Transforming a Middle and High School Robotics Curriculum from Formal Classrooms to an Informal Learning Environment

Mercedes McKay, Stevens Institute of Technology
Susan Lowes, Columbia University
Devayani Tirthali, Columbia University
Elisabeth McGrath, Stevens Institute of Technology
Jason Sayres, Stevens Institute of Technology
Karen Peterson, EdLab Group
WaterBotics®

• Underwater robotics curriculum using LEGO Mindstorms equipment
• Series of design-based challenges using science, engineering, and programming knowledge/skills
• Initially developed and piloted with formal classroom teachers & students in NJ
• In 2009, scaled up to include informal educators & youth
Scale-Up Implementation

• 2 Community College Hub Sites (formal):
  • Training formal classroom teachers to implement with MS and HS students
  • Conducting limited camp programs
• 2 National Girl Collaborative Project (NGCP) Hub Sites (informal):
  • Conducting numerous summer camp programs with girls
  • Training other Girl-Serving STEM organizations to offer WaterBotics
• Staggered Implementation; 2 sites started in yr 1 & 2 more in yr 2
Curricular & PD Adaptations

- Curriculum modified and enhanced for use in informal learning; especially that targeting girls
- 2 versions exist: formal & informal
- Essential “core elements of success” defined for both formal and informal versions

Adaptations include the following....
MISSION 1:
OCEAN RESCUE

GOAL: CREATE A ROBOT THAT CAN RESCUE A DISTRESSED SWIMMER

MISSION REQUIREMENTS:
Your team's robot must move forward along the surface of the water from one end of the pool to the other, where it will change direction and move backward to the start.

MISSION CONSTRAINTS:
- Robots must float on the surface of the water
- Move forward and backward in a straight line
- Use only 1 motor
- Include as many small boat propellers as necessary
- Use any sensor for the controller except the buttons on the NXT device
- Program your robot using loops and switches
- Experiment with gears to change the robot's speed
- Allow each teammate to operate the robot

Robots are often created to perform tasks that humans cannot do because of environmental constraints. The marine environment can present harsh conditions for human survival, and consequently, their rescue. Imagine a distressed swimmer that is far from the beach and the lifeguard station. How might a robot help in this scenario?

In this mission, you will create a robot that can be driven along the surface of the water to a distressed swimmer. The swimmer can then grab ahold of the robot and be driven back to the shore where they will be taken care of by a lifeguard.

FYI
The robot in the picture above, named EMILY (Emergency Integrated Lifesaving Ianyard), can rescue people up to six times faster than a human lifeguard. It can zoom along the water at 28 mph, and has a camera and speaker for easy communication between the lifeguard and the swimmer. For more information on EMILY, check out: http://students.egfi-k12.org/robot-soaks-up-the-sun-and-saves-lives-too/
## Agenda and Logistics

### Schedule

Below is a suggested schedule for a week-long camp. Depending on your situation, you may adjust the start and end times of each day, change the length of certain activities, move lunch, etc.

<table>
<thead>
<tr>
<th>Time</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30 AM</td>
<td>Setup</td>
<td>Setup</td>
<td>Setup</td>
<td>Setup</td>
<td>Setup</td>
</tr>
<tr>
<td>8:45 AM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9:00 AM</td>
<td>Warm-up and Pre-Project Survey</td>
<td>Icebreaker</td>
<td>Icebreaker</td>
<td>Icebreaker</td>
<td>Icebreaker</td>
</tr>
<tr>
<td>9:15 AM</td>
<td>Recap of Day 1</td>
<td>Recap of Day 2</td>
<td>Recap of Day 3</td>
<td>Recap of Day 4</td>
<td></td>
</tr>
<tr>
<td>11:45 AM</td>
<td>Day 1 Mission</td>
<td>Lunch</td>
<td>Lunch</td>
<td>Lunch</td>
<td>Lunch</td>
</tr>
<tr>
<td>12:00 PM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:15 PM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:30 PM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1:00 PM</td>
<td>Brainstorm, Prototype</td>
<td>Mission 2: Briefing</td>
<td>Mission 3: Pre-Mission Log</td>
<td>Mission 3: Briefing</td>
<td></td>
</tr>
</tbody>
</table>
Use of Interactive Embedded Assessments

Pictures to Sort: 11

To sort the pictures, drag them into the boxes below. Double-click a picture to send it back to the top.

- Test blood samples to diagnose disease
- Create a system to clean water
- Drive a backhoe
- Work in a team
- Analyze soil conditions before building a bridge
- Fix a computer
- Design a kitchen
- Analyze water contamination and build a water system
- Construct a building
- Test a model of a robot that helps injured people
- Plan a network

Engineers Num: 2
Not Sure / Don't Know Num: 1
Not Engineers Num: 2
Hands-on Science Learning Activities

Human Gears
Focus on Role Models & Careers

Electrical engineer at Monterey Bay Aquarium Research Institute
Use of Video Demonstrations for Enhancing Science Content
Step 12: Add a Loop Block

Sample Programs and Exercises
Culminating Showcase
Core Elements of Success

Formal Curriculum
- "Challenges"
  - Competition
  - Lesson Plans
  - Emphasis on Content Knowledge
  - Hands-on Activities as Optional Elements
  - In-depth Science Lessons as Core Elements

Informal Curriculum
- "Missions"
  - Programming Lessons
  - Engineering Design Process
  - Engineering Career Awareness
  - Four Iterations to Complete Robot
  - Online Videos and Simulations
  - Setup Instructions
  - Materials List
  - Showcase
  - Activity Plans
  - Emphasis on Attitudes and Engagement
  - Hands-on Activities as Core Elements
  - In-depth Science Lessons as Optional Elements
Research Questions

- Are student outcomes similar regardless of the teaching environment (formal vs. informal)?
- To what extent was the curriculum taught as designed? Is greater fidelity of implementation associated with better student outcomes?
Student Outcomes Hypotheses

• Students in formal classrooms would perform better on content assessments
• Youth in informal environments would show higher levels of engagement and interest in engineering
• Results complicated due to variation of grade levels, number of participants, and gender at each site
• Comparisons of the 2 environments proved difficult
Year 2 Student Results

• Informal environment had higher student ratings for enjoyment and learning

• Increases on content assessments statistically significant at all sites; but all final mean scores < 70%

• Strong correlation of student post-test scores with educator knowledge for programming content
Year 2 Student Results

• Higher percentage of student in informal environments expressed interest in science and engineering

• At all sites, participants’ ratings of enjoyment and learning was highly correlated with their interest in engineering
Fidelity Hypothesis

• Higher levels of fidelity would be associated with better student outcomes

• Implementation practices included:
  – Adequate time with curriculum
  – Using supplementary materials (videos & simulations)
  – Using sample Mindstorms programs
  – Engineering activities
Year 2 Results

• Time spent on curriculum strongly correlated with post-test mean scores
  – Camp program (informal) more likely to spend the recommended time

• Participants’ use of sample programs *negatively* correlated with programming post-test scores

• Supplementary materials and engineering activities not correlated to post-test scores
• Contrary to hypothesis, students from informal sites did better on content learning than students in formal classes

• Informal sites did better on STEM interest and engagement, as hypothesized

• Educator knowledge of topics not correlated with student post-test scores except for programming

• Worked best in informal sites
Next Steps

• Since hub sites are not easily comparable, are now looking at factors that are associated with success across all sites

• Continuing to examine differential impacts on different student groups and implementation scenarios
Questions?

www.waterbotics.org
Acknowledgement

This material is based upon work supported by the National Science Foundation under grant 0920674