Evaluating K-16 Student Engagement In STEM-based Drone Racing

Timothy F. Slater, University of Wyoming, USA
Richard L. Sanchez, Johnson County School District #1, USA

ABSTRACT

Increasing the number of students interested in pursuing careers in STEM, computer science, and technology is of widespread interest to education stakeholders. Yet, despite the tremendous amount of human and fiscal resources directed at increasing the STEM, CS, and CTE career pipelines, numbers are less than satisfying. In a purposeful effort to create a more rapid onramp to high tech careers, the project team implemented a series of competitive, quadcopter drone races for students. In these races, student drone pilots race through a timed obstacle course to determine which pilots navigate the challenge in the shortest amount of time. These events that served as a focal point for motivating students to learn about drone technology, encouraging students to develop precision flight skills, and providing educators both inside and outside of formal classrooms with a foundational structure to increase the quantity and quality of technology education. Assessment of students' and educators' perceptions suggest that the developed program provided a low barrier to entry and engagement pathway for students to become more deeply engaged in technology.

Keywords: STEM Education; Career & Technical Education; Drone Education

To more fully participate competitively in the 21st Century high-tech world economy, education policy makers are continuously calling for more effective STEM (science, technology, engineering, & mathematics), ICT (information & computer communications technology), and CTE (career & technical education) education programs to be provided to students and teachers across the U.S. In comparison with to the traditional science education curricular pathway for college-bound high school students of starting with an Earth science course, followed by biology course, then followed by a chemistry course, and finally concluding with a physics course, many education reformers today are advocating for a less siloed and more integrated approach to STEM, ICT, and CTE education for a wide diversity of high ability students who they hope can be influenced to pursue focused high technology-based careers. (*viz*., Burrows & Slater, 2015). Naturally, educators and educational entities are well positioned to provide education programs supporting modern, high tech careers pathways.

Inarguably, there are countless innovation programs being funded across the U.S. by federal agencies such as NSF, NASA, NIH, and DoE as well as by philanthropic entities, reaching funding levels exceeding hundreds of millions of dollars each year. Funded education projects are wide ranging in nature and stretch from supporting individual, talented students to shadow or intern with successful high-tech professionals to extended residential group learning programs on university campuses or at national laboratories, and, of course, everywhere in between. And, fortunately, many of these projects produce flowery, summative evaluation reports showing the tremendously positive impacts each of these sincere efforts have had on students' intentions to pursue high-tech careers and on participating teachers' new abilities to teach their students better than before. Yet, at the same time, stakeholders are unabatedly continuing to call for even more fruitful and ever more diverse flow of students into high-tech career pipelines.

In response to continued calls for new, innovative, technology-based education programs for an ever-widening diversity of students, a unique opportunity for schools presently exists with the advent of new, low-cost, unmanned aerial quadcopter vehicles. These remotely controlled aircraft—most commonly known as *drones*—hold tremendous promise for engaging students in an exciting new technology area and have recently become within reach of K-12 school and technical college classrooms for at least three reasons. The first reason is that cost of drone technology has dropped precipitously. Whereas a few years ago, purchasing even a simple drone cost far more than a thousand dollars;

today, in contrast, high quality drones can be purchased for less than $100. The second reason drones are now more attractive to educators for teaching is that the computer control flight technology equipping many of these low-cost drones makes successful drone flight for novices surprisingly easy to accomplish. Just a few drone generation control systems in the past, learning to fly a drone often resulting in serious and debilitating crashes. Today, many low-cost drones often largely fly themselves and can adjust to quickly changing windy weather conditions and, at the same time, even automatically avoid collisions with potentially hazardous, inanimate objects.

Moreover, the third reason that drones are highly attractive for teaching technology concepts is that drones and their capabilities are inherently captivating intellectually. Internet sites such as *YouTube* and *AirVuz* host thousands of drone-based videos created by professionals and amateurs alike that have not gone unnoticed by today's students (*viz.*, Slater, 2020). Many of these uploaded videos serve as artful scientific expositions of landscapes and documented community festivals. Today's drones afford students with a new and unique ability to engage in activities that can simultaneously be both scientifically useful and artistically creative expression.

Taken together, these listed reasons are powerful characteristics that motivate us to investigate drones as a focal point for new STEM, ICT, and CTE education programs. This paper describes and documents an educational effort to respond to this "drone opportunity" by creating, implementing, and evaluating a series of drone racing events to encourage educators to teach students technology concepts by including drones in their teaching.

CONTEXT

Racing is perhaps one of the oldest forms of competition. Since the dawn of history, as soon as one person learned a skill, our ancestors would find someone else to compare their skill levels in head-to-head competition—running, horse racing, automobile derbies, and the like. Similarly, authors like Abernaty and Vineyard (2001) have documented that competitions used in an educational context can produce great rewards for competition students. By and large, feminist pedagogical strategists (*viz*,, Briskin & Coulter, 1992) advance the notion that Caucasian male students are more likely to be attracted toward learning events that feature competition as a primary characteristic than female students are. Using this line of thinking, learning events that inherently compare students' knowledge and skills such as science fairs, quiz bowl knowledge competitions, spelling bees, and the like might need to be deemphasized across STEM education in order for a wider diversity of students—especially females—to be engaged in learning. At the same time, as a starkly contrarian example, one should consider the wildly successful case of robotics education and its positive impact on both male and female students. Over the past few decades, the ultimate focus event driving robotics education has been an end-of-year culminating, competition event (Chung, Cartwright & Cole, 2014) of which researchers have consistently found is a positive experience for female participants (Hartmann, Wiesner & Wiesner-Steiner, 2007; Weinberg, Pettibone, Thomas, Stephen & Stein, 2007). Naturally, robotics education and drone education programs share significant similarities.

As part of our preliminary needs assessment leading up to the project described herein, the author team also tested the notion of providing less competitive learning events by running a week-long "drone flying boot camp" at an all-girls school. Influenced heavily by the literature cited earlier about the importance of feminist pedagogies, we had anticipated that the female students would be more naturally drawn to what is often considered the "less competitive and more nurturing" aspects of drone flying—drone videography for capturing aesthetic human events and precision drone flight mission challenges simulating the provision of human relief efforts in hypothetical disaster events, such as delivering first aid and food supplies to those in need. In much the same way, we had anticipated far fewer female students being enthusiastically interested in the more competitive aspects of drone flying, specifically head-to-head racing. Unexpectedly, we found that the portion of women most interested in non-competitive events as compared to competitive events was not significantly different than we experienced with other, more mixed or even male dominated student populations. In other words, students found participating in competitive racing to be motivating and exhilarating—emotions that the project leadership team wanted to capitalize on.

Taken together, the success of competitions as a learning motivator in the context of robotics education and our own needs assessments pointed us toward the question of, "can an organized drone racing league support students' interest in STEM and technical careers?"

METHOD AND RESULTS

The context for this project is a mostly rural, large western state in the northern Rocky Mountain region. Along with participating partners, including the state's flagship research university and the state department of education (Slater, Biggs & Sanchez, 2021), the project leadership team instituted a series of six organized drone racing events across the state. Students were allowed to bring their own drone or use one of the drones provided by the program. Most of the time, students used their own personal drones that were purchased commercially.

**Figure 1**. Illustrative Drone Racing Track Configurations

Races were held in school or college gymnasiums on a Saturday. The race organizer adapted one of the conventional race-track designs, illustrated in Figure 1, spanning a maximum distance of about 120 feet. The "number 13" course seems to be the most common, as it provides both a section for precision flight demonstration as well as a straight section for high-speed flying. The specific rules given to racers are shown in the appendix.

Racers were timed using standard stopwatches starting from the moment their drone left the ground until they had successfully passed through all of the obstacles and landed again on the starting point. There were two categories or divisions of competitors, those using drones larger than 5" and those that were smaller—the smaller drones generally being faster. Winners were determined by which racers finished the course in the shortest amount of time. Obstacles were constructed in the form of various shaped "gates" with varying heights created using 2.5' long 1/2" diameter PVC pipes, as illustrated in Figure 2. Some of the PVC tubes were covered with a foam pool noodle to help protect the drone's propellers from damage, as shown in the photograph in Figure 3.

Figure 2. Sketch of a ½" diameter PVC constructed gate
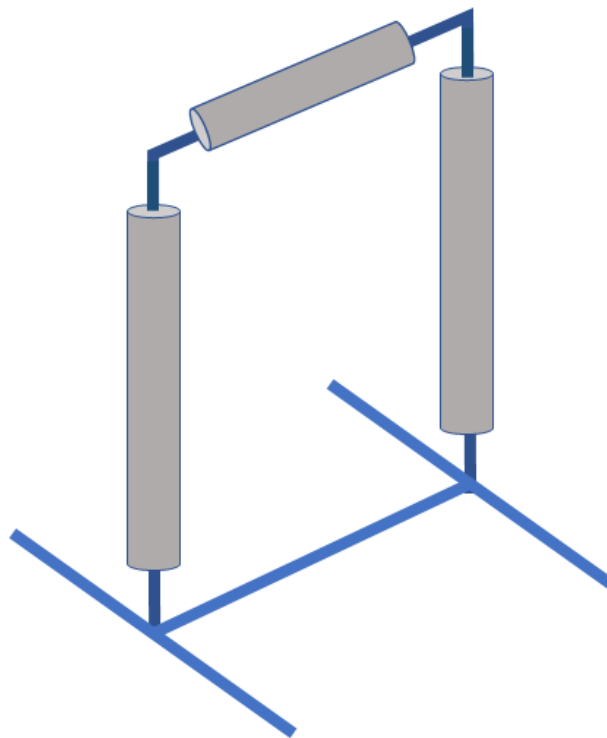
Figure 3. Photograph of Simple Drone Racetrack
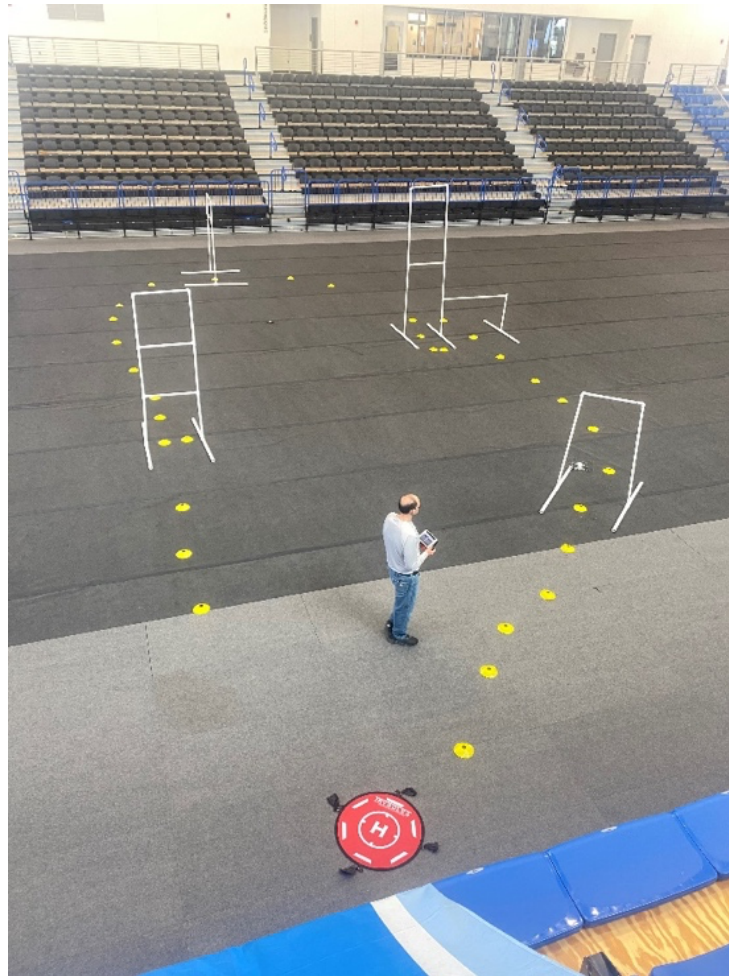
The study participants for this project were middle and high school students who volunteered to take a short, anonymous, Likert-style survey at the conclusion of the race event. The study design was post-test only because the research team was unsure how a pre-test administration might influence the results (*viz*., Slater, Slater, Heyer & Bailey, 2015).

The results of the survey are summarized in Figure 4. Because of the anonymous nature of the survey, it was not possible to disaggregate data by age or sex. The results strongly suggest that students find drone flying to be a valuable activity worth their time. All of these respondents appear to have flown drones before the event at which these surveys were given, and more than half of the students claim to be able to describe career fields that employ drones. This first-steps survey motivates us to look deeper at the benefits of flying drones in a competitive format in future years.

Figure 4. Post-event Survey Results

Likert-scale Item	Total Responses	Strongly Disagree	Disagree but not strongly	Neutral or no opinion	Agree but not strongly	Strongly Agree
It is a valuable use of my time to learn to fly a drone	41	-	-	-	10	31
I practiced flying a drone before today's race	41	-	-	-	2	39
I enjoy the competitive nature of the drone races	41	-	3	5	2	31
I would like to compete in future races	41	-	-		10	31
I can name at least three careers where people use drones in their job	41	-	1	10	14	6

CONCLUSIONS

In this broad, first-steps exploratory study, students reported finding the act of drone flying and the competitive nature of drone races to be a worthwhile endeavor. More importantly, what we learned is that it is possible to create a drone competition event that is not exceedingly difficult to create and, at the same time, that students will attend.

Although high-speed drone racing is in and of itself an intriguing activity, there are few highly paid, high-tech careers based solely on how fast one can navigate an obstacle course. What drone racing does seem to do is motivate students to become precision pilots, capable of remotely controlling equipment. In the realm of drones, this might be navigating a mineshaft or safely inspecting a towering wind turbine. Or, similarly, inspecting homes for roof damage after a hailstorm or monitoring fields for water erosion. Each of these tasks require a knowledgeable pilot who exhibits precise control of their drone, especially in unfavorable weather conditions. It is to this end that engaging in drone racing competitions is aimed.

ACKNOWLEDGEMENTS

AUTHOR BIOGRAPHIES

Tim Slater serves as the University of Wyoming Excellence in Higher Education Endowed Chair of Science Education where his is appointed as a Professor of Science Education and an Adjunct Professor of Physics. A Sequoyah Fellow of the American Indian Science & Engineering Society, Professor Slater earned his Ph.D. from the University of South Carolina in 1993 and has been a tenured professor at several U.S. universities. His primary area of scholarship is teaching and learning of STEM among future teachers and students who are seeking careers outside the STEM career pipeline. Email: timslaterwyo@gmail.com

Rick Sanchez is an FAA-certified pilot and a highly experienced secondary-level technology and robotic drone teacher from Clear Creek Middle School in Buffalo, Wyoming. A graduate of the University of Wyoming, his scholarly focus is dedicated to helping K-12 teachers innovate their integrated teaching efforts across the STEM spectrum.

REFERENCES

Abernathy, T. V., & Vineyard, R. N. (2001). Academic competitions in science: What are the rewards for students?. *The Clearing House*, *74*(5), 269-276.

Briskin, L., & Coulter, R. P. (1992). Introduction: Feminist pedagogy: Challenging the normative. *Canadian Journal of Education/Revue canadienne de l'éducation*, *17*(3), 247-263.

Burrows, A. C., & Slater, T. F. (2015). A proposed integrated STEM framework for contemporary teacher preparation. *Teacher Education and Practice*, *28*(2/3), 318-330.

Chung, C. C., Cartwright, C., & Cole, M. (2014). Assessing the impact of an autonomous robotics competition for STEM

education. *Journal of STEM Education: Innovations and Research*, *15*(2).

Hartmann, S., Wiesner, H., & Wiesner-Steiner, A. (2007). Robotics and gender: The use of robotics for the empowerment of girls in the classroom. In *Gender designs IT* (pp. 175-188). VS Verlag für Sozialwissenschaften. http://ndl.ethernet.edu.et/bitstream/123456789/515/1/48.pdf#page=168

Slater, T. F. (2020). Exploring science fiction, science, culture and science education with a drone film festival at the HawaiiCon Fan Convention. In *Proceedings of the 2020 Science Fictions, Popular Cultures Academic Conference* (Slater, Cole & Littmann, Eds). Hilo: Pono Publishing, pp. 153-161. ISBN: 979-8689344874. https://amzn.to/2XoX7Az

Slater, T. F., Biggs, C. N., & Sanchez, R. L. (2021). Building education partnerships to teach integrated STEM through drone competitions. *Journal of Astronomy & Earth Sciences Education, 8*(2).

Slater, S. J., Slater, T. F. Heyer, I., & Bailey, J. M. (2015). *Discipline-Based Education Research: A Guide for Scientists*, 2nd Edition. Hilo, HI: Pono Publishing. ISBN: 978-1515024569 , https://amzn.to/3lohohF

Weinberg, J. B., Pettibone, J. C., Thomas, S. L., Stephen, M. L., & Stein, C. (2007, June). The impact of robot projects on girls' attitudes toward science and engineering. In *Workshop on research in robots for education* (Vol. 3, pp. 1-5). http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.164.6388&rep=rep1&type=pdf

APPENDIX

Stem Drone Racing Challenge

Rules & Guidelines

The Drone STEM Challenge Series (drone-challenges.org) announces its call for entries for the *Drone Racing Challenge*.

1. Eligibility: The competition is open to individuals or groups of professionals, amateurs, residents, students, and visitors, as per specific guidelines and constraints of contest host (*e.g., students only*)
2. Fees: See the submission guidelines provided for each individual contest.
3. Specifications: In a stop-watched timed flight mission, pilots will use their own remotely controlled drone (for indoors competitions, drones must weigh less than 300 grams with "protected propellers") to quickly navigate a 3D obstacle course. *Winners are determined by the shortest time to successfully navigate all obstacles in the 3D course in sequence and land in the specified landing area.*

1. FAA certification or licensure is not required of any competing drone pilots or optionally assisting visual observing team members for indoor competitions.
   Hobbyist/Educator Drone Flying Licenses are required for pilots flying drones out of doors that weigh between 250 grams and 55 pounds, available at: https://www.faa.gov/uas/recreational_fliers/
2. Pilots may bring FPV first-person-view goggles if they wish, but must provide an assisting visual observer for safety if being used
3. Pilots will only be allowed one attempt at the obstacle course and must complete obstacles in the prescribed sequence and within 6-minutes or be disqualified
4. Pilot team agree not to power on their drones or controllers until cleared to do so in order to avoid contaminated signals with other drones. *Pilots must agree to immediately power down their drones and controllers as soon as the obstacle course is completed.*
5. The event will be mostly likely held indoors in a cleared gymnasium or cafeteria space. Tournament officials will not announce the precise room or course dimensions in advance of the competition, but will have widths ranging from approximately 20 to 30 feet in width by 60 to120 feet in length with a celling height of at least 8 ft. *In no case will participants be required to fly higher than 30 ft to complete the obstacle course*
6. The obstacle course sequence will be created using 4 to 8 gates for the drone to pass through. Gates will have openings varying from a minimum of 1 ft to 7ft wide and can be in a variety of shapes including hoops and rectangles. The center of the openings will range from 1.5 feet to 28.5 feet above the ground. *The precise position of the gates will not be announced prior to the event*
7. In the unlikely event that a drone is damaged during the competition, the tournament officials nor hosts nor sponsors bear any responsibility whatsoever for any damages nor injuries of any kind
8. Official timing will be done using a stopwatch or a photogate by a designated tournament official
9. If prizes are awarded, competitors will likely be categorized by propeller size: those drones weighing less than 250 grams with propeller spans of more than 3.3" (8.4 cm) and those with smaller diameters.

Commonly, small-sized drones are less than 3.75" (96 mm) on their longest side. Examples include NewBee FPV Drones, TinyHawk Drones, Voyager Drones (without camera); and Holy Stone Mini-Drones (without camera).

Common medium-sized drones are more than 3.75" (96 mm), but less than 250 grams (or less than 300 grams when propeller guards are added). Examples include the Tello Drone, the DJI Mavic Mini Drone.

Common large-sized drones more than 250 grams, which are not often flown in indoor competitions as they require FAA licensing, include the DJI FPV Racing Drone, the DJI Mavic Pro Drone, and the DJI Phantom Drone.

EVENT SEQUENCE: Pilots will be given notice to power up their drone and controller approximately 30-seconds prior to the start of the race. Drones will be launched from a marked spot on the floor. Timing starts when the tournament officials announce, "ready-3-2-1-fly!" Pilots are to complete the obstacles in sequence—if an obstacle is missed, the drone needs to turn around and try again, if the drone crashes, the team's PIC or assisting VO (optional) may cautiously enter the course and set the drone upright if needed.

When the drone completes the obstacle course and lands on the "launch pad" then a tournament official will announce the course completion time. *At that point, the team is to power down the drone and the controller immediately or be disqualified.*

In some cases, prizes may be awarded by sponsors. Please show sponsors your appreciation for their support.

NOTES