

Drone Labs to Promote Interest in Science, Technology, Engineering, and Mathematics (STEM)

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This paper describes the development, implementation of STEM activities that promote the interest of High School students to pursue STEM education in college. The five-week program is designed to introduce students to Robotics and critical thinking. The development and implementation of the summer program is supported by the grants funded by the US Army and the Robert Noyce grant funded by NSF. Educators are always looking for approaches to integrate exciting hands-on activities in teaching and learning to engage and build interest of High School students in STEM disciplines. Participation of High School students in land robotics has attracted many students to choose STEM education and careers. Technological advancements have introduced a new kind of flying robot called a Drone, which is an unmanned aircraft. The drone may be remotely controlled or can fly autonomously through software controlled flight plans along with the embedded microcontroller chip working in conjunction with onboard sensors and GPS receiver. Recently, flying robots has further enriched the interest of students in STEM disciplines which includes electronics, control, fabrication, mathematics, critical thinking, and computer programming. This paper presents the results of a five-week summer program for high school students. The participants of the program were 15 underrepresented students from rural school districts. During the five-week period, students were assigned several activities to program Quad-Copter Drone by using the software called scratch developed by Massachusetts Institute of Technology (MIT). This paper will also discuss the student group projects presented on the last day of the summer session and performance based on attainment of learning outcomes are evaluated by the faculty members. Some the items that were evaluated during the labs were how to follow Federal Aviation Administration Part 107 Regulations including pilot certification and drone safety, drone system components, aerodynamics, programming, flight preparation and planning and lastly summary reporting. In addition, the paper will also present the results of the survey given to the participants to determine the effectiveness of the five-week summer program.

Introduction:

Through grants funded by the US Army and Robert Noyce grant funded by the NSF, a course was developed and implemented to provide STEM activities that promote the interest of High School students to pursue STEM education in college. The course developed was five weeks given to High School students during their summer break. We used hands-on Robotic activities to motivate the students to further their knowledge and interest of STEM disciplines. Robotics is an interdisciplinary field that combines a number of disciplines in STEM education. Aerospace activities also provide an interesting juxtaposition of many STEM fields. Programming flying robots or drones were chosen as a major activity during the course [1, 2]. Quad rotor Drones are used today in all sort of capacities like agriculture, surveillance, photography, firefighting, search and rescue, mapping, etc. Human Robot Interaction (HRI) is the field of study dedicated to the design of robotic system for use by or with humans. In the five-week course focus was placed on HRI implementations and design. The final project for the student teams was to write a program to control the Drone.

Student group programming projects were presented on the last day of the summer session and performance based on attainment of learning outcomes are evaluated by the faculty members. Some the items that were evaluated during the labs were how to follow FAA Regulations including and drone safety, drone system components, aerodynamics, programming, flight preparation and planning and lastly summary reporting. In addition, the paper will also present the results of the survey given to the participants to determine the effectiveness of the five-week summer program.

Robot and Drones:

Robots are like high maintenance children that need clear directions on what they need to do. Robotics is the culmination of various disciplines including Mechanical, Electrical, Computer Science, and Computer Engineering. But it also can include various other disciplines like environmental, psychology, biology. In order to program robots successfully we need to relay as many detailed instructions as possible and let the robot have enough time to think about those instructions.

If we tell a human to move forward, they will keep going until they hit an obstruction

If we tell a drone to move forward it will eventually crash into something. When programming a robot you need to specify:

- 1) Speed
- 2) Direction
- 3) Time to Execute Action
- 4) Time to Process Information

Quad-Rotor Drones are used today in all sort of capacities like agriculture, surveillance, photography, firefighting, search and rescue, mapping, etc.

The main question we posed to the student for the course was “How do drones become smart and how can they interact with humans?” Human Robot Interaction (HRI) is the field of study dedicated to the design of robotic system for use by or with humans HRI includes the ability to control robots, such as with your hand or with a controller [3]. Students watched two videos for inspiration on two different Drone HRI Interfaces. The first video was on the HRI for the DJI Spark Drone and the second for the AR Parrot Drone [4, 5].

Programming assignments in the course built upon one another giving scaffolding for the final project. The final project was to create their own HRI for the Parrot Quad-Copter Drone.

The student group's final project was to create their own unique app that will control the drone using Scratch. They were judged on functionality, usability, and drone control. Similar to the AR.Freeflight on student's phone they used to control the drone, groups were required to use the graphic display area of Scratch window to control App. The App needed to control all aspects of the drone and needed to also output data coming from the drone. The groups had to make sure their designs were user friendly. Groups presented their design to the class and needed explain and justify their design.

The groups used Google to get pictures of what current drone apps look like for inspiration. Groups had to design the app on paper first and ask instructor if they are missing anything. Groups were encouraged to Import graphics to enhance their designs. Groups were encouraged to not limit designs to clicking things on the animation screen, but move objects within the animation pane to control the drone

How AR Parrot Quad-Copter Drone Fly:

The Drone utilizes two pairs of counter-rotating propellers

All rotors moving at the same speed to allow the robot to hover and to provide the lift necessary to keep it in the air to move the drone forward, the drone tilts forward by increasing the speed of its back motors Lift overcomes the downward force of gravity and the drag force caused by the air resistance as the quad rotor moves through the air. A component of lift is in the forward direction and causes the craft to fly forward. A more detailed description of how the Drone fly's is given in the section on Manual Control of the Drone.

Robots need time to process the information students code are giving them, students needed to make sure it had enough wait time for the requested action to take place. We recommend students use wait times of more than 3 seconds.

Drones get tired now and then, and their sensors often get confused. The AR Parrot 2.0 Mobile App was used to calibrate the drone for any drifting. Battery Life was 12 min on your drone when fully charged. The Battery life of 12 min was more than enough time for our labs.

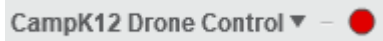
Visual Odometry:

There is a camera on the bottom of the drone that helps keeps it stabilized while in flight. If the drone sees a consistent surface or patterned surface it has trouble finding where it is in the world and starts to drift. However, if there are inconsistencies on the surface then the drone can use those inconsistencies on the ground to see where it is in the world and remain stable.

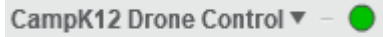
Drone Safety:

Drones are fun, but they can really hurt you. Many researchers often get injured for not executing proper drone research safety. The rotors on the drone can cause serious injuries and setting the drone at high speeds while running experimental code can be dangerous. The main points for safety were given were provided to the students shown below:

- Keep the indoor hulls on at all times. Do not use the outdoor hull.
- When picking up the drone, close the server command prompt to disconnect communication to the drone. **Unless you want to execute your code close the terminal and make sure the below indicator is red.**



- Keep a good distance from the drone. About 2 meters worth.
- Do not pick up the drone while the server connection is active. The connection is active when the below indicator is green.



- Flying drones indoors can create a lot of wind, if there are objects around you like chairs, wind can bounce off those objects creating a down draft on the drone, causing it to lose control. Keep the space where you are flying the drone as empty as possible.
- Always keep your drone in your line of site, if the drone is not doing what you want it to, kill the program immediately
- If the drone is not responding to your commands, properly keep your distance away from the drone and have a supervisor handle it
 - o All code needs to have a land command available like the one below in Figure 1.



Figure 1. Landing Code

- Do not put any speed greater than 40 in your code (0.4 meters/sec).

Scratch:

Students wrote all there code using the Scratch Integrated Development Environment (IDE) and graphical programming language [6]. Scratch was developed by Massachusetts Institute of Technology (MIT) to teach students programming. We also used software developed by the Camp12 India STEM program that provides a interface between Scratch and the Parrot Quad-Copter Drone [7].

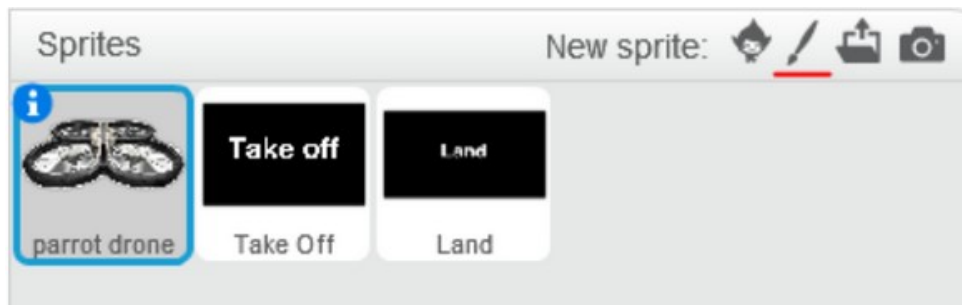


Figure 2. Sprites for Parrot Quad-Copter Drone and Camp 12 Extension

Scratch is an introductory programming language IDE (Integrated Development Environment) that helps students learn how to actually think like a programmers. By moving various blocks around, you can control aspect of what happens on the animation screen on scratch and control the Drone though extension blocks and Sprites. Sprites are objects in Scratch that have code attached to the Sprite. The Sprite is displayed and the graphics window of Scratch. Events trigger different Threads of Scratch

code. Events can occur for a number of reasons, such as starting the Scratch. The students learned Scratch through Video Tutorials that made games [8]. Pseudo-Code was used to help students learn how conditional statements work. Students were given Pseudo-Code they had to implement in Scratch, and as an aid to designing there Scratch Drone programs.

The Camp 12 Extension blocks that could be added to code controlled the drone as well as read the sensors from the Drone such as altitude. Table 1 shows all the Camp 11 Extension blocks for the Parrot Quad-Copter Drone [9].

"takeoff"	"land"	"stop"	"disable Emergency"
"up"	"down"	"left"	"right"
"front"	"back"	"clockwise"	"counter Clockwise"
"flip Ahead"	"flip Left"	"yaw Shake"	"wave"
"battery Percentage"	"clockwise Degrees"	"altitude Meters"	"front Back Degrees"
"left Right Degrees"	"x Velocity"	"y Velocity"	"z Velocity"

Table 1. CampK12 Drone Control Commands

The commands altitude Meters, x Velocity, Y velocity and z Velocity were the feedback from the Drone sensors. Speeds in Scratch for the Drone is specified from 0-100. The students had to divide the number by 100 after reading the value and convert from m/s to 1/100th m/s units when commanding the Drone to move. Students learned to do the conversion by canceling units as in the example shown in Figure 3. We put a speed of 30 for 10 seconds to move forward. Speed of 30 in Scratch is 0.3 m/s.

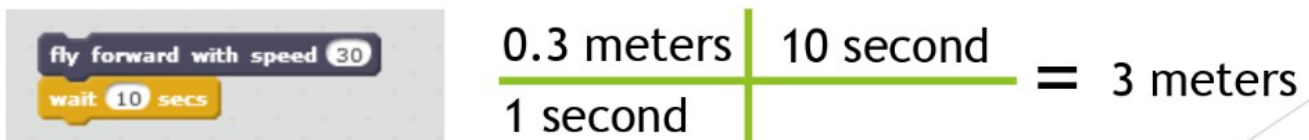


Figure 3. Example of How students learned Conversion for Speed.

The procedure start Camp 12 Extensions and the student’s first assignment with the Drone is given in Appendix A.

The first Scratch program using the drone and a condition statement had as a goal is to have the drone move up and down based on the output of altitude sensors. At the bottom of the drone, there is an Ultra Sonic Sensor which helps determine the drone’s altitude. Additionally the drone is equipped with an Internal Measurement Unit (IMU) that provides information of the orientation and position of the Drone.

Using the output of the sensors, the students were ask to have the drone move up till it reaches a height of 3 meters and then move down till it reaches a height of 0.5 meters with Scratch. The drone should keep doing this until the “l” key was pressed to make the drone land. Figure 4 is a student’s Scratch code to solve this problem.



Figure 4. Example of Student Code

Manual Control:

Prior to programming the Drone to actually fly with Scratch students had to learn on to fly the Drone Manually using AR.Freeflight App on student phones. Rather than a lab report students turned in a Flight Plan and After Report to get use to the concept. Students first watched a video on using AR.Freeflight App on computers, before do actual flights 1 to 8 listed below:

1. Lift the drone to a 3ft hover and stabilize hover.
2. Fly the drone 10ft forward and stabilize hover.
3. Fly the drone 10ft left and stabilize hover.
4. Turn the drone direction 180 degrees to the right and stabilize hover.
5. Fly the drone at an angle so it is 2 meters in front of the pilot and stabilize hover.
6. Turn the drone 360 degrees to the left so the drone is again pointing away from the pilot.
7. Fly the drone backward to just in front of the pilot (slowly)
8. Land the drone 2 meters away in front of the pilot.

Student Flight Plans for 1-8 consisted of hand drawn flight graph paper, with the planned flight route and maneuvers depicted. The After Report consisted of a one paragraph summarizing success and any problems in controlling the Drone, a What, When, where and Why errors happened. If a pilot had trouble with a maneuver the instructor assisted the pilot. Completion of these assignments 1-8 gave the students a good idea of flying drones manually. After showing basic proficiency with the Drone students could plan their own flights. While a student's flew the Drone Manually, the rest of the drone pilots spent their time working on their Scratch programs.

FAA Regulations:

Since we were flying under student developed software code, we needed to fly indoors to meet FAA regulations. Even indoors we set the configuration to 12ft altitude for the area in lab and 20ft for the gym. Since students were excited about Drones, we wanted them to know what the FAA regulations were [10].

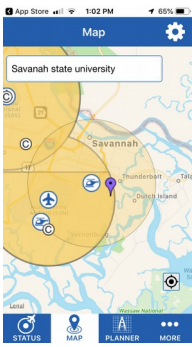


Figure 5 B4UFLY

We reviewed the FAA resources to become a Drone pilot and talk with a Commercial Pilot about Aviation and Drones. Screen shot of the FAA B4UFLY App in Figure 4 showing University and Airspace surrounding University. As can be seen in the screen shot Hunter's Army Airbase and a Hospital helicopter pad is near the University. The B4UFLY App needs cell phone reception to work and helps determine what the airspace restrictions are where you are flying. As a drone pilot students must understand how to meet the Federal Aviation (FAA) regulations and work as part of the aviation community.

Students explored FAA's website at this address with the resources and regulations regarding flying drones:

<https://www.faa.gov/uas/>

Next is the link to where students can fly their own drones:

https://www.faa.gov/uas/recreational_fliers/where_can_i_fly/

Conclusion:

There were five student groups of three students each, to create their own HRI to control the Drone. Three groups mainly used the keyboard to control the Drone. These groups took advantage of the Takeoff and Land sprites in the graphic area.

The last two groups used the mouse to control the Drone, using the graphics area to click on sprites that were stationary on the graphics display. The graphics display was similar to AR.Freeflight display.

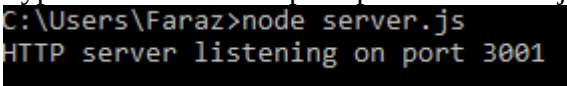
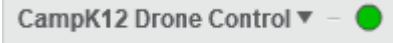
The students gave positive feedback about the summer program. One student said "could not believe" he wrote a program to make the Drone takeoff, fly forward, and flip in the air and land.

References:

- [1] Best drones for stem <https://edventures.com/blogs/>
- [2] Drones in Education <https://www.halfchrome.com/>
- [3] Human Robot Interaction https://en.wikipedia.org/wiki/Human%E2%80%93robot_interaction
- [4] DJI Spark HRI: <https://www.youtube.com/watch?v=74Cm1p3fr0g>
- [5] HRI with AR Parrot Drone:
<https://www.youtube.com/watch?v=tsVPTTDCBKw&list=PLhQQrDRVtg-5k2BSm9TC6AJF8UjGDFAOD&index=2&t=0s>
- [6] Scratch IDE <https://scratch.mit.edu/download>
- [7] Camp12 Founded by an MIT alumnus, edtech startup Camp K12 aims to catch entrepreneurs and innovators young by [Harshith Mallya](#) posted on 2nd December 2016
<https://yourstory.com/2016/12/camp-k12/>
- [8] Scratch Tutorial Games <https://scratch.mit.edu/projects/editor/?tutorial=getStarted>
- [9] Camp12 Scratch for AR Parrot Quad-Copter Drone
<https://github.com/campk12/ScratchForARDrone>
- [10] FAA Website FAA <https://www.faa.gov/uas/>

Appendix A Flying the Drone via Scratch

Your first assignment will be to have the drone take off, rotate 90 degrees, and then land.

1. In your “Intro to Drones” folder, open the script that says Take off and rotate _Student
2. This script will have the drone take off and then land.
 - a. There is an issue with this script, see if you can fix the issue. You should be able to fix it without having to add any extra blocks
 - b. To connect to the drone
 - i. Turn the drone on by connecting the battery.
 - ii. Wait until all the drone’s bottom lights are green, this means it is in pairing mode
 - iii. Next, connect the Laptop to the drone’s Wi-Fi, like how you did on the phone. Only connect to the drone’s Wi-Fi
 - iv. Once you are ready to run script, open the command prompt on your computer (you type “command” in the search bar)
 - v. Type in the command prompt “node server.js” and this should come up

 - vi. The below indicator should turn green
 1. 
 - vii. **THE ABOVE INDICATOR SHOULD ONLY BE GREEN WHEN YOU ARE EXECUTING THE DRONES SCRIPTS, THE INDICATOR SHOULD BE RED AT ALL OTHER TIMES. AFTER EXECUTING YOUR SCRIPT, CLOSE THE COMMAND PROMPT.**
 - c. Test out the given script to do a take off and land and see if you can fix the problem with the script
 - d. Next, write a script that will have the drone take off -> hover -> rotate about 90 degrees clockwise -> then land
 - i. Remember what we talked about for wait times
 - ii. Rotations are done in degrees per second in Scratch for the drone
 - iii. Remember what we talked about for visual odometry
 - iv. All the drone commands can be found under “More Blocks” which are all dark purple in color. Meaning, all dark purple blocks in your script control the drone
 - v. The “Stop Everything” drone block is the hover state for the drone
 - vi. Under the drone blocks, there are some check boxes that help you read some data. Perhaps these can be useful for your take off and rotate script. Check the battery percentage block.