Journal of Sustainability Education
Vol. 22, March 2020 Water and Climate
ISSN: 2151-7452

Improving Water Resilience Through Environmental Education

Molly Nation, Ph.D. (Florida Gulf Coast University) mnation@fgcu.edu
Serge Thomas, Ph.D. (Florida Gulf Coast University) sethomas@fgcu.edu
Sara Combs (Florida Gulf Coast University) smcombs0316@eagle.fgcu.edu
Emily Daniels (Florida Gulf Coast University) eldaniels6275@eagle.fgcu.edu
Chaquer Talamas (Florida Gulf Coast University) cdtalamas6597@eagle.fgcu.edu
Gabrielle Vignet-Williams (Florida Gulf Coast University)
gvignetwilliams3283@eagle.fgcu.edu

Abstract: Anthropogenically-induced water quality issues are plaguing the people and environments of Southwest Florida. In 2018, nutrient-rich runoff into waterways caused one of the largest and longest occurring algal blooms in the area; however, many were unaware or misinformed about the causes or impacts of these blooms. Young people are at the forefront of this changing environment and will continue to face water reliance issues in the years to come (Leal, et al., 2015). However, gaps within the existing science curriculum do not address the anthropogenic actions that are leading to these crises (National Research Council, 2012). Southwest Florida is being drastically altered by the large number of people who move to the area each year; urban sprawl, habitat loss, and human-induced climate change are impacting the region (McVoy, et al. 2011). Local water quality issues necessitate a more focused, specific effort to build awareness and knowledge to ensure clean and safe water is locally available. Therefore, the need for Environmental Education (EE) is becoming increasingly important for students to be able to make informed decisions about personal actions contributing to these issues. The project, Future Leaders of Water Quality (FLOW) focused on educating teachers and students by engaging them in environmental literacy, specifically focused on water quality education in local middle schools. Project FLOW worked with local teachers to develop an innovative, five-day, lesson plan focused on the causes and implications of anthropogenically-induced eutrophic conditions. Data were collected throughout the implementation to measure the impact of the curriculum intervention that addressed water quality issues of the region. The results of the study suggest exposure to the lessons increased student understanding of water

Molly Nation is an Assistant Professor of Environmental Education in the Department of Ecology and Environmental Studies at Florida Gulf Coast University. Her research and teaching interests include climate change education and issues of environmental justice.
Serge Thomas is an associate professor in The Water School at Florida Gulf Coast University. He studies what factors of natural/human origins, and especially nutrients, trigger (harmful) algae blooms in various inland/nearshore shallow ecosystems.
Sara Combs is a senior at Florida Gulf Coast University, where she is majoring in Environmental Studies. During her schooling, she became interested in environmental education. In her future career, she hopes to combine her passion for animals and love of teaching others about environmental issues. She hopes to continue on in the zoological field as a keeper or conservation educator.
Emily Daniels is a Florida Gulf Coast University undergraduate student working toward a B.A. in Environmental Studies focusing on Water Resources & Management. Afterward, she plans on pursuing a Master's degree in Environmental Studies. Originally from Southwest Florida, she has a deep interest in local water quality and storm water pollution prevention.
Bolivia Chaquer is from La Paz, came to the United States in 2005. He is currently a senior undergraduate at Florida Gulf Coast University majoring in environmental studies. With a great interest in agriculture, he hopes to study and advance in vertical hydroponic farming and find ways to make food systems more sustainable and economically viable.
Gabrielle Vignet-Williams is from Ft. Lauderdale and is fourth year Environmental Engineering student at Florida Gulf Coast University. She is currently doing research on a life cycle assessment of anaerobic digestion of food waste.

quality issues and motivated students to take personal action to improve water resiliency within their local communities.

Keywords: Environmental Education, Sustainability Education, Water Resiliency, Water Quality, Environmental Stewardship.

Background

Algal blooms occur when conditions cause the rapid growth of algae in coastal water bodies or inland lakes and waterways. The Southwest coast of Florida, where the research study took place, saw extensive harmful algal blooms (HABs) along the Gulf Coast from Clearwater Beach to Naples (See Figure 1). The bloom lasted over a year, picking up in intensity during the late summer months of 2018. At the same time, a freshwater blue-green algae bloom was growing in Lake Okeechobee and the Caloosahatchee River. Public outcry regarding discharges of freshwater from Lake Okeechobee released down the Caloosahatchee into the Gulf of Mexico triggering algae proliferation, captured headlines and resulted in a State of Emergency Executive Order.

Along the Gulf Coast the predominant species of algae in HABs is *Karenia brevis*, which is a dinoflagellate that produces brevetoxins. The release of these toxins can cause massive fish kills, kill marine mammals, sea turtles and seabirds. Dead zones or hypoxic conditions, caused by the blooms can result in die-offs of organisms in the benthic zone (Pierce & Henry, 2008; Rabalais, Turner, & Wiseman, 2002). People can become ill by breathing in the toxins or by eating contaminated shellfish (Granéli and Turner, 2006). The development of HABs are stimulated by warmer surface water temperatures, lower salinity, higher nutrient content, and rain followed by sunny days during the summer (NOAA, 2018). What remains unknown is what triggers the large-scale blooms, however, researchers believe algae feeds on the nutrient-rich runoff from land (Finkl & Charlier, 2003; Weber & Perry, 2006). As more people move to Florida, more stormwater, domestic, and agricultural runoff is produced, more nutrient-rich waters flow from Lake Okeechobee down the Caloosahatchee river out into the Gulf of Mexico each year (Wei-Haas, 2018). Therefore, the study involved collaboration among university researchers and local classroom teachers to develop a curriculum that would help students examine potential source contributors of downstream pollutants.

The health of Southwest Florida's water is important to the health of local people and ecosystems, the local economy, and the nearly five million visitors to the area each year. Poor water quality caused by pollution can negatively impact the surrounding ecosystem and limit human activities such as fishing, diving, beach tourism, and seafood consumption. Southwest Florida has experienced declining water quality over the last several years due to increased pollution from human populations, development, automobiles, overuse of fertilizer, faulty septic systems, and agricultural runoff (Florida Department of Environmental Protection, 2008). Local water quality issues require a more focused effort to build awareness and knowledge to ensure water resiliency within our community that warrants clean and safe water. Project FLOW was a partnership between university scientist and local classroom teachers. Over the course of the year-long study, the team of researchers and practitioners worked together to develop curriculum that would help address these local water quality issues in middle school classrooms.

With over 10,000 artificially constructed detention ponds within Southwest Florida, these water bodies are a critical component in managing stormwater runoff in developed areas. Nearly every school in the district, where the study took place, had access to a detention pond on their campus for these purposes (Thomas & Lucius, 2016). Poor pond management practices result in the ponds becoming a source of downstream pollutants. Increasing environmental education and local community awareness of the role of detention ponds and enhancing their functioning as green infrastructure to filter water through littoral edge management, is a key part of place-based

initiatives (Dresner & Fischer, 2013; Persaud, 2016). Further, by increasing the filtering of ponds, which connect to the coasts, by adding native wetlands vegetation (i.e. wetland phytoremediation), students can connect personal mitigative actions to that of scientists working to restore the historical flow of the Everglades to improve the quality of water regionally and ensure continued water resiliency.

Outdoor Learning

Educating teachers and students to mitigate human impact on local water quality through environmental stewardship of informed choices and responsible action is necessary for the future of our local watershed (Stevenson, et al., 2013). Outdoor experiences can help students develop self-respect, feelings of trust, and self-confidence which can in-turn affect their future decisions (Palmberg & Kuru, 2000; Margadant-van Arcken, 1990). Project (FLOW) addressed local community needs for mitigation strategies and environmental literacy by working with local middle school teachers and students to improve local water quality within the Southwest Florida watershed, from their own detention ponds (Dresner & Fischer, 2013). The use of the school detention ponds to participate in authentic research, provided teachers and students with immediate access to outdoor laboratories. Kenney et al., (2003) and Mansuroglu and Sabanci (2010) found adapting schools' immediate surroundings for experiential learning is a cost-effective way to engage students in authentic science experiences.

Additionally, Assaraf and Orion (2010) found that inquiry-based outdoor education, helps develop students' abilities to cultivate basic systems thinking capacities at a young age. Smith, (2007) suggests that through inquiry-based, personal, and place-based authentic science experiences, curriculum can promote connections to the community within the context of classroom activities. Place-based student investigations involve local environmental monitoring and advocacy, and real-world problem solving, which can foster support for improvement of their communities and neighborhoods (Smith, 2002). Outdoor learning experiences can also lead to more environmentally conscious actions among young people (Boegeholz et al., 2000). As informed citizens, students are better equipped to weigh the economic interests of both conservation and development, including restoration of the altered flow in the Everglades to improve water quality, as well as recharging the local aquifer, the primary regional supply of potable water (de Bruin & Bostrom, 2013; Lambright et al., 1996;). Lastly, studies have found that students who take part in outdoor learning tend to exhibit positive attitudes towards nature and display a deeper understanding of the content studied (Parry, 2002; Bogner, 1998).

Research Objectives

The following research questions were addressed in the study:

1. Did participation in the curriculum increase the students understanding of human impacts on water quality issues?
2. Did experiencing the curriculum increase students' willingness to take personal action to improve local water resiliency?
3. Did the use of outdoor place-based learning motivate students to participate in authentic science?

Participants

Project FLOW took place within three middle school classrooms (N~252) in a rural middle school within Southwest Florida during the 2018-2019 School Year (SY) The identity of

the participants is protected due to compliance with University Internal Review Board (IRB). Project FLOW was a continuation of a pilot study that took place the prior year. The project was developed specifically for the middle school science classrooms and addressed the Next Generation Sunshine State Standard (NGSSS) SC.7.E.6.6- 'Identify the impact that humans have had on Earth, such as deforestation, urbanization, desertification, erosion, air and water quality, changing the flow of water' (Florida Department of Education, 2008). 80% of the student participants were identified as economically disadvantaged. 47% of the population identified as Hispanic, 27% Black, and 22% White, as well as 18% of the population was identified as having a disability. Parent and student consent were obtained for data collected from the implementation.

Recruitment of teachers for the 2019-2020 school year occurred through pre-service day recruitment presentations in August 2019. Project FLOW targeted middle school teachers and students, primarily teaching grades 6-8, who were studying human impact on water quality and flow. The recruited teachers implemented the curriculum consistent with the objectives of Project FLOW. Incentives for participation included, portal access to digital content, curricula materials, lab supplies, and enhanced professional development (PD) with local university scientists and educators for further curriculum development and support. Monthly workshops provided participants with over 20 hours of professional development. During these times, participants worked with university scientists, local agency representatives, undergraduate researchers, and other classroom teachers within the community to discuss issues associated with the watershed and get feedback about pedagogical approaches for teaching the curriculum (Wenger, 2011).

Curriculum Design

Project FLOW involved development of a five-day innovative curriculum prototype, in which students investigated the water quality of their campus detention pond. The curriculum developed addressed the Florida State Standard *SC.7.E6.6: Identify the impact that humans have had on Earth, such as desertification, urbanization, deforestation, erosion, air and water quality and changing the flow of water.* School detention ponds display the characteristics of shallow water bodies typical of the region, and over 10,000 similar water bodies exist within the region. The curriculum was designed to promote personal knowledge and action to mitigate human impact on water resources. Students engaged in hands-on laboratory activities and applied the laboratory skills to measure the physical and chemical properties tied to water quality within their campus detention ponds. Students engaged in fieldwork, and civic engagement, designed to encourage student-led action and citizen science initiatives. Through increasing awareness, and knowledge about water quality, students developed personal understandings of local water resiliency.

Objectives of the curriculum:
Project FLOW addressed local issues of water resiliency in Southwest Florida and the necessary steps to help reduce human impact on the watershed through environmental stewardship among community members, including young people by:

- Demonstrating a fundamental and working understanding of the interrelation of local watersheds and the Florida Everglades.

- Developing a list of prioritized factors influencing our watershed as it relates to point and nonpoint source pollutants.
- Effectively communicating about issues related to the watershed.
- Developing solutions to the local issues of water health and sustainability that are impacted by the local watershed, especially the environmental and social aspects within the context of the coastal region.
- Engaging in informed and responsible decision-making, and environmental stewardship, related to water quality at the local scale in the context of the entire globe as a whole.

Through the five-day curriculum, students investigated the role of detention ponds in managing storm runoff and stormwater pollutants and examined the efficiency of ponds to manage stormwater runoff (State Requirements for Educational Facilities, 2012). A major focus of the curriculum was placed on point and nonpoint source pollutant management, including regulating fertilizer application and littoral edge planting (Lee County Fertilizer Ordinance 08-08). Project FLOW worked to prepare local students to become informed, active community members equipped with knowledge, scientific skills, and practices to help mitigate anthropogenic impacts and improve water quality.

Through participation in the project, students made observations by creating diagrams of the pond and identifying potential downstream sources of pollutants. They then collected and analyzed water quality data in a laboratory activity, during which, they evaluated the effectiveness of the detention pond for managing stormwater runoff including nonpoint pollution sources. Through the laboratory activity, students measured the quality of the water by testing the chemical and physical properties of it in their classroom laboratory, including pH, temperature, dissolved oxygen (DO) levels, presence of algae, and turbidity. Students identified multiple relationships between the different properties measured were able to correlate properties, such as the relationship between temperature and dissolved oxygen (DO). Students also identified the relationship between nutrients and algae proliferation, which can lead to rapid eutrophication of water bodies given influx of unmitigated human impacts (Glibert & Burkholder, 2011). Using data available to them from university scientists, students compared findings with regional detention ponds to compile comparative laboratory reports. Lastly, students identified and participated in engineering practices and environmental stewardship to enhance the function of the pond with green infrastructure by planting native littoral edge vegetation around their detention pond (phytoremediation). Project FLOW connected students' personal actions and tangible positive effects on the environment, while fostering positive perceptions of civic engagement for their communities. The curriculum prototype was shared with other teachers in the district at the Quarterly Environmental Education Resource Teacher meeting and made available online via Google Classroom. Currently, similar versions of the curriculum are being taught in more than ten teachers' classrooms.

Results

A fully mixed-methods concurrent equal status (F1) research design was used. Quantitative and qualitative data were concurrently collected throughout the research process and both types of data were given equal status (Leech & Onwuegbzie, 2009). Quantitative data were gathered from a summative learning assessment and student surveys. Qualitative data were gathered from student workbooks and surveys. With assistance from undergraduate students and faculty, member-checking occurred with the teacher participants as part of the monthly PD.

Qualitative data were coded to categorize (See Table 1) key themes identified within the workbooks and open-ended survey responses. Coding of common themes within and across the qualitative data collected were categorized to create a framework (Hesse-Biber, 2010). The following major themes were identified among the data;

- Place-based outdoor learning had a positive impact on student outcomes (engagement and learning).
- Students recognized ways to improve water quality and reduce nonpoint source pollutants though filtering of water in local ponds.
- Students generated and supported ideas about habitat restoration, including that of the Everglades to restore water resiliency in the area.

Qualitative and qualitative results from the survey suggest experiencing the curriculum resulted in a positive outdoor experience. 81.2% of students (N~252) agreed or strongly agreed that "outside activities help [them] learn about sources of pollution, and the role retention ponds have in filtering water." The survey also suggested the curriculum encouraged them to come to school and become engaged in learning the content. 79.3% of the respondents gave positive feedback, including specific motivators including going outside (16.27%), working with classmates (20.24%), working with university partners (3.17%), or just having a positive attitude toward the curriculum (63.1%). One student stated, "[I] love that we got this opportunity with the university and I want other students to get the once in a lifetime experience."

Results from the independent t-test (see table 2) suggest students who experienced the curriculum scored significantly higher ($p<0.05$) on the summative assessment, measuring understanding of water quality parameters and human impact on the environment, than comparable students who did not experience the curriculum. Additionally, an increase in students' understandings of human impacts on local water quality issues were identified through qualitative analysis. 54.7% of workbook responses identified human actions, such as the use of fertilizers, that could be altered to mitigate human impact on water quality. 24.4% of responses addressed human-induced impacts on water quality and identified ways which humans could have a positive impact on water resiliency including, "… I think that people who live [in the path of the Everglade's old flow] should go live somewhere else so they stop changing the flow." After experiencing the curriculum, 45.4% of respondents agreed or strongly agreed to taking action and making personal choices that improve water quality. Results from the survey suggest students were more willing to take personal action to improve local water quality after experiencing the curriculum, and further illustrated personal actions they or their parents could take within the survey and student workbooks. However, while results from the assessment, survey, and workbooks indicated students recognized human impacts on water quality, such as habitat destruction and over fertilization, proposals for improving water quality on an individual level mainly included stopping littering, i.e. "I would tell my family not to litter." It is not clear if students who suggested this were able to distinguish nonpoint source pollutants from other sources of water pollution. This is not uncommon, as previous studies have found that people see any pro-environmental behavior, including recycling or reducing litter as an accessible action they can take, but can fail to make the connection between impaired water-quality and human-induced eutrophication (Kollmuss & Agyeman, 2002).

Discussion

Project FLOW focused on promoting place-based environmental literacy and conservation stewardship among students using their school's detention pond as the site of the investigation. Findings suggest, experiencing the curriculum promoted personal knowledge and action in efforts to mitigate human impact on water resources, through increased awareness and knowledge about water quality, development of personal understandings, and application of laboratory skills to measuring properties tied to water quality. Students were engaged in hands-on laboratory activities, fieldwork, innovative green infrastructure development, and civic engagement through this project. The implementation of the curriculum led to initiatives that improved the overall quality of water entering the campus detention pond as runoff, including identifying, reducing and/or removing point and nonpoint source pollutants, and through phytoremediation strategies.

Findings suggest a desire to be part of a larger community and the recognition of a need for more community-based projects. Participation in this project led students and teachers to engage in service-learning, an experience-based methodology, which combines classroom pedagogy with community action. Students learned and developed through active outdoor learning and participation in an organized service experience that met actual community needs to improve the water quality of their campus' detention pond and identify ways to limit nonpoint source pollutants. This is consistent with The National and Community Service Act (1990) findings, suggesting service-learning experiences can put abstract concepts, such as water resiliency, into concrete form and provide meaningful opportunities to test and refine theories while helping to meet the needs of a community, improving the health of their school's pond and contributing to the restoration of the local watershed.

Findings also suggest the collaboration of university scientist, undergraduate students, and classroom teachers increased awareness and knowledge about water quality among a diverse group of students within the context of a place-based setting. Through increasing awareness of human impacts, students will become better prepared to make informed decisions and communicate effectively about water quality. Students indicated they were more likely to take personal action to mitigate impact on water resources after experiencing the curriculum, suggesting implementation had a positive impact on future decision-making. Students also developed the skills and ability to develop and maintain green infrastructure solutions for water resiliency within their own detention ponds. Lastly, they recognized the value of restoring the natural flow in the Everglades, which has been altered by urbanization.

Through implementation of water resilience-based education within local middle schools, Project FLOW created a more water-centric community, in an area that relies heavily upon the local watershed for drinking water, recreation, and flood mitigation. Water resilience education is vital for the future of place-based environmental education. Through participation in the project, students were encouraged to share their personal takeaways and knowledge with their families and peers, encouraging environmental stewardship beyond the classroom and into the community.

Future Research

A continued effort to integrate water resiliency education within science classroom curricula is needed. Efforts to help increase outdoor learning within place-based settings to teach water resiliency are necessary through district-wide initiatives. In order to create more environmentally conscience students, teachers, and community members, teachers need

opportunities to develop professionally. Pedagogical and content training, similar to that of Project FLOW for others within the district and beyond will support further water resiliency education. Based on the findings, further critical thinking strategies within the water resilience-based education is necessary for students to better examine their personal habits and recognize how they affect the local community and watershed as a whole.

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Table 1: Code book

CODE	THEME	DEFINITION	EXEMPLAR	OCCURRENCE
1^	Overall enjoyed the experience: good/great/fun/awesome/exciting/nice/ok/cool	Students showed enjoyment in this project and desire to repeat.	"This was the best project we did in science for this year"	159
5--	Students felt they learned/lesson was informational/booklet helped.	Students recognized that they learned something from this lesson.	"I learned a lot of things in the booklet."	56
6^	Teamwork/Friends	Students liked working in teams or with friends.	"I like working with partners because I have more fun and get more work done."	51
2^	Wanted more outdoor time/outside was favorite part/nice to be outside	Student identified outdoor time as their favorite part or a nice change of pace.	"…mostly when we went outside was my favorite part"	41
4//	Lesson felt useless/boring/not fun	Students showed disinterest in the material, thought it was boring.	"I think that it was not as exciting as I thought it would be."	14
7^	Working with FGCU partners	Student expressed enjoyment in working with FGCU partner.	"I liked this project and working with FGCU partners was good."	8
3//	Lesson was difficult/hard/too much work	The student thought this lesson was too hard or too much work to do.	"..the booklet I felt was too long"/ "...on my own some of the words I didn't understand"	7

4**!	BMPs, water monitoring/testing	Student offered BMPs to help prevent pollutants from entering waterways	"When you put pesticides on your lawn do it professionally so it won't go in the pond."	19
2//	Physical barrier/ mechanical filter	Student mentioned using a mechanical filter/physical barrier to improve local water quality in the retention pond.	"A granulated carbon filter that improves taste and odor and removes some chlorine and sediment. Water passes through a series of three filters."	12
3**	Community effort/call to action/ things people should do	Participant promoted community service-based effort to prevent pollutants from entering waterways/ public service announcements to teach "people"	"To do community service, to pick up trash around the lake."	7
7--	Filtering water with plants	Student identified that plants are an option for filtering pond water.	"I think we should put plants all around so they can reproduce in the water so we can have cleaner water."	3
5**!	Recycle/reduce waste produced/ make into art/reduce litter	Student identified ways to reduce waste/point source pollutants by either recycling trash or turning it into artwork.	"Recycle or compost it (instead of throwing in the trash)."	2
1*	Pollution can harm biodiversity/animals	Participant showed understanding that pollution can adversely affect biodiversity	"...for sea animals lose their home and die."	2
6**!	Create a law about littering	Participant stated that maybe a law about littering could be beneficial to preventing littering.	"Also should make a law litter anywhere bill."	1
4**!	BMPs, water monitoring/testing	Student offered BMPs to help prevent pollutants from entering waterways	"When you put pesticides on your lawn do it professionally so it won't go in the pond."	19
2//	Physical barrier/ mechanical filter	Student mentioned using a mechanical filter/physical barrier to improve local water	"A granulated carbon filter that improves taste and odor and removes some chlorine and	12

		quality in the retention pond.	sediment. Water passes through a series of three filters."	
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5**!	Recycle/reduce waste produced/ make into art/reduce litter	Student identified ways to reduce waste/point source pollutants by either recycling trash or turning it into artwork.	"Recycle or compost it (instead of throwing in the trash)."	2
1*	Pollution can harm biodiversity/animals	Participant showed understanding that pollution can adversely affect biodiversity	"...for sea animals lose their home and die."	2
6**!	Create a law about littering	Participant stated that maybe a law about littering could be beneficial to preventing littering.	"Also, should make a law litter anywhere bill."	1
1--	Loss of biodiversity/ possibility of extinction/animals die	Student recognized that loss of wildlife/plants is a possible repercussion of habitat loss	"I support to fund the Everglades this is because the animals are disappearing"	13
3--	Conservation of habitat & biodiversity of everglades/ help the animals	Student identified that protecting habitat improving water quality or restoring flow to the Everglades will help wildlife survive.	"I want to remove all dirty water and put clean water in, so the fish can breathe better."	12
4!	Human caused pollution/Loss of	Student showed understanding that	"Humans started to drain the Everglades to try to	10

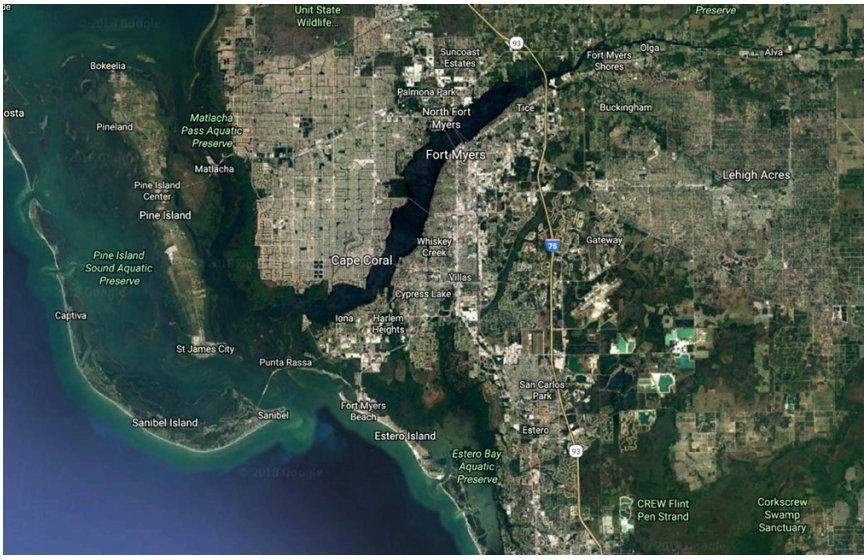
	habitat/habitat destruction/human-caused "altered flow"	humans have greatly affected the habitat and natural systems in the local area.	reduce damage from hurricanes and flooding water."	
2--	Green infrastructure/using plants to filter water & increase DO	Student showed understanding that plants filter water and is a solution for cleaning water or increasing dissolved oxygen content for wildlife.	"Plants will make the water clean and will filter it."	7
12//	Misunderstood a concept(s)	Student showed partial or complete misunderstanding of water quality issues.	"I want to spend my money by cutting the grasses and roots so that fish can move better and get stuck in the roots and so they can eat better."	6
5--	Recognition of water quality issues/dirty & clean water/identified water quality as important/filtering	Student recognized that water quality issues are important and have damaging impacts.	"...if we don't restore it, it can cause algae, loss of nature, loss of DO that fish. It can affect plant and open water areas."	5
7--	Algal blooms/red tide	Student referenced algae as undesirable/ a potential problem.	"…change the flow of water and not have the ocean get algae."	5
9**	Call to action concerning money	Student recognized money may help improve water quality/restore flow.	"I know it will cost a lot of money but if we collect donations and taxes it might be more than enough to fix it."	5
10**	Call to action/what people should do	Student identified that people (us/we/they) must take action in protecting local environment.	"We need to clean the ground, throw trash away so that it won't go in the pond."	5
8--	Nutrient overload/ eutrophication	Student noted that eutrophication is a problem	"…all the animals will die due to the nutrients that had overgrown."	3
11--	Economic impact/tourism	Student recognized an economic impact, positive or negative, resulting from human	"It would be cool to see the water and ride an airboat to see animals."	3

		altered water flow or water quality issues.		
6--	Amount of water	Student referenced amount/lack of water as problem, rather than the quality of the water.	"The animals would die of not much water."	2

Table 2: Independent t-test results

Independent Samples Test Levene's Test for Equality of Variances			t-test for Equality of Means					
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
Equal variances assumed	.015	.903	-3.882	515	.000	-.865	.223	Lower -1.303 / Upper -.427
Equal variances not assumed			-3.894	335.417	.000	-.865	.222	-1.302 / -.428

Figure 1



Arial map of the region, where the study took place. (Retrieved from: Google Maps)

Molly Nation, Ph.D.
mnation@fgcu.edu

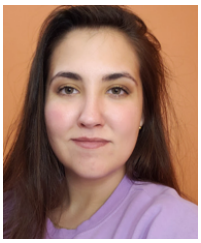
Molly Nation is an Assistant Professor of Environmental Education in the Department of Ecology and Environmental Studies at Florida Gulf Coast University. Her research and teaching interests include climate change education and issues of environmental justice.

Serge Thomas, Ph.D.
sethomas@fgcu.edu

Serge Thomas is an associate professor in The Water School at Florida Gulf Coast University. He studies what factors of natural/human origins, and especially nutrients, trigger (harmful) algae blooms in various inland/nearshore shallow ecosystems.

Sara Combs
smcombs0316@eagle.fgcu.edu

Sara Combs is a senior at Florida Gulf Coast University, where she is majoring in Environmental Studies. During her schooling, she became interested in environmental education. In her future career, she hopes to combine her passion for animals and love of teaching others about environmental issues. She hopes to continue on in the zoological field as a keeper or conservation educator.



Emily Daniels
eldaniels6275@eagle.fgcu.edu

Undergraduate Student in Environmental Studies
Emily Daniels is a Florida Gulf Coast University undergraduate student working toward a B.A. in Environmental Studies focusing on Water Resources & Management. Afterward, she plans on pursuing a Master's degree in Environmental Studies. Originally from Southwest Florida, she has a deep interest in local water quality and storm water pollution prevention.

Chaquer Talamas
cdtalamas6597@eagle.fgcu.edu

Bolivia Chaquer is from La Paz, came to the United States in 2005. He is currently a senior undergraduate at Florida Gulf Coast University majoring in environmental studies. With a great interest in agriculture, he hopes to study and advance in vertical hydroponic farming and find ways to make food systems more sustainable and economically viable.

Gabrielle Vignet-Williams
gvignetwilliams3283@eagle.fgcu.edu

Gabrielle Vignet-Williams is from Ft. Lauderdale and is fourth year Environmental Engineering student at Florida Gulf Coast University. She is currently doing research on a life cycle assessment of anaerobic digestion of food waste.