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Water Analysis Quadcopter Platform Development for Mosquito Research via Capstone project

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Abstract

Mosquitoes are known as responsible for the deaths via the transmission of deadly disease pathogens. Mosquitoes are responsible for harmful diseases such as West Nile, dengue, Zika, Malaria, and others. By understanding more about mosquito populations, it can assist in developing effective mosquito population control methods. One of the potential mosquito breeding spots are stagnant waters. It would be beneficial to the mosquito research to monitor and analyze the water properties of the potential mosquito breeding spots. This project used a quadcopter platform to allow a user to pilot the quadcopter to these locations from somewhere further away. The difficulties, time, and resources can be cut by utilizing a quadcopter platform. This saves time, manpower, and resources as it condenses a trip by boat or foot through hard to access areas and allows for safety of the researchers. This water analysis quadcopter platform includes various sensors used to analyze the water composition and properties. These include pH, saturated oxygen, and temperature. They are connected to a custom PCB, and the data can be collected and stored to the device. The data can be retrieved once the measurement mission is complete. The rate of reading sensors can be chosen. Moreover, this water analysis quadcopter platform is capable of collecting water samples for further analysis in a laboratory. This is based on the use of a custom designed peristaltic pump. The pump speed can be controlled, and it will control the amount of the water sample and the speed of the collection. Furthermore, this water analysis quadcopter platform has an underwater camera, and it can record the underwater images and videos. It can potentially be used in detecting mosquito larvae and pupae under the water. This project was carried out by a capstone team of four undergraduate engineering students. One faculty member supported this work and advised this student team. There was one graduate student assigned to help and mentor the team. In this paper, the details of the water analysis quadcopter platform development via a capstone project will be presented.

I. Introduction

Mosquitoes are known as responsible for the deaths via the transmission of deadly disease pathogens. Mosquitoes are responsible for harmful diseases such as West Nile, dengue, Zika, Malaria, and others. By understanding more about mosquito populations, it can assist in developing effective mosquito population control methods. One of the potential mosquito breeding spots are stagnant waters [1-4]. It would be beneficial to the mosquito researchers to monitor and analyze the water properties of the potential mosquito breeding spots [5][6].

Researchers who may want to analyze the water in these breeding hotspots need a way to collect the sample. This can be very difficult as these areas can be very hard to access [7][8]. Current methods of collecting these samples may include a researcher taking a boat out onto the water to collect samples or being within reaching distance of the source. Therefore, the instrumentation presented in this paper is to create a way to aid in research for mosquito population control as many places that have high populations of mosquitoes are stagnant waters that are not easily accessible. This project used a quadcopter platform to allow a user to pilot the quadcopter to these locations from somewhere further away. The difficulties, time, and resources can be cut by utilizing a quadcopter platform [9][10]. This saves time, manpower, and resources as it condenses a trip by boat or foot through hard to access areas and allows for safety of the researchers

This water analysis quadcopter platform includes various sensors used to analyze the water composition and properties. These include pH, saturated oxygen, and temperature. They are connected to a custom PCB, and the data can be collected and stored to the device. The data can be retrieved once the measurement mission is complete. The rate of reading sensors can be chosen. Moreover, this water analysis quadcopter platform is capable of collecting water samples for further analysis in a laboratory. This is based on the use of a custom designed peristaltic pump. The pump speed can be controlled, and it will control the amount of the water sample and the speed of the collection. Furthermore, this water analysis quadcopter platform has an underwater camera, and it can record the underwater images and videos. It can potentially be used in detecting mosquito larvae and pupae under the water.

An embedded system was developed for this platform. As the main intelligence, a Raspberry Pi 3 A+ was adopted, and a Navio2 was used as a flight controller unit [11][12]. The Navio2 has a UART (Universal Asynchronous Receiver-Transmitter) radio communication unit that can be connected to a custom-built external base station. This base station is similar to a customized small sized computing system. It consists of a Raspberry Pi, a small screen, wireless combo keyboard, and a USB radio module that can be connected to the quadcopter. The base station can run flight planner software such as Mission Planner. This allows the user to pilot the quadcopter and plan autonomous missions.

This project was carried out by a capstone project team of four undergraduate engineering students. Dr. Hur supported this work and advised this project student team. There was one graduate student assigned to help and mentor the team during the capstone project period. In this paper, the details of the water analysis quadcopter platform development via a capstone project will be presented.

II. Capstone project management under the impact of COVID-19

A capstone project is related to experiential learning, and it has been an important part of the engineering education in Engineering Technology. For the capstone project in this paper, this was a two-semester project. The capstone team was created in Fall 2020, and this capstone project was concluded in Spring 2021. For the authors' institution, the school had experienced the forced remote transition in Spring 2020 [13][14]. In Fall 2020, the authors' institution had implemented a university-wide mixed mode of in-person and remote classes for Fall 2020, and it had continued through Spring 2021. For this capstone team, the mode of operation was limited to COVID-19 during their capstone project period. The team had regular weekly meetings with the faculty member over on-line Zoom meetings. Although it was limited, the team could come to the campus and meet the faculty member individually, when it was needed.

There were four undergraduate engineering students working on this capstone project. The name of this team was Pond Hoppers [3]. For this specific water analysis quadcopter project, Dr. Hur, one of the faculty members in this paper, created and supported this capstone project. There was one graduate student assigned to mentor the team. During their two semester capstone classes, two other faculty members taught their two semester capstone courses. This project was concluded as a capstone project in Spring 2021. Moreover, currently, it is also an on-going project as one of the students has been continuing the further development as a graduate student.

III. Water Analysis Quadcopter Platform for Mosquito research

The primary goal for this capstone project was to design and build a quadcopter platform that can land on the surface of still water and take water samples and various environmental measurements of the area for the purposes of mosquito research. This quadcopter design would allow the pilot to control the drone to the location needed to take these samples and return once the samples are taken to further test the water sample and examine the environmental data samples. The flight of the drone would have a manual as well as autonomous flight mode that would be handled using a predetermined path utilizing GPS location. This autopilot mode would allow the drone to autopilot itself with a premade mission, thus flying out to the water, performing a data collection procedure, and autonomously returning to its starting location. This project will aid environmental researchers in testing remote or otherwise inaccessible bodies of water for quality and biological contents without needing direct access to those bodies of water.

The conceptual block diagram is shown in Figure 1. This platform is a multirotor, remote-controlled platform which is capable of performing the standard set of water chemistry measurements as well as collecting a small water sample by landing directly on the surface of a pond. The quadcopter carries pH, temperature, and dissolved oxygen sensors. It also carries a camera in a polycarbonate dome on its underside to record the conditions under the surface. Moreover, a small peristaltic pump is built into the body to take a sample of the water for future observations.

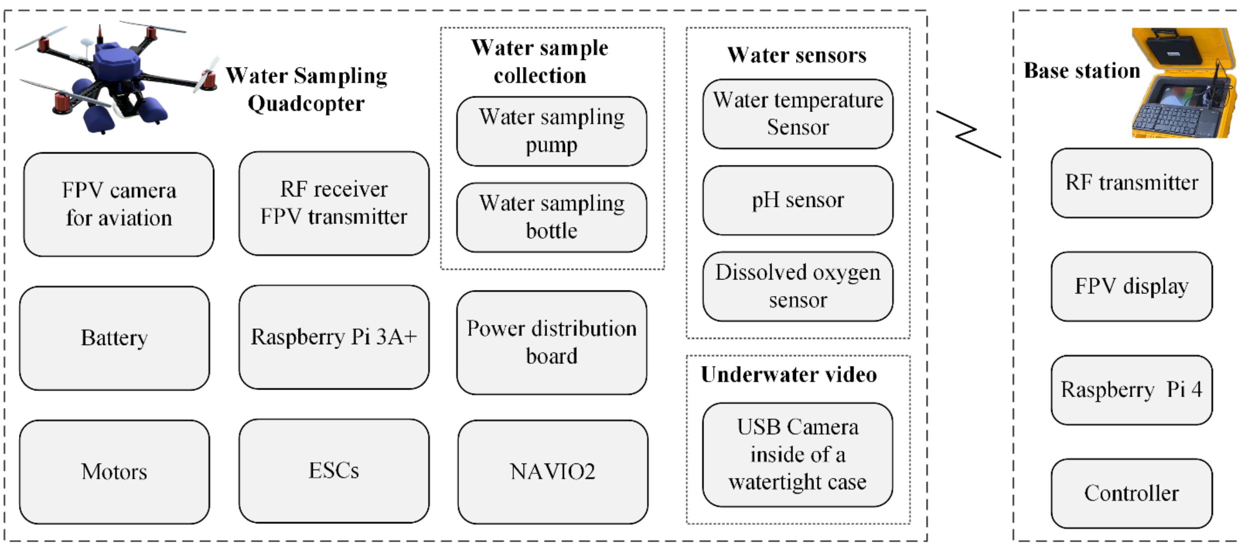

Figure 1. Conceptual Block Diagram of a water sample quadcopter

The first area to discuss is the sensing capabilities. There are different sensing probes and two different cameras. Two cameras are needed as they serve two different functions. One of them is a FPV (First-person view) Camera, and it is for visual feedback to the pilot in order to better operate the drone. Using a connected video transmitter, users are able to see from the quadcopter's perspective on the FPV video Display in the base station. Another camera is an

Aquatic Camera, and it is for visual inspection of the conditions under the water. This video is locally stored and will be able to answer questions about the water's clarity and potential stagnation.

The three probes are for measuring temperature, dissolved oxygen content, and pH. These properties reflect the quality and condition of the body of water and are important for determining if the water is able to host mosquito breeding. Moreover, for a water sampling pump, a stepper motor is used and it is operated as a part of a peristaltic pump. In order to operate the pump, additional Arduino Nano is used.

For motors, Propdrive 2836 brushless motors were chosen to provide sufficient power to lift the drone and its payload. This decision on motors is related to the choice of 40A ESCs (ESC Electronic Speed Controllers). Some other peripherals we have on the drone include a GPS (Global Positioning System), a Telemetry Antenna, a RF Receiver, and a FPV video transmitter which communicate wirelessly with the Base Station and RF Controller respectively.

The intelligence on the drone consists of a Raspberry Pi 3 A+ with a Navio2 hat. The Navio2 is a board that essentially transforms the Raspberry Pi into a drone controller with extra ports for GPS, telemetry antenna, etc. Use of the Navio2 also allows access to the ArduPilot open-source autopilot software. In our design we use the combination of Raspberry Pi and Navio2 as well as a GPS module, a Telemetry Antenna, a RF receiver, and an Aquatic Camera.

The Base Station is used for further monitoring and control of the drone during its mission. The FPV video display receives the signal from the Video Transmitter and is able to display a video feed from the quadcopter's perspective. The display is battery operated and is functionally independent of the other components in the Base Station.

B. Hardware design

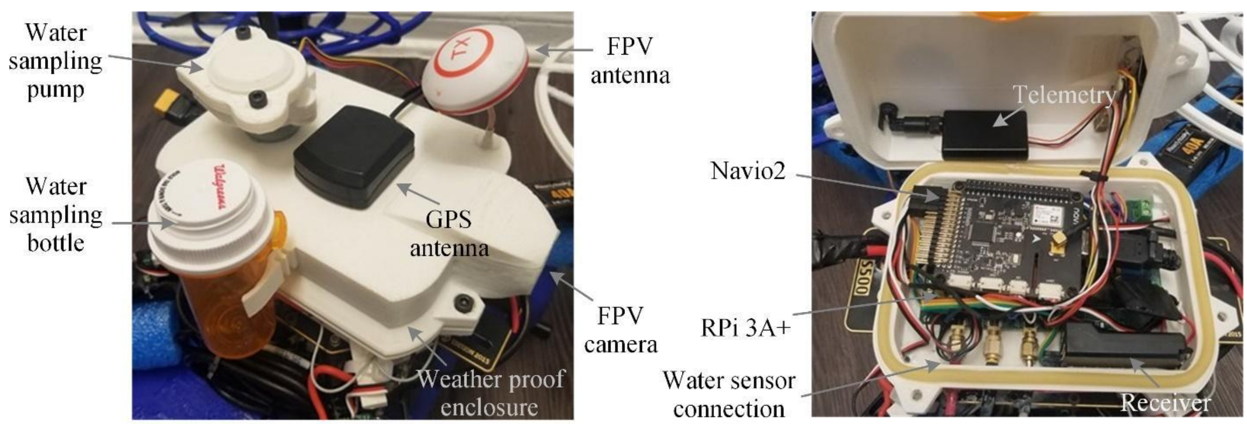

Figure 2. Water Analysis Instrumentation

The portion of the water analysis instrumentation is shown in Figure 2. On the left side, it shows a custom designed weather-proof enclosure. On top of it, it has a water sampling pump, and it is connected to the water sampling bottle. Also, FPV (First-person view) camera and GPS antennas are mounted. On the right side, it shows the inside of this enclosure. The Navio2 is mounted on a Raspberry Pi 3 A+. This is the main unit that controls the water property sensors and the quadcopter. The water sensor connection and the receiver portions are shown on the bottom. The telemetry for the communication is shown on the top.

The weather-proof enclosure was designed and 3D printed using ABS materials. The design of the custom enclosure is shown in Figure 3. It shows the top and bottom cases, and the details are shown. As a gasket, the same tubing used in the sampling pump was used. This application was effective and could achieve watertight as it was proved by submerging and drop tests. This watertight box contains most of the electronics of this system.

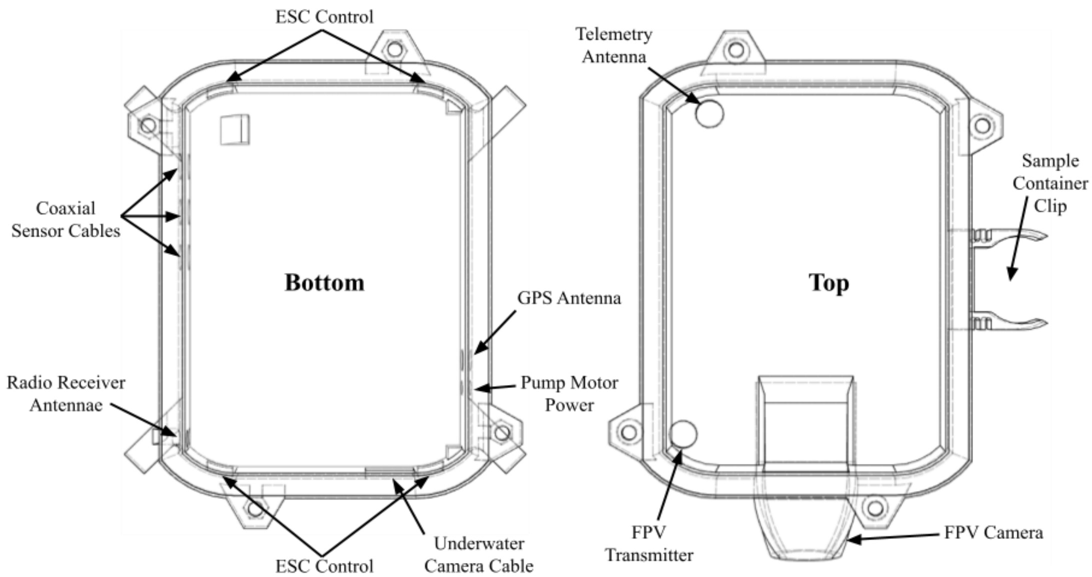

Figure 3. Weather-proof enclosure for the water analysis quadcopter

The camera in a watertight enclosure and the water sensors are shown in Figure 4. The camera is an auto-focus USB camera that is connected to the Raspberry Pi 3A+. This was put inside of the sealed plastic dome. This is the bottom side of the drone, and this portion is designed to be submerged. Moreover, there are pH, Dissolved Oxygen, and water temperature sensors. They will measure the water properties.

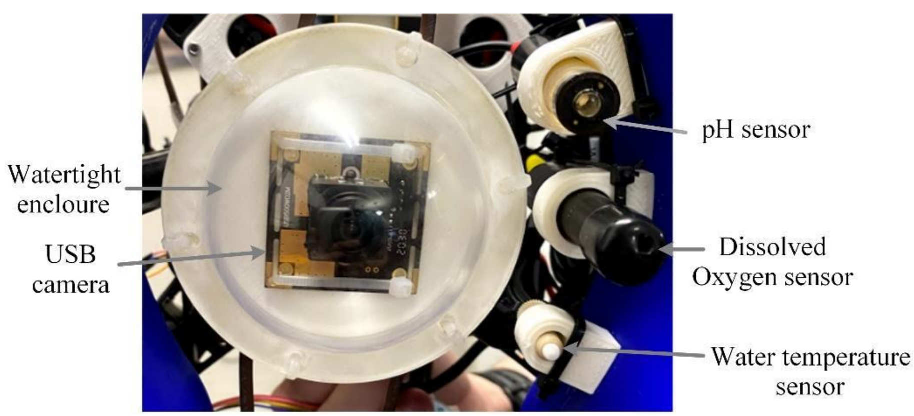

Figure 4. Camera and Sensors

The assembled water analysis quadcopter is shown in Figure 5. The water analysis instrumentation is mounted on the quadcopter platform. Floating materials and 3D printed materials were applied to the bottom of the quadcopter to make the device float.

Figure 5. Assembled water analysis quadcopter

The base station of the water analysis quadcopter is shown in Figure 6. As mentioned, this is similar to a customized small computing system. On the left side, the configuration when it is opened is shown. The keyboard is folded and stored. It can store three water sample bottoms. On the right side, it shows the configuration for operation, the keyboard is unfolded. The telemetry is connected to the USB and the antenna is set up for communication. In order to render it waterproof and shock resistant a standard watertight equipment case with customizable foam was used.

Figure 6. Base station of the water analysis quadcopter.

C. Software design

Windows based application can be executed on a Linux based operating system. This can be accomplished by using Mono which allows for cross-platform development. In this capstone project case, this was implemented using the Raspberry Pi 4 and Raspberry Pi OS. In this way, Mission Planner software can be executed. Next, a proper set of software and libraries may need to be installed on the Raspberry Pi 3A+ for the quadcopter for ArduPiolt and Navio2. Then, the quadcopter and the base station can be operated communicated and operated together using telemetry radios.

The proper configuration using Mission Planner was needed. The screenshot of the Mission Planner for the water analysis quadcopter is shown in Figure 7. After being able to establish a connection between the base station and drone, the mandatory hardware setup could take place which included an accelerometer calibration, compass calibration, radio calibration, and ESC calibration.

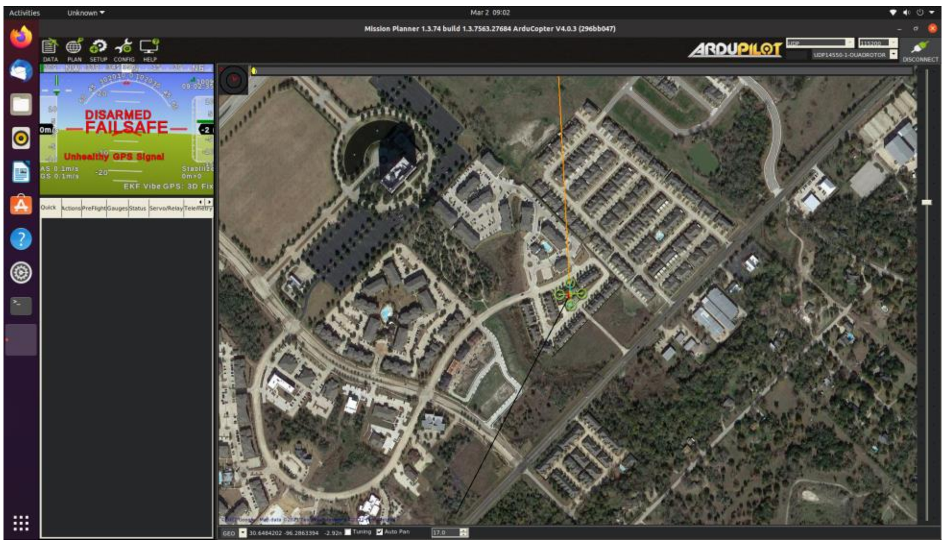

Figure 7. Mission Planner for the water analysis quadcopter

This is the running sequence. The sensor data will be stored on the SD card on boot, and the videos from the Aquatic Camera unit will be stored on the SD card. A Python script will be run to record video and save the sensor data on boot. After a successful boot and connection to Mission Planner via telemetry radios, the next major step is the RC controller calibration and set up.

D. Tests and Measurements

To ensure the functionality of our components and platform of this project, tests and measurements were carried out. A small plastic pond was used for testing. The water analysis quadcopter platform was dropped on this plastic pond for testing as shown in Figure 8. Since it is still in development, due to safety, actual flight testing in the air was not carried out. However, in order to test the durability and whether it could land on the water, the platform was dropped into water from 10 cm height, and it was left for 10 minutes to see whether there was any water leak.

Also, as mentioned, it was not pushed high enough to fly, however, the thrusters were tested whether the propellers can be controlled and engaged.

As shown on the bottom left side of the figure, the water sample was collected. It shows the water collected inside of the bottle. On the top right side of the figure, it shows the recorded sensor data. The timestamps and the sensor readings for dissolved oxygen, pH, and water temperature sensors were recorded in CSV format. On the bottom right side, it shows the recorded underwater video.

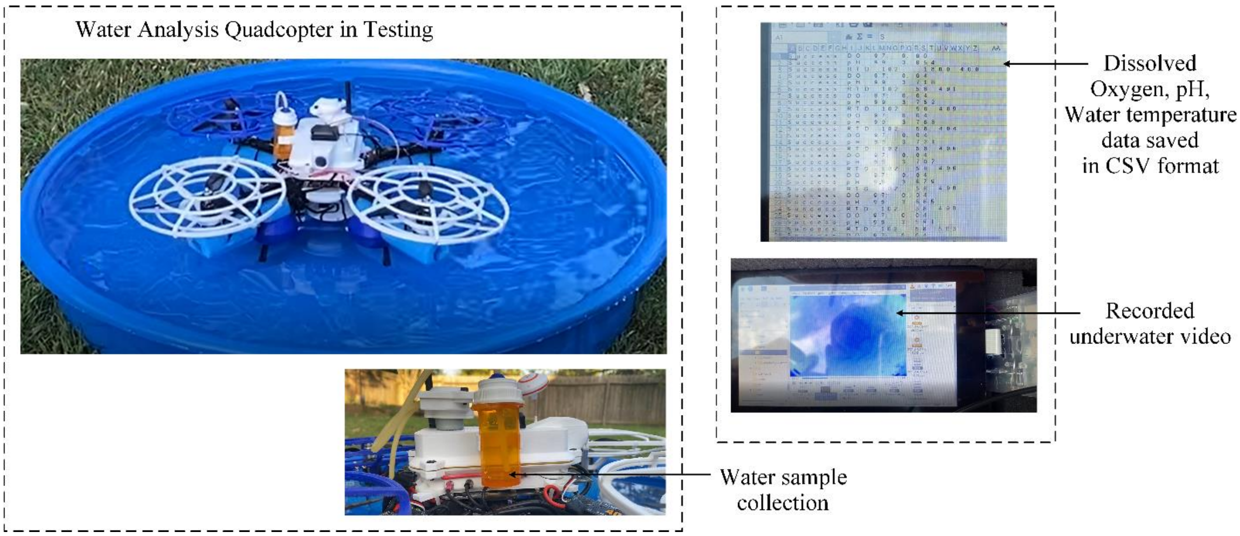

Figure 8. Water Analysis Quadcopter in Testing and Measurements

To ensure the functionality of the components and the platform of this project, tests and measurements were carried out. The small plastic pond was used for testing. The water analysis quadcopter platform was dropped on this plastic pond for testing as shown in Figure 8. Since it was still in development, due to safety, actual flight testing in the air was not carried out. However, in order to test the durability and whether it could land on the water, the platform was dropped into water from 10 cm height, and it was sprayed. Then, it was left for 10 minutes to see whether there was any water leak as a weather resistant test. Also, as mentioned, it was not pushed high enough to fly, however, the thrusters were tested whether the propellers can be controlled and engaged.

The summary of the tests that were performed is shown in Table 1. It shows the Sensor Test, Drop & Float Test, Splash Test, Thrust Test, and Power Test. The components of the tests were shown.

	Sensor Test	Drop & Float Test	Splash Test	Thrust Test	Power Test
Surface landing		V			
Float		V			
Operational endurance				V	V

Weatherproof -quadcopter			V		
Weatherproof - base station		V	V		
Temperature measurement	V				
Oxygen measurement	V				
pH measurement	V				
Water Sampling	V				
Non-contamination	V				
Underwater video	V				
Altitude measurement			V		
Safety	V				

Table 1. Test Matrix

E. Educational value and evaluation

This capstone project was carried out under the COVID-19 restrictions and concluded in Fall Spring 2021. Three undergraduate students graduated and joined the industry. One of them decided to stay for his master's degree in this department. He has been continuing this research and development on the water analysis quadcopter platform for mosquito research. This specific capstone project has shown the education value of successful vertical integration.

An initial post-capstone survey was previously collected for the analysis for a bigger scope of multiple capstone projects [3]. For this paper, another post-capstone survey was collected in May 2022 to analyze the educational impacts on this project only. The questions in the on-line survey are shown as follows:

1. *In your experience and opinion, did COVID-19 affect your capstone project?*

Strongly agree	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**	**N/A**
5	4	3	2	1	0

2. *Briefly state the impact on your capstone experience due to COVID-19.*

3. *Do you think this capstone has been beneficial to your current or future career?*

Strongly agree	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**	**N/A**
5	4	3	2	1	0

4. *Briefly state the impact and/or influence of this capstone project related to your current or future career.*

5. *Did this capstone project enhance your learning about relevant technical skill sets?*

Strongly agree	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**	**N/A**
5	4	3	2	1	0

6. Briefly state the technical skills that you learned during this capstone project.

7. Did this capstone project enhance your learning about working in a team environment?

Strongly agree	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**	**N/A**
5	4	3	2	1	0

This survey was created and conducted using Qualtrics. This voluntary survey was designed to ask a few questions related to the educational impact and their feedback related to their capstone experience. “Anonymize responses” option in Qualtrics was used. The summary of this post capstone survey results is shown in Table 2. All the students have participated in this post capstone survey. Participants have shown positive responses toward their capstone project related to the impact on their career (Q2, Average: 4.50), technical skills (Q6, Average: 4.50), and teamwork (Q7, Average: 4.50).

Table 2. The post capstone survey results for the team of Pond Hoppers

Survey participation rate	100% (4/4)
1. In your experience and opinion, did COVID-19 affect your capstone project?	4.50 (Mean) (Std. deviation: 0.50)
2. Briefly state the impact on your capstone experience due to COVID-19. Summary of the selected answers: * Limited access of facilities and tools including 3D printers * Limited in-person meetings	
3. Do you think this capstone has been beneficial to your current or future career?	4.50 (Mean) (Std. deviation: 0.50)
4. Briefly state the impact and/or influence of this capstone project related to your current or future career. Summary of the selected answers: * Educated to be an electrical/firmware engineer * Taught design principles and project management * Learned about a team project * Helped with a job interview	
5. Did this capstone project enhance your learning about relevant technical skill sets?	4.50 (Mean) (Std. deviation: 0.50)
6. Briefly state the technical skills that you learned during this capstone project. Summary of the selected answers: * PCB design tool * Additive manufacturing tools	
7. Did this capstone project enhance your learning about working in a team environment?	4.50 (Mean) (Std. deviation: 0.50)

The impacts on their career include the relevant education to be an electrical/firmware engineer, learning about design principles, project management, and a team project. It helped with a job interview. The technical skills that they learned include a PCB design tool and additive manufacturing tools. For the COVID-19 related impact, the limited access to some of the facilities and instructors made the project difficult. Some of the 3D parts ended up being printed using a student's own printer at home. Due to the COVID-19 restrictions during this project, in-person meetings with the entire team members were limited. Two or three students could meet to work in separate time blocks. The limited mode of operation seemed to have made this project more difficult. From a faculty perspective, this capstone project team showed the dedication to the given challenging project and the students were willing to learn new things to adapt to the situations. In the end, this capstone project team was able to deliver the requested functional prototype and complete their project successfully in Spring 2021.

IV. Discussion & Concluding remarks

A water analysis instrumentation that has a form of a quadcopter has been presented in this paper. The project was carried out via a capstone project. This development task was carried out for two semesters of Fall 2020 and Spring 2021. The capstone project was completed, and the research and development on this work has been continuing. This quadcopter platform for mosquito research is an on-going project for further development by one of the graduate students who had worked on this team. Students in this capstone project stated that they have gained significant knowledge and experience via this experiential learning process. The further development of this task can assist in advancing and understanding of the stagnant water properties where some of them are potentially mosquito breeding spots. The authors plan to continue to pursue this research and to extend the study and applications using this quadcopter platform

Acknowledgements

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