Integrated STEM Helps Drone Education Fly

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***Abstract* - The emerging drone industry presents an ecosystem rich with STEM careers. This paper discusses the development of an integrated STEM curriculum, the Drone Innovators Program, designed to immerse middle school and high school students in STEM careers through drone education. A work in progress curriculum presented in this paper is a competency-based system of online micro-courses for both online schools and brick-and-mortar classrooms. The curriculum is being piloted in an online charter school that serves students throughout the state of Pennsylvania, reaching a vastly diverse demographic. The course design uses research-based instructional models to capture a wide range of student interests, skills, and abilities. We will present the program framework and a lesson from our first unit.**

Index Terms – Drone education, Integrated STEM, Career and Technical Education, Engineering Design Process, EDP, 21st Century Skills, Creative problem-solving instruction, Competency-based learning.

INTRODUCTION

The emerging drone industry is forecasted to be a one-hundred-billion-dollar market in the private, civil, and government sectors [1]. The myriad job options range from technology, engineering, and sciences, to agriculture, construction, and art. The drone ecosystem presents an opportunity to teach the STEM domains while connecting directly to career paths in the STEM fields.

Our goal for this curriculum is three-fold. First, introduce STEM domains' standards in ways that are accessible, engaging, and supportive to a diverse demographic of students. See Figure I for Achievement House statistics.

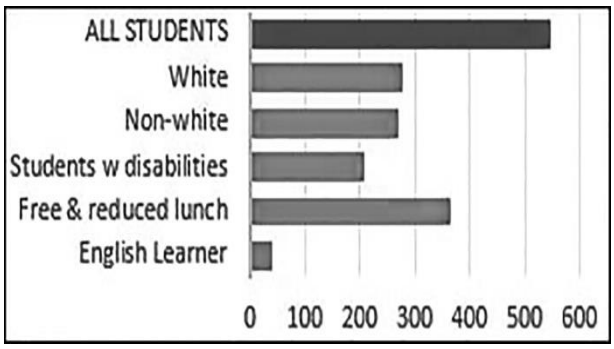

FIGURE I
ACHIEVEMENT HOUSE STUDENT DEMOGRAPHIC

The lack of underrepresented students pursuing STEM studies is a factor in the inability of the United States to meet STEM workforce diversity goals [2]. Our intention is to remove barriers for all students.

Second, the coursework will link student interests and future aspirations to real careers, increasing motivation and academic success. Figure II illustrates the extensive spectrum of career paths in the drone ecosystem. Drones are forecasted to be a disruptor in commerce as drone technology advancements offer substantial cost-effective solutions across industries. Students will engage in competency-based coursework, preparing them for this emerging job market.

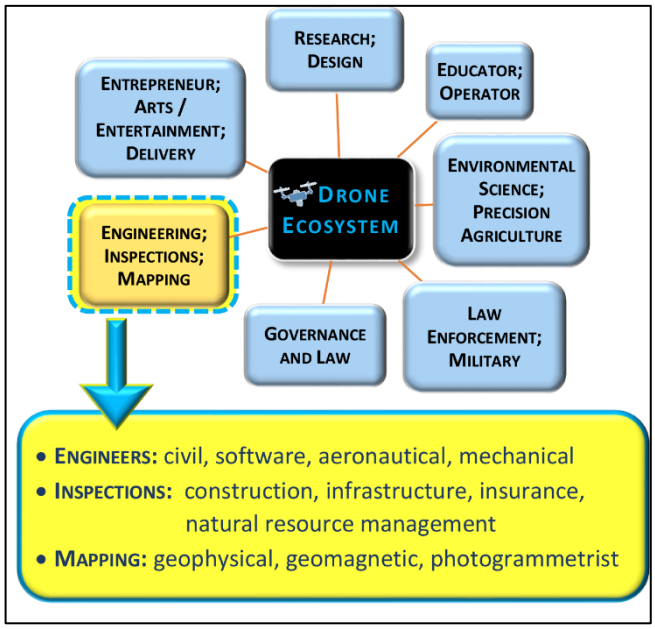

FIGURE II
DRONE ECOSYSTEM

Lastly, our third curriculum goal is to teach lasting 21st-century skills and problem-solving strategies through the Engineering Design Process (EDP) [3]. Cultivating perseverance and strategic thinking will prepare students for STEM studies and careers. The decline of students completing STEM majors has been traced to high school STEM programs ineffectively preparing students with the level of problem-solving skills needed for college-level coursework. [4].

DRONE INNOVATORS PROGRAM FRAMEWORK

The Drone Innovators Program offers a series of quarter credit online micro-courses that can be taken simultaneously for advanced students, stretched over two marking periods to add more instructional support, or audited to earn badges. All lessons are presented as real world, complex mission

simulations to foster immersive role-playing within an engineering design model, building inquiry skills, critical thinking, and deeper understanding. As students become vested in the outcome of their mission, the resilience needed to work through obstacles will support their efforts. Additionally, a creative problem-solving model will underscore the collectivist values of many of our sub-groups, building internal motivation and connection to STEM goals [5].

Courses emphasize data collection, output, analyses, programming, and collaboration. The program is designed with online instruction in mind, developing robust digital communication skills and software agility needed for careers in our global technological economy; however, the course will translate easily to brick-and-mortar classrooms, with or without one-to-one technology.

I. STEM Domain Standards

Framed as virtual missions, the lessons capitalize on cross-curricular applications. STEM domains easily align as students learn about flight, civil engineering, natural resources, agriculture, and search and rescue. For example, technology standards are met in the intro courses as students program autonomous flights with DroneBlocks. Figure III is a screenshot of the drag and drop Blockly program. Advanced students will learn to code with Python.

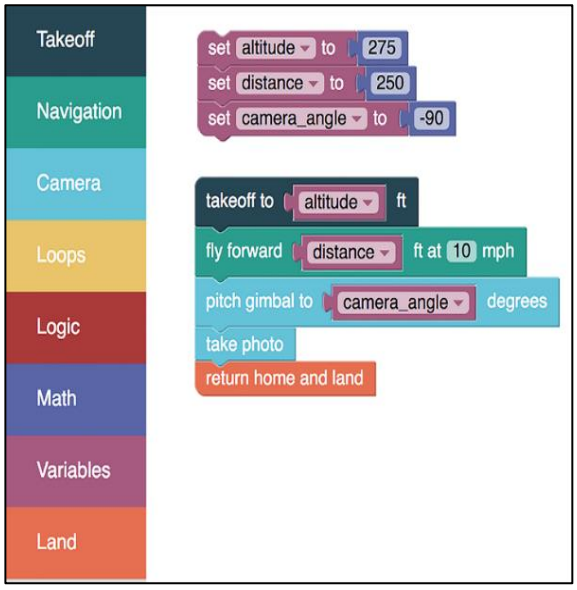

FIGURE III
DRONEBLOCKS

Students will also collect, manipulate, and analyze data from drone cameras and sensors. Students will use Excel, video editing software, and sample Pix4D – a photogrammetry software used in the drone industry. Math proficiency is integral to successful missions as students must accurately calculate distance, area, weights, and flight time. Physics, environmental science, and meteorology offer the foundation for drone flight, payloads, sensors, weather, and environment, key topics in drone education.

II. Career and Technology Readiness

The number of trained professionals in STEM careers in the United States continues to fall short of demand [6]. Science, technology, engineering, and math is a career cluster in The National Career Clusters Framework. High-quality CTE programs align rigorous standards, post-secondary expectations, labor market needs, and 21st-century skills. Applied, contextual learning help students connect their learning to career goals [7]. The complexity of each drone mission showcases the many opportunities in the drone ecosystem. As student skills and interests develop, guidance counselors will help students find courses that will prepare them for these careers. Students will take part in internships; university partnerships will facilitate student mentorships. Students who complete the Drone Innovators Program will be prepared to sit for the FAA 107 Remote Pilot License exam.

III. Engineering Design Process

The EDP teaches students to organize thoughts, improve decision making, and develop critical thinking needed in engineering and technology [8]. Students will take ownership of the mission's outcome. We have customized the EDP for the Drone Innovators Program, using the acronym D.R.O.N.E. illustrated in Figure IV. The D.R.O.N.E. EDP allow students to navigate through the mission criteria toward a successful outcome.

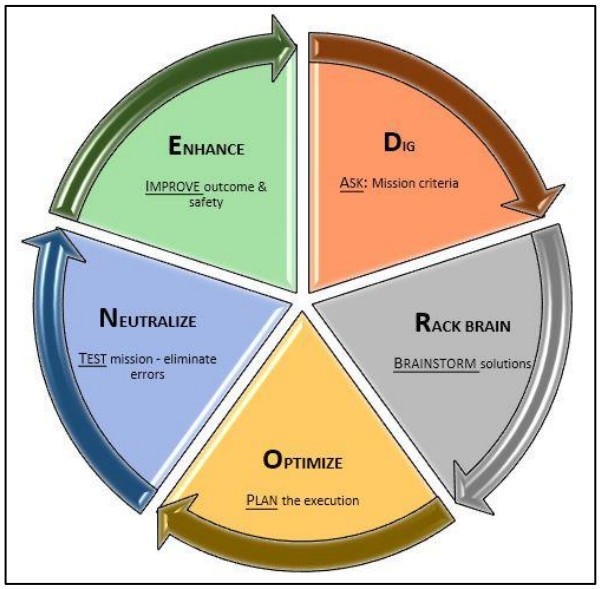

FIGURE IV
DRONE INNOVATORS PROGRAM EDP – D.R.O.N.E. EDP

- DIG: (Ask) Students watch a video about the mission presentation and review the materials contained in their Mission Portfolio, documents specific to the mission. Students role play the professional character assigned at random while performing the design process. Students will document questions pertinent to the mission and their character in their Drone Innovator Mission Book. Students begin researching answers and will move to the

next step once they are comfortable with the mission criteria and their role.

- RACK BRAIN: (Brainstorm) Students will role play and brainstorm with their team for solutions. The teacher may supply guiding questions to help students assimilate to their professional character.
- OPTIMIZE: (Plan) Detail how the mission will run.
- NEUTRALIZE: (Test) Students will program their flight using drone blocks and use a simulator to test the success of their mission.
- ENHANCE: (Improve) Students will discuss the outcome and revisit steps in the design process to improve accuracy, speed, and safety.

The structure of the D.R.O.N.E. EDP will cultivate trust in the collaborative approach and allow for creative solutions. In addition, the missions are humanitarian in nature, asserting the value of ethical and responsible uses for drones. Students will become visionaries for drone applications as they look to solve a variety of relevant issues.

IV. Drone Innovators Mission Book

The D.R.O.N.E. EDP helps organize the student digital lab book, Drone Innovators Mission Book, where their work is documented. Figure VI is a screenshot of OneNote Class Notebook, the application selected for this purpose. The program offers individual student electronic notebooks, resource sharing capabilities, and a place for team collaboration. The teacher can easily push out information, lessons, and activities to the class in addition to grading individual student notebook content. The Drone Innovators Mission Book is formatted with a section for the Mission Portfolio and tabs aligned to the D.R.O.N.E. EDP so students can input ideas, notes, data, calculations, and drawings.

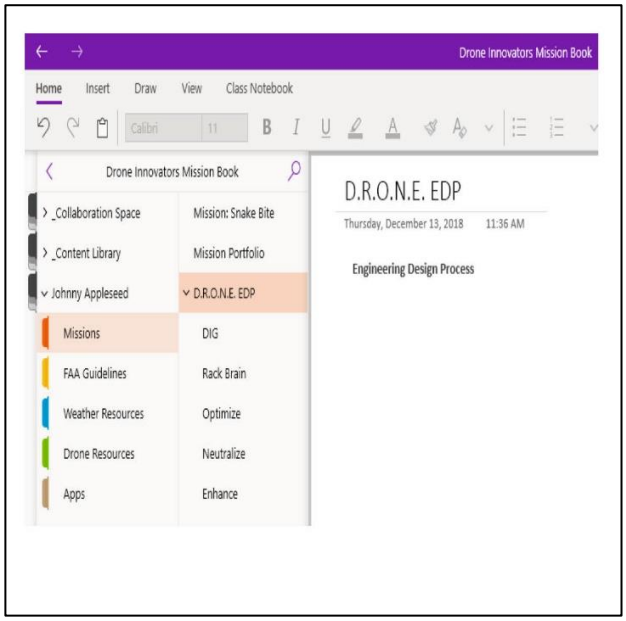

FIGURE VI
DRONE INNOVATORS MISSION BOOK – ONENOTE CLASS NOTEBOOK

LESSON

The lessons and D.R.O.N.E. EDP can take place in a virtual classroom where students can interact as a team. We currently use Blackboard Collaborate that features a virtual whiteboard for posting questions, notes, research findings, and designs. It also offers speech, chat, and screen sharing capabilities to enhance collaboration.

The teacher is in the role of facilitator to guide discussions. A single mission can take several instructional sessions of forty-five-minute blocks. Students will be expected to participate in discussion forums posted on our learning management system to continue collaboration with their team after class.

I. Mission: Snake Bite

A two-minute video introduces students to their fictional mission: a drone must fly antivenom to two hikers bitten by rattlesnakes, now miles from the nearest rescue station. Students will review their Drone Innovators Mission Book and Mission Portfolio featuring the items bulleted below. Students also receive a physical Mission Portfolio that is a reusable set of these items. All documents in the Mission Book and Mission Portfolio use industry vernacular and standards to replicate authentic experiences, provide scaffolding for the FAA Remote Pilot License course, and prepare students for a career in the drone ecosystem.

- MISSION CARD – describes the goal & criteria of the drone mission.
- OUTPUT CARD – describes a finished product for presentation in addition to the completed mission – video footage, photos, data analysis, or a findings report, for example.
- PRE-FLIGHT CHECKLIST – required safety tasks.
- REGIONAL CARD – area map, weather, hazards, plant, and animal life.
- SECTIONAL CHART – an aeronautical map of airports, controlled airspace, restricted areas, and obstructions.
- INJURED CARDS – medical/health status of any injured animals/humans, if applicable to the mission.
- FAA DRONE FLIGHT REGULATIONS – per United States Department of Transportation.
- DRONE SPECIFICATIONS CARD – drone type, battery life, flight speeds, cameras, sensors.
- PROFESSIONAL CHARACTER CARDS – describes specific characters to be role played by students while working on the mission. For example, a programmer, videographer, drone engineer, medic, meteorologist, and geographer are professionals needed for this mission. Students are randomly assigned a Professional Character Card at the start of the mission. Each card explains the character's specialty (see Figure V). The team will have an opportunity to strategically switch character cards during the Enhance (Improve) step of the design process if the team determines a teammate's skills/talents would be better suited in a different professional role. This will allow students to explore more careers, uncover special

interests, and take note of emerging talents in their teammates, further supporting the Career and Technical Education goals of this program.

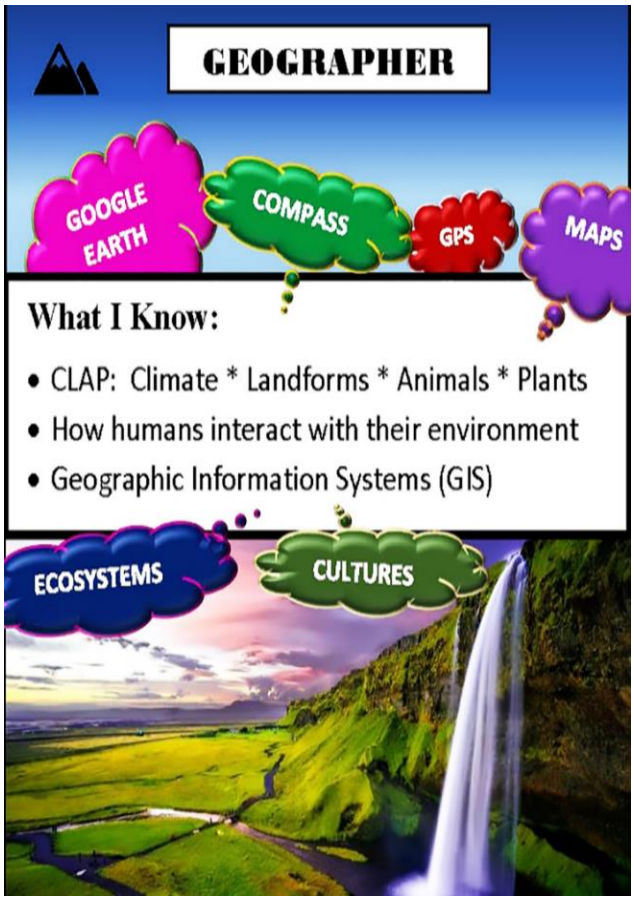

FIGURE V
PROFESSIONAL CHARACTER CARD

The students work together to solve the mission using the D.R.O.N.E. EDP. The teacher facilitates the EDP, creating a safe space for students to dive deep into content. Student abilities advance as their learning becomes self-directed, investigating solutions beyond the boundaries of the Mission Portfolio. They are vested in the outcome of the mission.

II. Formative Assessment

The student's digital lab book, the Drone Innovators Mission Book, provides formative assessments over the course of the mission. The teacher feedback will guide the student toward growth and competency in specific skills. Students will have time to make revisions and additions to their Mission Book.

Discussion forums will serve as formative assessments as the collaboration therein is a vital ingredient to successful missions. Students will be asked to add entries and/or respond to their teammates.

III. Summative Assessment

Upon successful completion of the mission, the student's Mission Book will be graded per the criteria outlined in the rubric.

Additionally, each mission will include the submission of a specific product common to those in the drone industry, detailed in the Output Card. This will be graded as a separate summative assessment.

CONCLUSION

We are currently designing the coursework for our Drone Education Program. We will continue to pilot lessons with our students to refine outcomes. Class surveys, student learning, and a qualitative increase in STEM career interests will guide adjustments to course content.

Global challenges and advances in technology demand a new generation of STEM experts and educators must help students prepare for this global shift [9]. Anchoring the Drone Innovators Program in an integrated STEM approach with a competency-based directive will allow us to promote deeper learning, marketable skills, and relevant career connections.

ACKNOWLEDGMENT

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REFERENCES

[1] "Drones Reporting for Work". October 2016. www.goldmansachs.com/insights/technology-driving-innovation/drones/index.html. Web. Accessed November 30, 2018.

[2] Estrada, M., Burnett, M., Campbell, A., *et al.* 2016 Fall. "Improving Underrepresented Minority Student Persistence in STEM". *CBE Life Sciences Education*, 15(3), es5.

[3] Purzer, S., Hathaway-Goldstein, M., Adams, R., *et al.* May 2015. "An Exploratory Study of Informed Engineering Design Behaviors Associated with Scientific Explanations". *International Journal of STEM Education.* 2(9).

[4] Duden-Street, C, Koff, R., Fields, H., et al. 2012 Winter. "Expanding Access to STEM for At-Risk Learners: A New Application of Universal Design for Instruction". *Journal of Postsecondary Education and Disability*, 25(4), pp. 363 – 375.

[5] Triandis, H., 2018. *Individualism and Collectivism.* New York. Routledge Taylor and Francis Group.

[6] Belser, C., Shillingford, A., Daire, A., *et al.* September 2018. "Factors Influencing Undergraduate Student Retention in STEM Majors: Career Development, Math Ability, and Demographics". *The Professional Counselor* 8(3), pp. 262 – 276.

[7] Brand, B., Valent, A., Browning, A., March 2013. "How Career and Technical Education Can Help Students Be College and Career Ready: A Primer". College & Career Readiness & Success Center at American Institutes for Research.

[8] Hynes, M., Portsmore, M., Dare, E., *et al*. January 2011. "Infusing Engineering Design into High School STEM Courses". *National Center for Engineering and Technology Education.* Paper 165.

[9] Kelley, T., Knowles, J. G., July 2016. "A conceptual framework for integrated STEM education". *International Journal of STEM Education* 3(11), pp. 1 – 11.

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