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# Exposing Students to STEM Careers through Hands-on Activities with Drones and Robots

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# Exposing Students to STEM Careers through Hands on Activities with Drones and Robots

Autonomous robots have been used in a variety of ways from collecting specimen in hazardous environments to space exploration. These robots can be found in various manufacturing systems as Autonomous Guided Vehicles (AGVs) to transport parts and assemblies throughout the manufacturing system. They have also been used as a vehicle to convey design thinking and other STEM-related concepts in mechanical engineering/mechanical engineering technology, electrical engineering/electrical engineering technology, computer science, and computer engineering. Various outreach events have included robotics based activities that engage students in building and programming autonomous robots for the purpose of achieving a specific task. These events are often found in schools in a form of STEM outreach, career days, robotic competitions, or during residential on-campus programs. This paper focuses on three robotics related sessions conducted during a three-day summer residential program for high school students offered at Old Dominion University, Norfolk, Virginia during the summer educational program named ODU BLAST. ODU BLAST is part of a Virginia Space Grant Consortium initiative called Building Leaders for Advancing Science and Technology (BLAST), offered at three different universities in the Commonwealth of Virginia.

## Introduction

Robots are a technological advancement used in multiple work environments in exchange for human labor. Robots have been used to replace humans in boring and repetitive jobs, e.g., welding [1] and assembly [2]; as substitutes for humans in unknown environments, e.g., Mars explorations [3, 4]; in decreasing human exposure in dangerous work environments, e.g., repairs in nuclear plants [5]; and in the collection of specimen and cleaning after hazardous spills [6]. Robots can lift very heavy loads, perform repetitive tasks with excellent accuracy, and with recent advancements in artificial intelligence, they can complete extremely complex tasks [7-9]. Recent developments in autonomous robotics have led to advanced flying robots, or drones. Drones have been used in both civilian and military applications [10]. They have been used in geological education [11], sports education [12], archaeological education [13], disaster and emergency management [14], and as educational tools to excite students about STEM education [15, 16]. Educators have used them in geoscience studies to help students understand the earth's shape and structure, as well as climate-related events [17]. Geospatial skills are of high importance for various programs and many courses are embedding drones as instructional tools in support of student learning [18].

## Use of Robots in Hands-On (Active) Learning

There are various learning styles recognized by the education community, such as those that cater more to the active and sensing learners, and styles that fit better with reflective and intuitive learners. Learning about robotics and including robots in the instruction engages learners through hands-on exercises [19]. Various researchers agree that hands-on activities can assist students to relate to the concepts that are behind the technology used in these activities [20-22]. This is especially important in academic areas like mechanical principles where mathematical and engineering theory are connected with manual methods [23].

In education, robots are used in outreach activities to motivate students to become interested in Science, Technology, Engineering, and Mathematics (STEM) starting in kindergarten [24] and elementary school [25, 26] and beyond. Some studies have shown that the use of robotics as an instructional tool can enhance student learning related to computational thinking [26, 27] and technological fluency [28]. As robots have become more affordable, they have also become more common in K-12 classrooms [29, 30]. Robots used for educational purposes include LEGO Mindstorms, Vex Robots, and Sumobots [31-33]. Robots are also used in undergraduate education to accompany instruction related to programming skills and issues related to human-machine interface [19]. Moreover, various robotics competitions, such as First Robotics, Robocup Junior, and Eurobot Junior are engaging K-12 and undergraduate students in the designing, building, and programming of autonomous robots [34-36].

Many modern toys are essentially autonomous robots. Some offer apps that include concepts related to programming and controls, such as block programming, which can be found in toys like Kamigami robots [37], and trajectory planning, which can be found in toys like the Sphero robot. Some toys include advanced vision capabilities [38] and an interactive learning environment, such as the Cozmo robot. The Cozmo robot (shown in Figure 1) is an autonomous robot that is shaped like a truck [39]. It integrates computer vision capabilities with artificial intelligence algorithms [40]. Children can interact with it and see how the robot can read information from the objects in its proximity, which is important for various applications in material tracking. It also has vision recognition capabilities that are similar to the algorithms that are used to identify parts in the manufacturing process. Kamigami robots have a platform that can be integrated with the app, available for installation on mobile devices, and has a human machine interface that can access various robot modes: code, dance, battle and tag. In this way, children can learn about various way that robots interact with each other and how they can receive instructions.

Figure 1: Cozmo robot [38] and Kamigami robots [37]

### Summer Residential Program focused on Climate Change and Sea Level Rise

Since 2016, at Old Dominion University, drones have been used in a summer STEM-related residential education program for high school students focusing on mitigating the impacts of, and building resilience to, climate change and sea level rise. The "Building Leaders for Advancing Science and Technology" (BLAST) is a collaboration among the funding agency, the Virginia Space Grant Consortium, and three state universities. The main focus of the program is to increase STEM interests in high school students and to ultimately impact their decision to choose STEM-related careers. The program is offered to students free of charge. The three-day residential program is designed around four three-hour, hands-on, intensive workshops taught by faculty and staff with the aid of graduate and undergraduate students. The program is intended for 80 rising 9th and 10th grade students, who have a minimum of a C+ average, are U.S. Citizens or permanent residents, and Virginia residents. Students can attend only once and have to be transported to the university by a family member or a legal guardian. Students stay on-campus from Sunday evening to Wednesday morning, sleep in dorms, eat in the dining halls, attend classes and work in the labs; in essence, they get to experience life as an on-campus undergraduate student. At the university BLAST sessions, there are two major workshop sessions and one special evening event that embeds the use of autonomous robotics in instruction: 1) Satellites, Lasers, and Drones; 2) Robots in Hazardous Environments; and 3) It's a Bird, It's a Plane, It's a Drone.

*Satellites, Lasers, and Drones.* This activity is led by the University's Director of Geospatial and Visualization Systems, who is also a graduate student in Ocean, Earth, and Atmospheric Sciences in the College of Science. In this session, participants are divided into four 5-person teams. They collect and measure geospatial data used to create maps of vulnerable areas due to flooding and sea level rise. This session conveys the critical importance of geospatial tools and technologies in recording, understanding, and communicating the impacts of sea level rise and storm surge flooding.

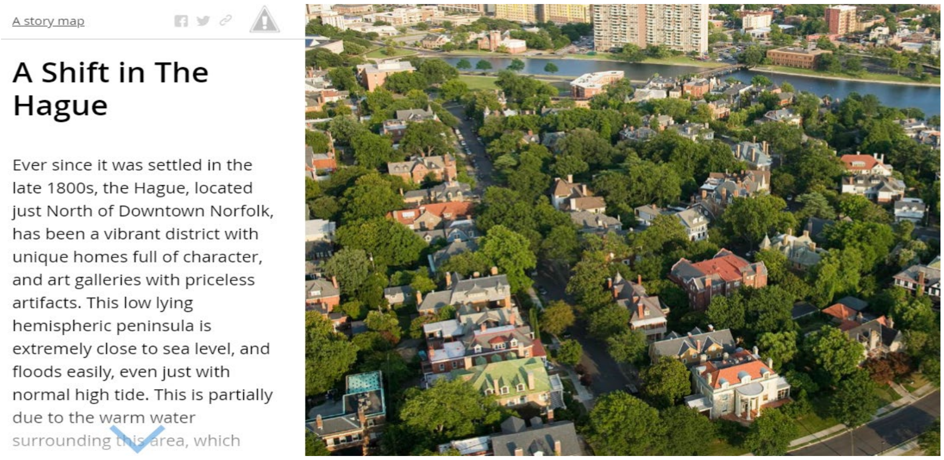
Students are introduced to a 4-step Geographic Information Systems (GIS) problem-solving cycle as a framework for how geospatial scientists tackle the problem of flooding. Students are tasked with answering the fundamental question: How will flooding from sea level rise impact my community? They conduct the following four primary tasks as they work towards developing their answer: Task # 1: Planning to collect location information and pictures of buildings and areas impacted by flooding; Task # 2: Collecting simulated flood damage data using GPS, tablets, and digital cameras; Task # 3: Performing visual overlay, analysis, and synthesis of flood hazard data; and Task # 4: Communicating their findings by creating an interactive “live” Esri Story Map website.

Figure 2: Hands-on session on the use of drones in geospatial technology to create a more accurate representation of flooding that happens due to the sea level rise

Students created videos with camera mounted on the drone, as can be seen in Figure 2.

Figure 3: Drone raw video created by one group of participants in the Satellites, Lasers, and Drones session, uploaded to YouTube [41]

Each group created a set of online data that focused on a different flood prone neighborhood in the Hampton Roads area. Examples of such story maps are given in Figures 4 and 5.

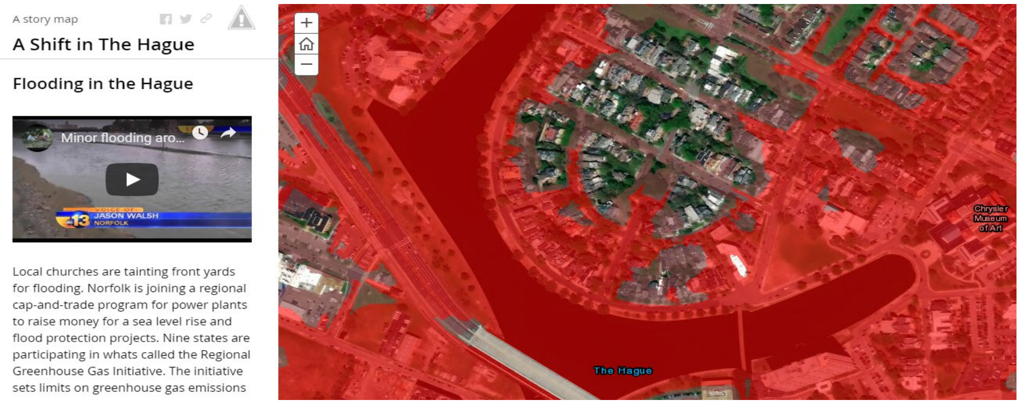


A story map

A Shift in The Hague

Ever since it was settled in the late 1800s, the Hague, located just North of Downtown Norfolk, has been a vibrant district with unique homes full of character, and art galleries with priceless artifacts. This low lying hemispheric peninsula is extremely close to sea level, and floods easily, even just with normal high tide. This is partially due to the warm water surrounding this area, which

Figure 4: Story map describing sea level rise issues in The Hague neighborhood, Norfolk, VA



A story map

A Shift in The Hague

Flooding in the Hague

Local churches are tainting front yards for flooding. Norfolk is joining a regional cap-and-trade program for power plants to raise money for a sea level rise and flood protection projects. Nine states are participating in whats called the Regional Greenhouse Gas Initiative. The initiative sets limits on greenhouse gas emissions

Figure 5: Webpage showing videos and different scenarios of sea level rise effects

*Robots in Hazardous Environments.* In this session, an Engineering Technology professor, along with graduate and undergraduate students, leads participants in the exploration and use of robots in collecting samples in hazardous environments. The session starts with peer-mentor introductions, answering questions, and an icebreaker activity. The workshop moves to a short presentation on robotics and a discussion on the different engineering and science fields related to designing, building, testing, and using robotics as a major technology in the workplace. Other than this initial lecture and technology exploration, the hands-on session is focused on exposing participants to robotics through educational manipulatives. One of the main goals is to expose students to different robotic technologies and resources including the humanoid robot NAO by Aldebaran Robotics, now known as SoftBank Robotics, Kamigami robots, and various small autonomous robots that can be bought in bookstores and are widely accessible for K-12 populations. Students also heard about engineering technology, mechatronics, and advanced manufacturing. They learned that the skills they build while exploring robotics through the use of educational toys can be applied for future careers in advanced manufacturing, such as technicians, engineering technology, or engineering graduates. While learning about engineering design and constraints, students build, test, and revise their robots. Throughout the process, students are assisted by peer-mentors who are proficient with LEGO Mindstorms, as shown in Figure 6. Mentors were from middle school, high school, and from graduate programs.

Figure 6: Graduate student teaching participants how to program LEGO Mindstorm robots.

*It's a Bird, It's a Plane, It's a Drone*. In this special evening event, an engineering professor, who has expertise in controls and aerospace, conducts a hands-on intensive build and fly drone event designed to introduce students to the basic principles of flying and the potential use of drones as a means to distribute food and medicine under adverse conditions due to climate change and sea level rise. Students are divided in two groups of 40 students each. The drones built during this session are shown in Figure 7.

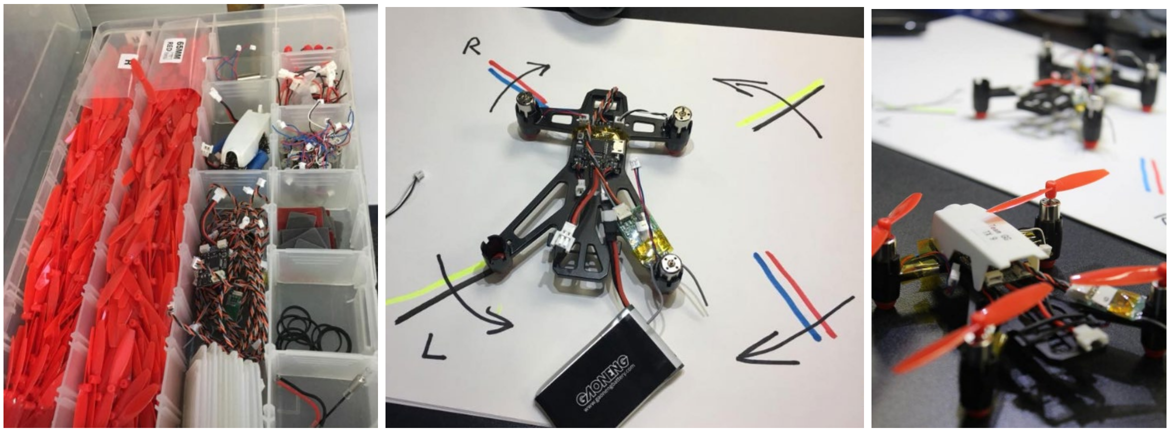


Figure 7: Drones to the Rescue session – hands on activity that includes building a drone.

The students are exposed to instruction from a professor who actually teaches a class focused on designing and building drones in the Department of Mechanical and Aerospace Engineering. The session ends with a drone flying competition, supported by students from the Drone Club. Multiple members are students from the Batten College of Engineering and Technology. They also shared their perspectives through these interactive activities. The Drone competition was conducted indoors due to flight regulations in the local area given its proximity to multiple airports; thus, students built and flew the drones inside the student recreational facility in one of the basketball gyms with a high ceiling.

## Continuous Improvement

This educational program has been delivered to 320 students in 9th and 10th grades in four sessions, which had 80 participants in each. It was first offered in 2016. The second year had two sessions (in 2017) and the third year had one session. Each one of the sessions had 40 female and 40 male students. Data was collected before and after the program by the Virginia Space Grant Consortium so that the same questions could be asked at all three universities. The survey was focused on capturing student interest in the areas of science, technology, engineering, and mathematics and feedback on the sessions. Collected data was used as a basis for internal continuous improvement. One thing the researchers learned over the years is that small drones get damaged during the flying so badly that they had to purchase new kits each year. The session that uses drones as a way to collect geospatial data uses more high-end drones and tablets that are reusable. LEGO Mindstorms, Kamigami and Cozmo robots can be recharged and reused. Thus, while the cost of the workshop is high for the initial setup, since it is recurring, the total cost is lower since these robots needs less maintenance, and while they might possibly need the replacement of some parts and batteries, the whole robots do not need to be replaced.

## Conclusion

Learners in the twenty-first century often have early access and exposure to the advanced robotic skills through such platforms. Such skills can be used to build a future workforce in the area of advanced manufacturing, more specifically in robotics. Learning about autonomous robots and the way that they are built and controlled is a transferable skill for future numerically controlled machines, such as CNC machines, additive manufacturing equipment, industrial robots, or autonomous robots like AGVs that can be found in industrial shop floors. Participants in this camp explored different STEM fields through the residential program that focused on the overall theme of sea level rise and building resilience and mitigation that provides scientific and engineering solutions to the ever-changing environments on Earth. Three of these sessions included interaction with autonomous robots. Students focused on building robots that can work in hazardous environments, but they also learned about different majors that explore robotics concepts in manufacturing, as well as the application of hydraulics for flood gates.

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