GUPPIE Program – A Hands-on STEM Learning Experience for Middle School Students

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***Abstract*—This paper describes the details of a theme-based and hands-on STEM learning program utilizing an underwater robot called GUPPIE. Glider for Underwater Problem-solving and Promotion of Interest in Engineering (GUPPIE) is an example of a robot with oceanographic and environmental monitoring application. GUPPIE helps students to learn about fundamentals of *physics* (buoyancy, gravity, drag and lift force), *electronics* (circuitry and power distribution), *programming* , *building* (using tools and assembly), and *testing* in a systematic way. In this work we analyse the effects of the hands-on activities with meaningful context on students' 1) confidence level; 2) attitude towards robotics; 3) and level of interest towards STEM careers. The survey results suggest that using robots with sensible real world applications improves young students' attitudes and interests towards robotics. Based on these results, introducing young students to topics that are not part of official school curriculum, such as programming, increases the excitement and confidence in early ages, especially for girls, and can result in pursuing STEM related subjects in higher education. Results also revealed that girls are more interested in building while boys are more attracted to programming.**

Keywords*—Marine engineering, STEM, Active Learning, Project-based learning, Student assessment, Survey, Motivation.

I. INTRODUCTION

There is no doubt that robotics generates excitement in young pupils, yet the big question of educational effectiveness of robots [1] and the risk of creating "techno-consumers" instead of "influencers of robotics" [2] still remains. This energy can be funneled to STEM learning while utilizing robots as educational tool. With the current rate of expansion, educational robotics will likely govern STEM education in the near future [2].

Robotics advocates in the past promoted STEM learning for pre-college students through platform-specific robotic curricula with kits such as Lego Mindstorm robots [3], [4], STORMLab robotic kits [5], Parallex BoeBots [6], Art & Bots [7], and AERobot [8]. More affordable and free learning kits such as Arduino kits [9] and Electronikits [10] have also been employed with the goal of using mechatronics to improve robotics education. The vast majority of these robots are terrestrial or humanoid and they are not introducing the young learners to the wide spectrum of the robotics field and their application in everyday life.

One robotics application is environmental studies. Today, Autonomous Underwater Vehicles (AUVs) are used for water quality monitoring and oceanographic data sampling. Unfortunately, very few educational marine robot kits are available for STEM learning such as SeaPerch [11] a Remotely Operated Vehicle (ROV), SeaGlide [12] an Autonomous Underwater Vehicle (AUV), and Lego's waterbotic [13] a surface Remotely Operated Vehicle. Hence, the existing educational marine robot platforms are either remotely operated, i.e., lacking autonomy, or not specifically designed for the promotion of STEM education for early ages and hence are coupled with a specified-project curriculum. The Glider for Underwater Problem-solving and Promotion of Interest (GUPPIE) was developed in the NASLab at Michigan Technological University to address these shortcomings.

The GUPPIE program started as a theme and project-based educational experience to broaden the audience of robotics programs. Underwater vehicle development is challenging due to the physical design constraints and unforgiving environment, typical of many real-world engineering problems [14], [15]. Hence, in addition to introducing the science and technology of autonomous underwater vehicles, the GUPPIE program also promotes education in engineering problem-solving and multidisciplinary applications that use robotics to learn about the environment.

The learning process in this program aligns with Bloom's taxonomy such that students' knowledge, skill, and attitude towards robotics will change as they experience hands-on curricula [16]. We theorise that if students' learning involves a meaningful process using real-life examples of a robotic application, then we can improve the domains of learning (cognitive, affective, and psychomotor) in younger students [16].

The GUPPIE program merges project-based and theme-based robotics education which are effective approaches in K-12 STEM learning [17]–[19]. The GUPPIE program features three main traits: 1) it has great potential in engaging students with a wide range of interests [20]; 2) it is a theme-based robotics program that has real-life applications [15]; and 3) it presents autonomy in an underwater environment that introduces new but intriguing challenges. This program encourages students to think, collaborate, and communicate while being creative and analytically critical. GUPPIE is an adaptable platform that can evolve with the age, needs, and prior knowledge of the students. In this paper, we focused on a middle school program conducted in 2016 at Michigan

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978-1-5090-5920-1/17/$31.00 ©2017 IEEE

Gender	N=	STEM camp	Robotics Experience	Family in Robotics
Girls	11	4	8	5
Boys	20	9	13	13

TABLE I: Summer 2016 program participants background information

Tech where GUPPIE was offered to 31 students in grades 4 to 6. Table I summarizes statistics on student genders, previous robotics experience, and their family background in robotics.

The remainder of this paper is organized as following: setup and overview of the program in Section II, implementation in Section III, survey results and analysis in Section IV. The summary and outcomes of the program in 2016 and future plans are discussed in Section V.

II. How does the GUPPIE Program work

The GUPPIE program follows the principles of scaffolding, breaking up complex tasks into smaller activities and building upon them [21]. The GUPPIE program is a combination of minds-on with hands-on activities [22], a pathway to learning and retaining concepts where there is no prior knowledge [23]

Most students in grades 4 to 6 have little prior knowledge about the science and technology concepts involved in robotics such as electronics and programming. We divided students into groups of two and each group received a set of hardware. This group division gives each student opportunity to work on every project while still working in a team.

The program takes place in 5 stages over 5 days and gradually builds up necessary skills. This division was based on the engineering design cycle [24] and Bloom's classification [16]. The GUPPIE program stands on five pillars: platform, students, instructors, structure, and program evaluation. This plan intends to be an introduction to electronics, programming, robotics, production, and testing for middle school students.

A. Platform

Michigan Tech's NASLab, with the support of the National Science Foundation, developed GUPPIE to be a low-cost and autonomous underwater vehicle that is suitable for middle school and high school students. The GUPPIE has two form factors based on the fuselage configuration; mini GUPPIE and GUPPIE. The mini GUPPIE is composed of a water bottle, syringe, continuous servo, remote start sensor, and 3D printed mounts to build the buoyancy drive. It uses Arduino Nano for controlling the glider and a 9 volt battery as the power source (Fig. 1). The mini version was designed for younger pupils. The other form of the GUPPIE encloses the mechanical components in a 22 cm polycarbonate tube. A rail based mount is designed for ease of installing of the buoyancy drive and other sensors. The sealing of the GUPPIE is more reliable in this configuration.

B. Participants

In 2016, two groups of middle school students, grades 4 to 6, eleven girls and twenty boys, attended the GUPPIE program. Most students were from low-income families which would not attend the program without scholarship support.

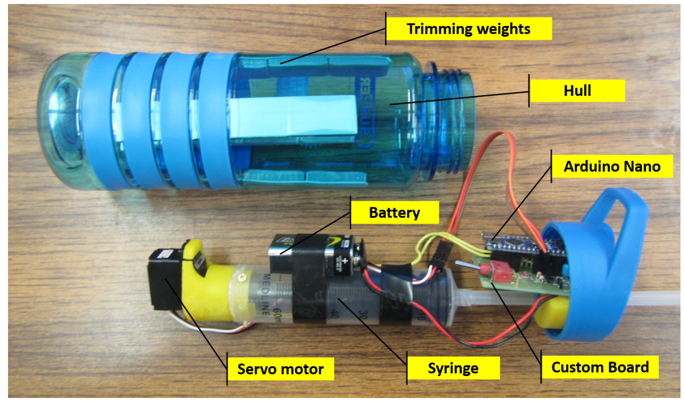

Fig. 1: Mini GUPPIE's internal components

Table I illustrates details about students previous experience and their family background in robotics. STEM camp refers to any previous STEM camp that students attended while robotics experience refers to their past robotics activities. To understand students' past experience in robotics camps and as a control input, they were asked in pre-survey what did they like or dislike about the previous robotic camps they attended. Girls mentioned they liked building, challenges, creativity, and designing. They did not like the competition, and they did not mention enjoying working with other people. Five girls previously participated in FIRST Robotics and three of them worked with robots in other school programs. In their previous robotics experience, boys liked: programming, building, design, challenges, fun activity during school year, team work, and competition. Boys gained their robotics experience through attending FIRST Robotics (10 out of 13), playing with RC cars, building a robot with dad, and personal robotics projects. Comparing the background of the two groups we realized that boys are more interested in robotics as a fun activity. They are open to challenges and prefer robotics competitions, while girls are more interested in building, the outcome of the activities, and being challenged.

C. Instructors

NASLab graduate and undergraduate students are mentored by Dr. Nina Mahmoudian and trained in how to integrate research with teaching and outreach to develop strong research, pedagogical, mentoring, and communication skills. To ensure the quality of the course materials and teaching, a group of two graduate students and two undergraduate students was selected for this program. The team collaboration ensures that students have immediate help during daily hands-on activities. The graduate students had already served as TAs and were trained through a Graduate Teaching Assistant Training course ED0510 through the Center for Teaching and Learning at Michigan Tech. All the team received specific training through Michigan Tech's Center for Pre-College Outreach. This center conducts an extensive interactive day-long training for all Summer Youth Program (SYP) instructors. The training provides participants with insight on generational traits, behavioral expectations, learning styles, multiple intelligences, and skills for engaging middle and high school students.

D. Structure

The GUPPIE program starts with introduction to robotics to introduce youth to different applications of robots in the real world. Autonomous Underwater vehicles (AUVs), a type of mobile robots, are next introduced. Students learn about the use of AUVs in oceanography, environmental monitoring, search missions for civilian and military applications. Students and instructors discuss operational challenges in the underwater environment such as GPS and radio inaccessibility underwater, restriction on recharging/refueling, and deployment. After defining the challenges, students are intrigued to learn necessary skills to solve these problems.

In day one, students learned how to use an engineering design software. Autodesk Inventor [25], a 3D Computer-Aided-Software (CAD) editor that is suitable for younger students was selected. Creating a mechanical or structural model of objects that students use or imagine is a constructive way of practicing visualization in engineering design. They learned the basics of 3D design concepts such as opening a new file, saving files, recognizing different planes, exploring through 3D views, sketching simple shapes, measuring dimensions, creating 3D shapes, and a few advanced editing features. The program continued with circuits and electronics. At this stage, students learned how to build a circuit. They became familiar with different electronic components and microprocessors. Students followed simple sketches to learn how electronic devices can connect to each other and complete a loop that is called a circuit. They learned about shorted and unconnected circuits, electronic component polarity, and parallel and series circuits. On day two, we started script-based programming rather than a drag-and-drop visual programming method. Five systematic programming projects were defined to cover the basics of programming. These projects integrate software and hardware, combining theoretical teaching with hands-on activities. We selected Arduino, a hobby level and open source processor, for the middle school students. The basic system consists of a micro controller with various peripheral interfaces that is programmed by an existing software platform. Arduino can come in a number of form factors, and this program used Arduino Uno and Arduino Nano interchangeably. The Arduino software platform is written in Java and is programmable based on a dialect of C language. On day three, students built the GUPPIE circuit using provided sketches, printed circuit board (PCB), and electronic components. Assembling and building the buoyancy tank is part of day three activities. In this day, students learned about buoyancy, gravity, energy consumption, drag and lift – an advanced topic in underwater dynamics. Fig. 2 shows students assembling their GUPPIEs. On day four, students reviewed the science behind underwater glider locomotion based on change of buoyancy. They followed a simplified programming language method, pseudo code, to build a layout or algorithm for GUPPIE motion in a saw-tooth pattern. At this point, they realized that the mass and time are the two variables that they can *control*. To alleviate the technical activities on the fourth day, we included wing design and decoration. Students learned about the effects of the wing on the vehicle motion and each team designed a wing. They cut their designs out of plastic sheets and painted them. On day five, students worked on trimming the glider. Trimming is the process of adding extra weights to the vehicle so that it stays neutrally buoyant at the beginning of the flight. After finalizing the trimming and leak testing, GUPPIEs were tested in the swimming pool.

Fig. 2: "I thought it would be really boring, but instead I had like a ton of fun and it passed my expectations." 2016 middle school girl participant.

E. Evaluation and Survey Methods

The outcome of this pedagogical program was evaluated through quantitative and qualitative surveys, conversational discussions, and behavioral observation. The mixed evaluation methods were used to study all aspects of the program and answer research questions [26]. Pre and post surveys were used to quantitatively determine the level of interest, confidence and attitude towards STEM related subjects. The quantitative pre and post survey included several statements with which students indicated their agreement or disagreement on a seven-point or five-point Likert scale. Students rated their interest in robotics, science, math, programming, and electronics before and after the GUPPIE program. Qualitative post surveys were focused on investigating the learning curve and students' interest and confidence in each discipline, especially engineering and technology. These surveys were computer-based to motivate more students to complete the questionnaire, although not all the surveys were turned in complete. Topics such as interest in programming, wiring, engineering design, and building robots were investigated. Post activity checklists determined students' improvements in learning, confidence, teamwork, and problem-solving through hands-on activities. Interviews and conversational discussions were conducted to qualitatively evaluate students experience and their feedback about the program. With the open questions students freely criticized the program or shared their exciting moments, expectations, and understanding of the program content. A third party observer monitored students and instructors behaviour as well as the program setup and implementation. The observation outcome revealed information about young students' focus span, teamwork behaviour, their attitudes towards each other and new subjects (programming and electronics), interest in hands-on activities, and the instructors' relationships with students.

III. How to Implement the Program Activities

The GUPPIE program is designed to be an adaptable curriculum that can be used in outreach, summer camp, after-hours school programs, or in school classroom activities. Depending on the time or age of the students, one can modify the projects while keeping the overall structure consistent. This scheme promotes scaffolded, project-based experimental learning in pre-college engineering education. The duration of the program can be extended, but a minimum of five days is recommended to ensure that new concepts such as programming become well-established.

A. Engineering design

Engineers use CAD software to model their design and perform analysis to ensure their device is suitable for the intended use. Besides Autodesk Inventor, other options suitable for young students include Sketchup, Thinker, and 123D CAD. When students became familiar with the software environment, they are instructed to sketch simple 2D shapes. Then they can use editing features to create 3D objects.

After learning the basics of the design software, students used calipers to measure dimensions of an object, such as a servo motor, and sketch it in the Inventor software. This helped their visualization of objects in 3D space. As a bonus assignment, one of the GUPPIE structural components, for example the servo mount or plunger, was presented and students were asked to model it in software. Completed models were fabricated by a 3D printer available in NASLab. Students inspected the parts and investigated if their design is suitable for the intended task.

B. Programming and Electronics

In the GUPPIE program, programming and electronics are closely related to one another. All the programming projects are integrated with electronics as hardware in the loop. In programming, students learned the basic syntax, programming logic and concepts such as variables, conditionals, loops, machine state, and debugging. In this program students were encouraged to learn the basics of script programming through fun projects instead of graphical programming. Interacting with a programming software, dealing with the microprocessor, uploading the code through the software platform, debugging, and integration with the hardware gave students a taste of reality while accomplishing progress at each stage.

To start, students were asked to simply connect their Arduino through the USB port to the computer, set the appropriate board and port on the software, and open project blink from the Arduino library. This project controls the blinking duration of a built-in LED light on the Arduino board. Students changed the timing of the blink and after re-uploading the code, they observed how their input affected the output on the hardware. We observed that this introduction to programming with hardware in the loop motivates and excites students to learn more.

The first programming project is Spaceship Interface, one of the open source projects of the Arduino [27]. Students learned how to wire a simple circuit following schematics, and then program multiple LED lights. Using a push button (switch), students turned on/off LEDs in different sequences. When the original task was accomplished, most of the students added more LEDs and switches to the basic design, making the project more challenging and more rewarding. In these extra "fun projects" students were motivated to step out of the curriculum and learn material to take their device to the next level.

Next, students were introduced to servo motors, the most common component in robots. They learned how to integrate a servo motor with the Arduino board and interface it with the software platform. To start, they used one of the examples from the Arduino library, project knob, and became familiar with the *servo* library and associated syntax. The related circuit design is available on the Arduino website documentation. We used this opportunity to discuss how to do research and find useful information in the World Wide Web. The third project was related to autonomous motion of the servo without using a knob.

The fourth Arduino project was a "fun project". Students learned how to interface an LCD (Liquid Crystal Display) to the circuit and use state machine programming to build a crystal ball to predict the future! The last programming project was integrated with a mechanical system which is further explained in section III-C.

C. Building and Assembly

In past robotic camps [28] all students and especially girls showed a high interest in "building things". Observing this trend, we populated the program with activities that include some type of building whenever possible. Building circuits, soldering, and utilizing tools helps students to learn about the scientific concepts while experienceing them.

Prior to building the GUPPIE's buoyancy drive, students built a servo-gear-rack system called "Ding-Dong-Ditch". This device is composed of servo motor, LEDs, push buttons (switches), gear, rack, and wooden frame. This activity introduces the concept of autonomy. Students manually activated a switch, which drove the rack to activate a second switch and turn the LED lights on. Then the rack autonomously retracted to the home position. This project addresses three aspects of robotics: 1) the autonomy of the device, which is achieved through establishing an algorithm; 2) the understanding of converting rotary motion to linear motion, which is achieved with measuring the amount of distance that the rack travels; and 3) the device control which in this system is a combination of bang-bang and time-based control.

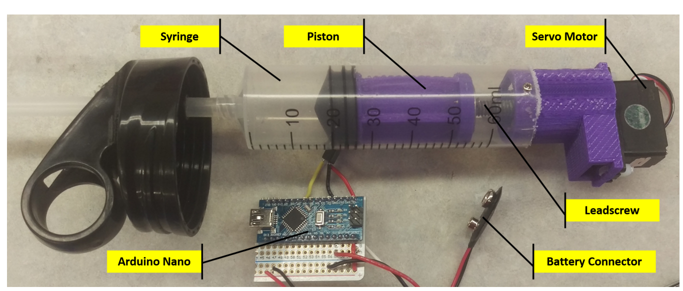

Fig. 3: Buoyancy drive of the mini GUPPIE

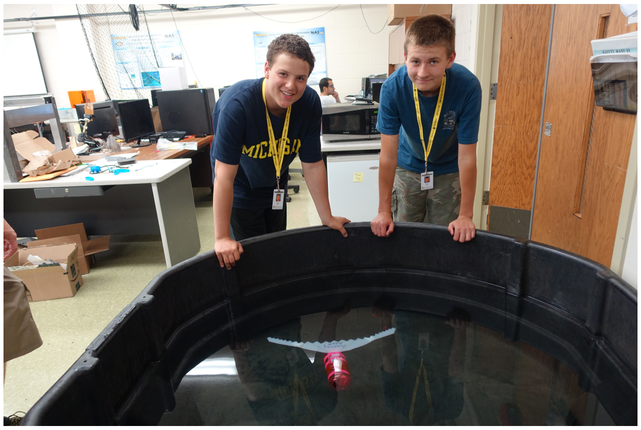

Fig. 4: 2016 participants are trimming the GUPPIE: "I did learn a lot about the different capabilities of robots, such as the GUPPIE with its buoyancy control, I thought that was really interesting."

The buoyancy tank works with the same concept demonstrated in the Ding-Dong-Ditch system. Instead of a rack, a lead-screw is used due to GUPPIE's small form factor. The tank itself is made of a disposable syringe. A servo motor is connected to the tank using a 3D printed mount. Students follow an installation manual to assemble the buoyancy drive and connect the circuitry and the battery to the internal system as shown in Fig. 3. The last component is the wing that students cut out from a plastic sheet and decorate. The wing shape and placement affect the performance of the GUPPIE.

D. *Testing and Troubleshooting*

Testing and re-evaluating the design, hardware assembly, and programming prepares younger students to practice the engineering design process. Learning this skill at a young age can change future generation attitude towards challenges and problems arising later in life.

Instructors assisted the students in troubleshooting and resolving issues without giving the final answer. This approach helps students to engage with rather than be frustrated by the challanges.

Before deploying the GUPPIE in the swimming pool, students tested the water tightness of the glider to ensure that water did not penetrate the hull casing. Trimming of the robot was the next step before the final test. Fig. 4 depicts students while trimming their GUPPIE. Weights were added to the vehicle after completion of the assembly. The GUPPIE is designed to be neutrally buoyant at the beginning of its flight underwater. After the satisfactory trimming test the GUPPIE was ready for its underwater mission. Students deployed their gliders in a swimming pool and swam with their robots. On the test day, students observed their home-made GUPPIE move in water and swam with them. Fig. 5 illustrates an enthusiastic student watching her GUPPIE.

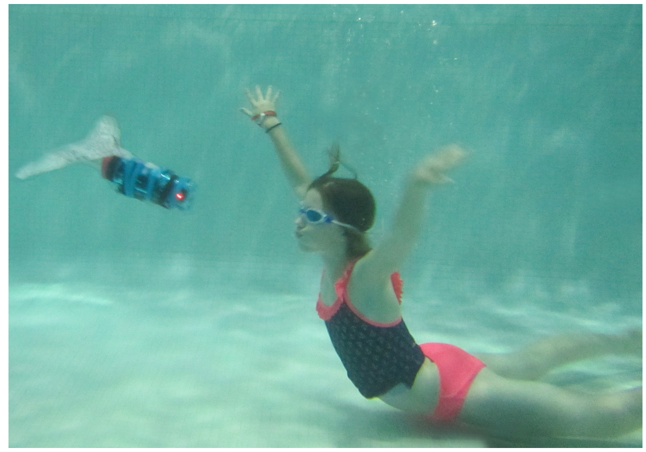

Fig. 5: 2016 participant is swimming with the GUPPIE, "I don't know what my expectations were, but they were blown out of the water!"

IV. What Did We Learn from The GUPPIE Program

Using targeted questions the team set out to find the answers to the following research questions: 1) if meaningful hands-on activities had a positive effect on students; 2) if students' confidence level increased by accomplishing tasks that they have not done before; 3) and if teh program influenced students' attitude towards robotics and STEM careers changes. To record students feedback, computerized surveys were used. Although, the method was user-friendly for both participants and researchers, small percentage of students submitted incomplete surveys.

A. *Quantitative Survey*

Quantitative Likert scale surveys captured students level of agreement or disagreement with the fundamental research questions. Table II illustrates students response to "Robotics is useful to my career goals" in pre and post survey on a five-point Likert scale. Pre and Post in the table refers to pre survey and post survey respectively. The results shows a positive change of attitude towards career choices in robotic fields especially in boys.

	Pre/boys	Post/boys	Pre/girls	Post/girls
Number responses	20	19	11	10
Not a factor	4	3	2	0
Strongly agree	3	10	4	5
Agree	7	2	4	3
Disagree	5	3	1	2
Strongly disagree	1	1	0	0

TABLE II: Effect of GUPPIE program on career choice

To evaluate the level of confidence students were asked to indicate whether a reason for their interest in robotics is "being good at it". Results are summarized in Table.III. The results show that students confidence increased significantly during the program.

Computer programming was a new subjects for most of the students. Their response to "rate your interest in computer

	Pre/boys	Post/boys	Pre/girls	Post/girls
Number responses	20	19	11	10
Not a factor	4	1	3	1
Strongly agree	1	4	0	2
Agree	8	10	5	7
Disagree	6	3	2	0
Strongly disagree	1	1	1	0

TABLE III: Confidence level- Pre/Post GUPPIE program

programing" is illustrated in Table IV. Results, based on seven-point Likert scale, show that both girls and boys were more interested in programming after the GUPPIE program.

	Pre/boys	Post/boys	Pre/girls	Post/girls
Average	4.7	5.1	5.4	5.5
Median	5	5	6	6.5

TABLE IV: Interest in programming- Pre/Post GUPPIE Program

Building and assembly made up majority of the program content. Students were asked "what is your level of interest in designing and making things". The answers were populated on a seven-point Likert scale. Table V illustrates that girls almost unanimously showed high interest in building things. Boys were interested in building before and the program did not change their level of interest.

	Pre/boys	Post/boys	Pre/girls	Post/girls
Average	6	5.9	6.55	7
Median	6	6	6.2	6.5

TABLE V: Interest in building- Pre/Post GUPPIE program

It is likely that students in the GUPPIE program were interested in robotics before enrolling in this program. Table VI summerizes how students rated "their level of interest in robotics" in pre and post surveys. Based on the data, girls' interest in robotics dramatically increased during the GUPPIE program.

	Pre/Boys	**Post/Boys**	**Pre/Girls**	**Post/Girls**
Average	5.65	6	5.55	6.5
Median	6	6	6	7

TABLE VI: Interest in robotics- Pre/Post GUPPIE program

B. Qualitative Survey

Qualitative surveys were part of the pre and post program survey. Considering the age group under study, inattentive response of some students to surveys was the main challenge for the research team. By using post activity questionnaires at the end of morning and afternoon sessions, we tried to minimize the error and likely retrieve thoughtful feedback from the young learners.

When students were asked "from the beginning of the week to the end, how did your ability to contribute to your team change?", 61% boys and 72% girls responded that "my abilities increased"; 14% of boys and 18% of girls expressed that their ability did not change; 25% of boys and 10% of girls did not answer the question.

What did you learn?	**Boys**	**Girls**
Programming/Coding	11	8
Using servo motors	4	1
Wiring	4	5
Underwater robots	4	–
How to build a robot	3	1
Design in Inventor	1	1
I need an Arduino	1	–

TABLE VII: Learning experience- Post GUPPIE program

The post survey asked students "what did they learn". The responses are listed in Table VII. The answers reveal that both boys and girls learned how to program and how to build a circuit.

They also were asked about their most favorite and least favorite parts of the GUPPIE program. As least favorite activities boys listed "Ding-Dong- Ditch" because "it was difficult to code". One person replied "wiring" because "the connections constantly fall out and are all messy", and one student found "GUPPIE assembly" frustrating because "fitting the GUPPIE in the bottle was hard". Girls mentioned "something did not work", "Feeling left behind by partner", and "programming" as their least favorite activities. For most favorite activities, boys listed programming/coding, building, GUPPIE, and watching robot videos because they were hands-on, fun, cool. Girls listed programming/coding, building, wiring, GUPPIE, and working with others because it was useful, challenging, interesting, rewarding.

We observed that girls and boys express their opinions about the activities differently. Girls showed more care about usefulness and the rewarding nature of the activities while boys enjoyed it because it was cool and fun.

At the end of the survey, students were asked "What could we change to make the robotics camp better?". The majority of students pointed to the following list:

- Make the program longer (boys and girls)
- Teach more programming (boys and girls)
- Let us take the robots home (boys)
- Add competition of the bottle-bots (boys)
- Give more projects with servo, switch, and Arduino (boys)
- Longer breaks (boys)
- Nothing, it was all great! (80% of girls)

C. Observations

Throughout the week an observer monitored the sessions without interfering with the flow of the daily activities. Some of the observations are listed as follows:

- Pairing experienced students with students with no previous robotics experience has postive impact in creating team work and improving engagement.
- TAs need to be aware of students who frequently lose focus and intervene as needed.

- Make sure to scan the room frequently. Many students are comfortable asking for help and demanding attention while some students struggle more quietly.
- Allow some struggles before assisting students will give them the opportunity to think and learn on their own, but also consider the time constraint of the daily activities.
- Girls are interested in the "helping people" aspect of robotics.

D. Discussions and Interviews

Although the computerized surveys are convinient for collecting feedback, they are not completely appropriate for middle school age group. To elicit more detailed responses, group interviews (groups of 3-6 students) were conducted at the end of the program. Students shared their excitements, problems, likes, and dislikes in a conversational manner. Encouraging testimonies and constructive criticisms were the outcomes.

Students were asked in focus groups "if the program fulfilled their expectation" and "what can we do to do to make the program better". A selection of the testimonials are listed here and some are used in the Figures captions.

- Boys
  - It changed the way I thought about robotics, the things I knew.
  - Most of it met my expectations, I didn't know we were going to be doing programming, so I was happy about that..
  - I programmed one from scratch instead of using the example, that was probably the moment I'll remember.
  - When we learned about the autonomous lab, the nonlinea and autonomous lab, that really interests me now, autonomous systems. That's something I'm more interested in after camp.
  - We should have another class for people coming back, more in depth class, so here's your supplies and at the end of the week you're battling, or more of a challenge.
- Girls
  - I don't know what my expectations were, but they were blown out of the water!
  - I learned how to program, and I thought programming would be really hard and confusing and that it would take loads of effort to do it, but it was actually kind of easy once you learned how to read it.
  - I thought that robots were just to like play with and stuff, like toys, but now they're helping, where people can't go, they're like searching, deep in the ocean... lives.
  - I always wanted to be an engineer, I think actually knowing more about it now makes me more sure of my choice.

Girls "loved the program and did not have anything that could make the camp better".

V. What are the Outcomes

In this paper, GUPPIE is introduced as a fun robotic platform with real world application in environmental monitoring to engage pupils in early ages in Science, Technology, Engineering and Mathematics (STEM) learning. Utilizing scaffolding theory the teaching content of GUPPIE program is built up in such a way that grade 4 to 6 students with no prior knowledge of robotics is able to assemble, program, and test an underwater robot. GUPPIE helps students to learn about fundamentals of *physics* (buoyancy, gravity, drag and lift force), *electronics* (circuitry and power distribution), *programming* , *building* (using tools and assembly), and *testing* in a systematic way.

The GUPPIE program was offerd as a week-long camp to 31 middle school students in the Summer of 2016. In this work, we analyse the effects of the hands-on activities with meaningful context on students confidence level, attitude towards robotics, and level of interest towards STEM careers. Based on the survey results 65% of boys and 70% of girls expressed that their ability increased after the GUPPIE program. This can be interpreted as an increase in their level of confidence and ability to finish tasks with newly acquired knowledge. Students especially showed interest about programming and "building things". In addition, the survey result suggests that using robots with real world applications that help human life improves young students attitude and interests towards robotics. Based on these results introducing young students in topics that are not part of official curriculum such as programming increases the excitement and confidence in early ages, especially in girls, and can result in pursuing STEM related subjects in higher education.

In 2017, we plan to increase the pool of students to 60, targeting more female students to study the impact of theme-based robots on changing prespective of female students regarding robotics and STEM learning. The goal is to recruit 30 middle school girls. We are working on new advertisement strategies in schools and social media. The GUPPIE program provides full scholarship for female students to encourage more girls' participation especially from low-income families.

The long-term plan of the GUPPIE program is to be adopted by schools nationwide. To achieve this goal, teachers have to be trained to conduct the classes. A pilot teacher's workshop is in-progress to help teachers learn the details of the program. The first teacher workshop is planned for the Summer of 2017 at Michigan Tech.

Acknowledgment

This work is partially supported by National Science Foundation and worked under grant numbers 1426989 and 1453886. Also, this work relates to Department of Navy grant N00014-15-1-2796 issued by the Office of Naval Research.

Fig. 6: “It was a lot better [than the other course I took], more in depth in programming, we did more hands-on stuff. I liked more of the programming and building part.” 2016 middle school boy participant.

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