CLEAN WATER Outreach Program

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Abstract

The CLEAN WATER program at Florida Gulf Coast University is an outreach experience that integrates engineering entrepreneurship and regional water quality issues into elementary and middle school classrooms. Coordinated by the U. A. Whitaker College of Engineering and supported by a grant from the EPA, the program combines hands-on classroom activities, physical and virtual field trips and a culminating engineering entrepreneurship challenge on the university campus. Classroom activities include physical models, laboratory testing and analysis, interactive lesson plans, computer simulations, and team based project learning assignments. This paper will discuss the various components of the program as well as provide results of student assessment. Participant feedback will be included along with a discussion on the future direction of the program.

Keywords

K-12 outreach, water quality, entrepreneurship

Overview and Program Significance

Educating and empowering the next generation to become stewards of clean water is a global necessity. Nationally, the U.S. Environmental Protection Agency has "Protecting America's Water" as one of their five key goals from their 2014 -2018 Strategic Plan[1]. In Southwest Florida the Water Management District has both the protection and improvement of water quality and the preservation, protection and restoration of natural systems as core missions of the organization[2]. The emphasis on improving water resources from the global to local scale led to the project focus on watersheds, aquifers and wetlands.

In 2011 Science devoted a section of their 19 August journal to topics related to "Investing Early in Education" with recommendations on methods to advance children's understanding of science and their scientific thinking[3]. It has been shown that interest in STEM careers peaks during middle school, especially for minorities and females, indicating that exposure to these fields should occur at this time to highlight the diversity of opportunities in STEM[4]. Additionally, students should develop critical thinking skills that allow them to make informed decisions on important scientific concepts[5]. Several outreach activities have been developed that focus on water quality issues in general[6-8], or seek more specifically to interweave science and environmental issues with societal concerns[9]. This integration responds to research emphasizing the importance of contextualizing activities in a way in which students can relate[10].

The Creating Learning Experiences and Addressing Needs of Watersheds and Aquifers Through Entrepreneurial Research (CLEAN WATER) Program seeks to improve environmental literacy and promote environmental stewardship among upper elementary and middle school students.

Using an entrepreneurship exercise as a culminating framework for the final educational component of our proposed program is an ideal method to foster environmental education. The program outcomes of the entrepreneurship exercise are not related to starting businesses, but rather actualizing a potential solution to identified water quality challenges. Entrepreneurship programs for youths use experiential learning to build a broad set of competencies, including improved self-confidence, teamwork, and communication skills[11]. Furthermore, using an engineering design process to solve problems in a real world context, with benefits matched to budgetary considerations is a critical step in developing critical thinking and problem solving skills. Finally, for environmental education, the very nature of stewardship being a balance of benefits and costs to society fits perfectly with this type of educational program.

Program Topic Areas and Activities

The CLEAN WATER program takes a multi-faceted and integrative approach to educating students about regional water quality issues. Program topics include the water cycle, aquifers, wetlands, and an introduction to engineering entrepreneurship. Modules on each topic involve lessons, laboratory experiences, and project-based learning. The culminating experience, a team-based entrepreneurial project designed to solve a regional water related issue, requires teams to prepare a poster, create a model, and present to a group of judges. The on campus event involves time for teams to view all projects, project judging, large-scale model demonstrations conducted by undergraduate students, a movie presenting both regional and national water quality issues, and the opportunity to showcase projects to friends and family along with a closing recognition and awards ceremony.

Lesson Plans and Coverage

One main purpose of the program was to demonstrate how engineering concepts and regional topics could be meaningfully integrated into an existing science curriculum. Because some of the material might be new to the teachers, program coordinators wanted to provide lesson outlines and resources to support program integration.

Water Cycle, Aquifers, and Wetlands

The topics of the water cycle, aquifers, and wetlands are ones that often already exist in a science curriculum, and many students have already been introduced to the concepts in previous classes. The goal with coverage then, is to refresh and strengthen understanding, present a more regional focus, and provide a foundation on which to build later concepts. The water cycle is reviewed using Project WET's interactive water cycle website[12]. The site takes a game-based approach to instruction – allowing players to enter the water cycle as a water droplet at a location of their choosing and spin a wheel to determine where they go next. At each "stop" players are given information about the water cycle or a scientist associated with the particular location and asked questions before they can continue to their next stop. Because the cycle is, by nature, continuous, the game ends after a preset number of stops and the player is provided a path summarizing the stops traveled to during the game. Because players may enter at any point, and spins determine the next step on the path, each summary is unique. This allows for small group discussions to take place after all students have completed the activity to compare the different "travel" experiences.

Although aquifers are introduced in the water cycle activity, this introduction is done in a general manner (which is intentional for the game). The aquifer module has students create small-scale individual physical models (cereal in milk) to better understand what the subsurface looks like and how water fills an aquifer. Students also investigate the different aquifers of the region and identify by name the aquifer from which they obtain their drinking water. In addition to small-scale models, a larger classroom model (developed by undergraduate research assistants at FGCU) is also available to demonstrate water flow, well drawdown, contaminant movement, and salt-water intrusion. Living in Florida, wetlands are a critical component of our regional ecosystem. The wetlands module highlights this complex system on both a local and state level. The activity related to this module is the construction of small scale wetland systems.

Engineering Design and Entrepreneurship

The engineering design process and entrepreneurship educational components of the program are designed to develop critical thinking, problem solving, and decision making skills. Tying learning activities to a self-directed solution (product) development project, we believe, gives confidence to young students to effect change, as they are not just learning about the problems but also developing potential solutions. Although seemingly different processes, engineering design and business plan development share similarities that can be combined into a single team-based learning activity. Both exercises share the critical steps of need identification and idea development. Engineering design then focuses on prototyping and testing to solve the problem, while the business activities investigate the customer and market for the product.

Lessons plans for engineering design begin with a simplified four step engineering process: identify the problem, develop solutions, prototype / test, and evaluate / communicate. Teachers are encouraged to let the students identify water-focused problems based on their interpretation of the prior activities and by asking questions at home. After the students share their ideas on needs, these ideas are used as prompts for solution brainstorming activities. Prototype generation can be a difficult task, so the approach suggested is to let the students develop a functional model or something simpler that helps with visualization of the solution, providing at least something to help with feasibility evaluation of the concept.

After need identification and solution identification, business model activities included determining the target customer and estimating price and cost. By identifying the target customer, the students begin to envision how the product will be purchased and used, giving consideration to how much someone is willing to pay for the solution, which may engender conversations about the public benefit of environmental stewardship. Students also must estimate how much it might cost to produce the product. This is also a challenging task, so guidance is provided to look for similar products and use a factor, e.g. 30%, of the retail price to estimate cost. This at least gives an order of magnitude for the students to use, and forces them to think about the costs versus benefits of products. In addition to these learning activities, students prepare a poster, based on a template provided, and a presentation (pitch) for their product giving them the opportunity to communicate their idea as a team.

Laboratory Activities and Field Trips

Laboratory activities are targeted to water quality testing. Students are encouraged to gather water samples from various locations and bring them to class for testing. Undergraduate research assistants created instructional videos using the same testing kits the students use. In these videos they collect samples, perform the different tests, and interpret the results. The first kit used prepackaged tablets and basic color scales to test for free chlorine, total chlorine, total hardness, pH, nitrite and nitrates of drinking water. The hydrometer used measures the specific gravity of water, and the third kit measures the turbidity, temperature, dissolved oxygen, biochemical oxygen demand, nitrates, phosphates, and pH for non-drinking water samples.

The undergraduate research assistants are also the content creators for the virtual field trip. Currently in development, this interactive website will integrate pictures and videos taken by the research assistants with information and questions. Locations visited include both a water treatment and wastewater treatment plant, as well as a kayak adventure at Manatee Park.

Physical field trip locations are at the discretion of the individual teachers. The only restriction is that the site be related to the instructional topics. If teachers are unsure about field trip locations, the program coordinators are happy to provide ideas.

Engineering Entrepreneurship Challenge

The Engineering Entrepreneurship Challenge was a forum hosted at FGCU for the teams to present their product ideas to a panel of judges. This ½ day event required students to focus on their goal, while adding a competitive spirit to their learning. The public was invited to attend, and undergraduate engineering student volunteers helped run the event. Upon arrival teams were assigned a table in the large presentation room to set up their poster and prototype. Rather than requiring students to stand at their posters during the entire judging time, judging was divided into two sessions. When students were not in a judging session, they were allowed to tour the interactive exhibit created outside. Manned by the undergraduate engineering student volunteers, the exhibit consisted of laboratory equipment and models used in the various engineering courses at FGCU. Students were able to:

- Create a rain event on a model watershed and see how water collects, is retained, or exists the system
- Adjust volumetric flow rates and weir sizes and shapes to observe changes from smooth to turbulent, or sub-critical to super-critical flow
- Change the shape of a river to see how water flow varies and erodes banks differently based on channel design

Our American Society of Civil Engineers (ASCE) student chapter also brought out their concrete corn hole boards, which were constructed by the students as part of a regional ASCE competition. While not a water-based activity, the boards are a unique engineering twist on a traditional game and provided an additional activity for the students.

Poster presentation judging was conducted by groups of three judges including professors from engineering and business, external advisors from the local community, and undergraduate

research assistants. After formal judging was complete for both groups, time was provided for students and guests to view all posters. Students were given the chance to vote for the "people's choice" award project. While judges were deliberating and awards being prepared, students viewed a water quality and water accessibility video contrasting challenges in Florida with those in Arizona. Parents who were present at the event were asked to complete a short survey at this time as well as part of our assessment process.

The awards ceremony at the end of the event began by recognizing the teachers of each of the classes and provided participation certificates for all of the students. First and second place in the elementary and middle school categories, as well as an overall people's choice winner were announced, with students receiving an awards certificate, a small FGCU related gift, and a custom 3-D printed medallion created by our undergraduate researchers.

Results of Initial Program Offering

The CLEAN WATER Program ran for the first time during the 2016 – 2017 academic year. Initially three teachers / schools were scheduled to participate, however one had to withdraw at the last minute due to teacher obligations. Both participating schools were in the same school district. The first was a STEM-focused middle school and included approximately 30 students from a 7th grade science class. The second was an elementary school with a part-time gifted program. Participants included roughly 40 4th and 5th grade gifted students. Due to some logistical issues, the program did not start until February, but was able to be completed on a modified basis. Program coordinators met with the teachers for a ½-day orientation meeting that took place at the Emergent Technologies Institute building located off campus and the site for the entrepreneurship event later in the semester. This session provided the opportunity for individuals to meet face-to-face, introduce program requirements, discuss program logistics, and answer any questions the teachers may have about their / their students' participation.

Physical field trip locations included a local slough walking tour on the boardwalks through the park to view wetlands and wildlife and an airboat tour of a larger wetland area. Teachers were able to cover topic activities and small scale models, as well as water quality testing and the engineering design and entrepreneurship activities. The engineering entrepreneurship challenge event ran smoothly, included a number of diverse projects, and a high level of energy and excitement. The idea of a people's choice award was particularly well-received, and encouraged students to really look at the other projects that were presented. Because this award was a single one for all students, it also encouraged students from the different schools to interact more than what might have occurred if it was one award per level. The 3-D printed medallions were also a popular aspect, with students, parents and teachers commenting on the uniqueness of the items.

Student Assessment

Students completed a survey at the end of program participation, which included several Likert-style questions as well as a couple of open-ended free response questions. Three of the Likert questions can be considered as relating to environmental stewardship, particularly in south Florida. Figure 1 summarizes students' responses to these three questions. All students either agreed or strongly agreed that protecting water resources is important in south Florida, with almost 70% in the strongly agree category. Most students also agreed or strongly agreed that

water pollution is a concern in this area and engineering and science are important skills to solve these problems.

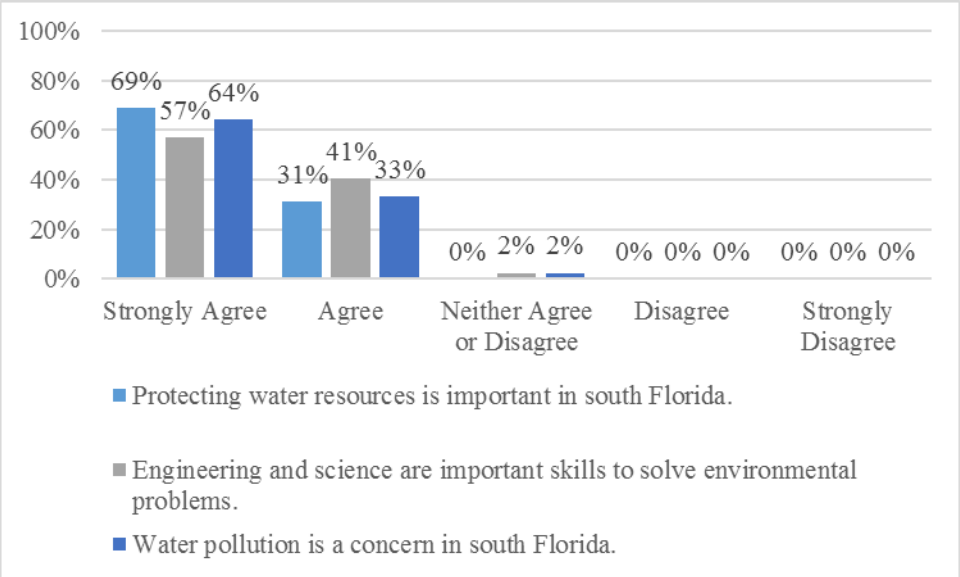

Figure 1: Summary of Students Responses to Survey Questions Related to Environmental Stewardship

A second category of questions, as shown in Figure 2, relates to student self-efficacy of skills aligned with project activities. There is more spread in this data, but it does show confidence in problem solving and a belief in their ability to make an impact.

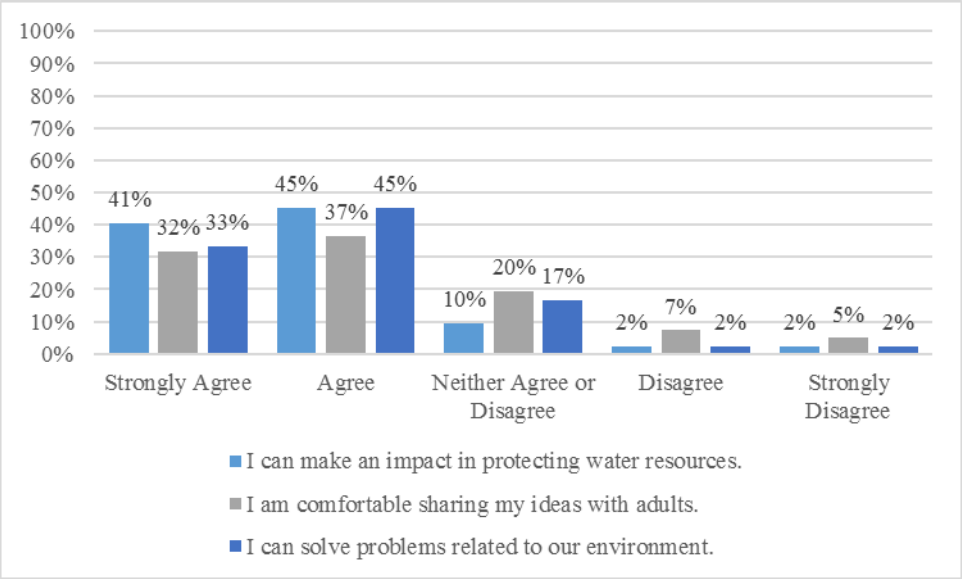

Figure 2: Summary of Student Responses to Survey Questions Related to Problem solving and Self-Confidence.

From the open-ended portion of the survey, categorized results from a question regarding the most interesting aspect of the project are shown in Figure 3. The results show a high interest in learning activities, almost on par with physical or hands-on activities. There was also clear enthusiasm for being able to present their work.

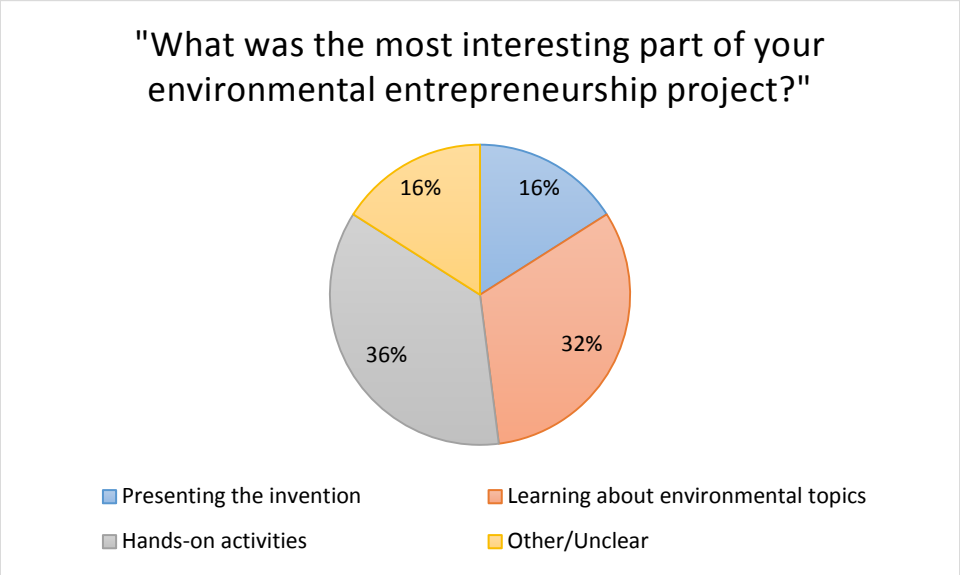

Figure 3. Categorized Responses to Open-Ended Survey Question Regarding Most Interesting Aspect of Project.

Another open–ended question in the survey asked, “Have you started any water saving activities at home?” Thirty percent of respondents indicated that they have started water saving activities at home, with an additional 15% indicating that they would like to start water saving activities.

Two final Likert style questions related to topic interest and understanding were asked on the survey. Eighty percent of the students indicated that they agreed or strongly agreed with the statement “I enjoy learning about the local environment.” Over 90% of the students agreed or strongly agreed (with half in the strongly agree category) with the statement “The models and field trips helped me understand water resources.”

Feedback from Parents

Parents of participating students were invited to attend the engineering entrepreneurship challenge event. Timing for the event was restricted based on travel logistics for the two schools however, and because of this the event itself was held both midweek and midday. While this did allow all students to participate, it resulted in only a small percentage of parents / family members being able to attend the event. Of those in attendance, seven completed our parent survey, which consisted of five multiple choice questions and two open ended questions.

When asked if they learned something about our local water resources / water quality from their child participating in the program, 6 / 7 (86%) agreed or strongly agreed. One hundred percent agreed or strongly agreed that managing our local water resources / water quality is important. Survey results suggest that students were talking about program activities and/or water quality

issues at home, with all parents indicating their children spoke about the topic at least once, and the majority indicating they spoke more than five times about the activities. Slightly less than half changed their behavior regarding water use at home, with water conservation being the primary change. Almost all (86%) indicated that their child taught them something about water resources / environmental water quality during the program time frame. These lessons included specifics on the various projects for the students and their classmates, the impact individuals have on water quality, efforts that are being done or that can be done to positively impact water quality, and the understanding that everyone can help contribute to the improvement of water quality in our area.

Future Direction of the Program

The program is currently finalizing participants for the 2017 – 2018 academic year. As the first two teachers were both from Lee county, efforts are being made to recruit teachers from the other four counties in the University's 5-county region. The original program anticipated four schools per year with roughly 25 students per school for a total of approximately 100 students impacted per year. The first cohort has larger class sizes but fewer classes, resulting in a slightly smaller population impacted than initially projected. Our funding disbursement is based on a school level however, so the program has actually impacted more students than originally anticipated (~70 for two classes as opposed to the estimated 50). This trend is expected to continue as one of the teachers in the second cohort plans to involve more than 100 students from her school. Because of these larger numbers, the target number of schools for this academic year is three, with an additional three the following academic year. These larger cohorts will necessitate changes in the logistics of the entrepreneurship event, one of the four main goals for this next offering. For the lesson plans, completion of the large class models for distribution to the teachers is the second of the main goals. While the first cohort of teachers had the small scale individual models, the development of the larger scale model took longer than anticipated and was not ready for teachers last year. The third of the main goals is the completion of the virtual field trip for use by the teachers during this second cohort. The final goal is that of a more comprehensive assessment of the program. Initial feedback suggests a positive impact, but more targeted assessment is desired.

Conclusion

The CLEAN WATER Program provides elementary and middle school students the opportunity to think critically about and proposed solutions to regional water quality issues. The program uses a variety of instructional practices to engage students, culminating in an engineering entrepreneurship challenge that allows students to interact with others in the program, present and receive feedback on their team project, practice written and verbal communication skills, and visit a local University campus. Undergraduate research assistants support the program directors in developing resources for teacher use. These resources are available in the cloud for easy access and timely updates if needed. Results of the first cohort suggests a positive experience and plans are currently underway for engaging the second cohort in the program.

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