WATERBOTICS®

A Novel Engineering Design Curriculum for Formal and Informal Educational Settings

Patricia Holahan, Mercedes McKay, Jason Sayres, Susan Lowes, Arthur Camins, Beth McGrath

January 2015
Acknowledgment:
The contents of this report are based upon work supported by the National Science Foundation under Grant Numbers 0624709 and 0929674. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Suggested Citation:
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXECUTIVE SUMMARY</td>
<td>1</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>3</td>
</tr>
<tr>
<td>BACKGROUND</td>
<td>5</td>
</tr>
<tr>
<td>LEARNING CONTEXT</td>
<td>8</td>
</tr>
<tr>
<td>LEGO® ROBOTICS PLATFORM</td>
<td>14</td>
</tr>
<tr>
<td>WATERBOTICS SUCCESSES AND CHALLENGES</td>
<td>16</td>
</tr>
<tr>
<td>ADDITIONAL INFORMATION</td>
<td>26</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>27</td>
</tr>
</tbody>
</table>
WaterBotics can be used effectively in a variety of formal and informal educational settings.
The underwater environment presents novel challenges that can facilitate unique learning experiences for students engaged in robotics programs. WaterBotics® is an underwater robotics curriculum using LEGO® MINDSTORMS® components and related materials. It has undergone an extensive, eight-year research and development phase. WaterBotics can be used effectively in a variety of formal and informal educational settings, such as school-based classrooms, summer camps, and after-school-programs. As part of a National Science Foundation scale-up grant, WaterBotics has been implemented with thousands of middle and high school youths in five U.S. geographic regions. Data from approximately 1,500 youth indicate that 53% have been girls, and almost equal numbers of youth have participated in formal, classroom settings as in out-of-school settings.

This paper describes the design of the mission-based curriculum and highlights lessons learned about effective education practices and their relationship to student learning outcomes in physical science, information technology skills, engineering design, and engineering career interest. Core elements of success and curricular adaptations are illustrated through presentation of five case studies – two that illustrate implementation of the curriculum in formal educational settings and three that illustrate implementation of the curriculum in informal educational settings. Common themes that emerged included: (1) The curriculum was effective in developing self-confidence, problem-solving, and persistence; (2) Students mentoring and/or teaching other students was a common observation; and (3) Educators noted that while some parents resisted recruitment of girls to WaterBotics camps, even girls who were initially reluctant to attend showed high interest by the end of their participation.
Designing and building a robot to explore an underwater environment is a highly interdisciplinary undertaking, encompassing science, engineering, and information technology fields of study. Real world applications of underwater, remotely-operated vehicles are numerous and include exploration and recovery of submerged shipwrecks; inspection and repair of submerged pipelines and structures; underwater mine detection; and oceanographic and environmental monitoring, among many others.

Robotics offers an exciting and engaging context for youth to learn science and engineering concepts and skills, as well as an educational strategy to increase learners’ interest and persistence in science, technology, engineering, and mathematics (STEM). It also offers youth an opportunity to practice 21st century skills such as teamwork, creative problem-solving, and iterative design. Designing, building and controlling a robot to function underwater presents a level of complexity that is not found in many land-based robotics program. To be successful, students must have an understanding of scientific concepts such as such as buoyancy, stability, and drag in order to create robots that will dive or ascend in the water, stay upright, and move in three dimensions instead of two. Because of this, the underwater context can level the playing field for mixed groups of learners, some of whom may have achieved a higher level of skill through other robotics programs.
The following pages describe an underwater robotics curriculum, called WaterBotics, that has been used by thousands of youths in classrooms and summer camps across the United States over the past five years. WaterBotics provides exciting and novel problem-solving opportunities for learners that have been shown to increase students’ interest in STEM disciplines. Five short case studies are presented that demonstrate how the curriculum has been adapted to varying educational settings and levels.
The WaterBotics curriculum was developed by the Center for Innovation in Engineering and Science Education (CIESE) at Stevens Institute of Technology in Hoboken, New Jersey through two successive National Science Foundation grants. It has been implemented with thousands of middle and high school youths nationwide. The results from our study of 1,500 of these youth indicate:

- 49% participated in classroom settings while 51% participated in out-of-school settings
- 53% female participants and 47% male participants

The WaterBotics curriculum is designed so that middle and high school participants:

- Learn, experience and apply the practices of engineering design;
- Develop increased understanding of core disciplinary ideas in physical science, engineering, and information technology;
- Gain 21st century skills, such as problem-solving, teamwork, and innovation/creativity;
- Develop increased awareness and interest in engineering and information technology careers.

Teams of students engage in problem-based learning (Barrows, 2002) as they collaborate to design, build, test, and redesign underwater robots made of LEGO® components, motors,
propellers, and other materials. The robots are developed through an iterative engineering design process. Student teams complete a series of design challenges or “missions” that increase in complexity and require more sophisticated solutions. Ultimately, students produce a fully functional underwater robot capable of maneuvering in a three foot deep pool. Students also learn computer programming as they design and program custom controllers for their robots using the NXT and LEGO® MINDSTORMS® software.

WaterBotics is flexible. It has been successfully implemented using multiple formats, including intensive, one-week summer camp experiences or as a sequence of science or technology classes in middle and high school (one or more classes per week). The modular design allows educators to implement the program according to their own schedules and needs. The length of time needed to successfully implement the curriculum varies with the age and abilities of the participating youth and according to the instructors’ learning objectives and time constraints. A typical implementation takes approximately 25-30 hours.

The curriculum guide includes a comprehensive and diverse collection of educational materials in a variety of formats. Materials include planning guides for program scheduling, equipment needs, location and workspace arrangements, and appropriate staffing needs and training. Equipment and technology setup and installation guides are provided using numerous illustrations. Additionally, each mission includes detailed activity/lesson plans. Explicitly illustrated student handouts accompany the science and programming lessons so that students may either follow along or learn on their own, depending on student needs and instructor preference. In addition to the curriculum, the WaterBotics web site contains numerous support materials that include screencasts of programming lessons, videos demonstrating physical science concepts, sample computer programs, interactive science simulations, and student assessments. See Figure 1 for an example of a buoyancy simulation (McGrath et al., 2012).
WaterBotics is designed for girls and boys from Grades 7-12 (ages 12-18). Modified curriculum designs have also been used with upper elementary students and undergraduate engineering students. National Science Foundation-funded research has shown WaterBotics to be: (1) engaging for both girls and boys, and (2) suitable for students ranging from special education to gifted and talented (McGrath, Lowes, Lin & Sayres, 2009).

Figure 1: Buoyancy Simulation
LEARNING CONTEXT

WaterBotics fosters an active, discovery-based learning environment that integrates many scientific, engineering, information technology principles, and 21st Century skills. While these elements may be common to a number of robotics programs, there are unique features of WaterBotics that distinguish it from other underwater robotics curricula.

First, WaterBotics is based upon the educational theory of social constructivism, which situates learning in dynamic, iterative, and authentic contexts (Piaget, 1952). In a constructivist-based environment, learners build upon their prior knowledge, but draw upon the learning of others within the community as well as new knowledge gained through experiential practice (physical and mental manipulation of objects) and independent or guided research to integrate new knowledge and arrive at deeper understandings (Driver & Bell, 1986; Piaget, 1952, 1972; Vygotsky, 1962, 1978). WaterBotics students test and re-design their robots through this collaborative, iterative process. The design missions are intentionally scaffolded to increase in complexity, building students’ understanding and confidence.

Second, LEGO® materials are used as the building blocks of the robots. These easily manipulated parts facilitate the rapid prototyping that leads to increased motivation, meaning, and accessibility.

Third, working in an underwater environment challenges even the most experienced robotics users to apply science and engineering concepts in order to produce a fully functioning robot with six degrees of freedom.

Lastly, student recognition and differentiated instruction is encouraged through the use of additional mission challenges and showcase events.

SCAFFOLDED LEARNING:

SCIENCE CONTENT IS EMBEDDED IN THE ITERATIVE DESIGN PROCESS

WaterBotics is unique. Its driving force is building a prototype to complete a relevant, student-friendly mission rather than competing to win a competition. As a result, it has wide appeal across diverse youth audiences including those with little or no prior robotics
experience. To ensure that students do not become daunted by building a complex robot right from the start, the curriculum is divided into a series of four “bite-sized” missions that gradually lead to the production of a fully functional robot. In each mission, students plan, design, build, test and iteratively improve a robot that possesses a specific subset of the capabilities of the final robot, always building on their knowledge and experience gained from the prior missions. As students address the challenge in each mission they gain first-hand experience with the Engineering Design Process (EDP) in which they build and test subsystems as part of a more complex undertaking. By understanding how the process is applied to this particular project, students gain familiarity and confidence to attempt even greater design challenges.

The curriculum’s approach to embedding science lessons within each design mission is an intentional and distinctive feature of the curriculum design. The goal is to attain measurable student learning gains in common physical science concepts. The science, engineering, and programming content of the WaterBotics curriculum is shown in Table 1 (McGrath et al., 2012). In addition to experiencing hands-on learning of these concepts, students engage in virtual simulations, view online videos, and access other web-based instructional resources to help them master these topics.

<table>
<thead>
<tr>
<th>SCIENCE</th>
<th>ENGINEERING</th>
<th>PROGRAMMING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gears and Gear Ratios</td>
<td>Critical Thinking</td>
<td>Loops</td>
</tr>
<tr>
<td>Action/Reaction Forces</td>
<td>Problem-Solving</td>
<td>Switches (Conditionals)</td>
</tr>
<tr>
<td>Drag</td>
<td>Engineering Design Process</td>
<td>Data Types</td>
</tr>
<tr>
<td>Buoyancy</td>
<td>Iterations and Design Cycles</td>
<td>Flow Charts</td>
</tr>
<tr>
<td>Mass, Volume, and Density</td>
<td>User Interface Design</td>
<td>Troubleshooting</td>
</tr>
<tr>
<td>Torque</td>
<td>Testing and Troubleshooting</td>
<td></td>
</tr>
<tr>
<td>Inertia and Stability</td>
<td>Synthesis/Analysis of Problems</td>
<td></td>
</tr>
<tr>
<td>Ratio and Proportion</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Science, Engineering and Programming Topics in WaterBotics
WaterBotics’ focus on the engineering design process aligns well with the engineering design standards called for in the Next Generation Science Standards (NGSS Lead States, 2013). Table 2 lists the engineering and physical science standards that are addressed by WaterBotics and the connections to project activities and practices.

<table>
<thead>
<tr>
<th>SCIENCE AND ENGINEERING PRACTICES</th>
<th>DISCIPLINARY CORE IDEAS</th>
<th>CROSSCUTTING CONCEPTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking Questions and Defining Problems</td>
<td>PS2.A: Forces and Motion: Propulsion, drag, buoyancy, and gravity combine to produce the robot’s motion.</td>
<td>Patterns: Which combinations of gears result in better propulsion? Which configurations of floats and ballast affect a result in stable robot orientations?</td>
</tr>
<tr>
<td>Developing and Using Models</td>
<td>PS2.C: Stability and Instability in Physical Systems: The controllable orientation of the robot must also be stable when submerged.</td>
<td>Cause and Effect: When a change is made to a robot, how does that affect its performance? Why?</td>
</tr>
<tr>
<td>Analyzing and Interpreting Data</td>
<td>ETS1.B: Developing Possible Solutions: Creative ideas are encouraged and then tested for viability.</td>
<td>Structure and Function: How does the shape and mass of a robot affect its motion?</td>
</tr>
<tr>
<td>Constructing Explanations and Designing Solutions</td>
<td>ETS1.C: Optimizing the Design Solution: Robots are repeatedly modified and tested until they achieve the mission goal.</td>
<td>Stability and Change: What makes a robot stable when underwater? How can the stability of an underwater robot be changed?</td>
</tr>
<tr>
<td>Engaging in Argument from Evidence</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: WaterBotics Alignment with Next Generation Science Standards
MISSION-BASED CURRICULAR DESIGN

The WaterBotics curriculum is designed as a series of four missions that gradually increase in difficulty and ultimately lead to a final robot design. Each of the missions is cast as a real-world application of underwater robots. For example, in the first mission students are challenged to create a robot to go back and forth across the surface of the pool. The motivating context is to build a prototype of a “rescue robot” that can go out to sea, reach a drowning person, and pull him or her back to shore. As shown in Table 3, in subsequent missions students improve their robot design to operate in two dimensions (e.g. clean up a surface oil spill), maneuver underwater (e.g. detonate an underwater mine), and eventually pick up objects from the bottom of the pool and deposit them elsewhere (e.g. salvage an underwater shipwreck.) To successfully complete the final mission, students must apply what they have learned about the science and engineering concepts previously listed and through frequent testing, refine their robots to optimize functionality and maneuverability.

Each mission ends with a friendly “showcase” event to focus students on a concrete milestone, interest them in what their classmates are doing and add an element
of excitement to the project. To provide students flexibility in their robot designs and optimizations, they are encouraged to work towards specific achievements within each mission. These are specific goals for their robots to accomplish within the context of the mission. For example, one achievement is to rescue a person (represented by a ping pong ball) within 10 seconds; another is to rescue 10 or more people in one trip. Each mission has a number of achievements that students may attempt, but only one must be accomplished for the mission to be considered a success. The achievements also serve to provide additional challenges for teams that may work more quickly than others. There is minimal downtime for students since they are always encouraged to improve their robots to earn additional achievements.

Table 3: WaterBotics Scaffolded Missions

<table>
<thead>
<tr>
<th>Mission 1: Rescue a Drowning Swimmer</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Use the robot to save one or more &quot;drowning swimmers&quot; represented by ping pong balls</td>
</tr>
<tr>
<td>• Design and build a robot using a single motor that can travel in a straight line—both forward and backward—on the surface of the water</td>
</tr>
<tr>
<td>• Use prototypes to optimize gearing to improve speed, control, or capacity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mission 2: Clean Up a Pollution Spill</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Improve the robot so that it can maneuver freely on the surface of the water to clean up a spill of &quot;hazardous pollutants&quot; represented by scattered ping pong balls</td>
</tr>
<tr>
<td>• Incorporate a second motor to the robot to enable steering and two-dimensional movement</td>
</tr>
</tbody>
</table>

To provide students flexibility in their robot designs and optimizations, they are encouraged to work towards specific achievements within each mission.
Mission 3: Minesweep – Disable Underwater Mines

- Further improve the robot so that it can dive to the bottom of the pool to disable underwater mines, represented by inverted plastic cups trapped with air, to make a shipping lane safe
- Use a third motor to dive under the water and move in 3 dimensions
- Combine high-density and low-density materials to achieve good buoyancy and stability, making the robot controllable underwater

Mission 4: Salvage a Shipwreck

- Combine the products of previous missions to produce a robot that can collect samples from a “sunken ship” and deposit them in various underwater collection bins
- Design the final, complete robot to dive under the water, grab a wiffle ball and deposit it in an underwater bin
- A fourth motor may be used to create a mechanism to grab and release the balls

Table 3: WaterBotics Scaffolded Missions CONTINUED
LEGOs® familiarity and ease of use make them accessible, enjoyable and intuitive learning tools for all students regardless of background. As a result, students quickly construct prototypes, test them, make appropriate changes, and test them again (rapid prototyping). Being able to quickly progress from an idea to a working prototype is a critical learning objective of the WaterBotics curriculum, a key aspect of the concept of iterative design. Students can be creative and innovative using any number and type of LEGO® pieces, their robots designs only limited by their imaginations. By project’s end, a variety of robots will be constructed.

Students use the LEGO® MINDSTORMS® NXT and NXT-G software design, build and program custom controllers to direct the movement and actions of their robot. Programs are easily constructed using this simple but powerful icon-based programming language. Even beginner programmers can learn and master coding by clicking and dragging symbols and typing in values rather than entering lines of text-based code.

In summary, there are four features that distinguish the WaterBotics curriculum from other underwater robotics programs for K-12 students:
1. the ability of teams to do rapid prototyping due to the ease of assembly and disassembly of the LEGO® components, making it possible to quickly design-build-test-redesign;

2. the novel missions associated with the underwater environment that present students with intriguing but unfamiliar problems to solve and that require team collaboration;

3. the integral and explicit focus on science, engineering, IT learning, and 21st Century skills for which learning is scaffolded through mastery of increasingly complex missions; and

4. the use of a culminating showcase event in which students demonstrate their robots, describe their design goals, list the achievements they successfully completed, identify areas for improvement, and receive supportive feedback and encouragement from their peers.

Students can be creative and innovative using any number and type of LEGO® pieces, their robots designs only limited by their imaginations.
WaterBotics is designed to be implemented in formal classroom environments, such as regular in-school, science or technology courses, as well as informal, extra-curricular settings, such as summer camps or after-school programs. Each of these educational environments presents different opportunities and challenges.

The following sections showcase implementations of WaterBotics in different environments. They are based on interviews conducted with the educators responsible for the implementation. When conducting the interviews, several themes repeatedly surfaced:

**Theme 1**: The curriculum was effective in developing self-confidence, problem-solving, and persistence. This comment was made repeatedly by classroom teachers and informal educators alike and by those who worked with both girls and boys.

**Theme 2**: Students were often observed mentoring and/or teaching other students. Students were also effective in problem-solving in situations where the instructor was unfamiliar with the content, especially for computer programming tasks. Several camp organizers brought back WaterBotics camp graduates as mentors/assistants in subsequent camps.

**Theme 3**: Parents often resisted sending girls to WaterBotics camps. A frequent comment heard during the interviews was, “Parents did not see the benefit for girls attending.” But in other instances, girls were sent to a WaterBotics camp by their parents against their wishes and ended up having a complete 180 degree turn-around! This suggests that interventions designed to change parental attitudes may be needed to further increase participant diversity.
EXAMPLES OF WATERBOTICS IMPLEMENTED IN FORMAL EDUCATIONAL SETTINGS

Bill Norvell teaches science to middle to middle-upper class, college-bound students. He has 15+ years of classroom experience and a Master’s degree in Biological Science. Bill implemented WaterBotics twice a week for four weeks as part of an elective Applied Science class for grades 10-12. Class periods were three hours in duration. The class was open to all students and class size was limited to 24 students.

“The WaterBotics curriculum fits perfectly with our pre-engineering program…the curriculum is very broad based and engages differing skills allowing students with varying strengths and expertise to learn from one another.” Bill observed that the real-world, team-based missions were highly engaging for the students and built student confidence and self-esteem when the team succeeded in achieving the mission. With respect to challenges, he noted the programming requirements were a stumbling block at first. However, that obstacle was overcome when a few of his students who were skillful programmers were able to teach him the required skills.
“The curriculum can be successfully used with an academically diverse student body. It engages differing skills, enabling the students to share their expertise and learn from one another. It promotes peer teaching and creates natural teachers.”

Bill had advice for educators thinking of adopting the WaterBotics program. He suggested that because the curriculum is well-designed and self-contained, new educators should not try to customize or add-on to the program initially. “Mastery comes with experience and you need to teach the entire curriculum at least once to master the curriculum. The first time through I felt a little overwhelmed.” However, by the third time through Bill had customized the curriculum to include introductory land-based robotics activities to familiarize students with LEGO® parts and their functions. This modification, Bill said, “Expands the curriculum somewhat and functions as a ramp-up. I have the students build a moveable land-based robot with certain capabilities to give them exposure to robotics and get them ready for the first water-based mission.”

In discussing some of the strengths of the program, Bill remarked, “The curriculum can be successfully used with an academically diverse student body. It engages differing skills, enabling the students to share their expertise and learn from one another. It promotes peer teaching and creates natural teachers.” He noted that in addition to being an academically rigorous curriculum, it is also a team-based curriculum. “The thrill for me was to see students engage as peer teachers, supporting one another, and learning to be effective team players.”

Debbie Szesko took an innovative approach to implementing the WaterBotics curriculum with her 7th and 8th grade students. She implemented the curriculum in the context of a Science Fair. Debbie has 15 years classroom experience, degrees in economics, math, and education, and currently teaches middle school science and math classes. She taught the WaterBotics curriculum over four consecutive days, with 45-minute class periods, over 9 weeks. Students worked in teams of 4 and each student was assigned
a specific role, e.g., programmer, engineer, electrician, nautical engineer, etc. Students were randomly assigned to teams, which led to mixed gender groups, in which students with and without experience worked together.

Debbie commented, "The student teams’ ability to work together is key to succeeding with the missions. At the same time, the teams were competing with the other teams in the context of the Science Fair." Debbie noted the student teams were highly engaged and quick to learn from one another, especially when they posted pictures of their robots on a dedicated website after each mission. Even though the student teams were competing with one another in the context of the Science Fair, they were highly supportive of one another, learning from one another and congratulating one another on their innovative ideas and design solutions.

Debbie’s students are largely second generation Hispanic students. “[The project] requirements gave [students] a valuable real-world context.” Their experience with WaterBotics “…was like they found this whole new world of engineering.”

The need for a pool was a challenge in Debbie’s school. However, she was able to find space in a basement room, although it could only accommodate a smaller pool than what the WaterBotics Educator manual called for. This solution sufficed. Although there are both challenges and benefits to implementing an underwater robotics program, Debbie noted that the need for water was the greatest challenge she experienced. For educators thinking of adopting the WaterBotics program, Debbie commented that it would be helpful if they made sure they had hands-on experience with all the roles involved, i.e., programming, electrical wiring, robot design, etc. so they could better assist the students.

In discussing some of the strengths of the program, Debbie noted, “The students loved the hands-on nature of the project and working on building something useful. They just lit up when they got to build the robot, wire it, etc.” Students actively coached one another throughout the project and Debbie noted several students blossomed in their roles as peer teachers and coaches.
Debbe Tipping has implemented WaterBotics in Girl Scouts camps for the past three summers. Debbe has six years of experience as an educator in informal settings. She holds a Bachelor’s degree in Zoology and is currently Tech Girls Program Coordinator for Girl Scouts of Central Texas. Her students were economically and culturally diverse middle and high school girls. For each of the camps Debbe has led, WaterBotics was taught four mornings a week over a one week period, with other STEM activities in the afternoon. On Fridays, the girls went on field trips to engage with engineers and acquire first-hand knowledge of engineering challenges. When implementing WaterBotics, Debbe was assisted by two middle or high school teachers, one to two high school-age helpers, and the camp was limited to 20 students.

“The scaffolded missions are a unique feature. After completing the first mission the teams felt a real sense of accomplishment and it snowballed from there.”

“The design of the WaterBotics curriculum gives the girls a real sense of accomplishment. The scaffolded missions are a unique feature. After completing the first mission the teams felt a real sense of accomplishment and it snowballed from there.” In Debbe’s opinion, the value of the curriculum for girls in an informal setting is its ability to build confidence: “WaterBotics gets them to do something different; something out of their comfort zone.” She reported that at first the girls were intimidated by aspects of the curriculum, such as the programming. However, once they engaged with the task they reported it was not as hard as anticipated and their confidence grew. Debbe noted that the program not only builds technical skills – critical thinking skills, problem-solving skills, iterative design skills, etc. – but it also strengthens a number of soft skills – learning to work in teams, learning to work in diverse groups, learning to be a teacher, as well as a learner.
For educators thinking of adopting WaterBotics, Debbe recommended recruiting other educators to help with setting up the required materials. Debbe noted that assistance is also useful to support the student teams as they progress through the missions at different rates. Debbe commented on the high quality of the videos that accompany the curriculum. In fact, she thought the girls gained more valuable insights after viewing the video, than if they had just experimented with LEGO® on their own. She noted that the girls were so engaged that they decorated the pool for each mission. For example, they added coral reefs and bodies on the bottom of the pool for the swimmer accident and mass rescue mission. Finally, Debbe commented that WaterBotics has become a very popular summer camp opportunity and is currently offered by the Girl Scouts of Central Texas in 46 counties.
Beth Dehn is the Education Coordinator and Curator of Education and Folk Life at the Washington County Museum. In an effort to expand the museum’s educational outreach within STEM disciplines, Beth and a retired 5th grade teacher decided to offer the WaterBotics curriculum as a summer camp program for middle and high school girls. While Beth holds degrees in English and Folklore and has several years of teaching experience, she had never taught any of the WaterBotics content before. However, she commented that, “The videos that accompany the curriculum are great and the curriculum itself is very well laid out. There are enough resources provided that I could do it. And when we got stuck, the girls would help us figure it out.”

The week-long WaterBotics camp (locally called “Splash Camp”) began at 9 am and ended at 2pm each day. Separate camps were held for high school and middle school girls. Each day a guest speaker visited the camp to give the campers exposure to STEM careers, contemporary challenges within various engineering disciplines, and practical applications of robotics within various industry sectors.

“There is a lot of good thinking going on...It’s not just robotics, but a vehicle for thinking.”

(Jo Rossman, Hillsboro Tribune, 06/28/2013)

Beth commented that two strengths of the program were that the missions were challenging and they built upon one another. “The girls felt they had really achieved something after completing the first mission and this provided interest and motivation to take on the next mission.” Beth and her team added training in leadership skills to the camp experience. Their long-term objective was for the high school girls to return and help run the camps for the middle school girls. Additional problem-solving activities were included at the beginning of the curriculum.

The Hillsboro Tribune, which ran an article on the museum’s “Splash Camp,” summed up several of the curriculum’s strengths as follows. They quoted Jo Rossman, former elementary school teacher and member of the museum’s education committee, as saying,
“There is a lot of good thinking going on…It’s not just robotics, but a vehicle for thinking. The best mentor inspires others to think and not just think for them” (Hillsboro Tribune, 06/28/2013). Nicole Hill, one of the campers, was quoted as saying, “My parents chose for me. I didn’t think I’d like it, and I was going outside my range (of experience). But on the first day it was so much fun. They gave us instruments to build robots, and we’re programming and engineering the design process to rebuild and fix problems – that’s the hardest part” (Hillsboro Tribune, 06/28/2013). Finally, Alisha Menon, a high school student with experience in robotics commented, “This camp is engaging and I’m so glad I came. Working with water robots is a huge difference from land robots. We’ve got more problems to deal with” (Hillsboro Tribune, 06/28/2013).

Robin Hollingsworth is the Community Education Director for Simpson County Schools. Though not a classroom teacher, Robin attended instructor training for WaterBotics and became so enthusiastic that she decided to partner with the local 4-H organization to offer WaterBotics as a summer camp for middle school students. The camp ran for a week, 8 am to 4 pm each day. In the summer of 2013 the camp was marketed only to girls. However, to attract a larger number of participants, in summer 2014 the camp was marketed to boys and girls. Robin hired a middle school science teacher as a “classroom
helper” with a science background to deliver the program in summer 2013. In summer of 2014 a second middle school teacher was hired to lead the program. The WaterBotics curriculum was augmented with lunchtime speakers -- engineers and scientists, who sometimes served as mentors to the campers. In summer of 2014 an industry visit was added to the camp program.

“The WaterBotics curriculum teaches problem-solving, decision making, teamwork, perseverance, and patience all in one week. It’s a high impact, high value curriculum.”

When discussing the strengths of the program Robin noted not only that the curriculum is effective in teaching science, engineering, and computer programming skills and concepts, but many soft skills are developed as well. Robin commented, “The WaterBotics curriculum teaches problem-solving, decision making, teamwork, perseverance, and patience all in one week. It’s a high impact, high value curriculum.” Robin credited the application of the engineering design process (EDP) which is central to the WaterBotics curriculum as underpinning many of these student outcomes. Specifically, she noted, “When the learners didn’t get the outcomes they wanted they were encouraged to apply the EDP to structure their problem-solving. This iterative process taught them perseverance, analytic decision making skills and the value of good teamwork.” Robin commented, “Though learners often experienced frustration when trying to overcome design or programming problems, when they finally succeeded it built self-confidence.” One parent sent a letter testifying to the transformation he had observed in his daughter’s confidence and decision-making skills over the course of the program.
When asked about other strengths and weaknesses of the curriculum, Robin indicated that the materials and resources available to educators on the WaterBotics web site are exceptional. She noted, “Everything is there. The curriculum is ready-to-go. Basically we opened up the instructor binder and did it just as it was laid out. The middle school science teacher who taught the curriculum had never touched LEGO® before.”

Simpson County schools have integrated WaterBotics into their 6th grade curriculum. Robin noted that the reliance on the engineering design process as a core competency is a great fit with the new national standards that require the development of critical thinking and problem solving skills. In addition, Simpson County 7th and 8th science teachers are also looking to incorporate WaterBotics into the classroom. There are also plans to expand the 4H summer WaterBotics camp programs, possibly with WaterBotics camp “graduates” as mentors.
Additional information about WaterBotics including curriculum details, research reports, photos and videos, news articles, and upcoming opportunities may be found at http://www.waterbotics.org.

Additionally, two recently published books on K-12 engineering and robotics include chapters on WaterBotics. The books include:


Barrows, H. S. (2002). Is it Truly Possible to Have Such a Thing as dPBL? Distance Education, 23(1), 119-122.


About the Center for Innovation in Engineering and Science Education

Established in 1988, the Center for Innovation in Engineering and Science Education (CIESE) at Stevens develops and supports effective innovative curricula and professional development and conducts research in order to inspire, catalyze and strengthen scientific, technological, engineering and mathematics literacy for K-12 and higher education. CIESE’s professional development programs have impacted more than 30,000 K-12 educators and nearly 9 million students worldwide. By exposing students to innovation and engineering in their K-12 education, CIESE is preparing the next generation to be successful in an increasingly technological, global economy and to contribute to solving the critical problems that face humanity.

Contact Us:

Stevens Institute of Technology | CIESE
One Ninth Street
Castle Point on Hudson
Hoboken, NJ 07030
Phone: 201-216-5375
www.stevens.edu/ciese

About Stevens Institute of Technology

Stevens Institute of Technology, The Innovation University®, is a premier, private research university situated in Hoboken, N.J. overlooking the Manhattan skyline. Founded in 1870, technological innovation has been the hallmark and legacy of Stevens’ education and research programs for more than 140 years. Within the university's three schools and one college, more than 6,800 undergraduate and graduate students collaborate with more than 380 faculty members in an interdisciplinary, student-centric, entrepreneurial environment to advance the frontiers of science and leverage technology to confront global challenges. Stevens is home to four national research centers of excellence, as well as joint research programs focused on critical industries such as healthcare, energy, finance, defense, maritime security, STEM education and coastal sustainability. The university is consistently ranked among the nation’s elite for return on investment for students, career services programs and mid-career salaries of alumni. Stevens is in the midst of a 10-year strategic plan, The Future. Ours to Create., designed to further extend the Stevens legacy to create a forward-looking and far-reaching institution with global impact.

www.stevens.edu

© Copyright 2015 - All rights reserved. Stevens Institute of Technology