Operation DroneDrop: A study into drones; their capabilities, governmental regulation and ethical considerations; with a deeper dive into drone usage in search and rescue operations

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ABSTRACT

Gear up, future sky captains! Prepare to dive into the fascinating world of drones, from their buzzing mechanics to their soaring capabilities. Unravel the mysteries of these aerial marvels, exploring their diverse uses in photography, delivery, and even environmental research. But technology comes with responsibility. We'll navigate the legal and ethical landscapes surrounding drones, learning to be responsible pilots mindful of privacy. Witness the heroic role drones play in search and rescue, saving lives where humans can't reach. Then, peek into the future with medical delivery drones, bridging mountains and deserts to deliver critical supplies. Through interactive activities and thought-provoking discussions, students will develop critical thinking skills and a nuanced understanding of drone technology's potential and challenges. This unit equips students to soar into the future, understanding not just how drones work, but also how to use them responsibly and for good.

Keywords: drone, UAS, UAV, RPA, autonomous flight, Blockly, CoDrone EDU, programming

Unit Content

This unit will provide an introduction to the disruptors of the sky; drones. "These devices are frequently called 'drones'; though, military and legal jargon speak of 'remotely piloted aircraft' ('RPAs'), 'unmanned aerial vehicles' ('UAVs') or 'unmanned aerial systems' (UASs')." [1] This may seem like we are talking about a Jetson-type future, but the reality is that drones or UAVs have been around for quite some time. "The term unmanned aerial vehicle (UAV) was first coined in the 1980s to describe the autonomous, or remotely controlled, multi use aerial vehicles that are driven by aerodynamic forces and are capable of carrying a payload."[2] This innovation marked a departure from conventional military technologies of the time, including balloons, gliders, and cruise missiles.

In military applications, drones demonstrated unparalleled access to critical and hazardous areas, operating with speed and stealth beyond human replication.The principles of flight for a drone

[1] Sara M. Smyth, "Keep Calm but Don't Carry on: New Drone Regulations in the United States," Journal of Law, Information and Science 25, no. 2 (2021): 49-88

[2] Rosser, James C et al. "Surgical and Medical Applications of Drones: A Comprehensive Review." JSLS / 22.3 (2018): n. pag. Web.

are very simple and easy to achieve. The quadcopter-type drone, of which we will be using in the unit, consists of four propellers. When in motion these propellers spin and push air downward, however, applying Newton's Third Law of Motion. This law dictates that for every action, there is an equal and opposite reaction, causing the drone to ascend when the upward force surpasses the force of gravity. [3]

But how does the drone move sideways, turn around, rise, and lower? It's all in the motors. Drones adhere to some of the same principles as a helicopter, they can tilt, roll, and yaw. To tilt means for the drone to move forward and backward. A positive tilt will propel the drone forward, while a negative tilt will propel the drone backwards. For a drone to roll, we are looking at the drone's horizontal or side-to-side movement. This movement is achieved through the manipulation of the motors on only one side of the drone. If the left propellers are spinning at a lower speed than the right side propellers, then the drone will move to the left and vice versa. Yaw is used to manipulate the drone's left and right rotation. To control the yaw, you will be employing the use of diagonal propellers. When one diagonal pair is rotating faster than the opposite diagonal pair, yaw is achieved.[4] This allows the drone to turn left and right. However, the capabilities of the drone do not stop there.

Drones can not only hover, fly, land, and maneuver that all important-figure eight, but they are also equipped with highly capable sensors. "Payloads can include remote sensing equipment, including electro-optical (E-O) with color, infrared, multispectral and hyperspectral cameras. Other options are synthetic aperture radar (SAR), light detection and ranging radar (LiDAR), ground penetrating equipment (receipt, transmission, and relay), and cargo."[5] These powerful sensors imbue the drone with capabilities no other piece of technology has been able to manage in one package. Drones can monitor vineyards and send an alert when they need watering. They can determine the health of crops and diagnose when and how farmers should intervene. In the construction industry, drones can survey hazardous areas to determine the structural integrity of a structure and determine the best repair solution. Our partners in the sky can even search for hazardous and radioactive materials, preventing unnecessary risk to human lives.[6] And one of its most important capabilities is in the search and rescue of humans. More about that later.

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[3] NASA. 2020. STEM LEARNING: Advanced Air Mobility: The Science Behind Quadcopters Reader—Student Guide.

[4] RoboLink. 2020. "2.2: Flight Directions – Robolink Basecamp." Robolink Basecamp. https://learn.robolink.com/lesson/2-2-flight-directions-senior-cde-blockly/.

[5] Rosser, James C et al. "Surgical and Medical Applications of Drones: A Comprehensive Review." JSLS / 22.3 (2018): n. pag. Web.

[6] Sara M. Smyth, "Keep Calm but Don't Carry on: New Drone Regulations in the United States," Journal of Law, Information and Science 25, no. 2 (2021): 49-88

All of the wonderful capabilities of our drone partners come with strings; governmental oversight. Although governmental agencies have been using drone technology far longer than many Americans realize, it wasn't until 2013, when FBI director Robert Muller testified that the FBI had been using unmanned aircraft for domestic surveillance.[7] It had come to light that drones were being used to patrol our borders, surveil populated areas, and monitor traffic patterns. This is above and beyond the various military operations and missions that utilize drone technology. But what do government regulations say about the hobbyists, the educational flyers, and the children who enjoy flying drones? The answer came in 2012 when Congress tasked the Federal Aviation Administration (FAA) "to develop a plan to integrate unmanned aircraft into the national airspace with a deadline of September 2015."[8] The initial task undertaken by the FAA was to categorize drones and establish an organized system, laying the groundwork for regulatory discussions. The criteria considered for classification included size, function, and usage. Following careful evaluation, they concluded that size, function, and usage would be pivotal factors in this classification process. They concluded that,

"Regulations pertaining to recreational drone use, defined as any operation not for profit or commercial gain, fall under the FAA rules for all model aircraft which prohibit careless and reckless operation. Recreational drones are prohibited from flying within five miles of an airport, operating within "drone free zones" (such as sporting events), must fly below 400 ft and within the visual line of sight of the operator, and comply with all state and local laws (Federal Aviation Administration Modernization and Reform Act of, 2012)." [9]

This implied that individuals engaged in recreational drone piloting with units weighing less than 55 lbs. were included in the discussions while also being under surveillance. Furthermore, in 2015, the FAA instituted a new regulation requiring all flyers 13 years and older to register their drone with the FAA.[10] That was also the same time the FAA commenced a *Know Before You Fly* campaign to educate the public about flying drones safely and responsibly. The campaign highlighted key parts of the FAA Modernization and Reform Act of 2012. Among the key points were:

- Do not fly over or near sensitive infrastructure or property such as power stations, water treatment facilities, correctional facilities, heavily traveled roadways, government facilities, etc.;
- Do not intentionally fly over unprotected persons or moving vehicles, and remain at least 25 feet away from individuals and vulnerable property;
- Do not fly in adverse weather conditions such as high winds or reduced visibility;
- Do not be careless or reckless with a UAV. [7]

[7, 8, 9, 10] Zwickle, Adam, Hillary B Farber, and Joseph A Hamm. "Comparing Public Concern and Support for Drone Regulation to the Current Legal Framework." *Behavioral sciences & the law.* 37.1 (2019): 109–124. Web.

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In October 2018, the state of Pennsylvania spoke up with their own drone regulation. It enacted Act 78 which states that UAS Law makes it a crime to operate a drone:

- to conduct surveillance of another person in a private place;
- in a fashion that places another person in fear of bodily injury; and
- to deliver, provide, transmit, or furnish contraband. [8]

What about the commercial industry you ask? This is a bit more complex. The United States airspace is controlled by the FAA and divided into several classes.

"Most commercial aircraft operate at altitudes between 18,000 and 60,000 feet above sea level, which is known as Class A. Classes B, C, and D make up the airspace immediately surrounding airports, mandating safe approach and departure. Classes B and C are used to control traffic flow around airports with heavy and moderate traffic; while Class D is used for traffic control at smaller airports, often with no control tower. Operations within Classes A, B, C, and D are strictly controlled, and each class has specific requirements, such as contact and clearance from air-traffic control, and communication between the airport and the pilot. The other two airspace classifications are E and G, which are not as extensively regulated as Classes A-D. Class E is everything above 60,000 feet and everything below 18,000 feet, down to about 700 feet above the ground that is not already classed B, C, or D. Class G is everything between Class E and the ground and it is completely uncontrolled." [9]

So what does this mean for drone pilots? This means that typically, drones that are used for surveillance, search and rescue, inspections, etc., weigh less than 55 lbs., and fly in Class G airspace, cause concern for the government and the general public. Why is all of this so concerning? To address that we need to look at two different aspects of the issue; safety and privacy.

With the multitude of recreational and commercial applications of drone flight, there are bound to be safety concerns. Sara Smyth addressed several of these concerns in her article, *Keep Calm but Don't Carry on: New Drone Regulations in the United States*. In her article, she speaks about three main safety concerns: Sense and Avoid Technology, Vulnerabilities in Command and Control, and Human Vulnerabilities and Unreliability.

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[8] Wolfe, Tom. 2018. CRIMES CODE (18 PA.C.S.) and MUNICIPALITIES (53 PA.C.S.) - UNLAWFUL USE of UNMANNED AIRCRAFT and PROHIBITING LOCAL REGULATION of UNMANNED AIRCRAFT. https://www.legis.state.pa.us/cfdocs/Legis/LI/uconsCheck.cfm?txtType=HTM&yr=2018&sessInd=0&smthLwInd=0&act=78.

[7,9] Sara M. Smyth, "Keep Calm but Don't Carry on: New Drone Regulations in the United States," Journal of Law, Information and Science 25, no. 2 (2021): 49-88

She explains the concern with the sense and avoid technology is that it will never be as responsive as a human. The smaller drones are not equipped with the array of technology that larger air vehicles carry to identify and avoid other aircraft and obstacles. Thus the FAA has spent an enormous portion of the regulation addressing this concern. The current solution is to restrict when and where drone operators may fly and to insist that the pilot maintain a line of sight with the vehicle at all times.

Another concern is the vulnerabilities in command and control. This is concerning because "_the command and control systems are not standardised nor are there standard 'fail-safes' in place if the link between a drone and a ground control station is lost due to environmental or technical problems."[10] Drones use public radio frequencies, the same or similar to WIFI used by mobile devices. In densely populated areas, the radio frequency can get congested and thus cause lost or unreliable connectivity leading to a loss in connection between the drone and pilot. This causes a major issue if the link between the drone and the pilot is disabled. The drone could lose control, crash, or cause harm to humans and damage property.

Smyth further goes on to state the issues with human vulnerabilities and unreliability. Even though drone usage was instituted as a way to mitigate human risks, this technology has created new challenges. One in particular is the inability of a pilot to have-first hand awareness of their surroundings. This causes a major issue when the situation changes rapidly and thus a costly delay in information transmission and reaction. Smyth reports that in a 2005 study, human operational or maintenance errors accounted for as many as 68% of military UAV accidents.[11] Part of this was due to the military's decision to move their UAVs from overseas locations to the US and conduct more flights in airspace shared with other aircraft. Smyth does note however, that the number of incidents has steadily declined over the years.

Although the government has dedicated many of its resources to addressing the safe integration of drones into our airspace, what about the issue of privacy? In the article, *Comparing public concern and support for drone regulation to the current legal framework,* by Adam Zwickle, he states that, "Risks to one's privacy, however, are significantly more difficult to both mitigate and regulate."[12]

Why are drones so concerning to the average person? What makes people apprehensive or untrusting of the pilot and their intentions? Zwickle proposes that, "The privacy concerns relating to drones stem from the types of technologies presently available which include high-

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[[10], [11]] Sara M. Smyth, "Keep Calm but Don't Carry on: New Drone Regulations in the United States," Journal of Law, Information and Science 25, no. 2 (2021): 49-88

[[12], [13, 14, 15]] Zwickle, Adam, Hillary B Farber, and Joseph A Hamm. "Comparing Public Concern and Support for Drone Regulation to the Current Legal Framework." Behavioral sciences & the law. 37, no. 1 (2019): 109–124.

resolution cameras, global positioning systems, night vision infrared cameras, thermal imaging devices, WI-FI sniffers, automated license plate readers, and facial recognition software." [13] These devices can locate, record, and disseminate information that was previously thought private. This causes concern on many fronts; ranging from concerns about how information gathered from government agencies is utilized, to stalking, harassment, and criminal trespass.

Through the study conducted by Zwickle's team, it was discovered that overall people were supportive of drone technology and did not want a complete ban, however, they were also in support of regulatory guidance to clarify the operation of the device. For example, the respondents were in favor of prohibiting drones from flying over private property, for an operator to obtain consent from anyone whose image was intentionally or unintentionally captured by a drone, and to impose a limit on how long a drone can fly or hover continuously.[14] Respondents were most supportive of drones being used for search and rescue missions, highlighting the clear understanding of the drone's ability to aid humans in risky situations. While individuals expressed apprehension about the prospect of drones handling package deliveries, this concern aligned with the government's existing position to restrict drone cargo delivery. So, what do the regulations dictate?

Currently, the FAA's stipulations only go so far as to direct drone pilots "to not fly drones in a careless or reckless manner."[15] To find regulations on public privacy, you need to look to the States. "As of 16 May 2017, 37 states have passed laws addressing UAV issues…"[16] However, there has been concern over the state's ability to enact laws over the National Airspace, which is under the domain of the FAA. On April 3, 2013, Virginia was the first state to tackle the issue of drone regulation and enacted the country's first drone law. The law imposed a 2-year moratorium on law enforcement's use of drones within the state.[17] This action was followed by Florida passing the Unwarranted Surveillance Act, which "protected citizens from 'privacy-invasive technology' by requiring a judicial warrant supported by probable cause before law enforcement can use a UAV".[18] Later, on October 12, 2018, Pennsylvania's then governor Tom Wolf signed Act 78 - *UNLAWFUL USE OF UNMANNED AIRCRAFT AND PROHIBITING*

[14] Zwickle, Adam, Hillary B Farber, and Joseph A Hamm. "Comparing Public Concern and Support for Drone Regulation to the Current Legal Framework." Behavioral sciences & the law. 37, no. 1 (2019): 109–124.

[15] Zwickle, Adam, Hillary B Farber, and Joseph A Hamm. "Comparing Public Concern and Support for Drone Regulation to the Current Legal Framework." Behavioral sciences & the law. 37, no. 1 (2019): 109–124.

[16] Sara M. Smyth, "Keep Calm but Don't Carry on: New Drone Regulations in the United States," Journal of Law, Information and Science 25, no. 2 (2021): 49-88

[17, 18] Sara M. Smyth, "Keep Calm but Don't Carry on: New Drone Regulations in the United States," Journal of Law, Information and Science 25, no. 2 (2021): 49-88

LOCAL REGULATION OF UNMANNED AIRCRAFT. This document essentially “makes it a crime to operate a drone:

- to conduct surveillance of another person in a private place;
- in a fashion that places another person in fear of bodily injury; and
- to deliver, provide, transmit, or furnish contraband.”[19]

While numerous states are deliberating on the matter, there is not a unanimous consensus on how to regulate the different aspects.

Let's tackle the meaty issues that hit close to home for all of us – property damage, stalking, harassment, criminal trespass, nuisance, and the blatant invasion of privacy. These are the real concerns that often slip through the regulatory cracks but matter a great deal to your average person.

Familiar with the drone light show fiasco in China on August~~on August~~ 2023? The connection between the pilot and the drone went haywire, witnessed by unsuspecting onlookers. This caused costly damage to nearby buildings and vehicles. Or the drone debacle in Perth, Australia, where a company watched over $100,000 of their drone technology fall into Swan Lake. Accidents happen, but who's left holding the bag? We're still waiting for clear-cut legislation to decide that.

Worried about becoming the star of an unwanted drone drama? Some states are finally waking up to the issue. While many already have harassment laws in place, they're now giving them a facelift to include drones. Take Arizona, for example – they're tweaking trespass statutes to cover the intrusion of drones. It's a sign that states are catching on to privacy worries and trying to rein in the shady use of this tech.

Privacy invasion, anyone? States are tinkering with laws to loop UAVs into the conversation, but there are gaps. In Idaho, for instance, they've put the brakes on citizens and law enforcement using photos or recordings without written consent. Yet, if your neighbor decides to spy on you undressing with a drone, it's not illegal unless they go full show-and-tell with the footage. The concerns are real and the legislation is trying to catch up, but one thing’s for sure, people agree that drones can definitely be used for the good of humankind.

Search, Rescue and Medical Applications

One of the most beneficial applications of drone technology is in the field of search and rescue (SAR). Drones have been used in military operations for several years, however, it wasn’t until

[19] Pennsylvania Department of Transportation. n.d. “Unmanned Aircraft Systems / Drones - Aviation.” PennDOT. Accessed November 20, 2023.

the technology became more cost-effective and the regulations more accessible for small organizations and municipalities to effectively utilize the technology.

So what makes drones a viable option for SAR? Drones can reduce the time needed for a broad search.[20] Instead of the time needed for the SAR team to mobilize, strategize, and then perform a foot-based search, a drone pilot and a single drone can cut down the time needed to reach the person in need by 50%. Drones also can carry payloads with various sensing equipment. “Payloads can include remote sensing equipment, including electro-optical with color, infrared, multispectral, and hyperspectral cameras.”[21] This type of equipment increases the efficacy of SAR missions tremendously. Drones can not only cover large distances quickly, but their high-resolution cameras enhance the ability of the pilot to locate lost, wounded, or otherwise disabled people. Furthermore, with an FAA Part 107.35 waiver and the advancements in navigation and object avoidance technology, the ability to use multiple drones or swarms is possible. This would allow one pilot to control multiple drones, providing for a broader search area. This would allow the drones to more rigorously survey one particular area and possibly use a lower altitude to collect more detailed information. However, more data means more time needed to analyze it. Now this is a job for machine learning. “Machine learning techniques, such as object detection algorithms can analyze tens of thousands of images quickly and accurately.”[22] Using this model will speed up the process of scouring through a multitude of images in search of humans with 83% accuracy.[23]

This leads SAR teams to another consideration, what if the person is injured and in need of medical attention? Drones are able to help locate the person but it will still take precious time for the rescue team to reach the area and administer medical care. In January 2023 a study was conducted to see if and how a drone could aid in a SAR mission with the added benefit of delivering medical equipment, thus endeavoring to reduce the treatment-free interval in the search and rescue operation. The study was conducted with multiple teams, half with the use of a drone and the other half without. The study concluded that the treatment-free interval was reduced with the teams outfitted with the drone than without. The drone teams on average were able to locate the patient in 14.6 mins. Whereas the non-drone-assisted teams were able to locate the patient with an average time of 20.6 mins. This was not the end of the drone’s capabilities. Once the patient and a planned bystander were located, the drone was instructed by the pilot to

[20, 22, 23] Project Vulture: A Prototype for Using Drones in Search and Rescue Operations by Quan, Andres; Herrmann, Charles; Soliman, Hamdy 2019 15th International Conference on Distributed Computing in Sensor Systems (DCOSS), 05/2019

[21] Surgical and Medical Applications of Drones: A Comprehensive Review by Rosser, Jr, James C; Vignesh, Vudatha; Terwilliger, Brent A ; More… Journal of the Society of Laparoendoscopic Surgeons, 07/2018, Volume 22, Issue 3

drop a parachute-equipped medical kit at a location close to the pair. "The kit was in a polystyrene box where there was a radio, first aid material, and personal protective equipment."[24] With this equipment, the bystander was instructed via the radio to give details about the patient and their injuries, and prevent further heat loss by applying a thermal cover to the patient. This action allowed for the patient to begin to receive medical attention, while also providing the SAR team valuable information. When the SAR team arrived, it took them less time to access and address the injuries and to provide needed medical care. In a real life situation, the use of drone technology could mean the difference between life and death.

The application of drones doesn't stop there. Drones have been used to deliver automated external defibrillators (AED) to be used by a willing bystander, as well as vaccines, antidotes, and other life-saving medications. While doing all of this in only a fraction of the time it takes conventional methods.[25] Furthermore, drones have been used to deliver telemonitoring with telemedical care. "Telemedicine - the remote diagnosis and treatment of patents by means of telecommunications technology. Telemonitoring is the provision of remote guidance by an experienced surgeon or proceduralist to a less experienced colleague_".[26] In a 1998 presentation, Dr. James C. Rosser, Jr. demonstrated how drones were used to "establish a wireless communication network between the surgeon and a robot to perform telesurgery." [27] This allowed the "surgeon to successfully operate robotic arms to perform exercises simulating surgical maneuvers." [28] This was all possible by using drones to establish a wireless communication network. Through this demonstration, it was highlighted that providing quality medical aid to patients in hazardous or challenging areas is still possible with the help of drone technology.

But let's think closer to home. Can drone technology be useful for transporting biological materials or delivering medications? Absolutely. "In 2014, the Medecins Sans Frontieres evaluated a drone-based system for delivering laboratory samples to hospitals for tuberculosis testing." [29] The study concluded that the drones were able to deliver the samples in less than 25% of the time it would take using conventional methods. The study also saw that the integrity of the blood samples was comparable to stationary blood samples. Looking at a more day-to-day

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[24] Project Vulture: A Prototype for Using Drones in Search and Rescue Operations
by Quan, Andres; Herrmann, Charles; Soliman, Hamdy
2019 15th International Conference on Distributed Computing in Sensor Systems (DCOSS), 05/2019

[25, 26, 27, 28] Surgical and Medical Applications of Drones: A Comprehensive Review
by Rosser, Jr, James C; Vignesh, Vudatha; Terwilliger, Brent A ; More...
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[29, 30] Surgical and Medical Applications of Drones: A Comprehensive Review
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approach, the United States has already approved a medical delivery system in rural Virginia, in which a drone was used to "expedite the drug delivery process, thus improving patient care." [30] Furthermore, the US military has been experimenting with using drone technology for patient transport. This would involve using VTOL drones to extract injured soldiers and safely deliver them to a designated space.

So far, we have counted numerous ways in which drones can be and are useful during SAR operations, as well as their ability to aid in telemedicine and medical delivery. But what of the considerations and concerns?

Drone Considerations and Concerns

One area of concern is the durability and capabilities of the drone itself. Drones aiding in SAR operations are great. They save precious time locating injured humans. They traverse hazardous and inaccessible terrain and collect and transmit real-time actionable data, however, this all comes at a cost. Drones are very susceptible to environmental conditions. When weather conditions turn unfavorable, it makes it more difficult for the drones to safely navigate. Rain, freezing temperatures, and extreme heat are all very real concerns for drone pilots. Flying a drone safely on such an important mission, to locate lost or injured people, in such unstable and hazardous conditions is a recipe for disaster. To make things more complicated, dark or low light conditions or communication and transmission issues make the task almost impossible. However, this issue was addressed in the FAA Part 107 regulation restricting flying during the night-time.

In the previously discussed study seeking to reduce the treatment-free interval of SAR, of the twenty-eight search and rescue missions that were performed, "four of the missions were unsuccessful because the drone experienced technical difficulties (due to camera live-image transmission failure) _". [31] Another camera concern is the quality of the images. Some cameras have shown shadows cast by geographic features, causing the pilot to instruct the drone to complete another pass of the area. In a time-sensitive situation, this is time the SAR team cannot afford to lose.

Furthermore, the battery life of a drone is yet another challenging aspect of using drones in SAR. Currently, drones capable of being used in SAR missions or medical delivery are typically in the 5-10 pound range, with a typical battery time of 30 - 60 minutes. This is fine if you know exactly where you're going and what you're looking for, however, this is rarely the case, therefore

[31] Michiel Jan van Veelen, Giulia Roveri, Anna Voegele, Tomas Dal Cappello, Michela Masè, Marika Falla, Ivo Beat Regli, Abraham Mejia-Aguilar, Sebastian Mayrgündter, Giacomo Strapazzon,
Drones reduce the treatment-free interval in search and rescue operations with telemedical support – A randomized controlled trial, The American Journal of Emergency Medicine, Volume 66, 2023, Pages 40-44, ISSN 0735-6757, https://doi.org/10.1016/j.ajem.2023.01.020

limiting its usefulness. Another consideration is the lack of reliable telecommunications between drones and pilots. Oftentimes the SAR operation occurs in a remote, dangerous, or dangerous location. These areas typically have very poor or nonexistent cellular or wifi connectivity that would normally aid in the data transmission or flight directions given to the drone. This can severely limit the capabilities and usefulness of the drone. This loss in connection could affect the drone's ability to return to the pilot or increase the time needed for the human team to find the lost or injured human by the inability to transmit images and data effectively and having to wait for the drone to return to do so. Furthermore, the concern about drones malfunctioning and colliding with objects, people or animals is frightening. Especially if it's an airspace collision. Some of the fears can be assuaged with many drones now employing flight controllers to help manage the actual flight of the drone while the pilot focuses more on the intended mission. Researchers and engineers are also tackling the unstable communications issue.

Conclusion

To wrap up our exploration into the fascinating world of drones, we've peeled back the layers, from the fancy 'remotely piloted aircraft' to the more down-to-earth 'drones.' And hey, don't let the tech lingo fool you – drones have been hanging around since the '80s, long before the Jetsons' era.

We demystified the mechanics behind those buzzing quadcopter-type drones. It's not rocket science – four propellers and some cool motor maneuvers, thanks to Newton's Third Law, make these gadgets soar. They're like flying superheroes, zooming into tight spots with military precision. Pitch, roll, yaw – it's all in the drone's playbook.

But here's the real kicker – drones are more than just airborne toys. They're decked out with super sensors, doing jobs that leave other gadgets in the dust. Think vineyard monitoring, crop health checkups, and even scanning construction sites. These high-tech buddies aren't just about fun and games; they're your eyes in the sky, doing things other gadgets can only dream of.

Now, let's get real about the red tape – the Government's keeping a close watch on these flying marvels. Since 2012, the FAA's been laying down the law for hobbyists, educators, and drone-loving kids. If you're flying for fun and your drone's under 55 lbs., you're in the game. Fast forward to 2015, now they want you to register that drone if you're 13 or older. It's all part of the "Know Before You Fly" campaign, schooling everyone on flying these gadgets safe and sound.

Commercial drone action? The FAA rules the airspace chessboard, dividing it into classes. Drones hang out in Class G, closer to the ground, doing their thing. But here's the kicker – the skies aren't just empty playgrounds. Safety and privacy are the hot topics. In a world of high-tech cameras and GPS, people are spooked about their privacy getting invaded. States are wrestling with rules, but it's like solving a puzzle.

Picture a drone zipping over your backyard, delivering packages, or, heaven forbid, snooping. Privacy concerns are real. Drones might be superheroes, but they come with strings attached – rules, regulations, and a dash of uncertaintyuncertatinty. From saving lives in search and rescue missions to stirring up a sky mishaps, drones are here to stay. The skies might be getting crowded, but the drone saga is just kicking off!

Teaching Strategies

To achieve the specified objectives and provide students with a comprehensive understanding of drone technology and its various applications, a well-structured teaching plan is essential. This teaching plan will incorporate a combination of hands-on activities, theoretical lessons, and ethical discussions to engage students effectively.

Module 1: Introduction to Drones: Anatomy, Regulations and Ethics

In the first module, students will be introduced to the fundamental concepts of drones, including their components and flight mechanisms. The focus will be on understanding takeoff, flight, and landing processes. To make this engaging, we will use real drone models to demonstrate these mechanisms along with class discussions. Students will have the opportunity to observe, discuss, and even pilot drones in a controlled simulated environment.

Regulations and Safety

Having gained an understanding of drone technology, it is important to acquaint students with the legal and safety dimensions. This module will also focus on exploring current and developing regulations surrounding the use of private and commercial drones. We will discuss the importance of following regulations to facilitate safe and legal drone missions.

Ethical Considerations

During this module we will shift our focus to the ethics of drone usage. Students will engage in discussions and debates regarding drone usage in various applications. They will be exposed to various points of view to develop ethical attitudes and practices when operating drones in different contexts.

Module 2: Let’s Fly Away - Drone Anatomy and Functionality

During this module, we will delve deeper into the various parts of a drone and their functionalities. Students will learn about essential components such as motors, propellers, flight controllers, and sensors. They will also understand the components and navigate a drone having the parts work together to achieve stable flight.

Module 3: First Mission with variables, conditionals and loops

Moving into the third module, students will transition to programming. We will use the Blocky CoDrone EDU coding platform to teach students how to create and execute programs for various drone operations. This includes tasks like hovering, pushups, and payload lifting. The emphasis will be on understanding the principles of flight and control systems through coding. Students will practice coding to have the drone perform these tasks autonomously.

Module 4: Advanced Programming and Applications

Within this module, students will further advance their coding skills, delving into the realm of intricate programming algorithms designed for obstacle avoidance and autonomous missions. This hands-on lesson will notably deepen their grasp of how technology can be efficiently applied to specific tasks and contexts. As part of this phase, students will actively participate in planning and constructing obstacle scenarios, challenging them to simulate hazardous and hard-to-reach terrains. This exercise will provide them with valuable opportunities to refine their programming abilities.

Having acquired a comprehensive understanding of drones, programming, regulations, and ethical considerations, students will now leverage this knowledge to conceive and execute their own drone missions. Working collaboratively in teams, they will strategize, execute, and assess the outcomes of these missions, effectively simulating real-world scenarios.

Assessment and Reflection

In the final activities, students will be assessed on their knowledge, skills, and their ability to apply what they've learned. They will also have the opportunity to reflect on their journey and how it has shaped their understanding of drones, from their flight mechanisms to their ethical considerations.

This teaching plan combines theory, practical experience, ethical discussions, and a focus on regulations to ensure that students are well-prepared to make informed decisions about drone capabilities and applications while adhering to legal and ethical standards. It provides a comprehensive foundation for students interested in technology, engineering, and drone operations.

Classroom Activities

Module 1 - Introduction to Drones: Anatomy, Regulations and Ethics

Objectives: Students who demonstrate understanding will be able to recognize and explain the roles and purposes of different components within a drone, equipping them to make informed choices regarding its capabilities when crafting and executing missions. Additionally, students will delve into both existing and emerging regulations pertaining to the utilization of private and commercial drones, ensuring the facilitation of secure and lawful missions. Lastly, students will engage in ethical debates surrounding drone deployment in search and rescue operations, fostering exposure to diverse perspectives and the cultivation of ethical attitudes and practices in drone operation.

Grade Level: Grades 9-12

Lesson Duration: 60 - 90 minutes

Key Terms:

1. Drone
2. CoDrone EDU
3. Propellers
4. Sensors
5. Controller
6. Aerofoil / Wing
7. Lift
8. Regulations
9. Ethics

STEEL Standards:[7]

3.5 9-12 E Evaluate how technology and engineering advancements alter human health and capabilities.
3.5 9-12 H Evaluate ways that technology and engineering can impact individuals, society, and the environment
3.5 9-12 L Interpret laws, regulations, policies, and other factors that impact the development and use of technology.

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[7] PA Department of Education. 2023. "STEELS Hub - SAS." Standards Aligned System. https://www.pdesas.org/Page/Viewer/ViewPage/58/?SectionPageItemId=12998.

PA Academic Standards[8]

Standard - CC.1.2.11-12.B
Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences and conclusions based on and related to an author's implicit and explicit assumptions and beliefs.

Standard - CC.1.2.11-12.C
Analyze the interaction and development of a complex set of ideas, sequence of events, or specific individuals over the course of the text.

Standard - CC.1.2.11-12.G
Integrate and evaluate multiple sources of information presented in different media or formats (e.g. visually, quantitatively) as well as in words in order to address a question or solve a problem.

Standard - CC.1.2.11-12.H
Analyze seminal texts based upon reasoning, premises, purposes, and arguments.

Standard - CC.1.2.11-12.L
Read and comprehend literary non-fiction and informational text on grade level, reading independently and proficiently.

Standard - CC.1.4.11-12.A
Write informative/ explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately.

Standard - CC.1.5.11-12.A
Initiate and participate effectively in a range of collaborative discussions on grade-level topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

Standard - CC.1.5.11-12.D
Present information, findings, and supporting evidence, conveying a clear and distinct perspective; organization, development, substance, and style are appropriate to purpose, audience, and task.

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[8] SAS. 2023. "SAS - Pennsylvania Department of Education Standards Aligned System - SAS." Www.pdesas.org. 2023. https://www.pdesas.org/default.aspx.

Materials and Resources:

CoDrone EDU Manual [9]

Google Slide Presentation

Attitude Survey Pre Post

Reading Materials:

FAA webpage on Recreational Flyers & Community-Based Organizations

Adapted passage and activity for low readability (grade 5)

Translated and adapted passage and activity for EL and low readability (grade 5)

Comparing public concern and support for drone regulation to the current legal framework

Keep Calm but Don't Carry on: New Drone Regulations in the United States

Instructional Strategies:

1. Engage: (Slide 1) Start by informing students that today's lesson will immerse them in the fascinating realm of drones. Clarify that drones are unmanned aerial vehicles, initially developed for military purposes, to handle tasks of high risk or sensitivity. Proceed to convey that the class will also investigate governmental regulations and the authorities accountable for enforcing them. Lastly, the lesson will delve into the ethical considerations when it comes to employing drones in both private and commercial contexts.

2. Explore: (Slide 3) Instruct the students to access the Attitude Survey and complete it. You may consider guiding students through specific questions, encouraging them to provide detailed explanations for their responses.

3. Explain:

- Continue using the Google slide presentation to facilitate the rest of the lesson.
    - (Slides 5-10) Explain the various major structures of the drone using the presentation and User Manual
    - (Slides 11-13) Discuss and demonstrate how a drone flies. Making a point to emphasize the principle of lift and how the aerofoil is instrumental in this process. Show the video on flight dynamics to further illustrate the point.

[9] Robolink. n.d. *CoDrone EDU User Manual*, Operation manual for the CoDrone EDU. v3.

- (Slide 14) Direct the students to a flight simulator to engage in simulated drone flight. Allow 10 minutes for students to explore the various simulations. Have the students notice and discuss the flight dynamics just learned.
- (Slides 15-19) Explain and discuss with the students the current governmental regulations concerning recreational and commercial drone operation
- (Slides 20-23) Pair Reading: Close Reading - Have students read the FAA web page on Recreational Flyers & Community-Based Organizations then have them read and discuss with a partner the text-based questions. Following the partner discussion, open it to the whole group to discuss and locate the text-based evidence supporting the responses. *Alternate activity - for students with low reading / comprehension skills or EL students, you may use the adapted activities;
- Adapted passage and activity for low readability (grade 5)
- Translated (Spanish) and adapted passage and activity for EL and low readability (grade 5)

4. Elaborate:

- Continue using the Google slide presentation to facilitate the rest of the lesson.
    - (Slides 24-26) Discuss with students the most popular uses for drone use. Guide the students to start making connections between the uses and the regulations just discussed.
    - (Slide 28 - 29) Have students think of challenges that may occur with drone use
    - (Slides 30-32) Facilitate a Socratic Seminar with the students focusing on the ethical considerations of drone usage. Discuss the Socratic Seminar norms then review the question prompts. Have each group select one prompt to discuss. Encourage students to use the Response Starters on Slide 32 to help formulate and articulate their responses. Choose one prompt to open to the whole class for discussion.

5. Evaluate: (Slide 33) Instruct students to complete the Post Attitude Survey. Engage the students in a discussion concerning shifting attitudes.

6. Closure: Have students share one new piece of knowledge they've gained about drones since the lesson began. Finally, inform the students about the exciting next lesson, which will focus on practical aspects – how to operate a drone using a controller and introduce them to basic programming for drones.

Module 2 - LET’S FLY AWAY

Objectives: Students will be able to demonstrate a comprehensive understanding of drone flight mechanisms by explaining takeoff, flight, and landing processes, as well as creating and executing Blockly programs for various drone operations, including hovering, pushups, and payload lifting, in order to gain a deeper understanding of the principles of flight and control systems.

Grade Level: Grades 9-12

Lesson Duration: 60 - 90 minutes

Key Terms:

1. Hover
2. Quadcopter
3. Yaw
4. Roll
5. Pitch
6. Throttle

STEEL Standards:[10]

3.5.9-12.N: Analyze and use relevant and appropriate design thinking processes to solve technological and engineering problems.

ISTE Standards:[11]

1.5.d Algorithmic Thinking

Students understand how automation works and use algorithmic thinking to develop a sequence of steps to create and test automated solutions.

PA Academic Standards [12]

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[10] PA Department of Education. 2023. “STEELS Hub - SAS.” Standards Aligned System. https://www.pdesas.org/Page/Viewer/ViewPage/58/?SectionPageItemId=12998.

[11] International Society for Technology in Education. 2023. “1. Students.” ISTE. https://iste.org/standards/students.

[12] SAS. 2023. “SAS - Pennsylvania Department of Education Standards Aligned System - SAS.” Www.pdesas.org. 2023. https://www.pdesas.org/default.aspx.

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Materials and Resources:

CoDrone drone and User manual[13]

Canva Presentation

Lesson 1.1

Lesson 2.1   PDF

[13] Robolink. n.d. *CoDrone EDU User Manual*, Operation manual for the CoDrone EDU. v3.

Lesson 2.2 PDF

Goggles - 1 per student

Blockly for Robolink website platform

Batteries (2 - AA for each drone)

Computers with internet access

Reading Materials:

CoDrone User Manual[14]

Instructional Strategies:

1. Engage:

(Slide 2 -3) Inform the group that the focus of today's session will be on drone flight mechanics. Begin by revisiting the fundamental principles of drone flight from the previous lesson. Review with the students the user manual to revisit how to operate the controls for flying the drone. Introduce the use of Blockly as a coding platform and understand how it can be used to control the drone's flight.

2. Explore:

Explain to the students that our CoDrone is a quadcopter, which is based on the design of a helicopter. Have students watch the video on Slide 6 of the presentation to understand the dynamics of drone hovering.

3. Explain:

Use the Canva slide presentation to facilitate the rest of the lesson.

- Have students go to the RoboLink website
- Click CoDrone Edu
- Scroll down to Blockly with CoDrone Edu

4. Elaborate:

[14] Robolink. n.d. *CoDrone EDU User Manual*, Operation manual for the CoDrone EDU. v3.

- (Slides 7-8) Have students use the Robolink platform to complete the next sections. Have students work in pairs to complete lesson 1.1 Pairing. Check to make sure all of the drones are paired and working properly before moving on.
- (Slides 9) IMPORTANT! - Bring your students back together to discuss safety. Students should wear their safety goggles, pull back and secure hair, and remove any fragile or important objects in the space.
- (Slides 10) Have students work in pairs to complete Intermediate Lesson 2.1 Flight Events. **Note - have the students only perform the movements in the lesson - not to fly.
- (Slide 11) Have students modify their code to complete the largest amount of pushups in a given time limit.
- (Slide 12) Engage students in a discussion about how a quadcopter flies now that they have practiced takeoff, hovering and landing. See if they can demonstrate and explain the principles of flight using their drone. Make sure to address any misconceptions.
- (Slides 13-18) Engage students in a discussion on flight dynamics key terms; roll, pitch, yaw, and throttle. Ask students to demonstrate or mimic the positive and negative movements of each direction.
- In Pairs, have students complete Lesson 2.2 Flight Directions.

5. Evaluate:

Observation of the completed ladder and spiral challenge. Ask students to explain their program while checking for understanding. Ask probing questions to extend the students' reasoning and critical thinking. (Slide 19) Debrief with the students about their experiences with Blockly and the drone.

6. Closure:

Have a quick discussion of the major points of the lesson (takeoff, hover, land, code blocks) and flight directions. Have students reiterate how a drone flies, ensuring to use academic language.

Module 3 - First Mission with variables, conditionals and loops

Objectives: Students will showcase their adeptness in drone programming by utilizing the Robolink Blockly coding platform to participate in autonomous flight, navigate obstacle avoidance, and implement intricate programming algorithms.

Grade Level: Grades 9-12

Lesson Duration: 60 - 90 minutes

Key Terms:

1. Variable

2. Conditional
3. If
4. Else
5. Else if
6. Loops
7. For loops
8. While Loops
9. Until Loops

STEEL Standards:[15]

Standard 3: Research & Information Fluency, which emphasizes the importance of students being able to locate, evaluate, synthesize, and communicate information using digital tools

Standard 4: Critical Thinking & Problem Solving, which emphasizes the importance of students being able to use critical thinking skills to solve problems.

ISTE Standards:[16]

1.5 Computational Thinker, which emphasizes the importance of students developing and employing strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions.

1.4 Innovative Designer, which emphasizes the importance of students using a variety of technologies within a design process to identify and solve problems by creating new, useful or imaginative solutions.

1.2 Digital Citizen, which emphasizes the importance of students recognizing the rights, responsibilities, and opportunities of living, learning, and working in an interconnected digital world, and acting and modeling digital citizenship in ways that are safe, legal, and ethical.

PA Academic Standards [17]

Standard - CC.1.2.11-12.B
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[16] International Society for Technology in Education. 2023. "1. Students." ISTE. https://iste.org/standards/students.
[17] SAS. 2023. "SAS - Pennsylvania Department of Education Standards Aligned System - SAS." Www.pdesas.org. 2023. https://www.pdesas.org/default.aspx.

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Standard - CC.1.5.11-12.D
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Materials and Resources:

CoDrone drone and User manual [18]

Canva Presentation

Blockly for Robolink website platform

Batteries (2 - AA for each drone)

Goggles for each student

Computers with internet access

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[18] Robolink. n.d. *CoDrone EDU User Manual*, Operation manual for the CoDrone EDU. v3.

Instructional Strategies:

1. (Slide 2-5) Engage: Introduce the students to today's lesson by having the students recall what they did in the previous lesson. Engage students in a discussion to review important concepts, check for understanding and to address any misconceptions. Make sure to reiterate the flight dynamics of a quadcopter (yaw, roll, pitch and throttle). Explain to the students that they will continue their programming learning with variables, conditionals and loops, which will aid in creating more complex algorithms.

2.(Slide 6) Explore: To help get students thinking and understanding variables, show this video. Make sure that students know the video was made for a different task, however, the explanation of variables are the same. Have students make connections with other topics and experiences.

3. (Slides 7-8) Explain: Use the Canva slide presentation to facilitate the rest of the lesson

- Set up the drones ((batteries))
- User manual to link the drone and the controller
- Have students go to the RoboLink website
- Click CoDrone Edu
- Scroll down to Blockly with CoDrone Edu
- Navigate to basecamp
- Make sure to review safety considerations

4. Elaborate :

- (Slides 9-10) Divide students into pairs or small groups. Instruct students to complete Lesson 2.3 Variables.
- Encourage students to iterate their program to make it more efficient.
- Bring the group back together to discuss the purpose of a variable and how to create, initialize and access a variable in a program.
- (Slides 11) Introduce the students to Lesson 2.4 Conditionals. Discuss decision making in their daily life. How are these decisions made? How do they change? What considerations go into making the decision?
- (Slide 12) Show the videos on Slide 12 to help the students understand what a conditional statement is and what it is used for.
- (Slides 13 - 17) Practice writing conditional statements with this document
- Instruct students to complete Lesson 2.4 Conditionals.
- Bring the group back together to allow students to discuss their programs. Have them explain which conditional statements were used and in which ways.

- (Slide 19 - 21) Introduce Lesson 2.5 Loops to the students by watching the video on Slide 20.
- Have the students complete the lesson and then the challenge (Zig Zag or Wave)
- (Slide 22) Bring the students back together to allow students to discuss their programs. Have them explain how they constructed their program. Have the groups think about how they could have made their program more efficient.

5. Evaluate: Ask students to present their drone programs and explain their strategies. Assess students' understanding by asking probing questions about their coding choices and problem-solving process. Provide constructive feedback and guide students towards improvements.

6. Closure: Summarize the key concepts and skills learned during the lesson (variable, conditionals and loops). Connect the lesson to real-world applications and potential career opportunities in the field of robotics and programming.

Module 4 - Search and Rescue

Objectives:

Grade Level: 9-12

Duration: 3 - 60 minute periods

Key Vocabulary:

1. Simulated Environments

2. Search and Rescue

3. Medical Supplies

4. Calibration

STEEL Standards:[19]

Standard 3: Research & Information Fluency, which emphasizes the importance of students being able to locate, evaluate, synthesize, and communicate information using digital tools

Standard 4: Critical Thinking & Problem Solving, which emphasizes the importance of students being able to use critical thinking skills to solve problems.

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[19] PA Department of Education. 2023. “STEELS Hub - SAS.” Standards Aligned System. https://www.pdesas.org/Page/Viewer/ViewPage/58/?SectionPageItemId=12998.

ISTE Standards:[20]

1.5 Computational Thinker, which emphasizes the importance of students developing and employing strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions.

1.4 Innovative Designer, which emphasizes the importance of students using a variety of technologies within a design process to identify and solve problems by creating new, useful or imaginative solutions.

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[21] SAS. 2023. "SAS - Pennsylvania Department of Education Standards Aligned System - SAS." Www.pdesas.org. 2023. https://www.pdesas.org/default.aspx.

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Standard - CC.1.5.11-12.D
Present information, findings, and supporting evidence, conveying a clear and distinct perspective; organization, development, substance, and style are appropriate to purpose, audience, and task.

Materials and Resources:

Canva Presentation
Sourced materials (cups, cardboard tubes, boxes, etc)
Cardboard
Tape
Glue
Shoe boxes
Poster Board
Small magnets
Spider wire or fishing line
Paper
Paper clips
CoDrone Color Pads
Hula hoops
Action figures for patients
Lesson 3.7 Calibrate Color Sensors
Attitude Survey - Post

Instructional Strategies:

1. (Slide 2) Engage: Begin the lesson by asking students about situations where drones could be used for search and rescue (SAR) operations. Facilitate a class discussion to illicit attitudes towards using drones in search and rescue missions. Also draw on attitudes towards using drones to deliver medical supplies.

2. (Slide 3-4) Explore: To help get students thinking and understanding how drones can be used in various SAR missions, show ~~this~~ these videos in the presentation..

3. Explain: Use the Canva presentation to facilitate the rest of the lesson

- Set up the drones. Don't not install drone battery until ready to fly
- User manual to link the drone and the controller

- Have students go to the RoboLink website
- Click CoDrone Edu
- Scroll down to Blockly with CoDrone Edu
- Navigate to basecamp

4. Elaborate:

- (Slide 5- 7) Lesson 3.7 Calibrate Color Sensor - Have students complete steps 1-6 to calibrate their drone to identify basic colors, which we will use in the SAR missions.
- Continue using the Canva presentation for the next part.
- (Slide 8-10) Divide students into small groups and assign each group a specific simulated environment and search and rescue scenario.
- Allow teams some time to research SAR efforts in their environment type. Have them focus on some of the challenges and hazards of the area / situation. Have students record their findings on the note catcher.
- (Slide 11) Conference with each team to discuss their ideas on how they will design their focused environment. Make sure as teams are designing their environment, to have them think about the scale and durability of their structures.
- Provide guidelines and constraints for the task, such as obstacles to navigate, specific locations to deliver medical supplies, mechanism for medical aid delivery, etc. Have students use at least one color pad in their scenario to simulate picking up a patient or delivering medical aid.
- Provide teams time to construct their focused environment with the sources and provided materials. Continue to have the teams focus on safety of the drone and of the people in the space.
- Have students develop a plan for using the sensors to gather necessary data per scenario. Example, temperature sensor for building fire, battery indicator to notify when to return to base, distance sensor for obstacle avoidance, etc.
- (Slides 12 - 13) In their groups, students will collaborate to create a Blockly algorithm that enables the drone to autonomously complete the assigned scenario successfully.
- (Slide 14) When each team has successfully navigated their own environment, bring the class back together to debrief.
- (Slide 15) If time allows, have teams switch environments and create an algorithm to successfully navigate.

5. Evaluate: Conduct a mini-showcase where each group presents their Blockly program and demonstrates the drone's search and rescue capabilities. Encourage students to ask questions, provide feedback, and offer suggestions for improvement. Assess students' understanding by asking probing questions about the programming concepts utilized and the rationale behind their design choices.

6. Closure: Summarize the key learning points of the lesson, emphasizing the importance of programming and technology in search and rescue operations. Highlight the significance of purposeful practice and effortful thinking in developing efficient and effective drone programs. Provide an opportunity for students to reflect on their learning and discuss how this activity relates to real-world applications. Also, have students complete the Drone AttitudeAtitude Post Survey to reflect on their possibly modified perspective of drones in our world.

Resources

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Course 4 - Artist: Variables. www.youtube.com. Accessed December 19, 2023. https://www.youtube.com/watch?v=_MkLbhIuvAM

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Brentwood Fire and Rescue Drone Program | Out and About. www.youtube.com. Accessed December 19, 2023. https://www.youtube.com/watch?v=zzKy0ip8WVc&ab_channel=CityofBrentwood%2CTN

Annotated List

1. Domański, Roman. "The Use of Drones in Mountain Search and Rescue (GOPR) in Poland – Possibilities and Limitations." LogForum. 18.3 (2022): 275–284. Web.

This article discusses the use of drones in mountain search and rescue operations in Poland, highlighting their potential and limitations.

2. Rosser, James C et al. "Surgical and Medical Applications of Drones: A Comprehensive Review." JSLS / 22.3 (2018): n. pag. Web.

This article offers a review of the surgical and medical applications of drones. It shares a bit of history while looking at the various medical applications. It also offers a brief glimpse into the search parameters used to locate information in the database.

3. M. M. Z. Shaheen, H. H. Amer and N. A. Ali, "Robust Air-to-Air Channel Model for Swarms of Drones in Search and Rescue Missions," in IEEE Access, vol. 11, pp. 68890-68896, 2023, doi: 10.1109/ACCESS.2023.3292517.

This article presents an air-to-air channel model for swarms of drones used in search and rescue missions. It proposes a cruising scheme for the safety of drones and a channel model for air-to-air links between drones.

4. Kotlinski, M., Calkowska, J.K. U-Space and UTM Deployment as an Opportunity for More Complex UAV Operations Including UAV Medical Transport. J Intell Robot Syst 106, 12 (2022). https://doi-org.proxy.library.upenn.edu/10.1007/s10846-022-01681-6.

This article explores the implementation of UTM unmanned traffic management system to increase the application of drones and looks at the use of drones in medical logistics.

5. Sara M. Smyth, "Keep Calm but Don't Carry on: New Drone Regulations in the United States," Journal of Law, Information and Science 25, no. 2 (2021): 49-88.

This article explores the evolving drone regulations in the United States. It also looks at safety and privacy concerns.

6. PA Department of Education. 2023. “STEELS Hub - SAS.” Standards Aligned System. https://www.pdesas.org/Page/Viewer/ViewPage/58/?SectionPageItemId=12998.

This site provides a detailed description of the Science, Technology & Engineering, Environmental Literacy and Sustainability (STEELS) Standards.

7. International Society for Technology in Education. 2023. “1. Students.” ISTE. https://iste.org/standards/students.

This site provides a detailed description of the International Society for Technology Education standards for students.

8. Zwickle, Adam, Hillary B Farber, and Joseph A Hamm. “Comparing Public Concern and Support for Drone Regulation to the Current Legal Framework.” *Behavioral sciences & the law.* 37.1 (2019): 109–124. Web.

This article examines the gap between public opinion regarding drone regulation and the existing legal framework governing their use.

9. Project Vulture: A Prototype for Using Drones in Search and Rescue Operations by Quan, Andres; Herrmann, Charles; Soliman, Hamdy 2019 15th International Conference on Distributed Computing in Sensor Systems (DCOSS), 05/2019

This paper introduces Project Vulture, a prototype system using drones for search and rescue (SAR) operations. It focuses on human subject localization through: deep learning image analysis, scalable and distributed operations, and prioritizing sensitivity.

10. Unplugged - Getting Loopy. www.youtube.com. Accessed December 19, 2023. https://www.youtube.com/watch?v=JoKTqHCni0M

This video introduces the concept of loops in a fun and engaging way, using dance moves as a metaphor. The video starts with Miral Cobb, the creator of Illuminate, explaining what loops are and how they are used in her work. She then introduces a new dance that incorporates loops, and breaks down the steps into simple movements that viewers can easily learn.

11. CS Discoveries: Conditionals part I. www.youtube.com. Accessed December 19, 2023. https://www.youtube.com/watch?v=D5fSbCKobko

This video provides an introduction to conditional statements, a fundamental concept in programming.

12. Course 4 - Artist: Variables. www.youtube.com. Accessed December 19, 2023. https://www.youtube.com/watch?v=_MkLbhIuvAM

This video teaches the programming concept variables through art creation activities.

Appendix

Standards

STEEL Standards:

3.5 9-12 E Evaluate how technology and engineering advancements alter human health and capabilities.
3.5 9-12 H Evaluate ways that technology and engineering can impact individuals, society, and the environment
3.5 9-12 L Interpret laws, regulations, policies, and other factors that impact the development and use of technology.
3.5.9-12.N: Analyze and use relevant and appropriate design thinking processes to solve technological and engineering problems.

PA Academic Standards

Standard - CC.1.2.11-12.B
Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences and conclusions based on and related to an author's implicit and explicit assumptions and beliefs.

Standard - CC.1.2.11-12.C
Analyze the interaction and development of a complex set of ideas, sequence of events, or specific individuals over the course of the text.

Standard - CC.1.2.11-12.G
Integrate and evaluate multiple sources of information presented in different media or formats (e.g. visually, quantitatively) as well as in words in order to address a question or solve a problem.

Standard - CC.1.2.11-12.H
Analyze seminal texts based upon reasoning, premises, purposes, and arguments.

Standard - CC.1.2.11-12.L
Read and comprehend literary non-fiction and informational text on grade level, reading independently and proficiently.

Standard - CC.1.4.11-12.A
Write informative/ explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately.

Standard - CC.1.5.11-12.A
Initiate and participate effectively in a range of collaborative discussions on grade-level topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

Standard - CC.1.5.11-12.D
Present information, findings, and supporting evidence, conveying a clear and distinct perspective; organization, development, substance, and style are appropriate to purpose, audience, and task.

ISTE Standards:

1.2 Digital Citizen, which emphasizes the importance of students recognizing the rights, responsibilities, and opportunities of living, learning, and working in an interconnected digital world, and acting and modeling digital citizenship in ways that are safe, legal, and ethical.

1.4 Innovative Designer, which emphasizes the importance of students using a variety of technologies within a design process to identify and solve problems by creating new, useful or imaginative solutions.

1.5 Computational Thinker, which emphasizes the importance of students developing and employing strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions.

1.5.d Algorithmic ThinkingStudents understand how automation works and use algorithmic thinking to develop a sequence of steps to create and test automated solutions.

Presentations and Materials

Module 1 Presentation
- Attitude Survey Pre Post
- Adapted Activity
- Translated and Adapted Activity
- Drone Safety Tips
- Principles of Aerodynamic Lift
- How Does A Drone Fly video
- Drone Racing Simulation

Module 2 Presentation
- Lesson 1.1
- Lesson 2.1
- Lesson 2.2
- Robolink Blockly platform
- CoDrone Curriculum
- Drone Flight Mechanics video
- World of Drones Education video

Module 3 Presentation
- Lesson 2.3
- Lesson 2.4
- Lesson 2.5
- Code.org Variable Video
- Code.org - Conditional Statements video
- Code.org - Loops Video

Module 4 Presentation
- The Rescue Video
- Brentwood Fire and Rescue Drone Program video
- Search and Rescue for Two Girls.. Video
- Lesson 3.7 Calibrate Color Sensors

- Scenario Note Catcher

Glossary

1. **Drone**: An unmanned aerial vehicle (UAV) or aircraft that is operated without a human pilot on board.

2. **CoDrone EDU**: A programmable drone designed for educational purposes, allowing students to learn coding and robotics.

3. **Propellers**: Rotating blades that generate thrust to propel a drone through the air.

4. **Sensors**: Devices that detect and measure physical properties, providing data for the drone to adapt and respond to its environment.

5. **Controller**: A handheld device used to manually operate and control the movements of a drone.

6. **Aerofoil / Wing**: The shape of the drone's wings, designed to generate lift and control during flight.

7. **Lift**: The force generated by the drone's wings or propellers that enables it to rise and stay airborne.

8. **Regulations**: Rules and guidelines set by authorities to govern the operation and use of drones in specific areas.

9. **Ethics**: Moral principles and values that guide the responsible and considerate use of technology, including drones.

10. **Hover**: The ability of a drone to remain in a stable position in the air without moving in any direction.

11. **Quadcopter**: A type of drone with four rotors, each providing lift and control.

12. **Yaw**: The rotation of a drone around its vertical axis, changing its direction.

13. **Roll**: The rotation of a drone around its longitudinal axis, tilting from side to side.

14. **Pitch**: The rotation of a drone around its lateral axis, tilting forward or backward.

15. **Throttle**: The control that adjusts the power and speed of the drone's motors.

16. **Variable**: A storage location identified by a memory address and associated with a data type, allowing for the storage and manipulation of values.

17. **Conditional**: A programming concept that involves making decisions based on specified conditions.

18. **If**: A keyword in programming used to execute a block of code if a specified condition is true.

19. **Else**: A keyword in programming used to execute a block of code if the specified condition in an 'if' statement is false.

20. **Else if**: A keyword in programming used to test additional conditions if the initial 'if' statement is false.

21. **Loops**: Programming constructs that repeat a set of instructions until a certain condition is met.

22. **For Loops**: A type of loop that iterates through a sequence of code for a specified number of times.

23. **While Loops**: A type of loop that continues to iterate as long as a specified condition is true.

24. **Until Loops**: A type of loop that continues to iterate until a specified condition becomes true.

25. **Simulated Environments**: Virtual environments that mimic real-world conditions, often used for testing and training drones.

26. **Search and Rescue**: The use of drones to locate and aid in the rescue of individuals in emergency situations.

27. **Medical Supplies**: Delivery of medical items or equipment using drones, particularly in remote or inaccessible areas.

28. **Calibration**: The process of adjusting and configuring a drone's sensors and components to ensure accurate and reliable performance.

Other Resources

Section 44807: Special Authority for Certain Unmanned Aircraft Systems

B4UFLY App

FAA Getting Started Guide

The Recreational UAS Safety Test (TRUST)

FAA Drone Informational Site

Part 107 Waiver

Remote Pilot – Small Unmanned Aircraft Systems Study Guide

FAA Drone Safety Day Events

AIAA Aerospace Micro-Lesson

Understanding Control Systems Video

What UAS Career Best Suits You? Career Exploration

Drone Safety Day Scavenger Hunt

FAA Temporary Flight Restrictions