teams achieved success since they were able to design robots that satisfied our criteria and each design was unique. Feedback provided by participants showed clearly that our workshops have had a positive impact on participants of both genders.

In terms of participant demographics, males were in the minority overall in the co-ed workshops and males did not outnumber females in the mixed teams (this happened without any guidance from the leaders). In the mixed teams, we observed that both the female and male team members participated with equal enthusiasm from the outset. This was encouraging because in other workshops we have seen that boys become dominant members in mixed groups, taking over the workshop materials and hands-on design activities.

Our observation that in mixed groups females predominantly took on the task of programming is consistent with those noted by Weinberg et al. (2007) in their study of the short term effects of STEM outreach programs using autonomous robots as a medium. The authors noted that "girls on mixed-gender teams were more likely to choose programming over building because they felt it would be easier" than constructing the robots. Weber and Custer (2005) similarly found that females are less interested than males in activities that involve constructing technologies and physical artifacts.

In our observations, we too found that males on mixed teams were more likely to take on the Lego construction tasks. In one case, a pair of males re-built the Lego mechanism and created a car-like vehicle that moved on wheels. We have also observed, however, that many female-only teams were eager to reconstruct and/or modify the prefabricated Lego components of their creations or robots. Indeed most of the teams in the Lego Mindstorms workshops (all female) added a third motor to their robot, and one female participant in particular spent a significant amount of time building a prop with Lego. Another team whose program repeatedly crashed their brick became quite skilled at dismantling and rebuilding the scaffolding around the NXT brick. Across all of the workshop evaluations, a number of males and females commented that they wanted to work with more complex parts or actions.

We feel that the participants' experience was enhanced through our consideration of the strategies outlined by Rusk et al.(2008) in the design of our workshops. The nature of the engineering design problems challenge teams to work together towards a design goal. In these workshops, the teams are not directly competing with each other since each design goal is unique. The opportunity to mix art and engineering further allows them to express themselves in their designs. Resnick (2006) suggests that children develop richer connections to their learning when they are personally invested in their projects. Consider the subjectivity of the project goal – for example - to design and build the "most creative dancing robot". A challenge like this naturally leads teams to incorporate inventive ideas and unorthodox designs. Moreover, the inclusion of multi-media or art components provides teams with an alternate context for robotics and technology in which both genders are on equal footing.

The literature suggests that females are more likely to enjoy collaborative activities focused on design – rather than tasks that involve constructing from existing project plans or instructions (Weber and Custer, 2005). Hartmann, Wiesner, Wiesner-Steiner (2007) believe that providing freedom, balanced with sufficient guidance, is the key to achieving success in robotics workshops designed to appeal to females. We feel that males similarly benefit from practicing robotics in a non-traditional context. A pair of Grade 9 students – one boy, one girl – with previous experience building robotic cars remarked that they enjoyed the freedom to build anything they wanted in the "Wild in the Rain Forest" workshop. Another female participant shared that she had taken part in robotics workshops before, but she much preferred the PicoCrickets kits, and was excited about the idea of doing something different with programming.

Weinberg et al. (2007) suggest that participation in robotics outreach activities can be effective in mitigating female participants' acceptance of gender roles. Although changing established cultural and social beliefs is not possible in the course of a 60-minute workshop, we consider it a success that the majority of participants left our workshops with an increased interest in technology and engineering. We could improve upon our existing workshop design by encouraging role rotation so that more than one or two team members become proficient in programming, and engage more team members in the construction related tasks.

Finally, although a few participants had some prior experience with Lego Mindstorms, we learned that many participants registered without knowing what the workshop would entail (e.g., participants registered for a larger program that included the robotics workshop or they were registered by a teacher), and were surprised with what they learned. Many of the participants remarked that they were quite pleased with the workshop regardless of their expectations.

CONCLUSIONS

In this work we have presented a model for robotics workshops, which engages students of both genders in engineering design, problem solving, and exploration of robotics technology. The workshops incorporate art and engineering, and teams decide what type of robot they will design within a common workshop theme. The exhibition component, based within a realistic physical setting, encourages story-telling and mitigates competition between teams. Although all of our workshops make use of Lego Mindstorms or PicoCrickets robotics kits, some of the elements we present here can be incorporated in different types of engineering outreach activities.

Resulting student projects, evaluation data and participant comments show that we have succeeded in increasing interest in engineering and computer science among middle and high school students, particularly the interest of female students. The challenge is maintaining this burgeoning interest in technology so that participation of women in engineering and computer science programs increases. The workshops did engage students over a wide range of ages and the themes offer considerable flexibility so participants could be encouraged to return to repeat offerings. This would provide more opportunities to interact with the female role models who lead the workshops. We think that the interaction with women who are enthusiastic about robotics and programming is a key factor in encouraging young girls.

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Melanie Veltman completed the MSc. in Computer Science at the University of Guelph in 2010. As a Project Manager for the NSERC/RIM Chair for Women in Science and Engineering – Ontario (CWSE-ON), Melanie designed and delivered hundreds of workshops in schools across the province to engage young people in science, engineering, and technology.

Valerie Davidson's academic background combines a Bachelor's degree and PhD in Chemical Engineering with a Master's degree in Food Science. Her career to date includes industrial, academic and administrative experiences. From 1990 to 1992, Valerie served as a member of the Canadian Committee on Women in Engineering. In 2002 she was a co-recipient of the Canadian Council of Professional Engineers (CCPE) Award for Support of Women in Engineering, an award that recognised noteworthy support of women in the engineering profession and engineering excellence. Between 2003 and 2011, Valerie held the NSERC Chair for Women in Science and Engineering for Ontario. In this role she developed activities to encourage women to study science and engineering and to move into careers in these areas. She is the chair of ONWIE (Ontario Network of Women in Engineering), a network that connects all of the schools and faculties of engineering in Ontario.

Bethany Deyell acquired a BSc (Hon) in Physics & Biology from Queen's University (Kingston, ON) in 2006. From 2008 to 2011, Bethany worked as Youth Outreach Coordinator for the CWSE-ON program. In this role, she led interactive workshops for young people and their leaders to bring engineering and mathematics to life. Prior to joining CWSE-ON, Bethany provided direction for First LEGO League (FLL) teams and educators using LEGO robotics to teach science concepts in the classroom.

APPENDIX A1 Figures Illustrating the Pico Crickets Kits

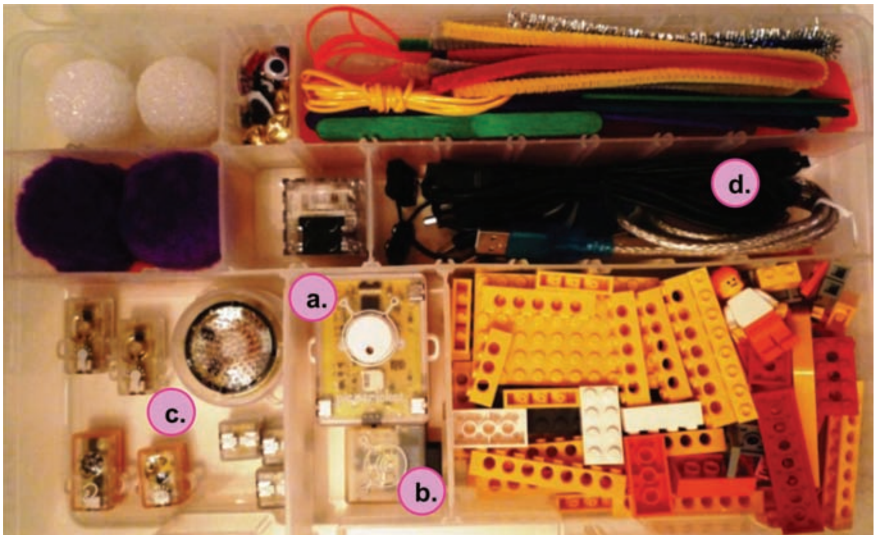

Figure A1.1. The Pico Crickets kit as configured for the Wild in the Rainforest workshops; a. the cricket robot itself; b. the beamer, which connects to a computer via USB cable and beams the program to the cricket; c. tiny outputs and sensors; d. cables to connect the sensors and output actuators to the cricket.

Figure A1.2. The gear components used to create the spinner and up-and-down motion frameworks.

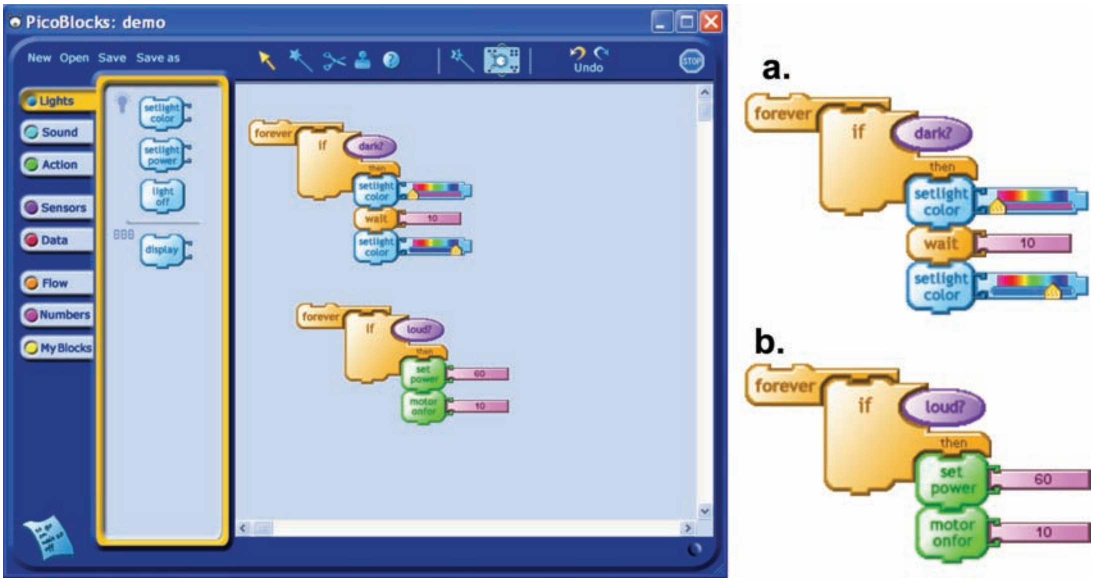

Figure A1.3. The Pico Blocks software. Logic components are color-coded based on functionality, and can be snapped together to create programs (see a. and b.).

APPENDIX A2 Wild in the Rainforest Workshop Materials

Figure A2.1. A visualization of the Wild in the Rainforest theme was presented to participants in this first slide of the introductory presentation.

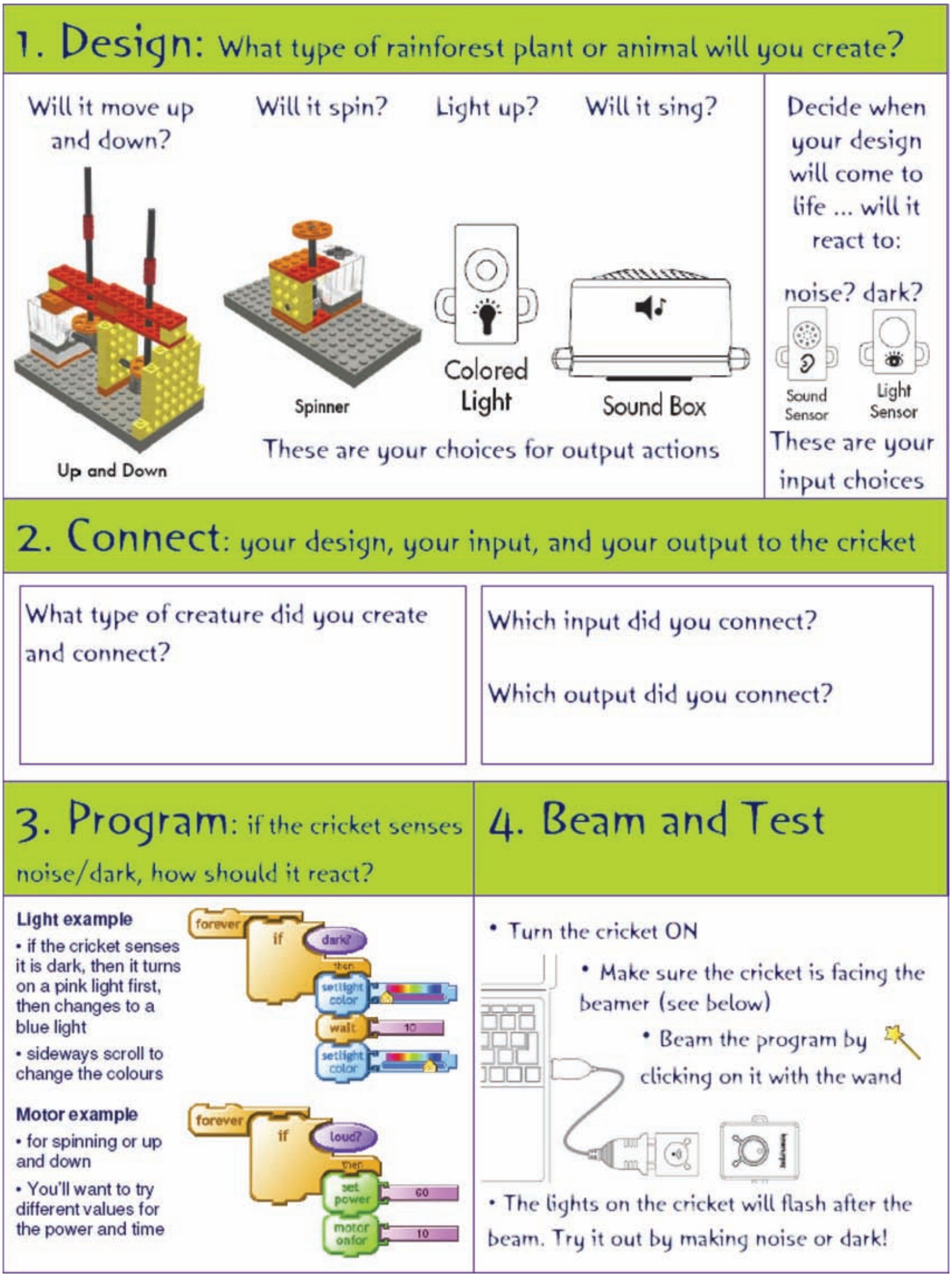

Figure A2.2. Design worksheet (distributed with cover page shown in Figure A2.3).

FigureA2.3. A visualization of the theme was included as a cover page for design worksheet (Figure A2.2).

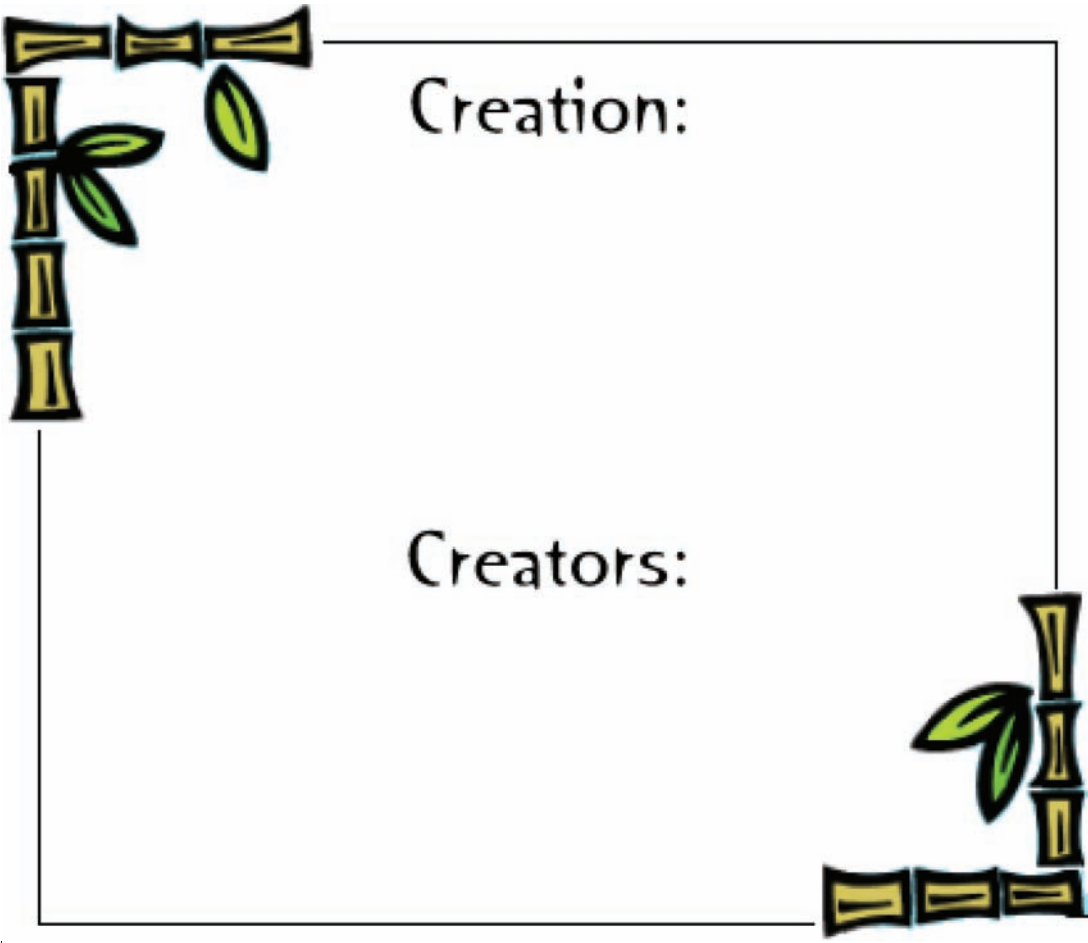

Figure A2.4. Teams were instructed to brainstorm a name for their creation and add their team member names on creator cards.

APPENDIX A3 WILD IN THE RAINFOREST TEAM CREATIONS

Figure A3.1. A dragon affixed on an up-and-down motion framework.

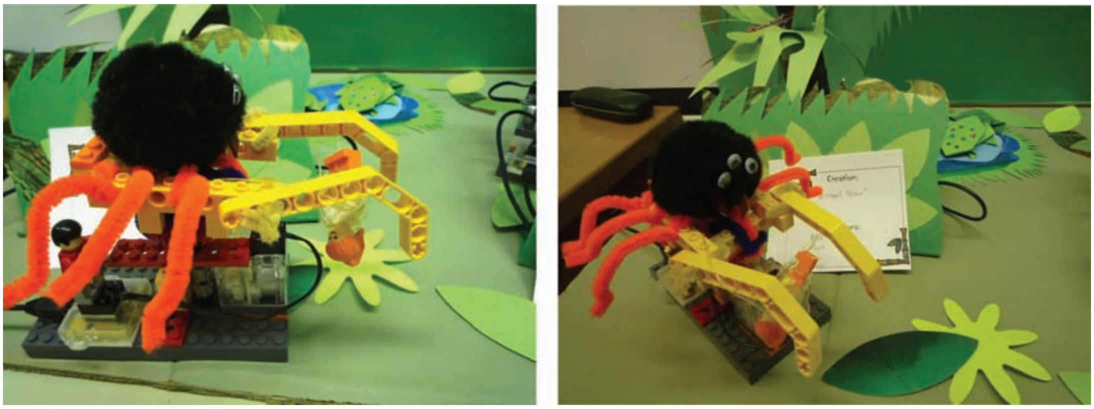

Figure A3.2. This creation tells the story of a male Lego person (lower left hand side,left photo) attempting to slay the 'Eight-legged terror' – a spider atop a spinning motion framework – to save the female person trapped in the spider's web.

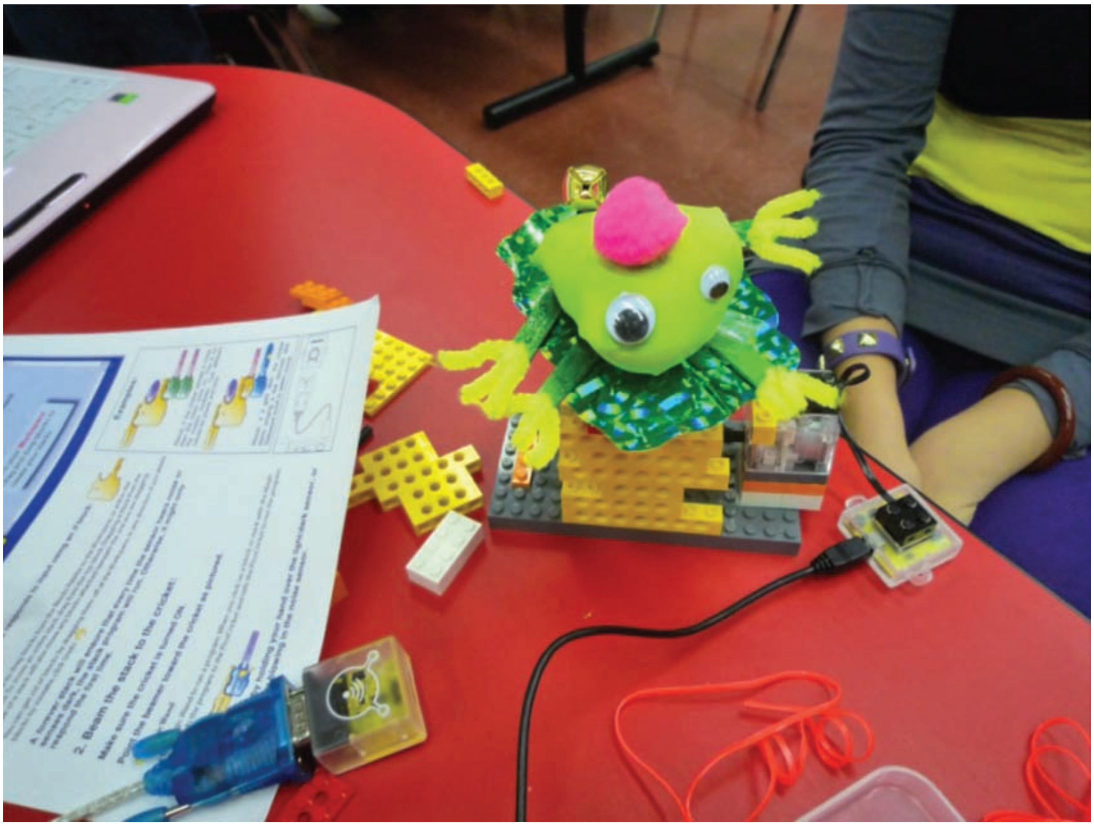

Figure A3.3. A jumping frog on a modified up-and-down motion framework.

Figure A3.4. 'Jean Little Bunkey' is a hopping monkey with a purse.

Figure A3.5. Penguins in top hats jump up and down.