Positive Influence Of Education Partnerships For Teaching Integrated STEM Through Drone Competition

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ABSTRACT

While enhancing the STEM career pipeline through improved quality and quantity of STEM teaching available to an ever-widening diversity is K-12 students is garnering significant attention across the U.S., there lacks widely adopted implementation and support models that efficiently make full advantage of the vast human and fiscal resources available. A wide swath of STEM education stake-holding partners—schools, businesses, government agencies, non-profit organizations, and institutions of higher education—frequently are compelled to provide support and guidance but lack easy to follow pathways in order to do so. This research study describes and documents a unique vehicle to bring often disparate partners to a unified effort under the banner of drone education designed to improve STEM and technology-oriented career pathways. Identified barriers that the collaborative partnership helped overcome to ensure success include providing: modest start-up costs for modern high-tech equipment for participating schools (drones); an infrastructure for leveraging the consistently successful approach to providing regional and statewide competitive events (precision drone flight and knowledge competitions); large-scale buildings and facilities to host competitive festivals and events (e.g., indoor sports stadiums); and K-12 teacher professional development programs along with classroom-ready instructional materials needed to nurture and sustain student drone education programs.

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

For many decades, there has been considerable interest in expanding the number of pathways that students can follow to enter the STEM career pipeline. In the U.S., this interest has been buoyed by the contribution of hundreds of billions of dollars each year coming from both governmental and philanthropic sources to stimulate students' interest in STEM careers (Slater, 2010). Considerable resources have been allocated toward introducing students to remote and computerized control of systems—often in the form of robotics spirited by robotics competitions. In recent years, this activity has become so widespread that many states are implementing computer science course requirements for its college-bound high school graduates (NCES, 2017).

Numerous authors, such as Miller and Nourbakhsh (2016) writing in Springer's *Handbook of Robotics* (ISBN 354023957X), as well as scholars contributing to Barker's (2012) *Robots in K-12 Education: A New Technology for Learning* (ISBN: 1466601825), have extensively described and documented how robotics education programs make tremendous impacts on future scientists' and engineers' lives and career plans. Moreover, robotics education programs reach far beyond high school age bands. Robotics education programs often start surprisingly early in the STEM pipeline, often in middle school and sometimes even before. Jung and Won (2018) recently reported significant, measurable successes across both cognitive and non-cognitive domains in terms of students' enhanced coding and computer programing abilities in their nationwide metanalysis summarizing 47 peer-reviewed, quantitatively focused papers documenting early elementary grades robotics projects over the last ten years.

The consensus bottom line message from scholars and evaluators to classroom practitioners and policy makers across all of these research and program evaluation reports are threefold: (*i*) a wide diversity of students love robotics and are motivated to pursue STEM career pathways as a result; (*ii*) students successfully learn STEM concepts and 21st

Century workforce skills while participating in robotics; and (*iii*) competitions and challenges serve as a unifying banner to move students forward in their learning. These same results seem to hold true for many aspects when considering robotics' close competitive cousins—*Science Olympiad* and science fairs (Abernathy & Vineyard, 2001).

Speaking to the value of and unifying call-to-action created by holding competitions and issuing challenges specifically, a casual observer new to robotics education as part of the STEM education enterprise might mistakenly think that there have always been a well-conceived, relatively comprehensive infrastructure of regional, national and even international competitions providing an important driving force for the success of robotics education. This is far from true: Forty years ago, robotics competitions and tournaments were by and large informal and highly dispersed communities of well-meaning robotics team coaches trying to do something good for their students. As a result, the rules, standards, and cultural flavors of robotics tournaments, leagues and competitions still vary considerably across the country, and even across the world, even though organizations have been attempting to standardize robotics competition rules and calendars.

At the same time that these far-reaching robotics-specific education programs are having great success, there are still rural, poverty-stricken regions and as yet underutilized populations of talented students that robotics education has been unable to reach. Among many complex interfering factors, two stand out. One challenge is that robotics programs are focused predominantly on helping students learn engineering and advanced computer science programing concepts that will help them be successful and perseverant along pathways for undergraduate and graduate STEM career fields. The problem is that many of the most underrepresented students—for example those living on impoverished Indian reservations and Hawaiian homelands—often have limited interest in moving away from their family and home-culture to attend some distant university to attend many years of education to prepare themselves for a STEM-related career that also keeps them far away from their home (Shields, 2004). In other words, although building and coding robots to accomplish tasks is definitely "cool," robotics education programs have by and large been unable to provide a relatively quick pathway to lucrative STEM careers in students' local communities.

A second challenge is that participating in robotics education programs eventually becomes quite expensive for all stakeholders, including the purchase and maintenance of the robotics equipment, subscriptions and registrations for competitions and challenges, and sometimes requires expensive travel for rural robotics team to overnight competitions, often held in expensive urban hotels. Although grant and philanthropy programs certainly exist to get schools started in robotics, the ongoing cost requires considerable school administrative support and often student-led fundraising efforts to continue participating.

These pragmatic issues combine to call for parallel solution to compliment robotics education programs that focuses on supporting students earning high school, 1-year technical, or 2-year associates degrees to quickly enter the STEM workforce in technical fields. Such a solution might be in the form of a comprehensive drone education program where students learn to engineer, pilot, and utilize remotely controlled quadcopter areal systems—drones. The features of drone education program can readily focus on rapidly turning technical STEM knowledge and 21st Century skills into technical careers that are relatively low cost and can be done by students committed to staying in and contributing meaningfully to their home communities. Such a program is well positioned to focus on students who want much needed STEM-related technical jobs now—not five to ten years in the future afforded by an undergraduate or graduate degree—that serve needs in their local communities focused on aeronautics, remote monitoring, videography, GPS mapping, 3D-parts printing, etc. These are the kind of technical jobs that can be performed from anywhere with cellular or Internet connections. Imagine helping students in a very short-time frame become valued and contributing members of their communities by frequent remote monitoring of crops supporting local agriculture, inspecting hailstorm damaged roofs for insurance and construction companies, creating video flyovers and fly-throughs for real estate companies, making updated videos for local tourism boards and nature preserves, monitoring forest fires, and supporting local law enforcement—STEM-related technical-level jobs that local communities need now.

Illustrative Examples Of Workforce Careers For Those With FAA Drone Certification

Figure 1. Illustrative Examples of Workforce Careers for those with FAA Drone Certification

Real estate marketing
Construction materials management
Nature preserve documentation
Forest fire prevention
Railway surveys
Radio tower inspections
Tourism development
Agricultural crop monitoring
Hailstorm inspections
Forest health monitoring
Disaster relief
Bridge infrastructure assessment
Emergency services support
Construction surveying
Cultural ceremony documentation

Done with purpose, such a drone education program can be fine-tuned to support immediate STEM, information/computer technology and high-tech vocational workforce needs in local communities that robotics education can only indirectly support. Additionally, a carefully constructed drone education program can overcome the aforementioned shortcomings of robotics education. One of these benefits is that by and large setting up a drone program costs far less than buying annual robotics kits. Another benefit is that observing racing competitions are naturally more exciting to watch for spectators than robotics competitions. Additionally, drone education programs can have an unlimited number of “driver/operators” fully participating on a drone team whereas most robotics teams have a single “operator.” Moreover, drones can even be flown off-site via the Internet and do not necessarily need a facility. There are already international drone competitions, races, and challenges done using simulators by students using their home computers which dramatically expands access to a wider diversity of students. Most importantly, there are far more immediate STEM career-prospects for skilled drone operators that do not require an advanced college degree.

Moreover, getting students excited about being involved in a competitive school-based drone team might not require significant marketing efforts. Nearly every high school student who has been on *YouTube* has already seen captivating videos made by drone operators and, frankly, most students already think drones are cool and immediately have creative ideas about what can be done with them. Drone education programs could provide new and rapid access pathways for underutilized and location-bound students (and their teachers) to (*i*) earn proper FAA commercial flying certifications, (*ii)* to have pedagogically effective and mentored experiences in learning to accurately fly and efficiently maintain drones (often through 3D printing of self-designed parts), and (*iii*) to learn how to use drones ethically while establishing STEM, ICT and high-tech vocational careers focused on remote-control and remote monitoring.

The conception, development, funding, and implementation of a comprehensive drone education program is unlikely to be successful if done by a single person or even a single entity. Rather, a robust partnership of stakeholders and resource providers seems like the most effective way to successfully implement a drone education program with a widespread footprint that addresses many areas of the curriculum (*viz*., Goodlad, 2016). At the same time, the selection and solicitation of partners requires knowing both what a drone program consists of AND what obstacles need to be overcome in order to achieve success. This naturally leads to the vital, overarching question of what are the barriers to success for a statewide drone education program? It is to this question that this paper is aimed at answering and overcoming.

MATERIALS AND METHODS

In order to describe and document a successful drone education program that resulted from the development of meaningful partnerships, this study team understood a research design to identify barriers to success and to nurture partnerships that were designed to overcome these obstacles. The first step was to identify barriers, followed by soliciting and engaging partners who had resources and disposition to overcome these barriers. In short, the strategy was to iteratively uncover barriers to participating student drone pilots and engage partners to overcome the discovered obstacles.

The underlying research foundation was a theoretical foundation and methodology of "narrative inquiry" where the research team sought to examine and understand where, how, and at what point in time human actions cause growth in an educational system. In brief, the narrative method as applied in this present context can perhaps best be summarized as an act of collecting disparate project partners' narratives and recombining key elements into a cohesive and explanatory story. In this context, the research team's systematic process of "restorying" results from analyzing key elements and then highlighting influential actions and events into a single cohesive narrative. This qualitative interpretative research tradition is eloquently described elsewhere by Creswell (2007, p. 53) as well as bySlater, Slater, Heyer and Bailey (2015, p. 86)), and an exhaustive explication of this research method here in this paper is beyond the scope of this paper and unnecessarily distracts the reader from the authors' main messages.

The study participants are representative individuals who played a major role in identifying barriers to success the project encountered and those entities who generously provided insights and solutions, often through casual, unsolicited conversation. Mostly unidentifiable, these happenstance participants include students, teachers, administrators, business owners, representatives from governmental agencies, and business owners who provided unsolicited insight to the project leadership team that led to the project's growth and success. Although the authors acknowledge that this convenience approach to "sampling" can suffer from uneven and perhaps even systematic error laden data acquisition, the insights and lessons learned are judged to have considerable face value for those iteratively planning and improving their pilot-testing programs. The end result of this study method is a descriptive retrospective, *post-hoc* analysis, and "restorying" of key events influencing the project's evolution.

Study Context

This study occurs in the context of a rapidly maturing, statewide drone education program being piloted in the Rocky Mountain region of the United States and is aimed at improving the number of pathways for a wide diversity of students to engage in interdisciplinary *STEM + Arts* —STEAM— education programs. In brief, the *STEAM Drone Challenge* program [www.drone-challenges.org] is an Olympiad competition-style a series of competitions that celebrate interdisciplinary STEAM education programs. Leveraging the excitement of competition, the *STEAM Drone Challenge* consists of a hexathlon of individual and team competition across six domains: racing, videography, engineering precision flights, VR flight simulators, business planning, and computer coding.

Figure 2. Components of a Hexathlon of Events Comprising the *STEAM Drone Challenge* Program

The first domain people naturally think of when they think about competitions involving drones is perhaps *drone racing*. Historically, as soon as the very first two cars were constructed, most certainly the owners pitted the two cars against one another to see which one was fastest. The same probably goes for horses. In drone racing, pilots race around an obstacle course to see which pilot can safely navigate the course in the least amount of time. Although this can certainly be done one drone at a time, we find that it is far more exciting to have multiple pilots on the obstacle course at the same time.

The second domain is *videography*. Many drones are outfitted with digital video cameras that can record still photographs or capture movies. For our events, we host a drone film festival where pilots capture videos and edit them together to create films. To keep things manageable, we ask that videos be less than 90 seconds in length, at least 50% of which are captured by a flying drone that is piloted within legal limits. Videos are judged in terms of being illustrative of precision flight, creative editing, appropriate adherence to a theme, inclusion of supporting music, and overall visual impact, as described elsewhere (Slater, 2020).

Because skilled pilots are valued, the third domain is *precision flying*. Our precision flying competitions challenge flight teams to complete a mission where they survey an obscured area using the video camera, land as closely as possible to a specified target, and navigate obstacles by avoiding collisions. Some of our competitions ask flight teams to slightly modify their drones by adding skyhooks created from pipe cleaners in order to move objects from one location to another. Another approach is to challenge flight teams to engineer and deploy specific tools attached to a drone that have been created using a 3D printer.

Not all pilots, particularly those too young to legally drive themselves, can readily travel to a competition or afford a high-cost drone. In response, we have created *virtual drone races* where pilots can simultaneously compete head-to-head via the Internet in a simulated obstacle course environment using a virtual reality simulator. Pilots need an internet connection, a computer equipped with a fast-gaming graphics card, a connected flight controller, and low-cost drone simulation software such as *VelociDrone*.

Many states across the U.S. are instituting computer science requirements, and programing drones for autonomous flight missions are fully in compliance with such requirements. For our competition events, student drone coding teams are presented with a flight mission challenge—such as starting atop of table, take off, circle underneath the table, and return to land on the launch site—that is to be completed totally hands-off. We find that using a graphical interface that drags and drops code blocks using *DroneBlocks* as a block coding software program is quickly within reach of young students, although more common student coding languages, such as *Scratch* or *Python*, work as well. Student flight teams are judged on how completely and how efficiently their code completes the task. These coding experiences embedded in co-curricular and extra-curricular student activities not only address emerging computer science standards and frameworks but can also attribute to the broader set of student academic and skill growth (Singh, 2017).

In order to fly a drone professionally as a commercial enterprise, or to fly drones larger than 250 grams, pilots need to earn formal government *FAA Part 107* certification. This is available to pilots at least 16 years of age and is done at an official FAA flight testing facility. To support students learning the legal aspects of drone flight, including formal airport operations and aviation weather, we provide *entrepreneurial business and drone knowledge test competitions* where students compete to earn the highest scores on tests that simulate the FAA knowledge tests. These tests include questions about commercial business operations for licensed drone pilots.

RESULTS

The process of building collaborative partnerships for initiating this large-scale and multifaceted drone education project turned out to be a chaotic "organic" process characterized by a repeating cycle of barrier identification and solution design for overcoming those encountered barriers. These identified barriers include a need for: modest start-up costs for modern high-tech equipment for participating schools (drones); an infrastructure for leveraging the consistently successful approach to providing regional and statewide competitive events (precision drone flight and knowledge competitions); large-scale buildings and facilities to host competitive festivals and events (e.g., indoor sports stadiums); and K-12 teacher professional development programs along with classroom-ready instructional materials needed to nurture and sustain student drone education programs. The solutions consistently came from the development of partnerships. Each of these are discussed in turn in the sections that follow.

Acquiring Start Up Funding

As with any technology-based school program, there are start-up costs to schools to acquire needed technology. The most common barrier we uncovered in this study was universally "where does one get drones to start a school-based drone team?" Our study participants consistently reported that nowadays there are rarely unallocated funds for schools to develop new programs that focus on drones. A high-quality drone can be purchased for less than $100 USD, which is potentially in reach for many school budgets. The same goes for volunteer scouting troops, church groups, and community clubs who want to add learning about flying drones to their programs. Drone programs have the potential to be quite inexpensive to initiate.

One rapid-implementation approach for schools or other educational entities to start a drone program or after-school club is to provide no direct financial support, but instead adopt a *Bring Your Own Device* (or, in the present BYOD context, Bring Your Own *Drone*) approach to cover any start-up expenses. Some drones fly using a smart phone or a tablet as a controller and video resource, and many students today already have their own powerful smart phones. And, in much the same way, students could bring their personal drones to a drone flying club. In some school districts, affluent parents might have purchased drones for their children, but no one in the family has any idea how to fly it and the drone is simply gathering dust in the back of the closet. This is also true regarding telescopes for school astronomy clubs—countless telescopes are sitting unused in a closet somewhere that could readily be put into service by an enthusiastic class or club leader

This is not to say that there are not serious disadvantages to a BYOD approach for running a school-based drone program. For starters, there can be a dramatic socioeconomic divide between those that can afford to purchase their own drone and those who cannot, and BYOD usually exacerbates this difference. For another, if club members bring their own drones, there is likely to be a lot of different types, sizes, and brands of drones in the same space, which is challenging to manage in the best of circumstances. Finally, there is the security and replacement issue of what to do when someone's personal drone is broken or unexpectedly disappears. In the end, if your institution usually provides golf clubs to the golf team or athletic shoes for sports teams, then BYOD is going to be problematic for your nascent drone club enthusiasts. Alternatively, if club members participating in these events usually provide their own, then it is probably worth considering adopting a BYOD strategy. This is much the same approach as many schools' tennis, golf, and marching band members bring their own equipment to participate.

At the same time, our study uncovered that there are often willing partners who can provide loaner or permanent equipment to schools. These partners were found primarily through an informal "word of mouth" networking process. To our great surprise, many communities have drone professionals and small drone-based companies who provide commercial drone services for real estate companies, wedding photography needs, and government agencies who often need to upgrade their equipment and, as a result, often have high quality and fully functioning drones that are unused that can be readily loaned to educational groups. These pilots are often drone enthusiasts who might even provide some instruction to students who live in their community and serve as volunteers to help run drone groups. We found great support among these individuals who quickly became full partners in our growing program. The same was also true in the partnership we formed with the state 4H program.

A more formal solution is to obtain funds by partnering with governmental agencies. In the present case, the pilot program described above received funding from its higher education partners including the University of Wyoming Excellence in Higher Education Endowment for Science Education, the College of Education, the Center for Geographic Information Systems, and the Trustees' Education Initiative. As one example, the UW Excellence in Higher Education Endowment provided $1500 USD "starter kits" (illustrated in Figure 3) to K-12 teachers that included several different types of drones to school classes and clubs. These partners provided the bulk of our program's financial resources.

Illustrative School Drone Team Starter Kit

Figure 3. Illustrative School Drone Team Starter Kit

Six (6) Holy Stone HS210 Mini Drones
Four (4) Ryze Tello EDU Drones (*with extra batteries*)
Two (2) BetaFPV Cetus Pro FPV 16AD02 Whoop Drone Kit
One (1) DJI Mavic Mini II Drone (*with SIM memory card*)

For our growing drone education program, significant funding was generously provided for teacher-training by the Wyoming State Department of Education through funds from *The Carl D. Perkins Career and Technical Education Act of 2006* (aka *Perkins IV Funding*), a principal source of federal funding to states and discretionary grantees for the improvement of secondary and postsecondary career and technical education programs across the nation. Perhaps surprising, conventional STEM funding sources for drone education are often seemingly difficult to obtain as drones in schools more often take the form of technical education than they do as traditional STEM education. For example, the nationwide program of *Science Olympiad* does not currently have drone competitions, whereas the nationwide *SkillsUSA* program does. In other words, developing partnerships with entities concerned with career and technical education were much more conducive to successful partnerships than with science and engineering firms.

Developing a Low-Friction Plug-and-Play Infrastructure

K-12 and college students are busy people. And, K-12 teachers, technical college faculty, and college professors are perhaps even busier. In this day and age, there are so many competing opportunities vying for the attention of talented individuals who could become active precision drone pilots, flight team members, and supervising mentors. Our study uncovered a widespread barrier that any successful drone program would need to be incredibly easy to enter and participate in. In other words, we learned that participation would require very low friction and very little ramp up.

This barrier of needing a low friction infrastructure was addressed by building a partnership with an institution of higher education. In the present case, faculty and staff from the partnering local state land grant university in this present case, created, advertised, and hosted easy-to-enter competition events for school drone teams and individual pilots. The underlying idea is that new school drone teams would only be created by educators if those participating students had something to go and do as a team. This solution strategy turned out to be a version of, “if you create it, they will come” because local educational entities are already too overloaded with existing tasks and reporting requirements to create something else; but, when events already exist where all participants had to do is “show up and fly,” then nascent school drone programs are stimulated to grow and mature. The different events created by our higher education partners are described earlier in Section 2 of this paper.

Community, regional, and state-level events also provide an opportunity for limited engagement partnerships with entities that otherwise not have a pathway to support a drone education program. For example, once-a-year, limited sponsorships where commercial entities can provide a small amount of funds for t-shirts, trophies, and facilities serve as an excellent and low-cost way to advertise and simultaneously support an important educational cause. The same goes for enthusiastic individuals who enjoy volunteering at such education events. Volunteers with only a modicum of training can serve visibly vital roles on the day of a competition event, including building obstacles for pilots to avoid during flight, serving as timekeepers and race officials, manning video cameras, and working as score keepers. For many similar events, volunteers are essential workers for an event’s success, and it is no different in the present case. Such roles of partnering volunteers are critically important but require only a minor time commitment for meaningful participation.

Acquiring Appropriate Facilities

One aspect our team initially overlooked was the barrier to having safe places where novice drone pilots could fly. Our study participants quickly pointed out that large-scale venues where drones can be flown are difficult to obtain—school gymnasiums are often booked full with school sports team practice schedules during the week and with “games” on nearly every weekend. One might initially attempt to only fly out of doors, but some community recreation parks have local regulations prohibiting the flying of drones in public spaces. Or, alternatively, one might try to fly drones around empty parking lots, but such an outside scenario is complicated because smaller, less expensive drones cannot be readily flown outside if weather conditions are windy—a common occurrence in Wyoming. Furthermore, larger and more expensive drones that can be easily flown in windy conditions often require federal FAA registration, making flying smaller drones indoors a far more attractive pathway for novice drone pilot flight teams.

To overcome this barrier, our team developed partnerships with local schools, technical colleges, and community colleges to provide flying spaces at low- to no-costs. These entities had conventional gymnasiums that were sometimes available, but more often had other often unused, large spaces that worked exceedingly well. These included high ceiling vocational shop teaching spaces, lunchroom and cafeteria spaces, and common foyer areas which worked perfectly well for our purposes. This strategy allowed partners to provide valuable spaces at no cost to the program. Worth of note, one of most dramatic of these spaces was the diesel truck repair and technology centers at the *WyoTech Institute for Advanced Diesel Technology* facility where pilots could fly their drones indoors through a naturally occurring slalom serpentine of giant over-the-road 18-wheeled trucks and large farm tractors.

Providing Professional Development

Affordable drone technology is relatively new. As a result, our study participants consistently explained that adults who could serve as drone class teachers, drone team coaches, and drone club sponsors likely had no drone flight experience and no drone flying licensure. Moreover, few of these people even had drones themselves. Taken together, this served as an enormous barrier to developing a statewide drone education program.

In this situation, partnering with a higher education institution provided the program with a solution in the form of formal, credit bearing, professional development workshops where teachers could be rewarded not only with new knowledge, expanded teaching skills, and enhanced confidence in mentoring students in flying drones, but also earn credits that can potentially move teachers up on a school district pay scale or move educators closer to a obtaining graduate degree, if desired.

In response, our team brought together a partnership that included university teacher preparation and geography professors, K-12 science educators and commercial drone pilots to (*i*) train K-12 teachers and community college faculty basic flight skills and (*ii*) prepare those educators to mentor students to safely fly drones and gain basal understanding of industry drone application and careers. The cross-discipline and cross-K-20 representation of this program bolsters the relationships, curriculum, and workforce pipeline across education, community, and industry (Garrison, McConnell, & Biggs, 2021).

In addition to bringing together educators from multiple levels for training, the research team considered the Fullan and Hargreave's (2016) professional learning and development (PLD) model, coupling tangible teacher skill and resource gains with shared and sustained commitment and experience of the educators involved. Awareness building workshops can be done in just 90-minutes, but we find two- to three-day workshops work best. Certainly, teachers need more supervised "flight time" to become expert pilots themselves, but we found that novice pilot teachers could surprisingly quickly develop sufficient confidence to supervise students, who the author team consistently observes that students learn precision flight skills considerably faster than adults. The 3-day training and additional 3-day conference, along with ongoing learning community contact and expansion of expertise and tools to bring to their students, are all steps toward a "culture of collaborative professionalism" (Fullan & Hargreaves, 2016, p. 21).

Simultaneously, we discovered that educators needed classroom-ready instructional materials to help their students learn how to fly drones safely and precisely, manipulate cameras, edit video, learn basic block coding skills, and develop comprehensive flight mission plans. In response, our team created a set of classroom-ready lesson plans, including flight missions and challenges to support educators in teaching their students to fly (Slater & Sanchez, 2021). These curriculum materials seem to work equally well in a formal school drone technology class, an afterschool drone extracurricular club, and with outside of school learning group formats like scouting, 4H, and summer camps.

Curriculum materials supporting professional development need to be of high quality. One unexpected challenge was that when we applied an *Interdisciplinary iSTEM Assessment* to determine the extent to which the project's developed curriculum materials met the definition of "integrated STEM" advanced by Burrows and Slater (2015), our employed materials did not score as high as we would have liked in terms of their interdisciplinary-ness.

Figure 4 shows the assessment of Slater and Sanchez's (2021) *Teaching Integrated STEM with Drones* curriculum materialsmaterials in terms of how reflective the project's instructional materials are of interdisciplinary STEM. Assessment of these materials by this paper's author team scored 6 of 15 possible points, placing it in the low category of *iSTEM Level One*. In retrospect, we judge this score to have face validity because the materials were created to teach students to fly safely and precisely while following the legal requirements for compliant drone flight. These materials do present topics that skim the edges of the various STEM disciplines, but the materials were not purposefully created to be interdisciplinary in that they do not intentionally draw from and carefully interweave and repeatedly interconnect the different pillars that compose conventional definitions of STEM. In other words, simply because the concept of "flying drones" itself sits in the spaces between traditional STEM discipline pillars, drone flight concepts in and of themselves are not automatically able to be defined as being inherently interdisciplinary.

Figure 4. *i*STEM LEVEL ASSESSMENT INSTRUCTION Scores for Slater & Sanchez (2021)

iSTEM Level Assessment Instruction *Teaching Stem from The Sky* (Slater & Richard, 2020)	**- 0 - no evidence**	**- 1 - implicit evidence**
1. Instruction and/or materials emphasize computational & arithmetic thinking as a frequent part of instruction on other topics		
2. Instruction and/or materials frequently exposes learners to the same phenomena or conceptual principle multiple times in the same discipline		1
3. Instruction and/or materials frequently exposes learners to the same phenomena or conceptual principle multiple times in the different disciplines		1
4. Engineering design projects are frequently employed to deepen students understanding and engagement with targeted concepts		
5. Instruction and/or materials consistently, frequently, and meaningfully provide multiple engagements with the same phenomena or conceptual principle using mathematics AND engineering design AND multiple disciplinary contexts	0	
Total (calculated by total points assigned)	6	

iSTEM Level Assessment Instruction *Teaching Stem from The Sky* (Slater & Richard, 2020)	**- 2 - some or inconsistent evidence**	**- 3 - strong, repeatedly observed evidence**
1. Instruction and/or materials emphasize computational & arithmetic thinking as a frequent part of instruction on other topics	2	
2. Instruction and/or materials frequently exposes learners to the same phenomena or conceptual principle multiple times in the same discipline		
3. Instruction and/or materials frequently exposes learners to the same phenomena or conceptual principle multiple times in the different disciplines		
4. Engineering design projects are frequently employed to deepen students understanding and engagement with targeted concepts	2	
5. Instruction and/or materials consistently, frequently, and meaningfully provide multiple engagements with the same phenomena or conceptual principle using mathematics AND engineering design AND multiple disciplinary contexts		
Total (calculated by total points assigned)	6	

Note: *Adapted with permission from Burrows and Slater (2015) who argue that a total of 0-3 points is generally considered iSTEM level Zero; 4-7 points is iSTEM Level One; 8-11 points is iSTEM level Three; and >12 points is iSTEM Level Four*

DISCUSSION AND CONCLUSIONS

The development and leveraging of partnerships proved to be the essential component to being able to envision, create, implement, and nurture a successful statewide drone education program. In this context, we define partnerships pragmatically as a community of individuals who all bring needed human knowledge and fiscal resources to unifying project—a statewide series of drone education and competitive events. In this sense, no individual contributor had all of the resources or expertise needed to develop and conduct the program. Instead, in this instance, the sum is truly greater than the parts.

Each partner not only contributed resources and expertise, but also gained benefits. Most of the partnering entities desire to support K-12 and college education, but don't often immediately have pathways to do so without devoting considerable time and expense. In this partnership, collaborators needed only provide a small effort to the larger project, and large numbers of students and schools were positively impacted. In much the same way, most of the partners desire positive public relations and advertisement and gained these attributes by participating in the project.

As this was a first steps implementation study, the project generated more questions than answers. These questions provide a pathway for future research studies that need to be undertaken to better understand the nature of effective, large-scale STEM education programs as well as better documenting the development pathway of effective partnerships. First and foremost, among these future research questions are to systematically study student outcomes of participation in drone education. At present, there are few widely vetted and agreed upon goals or standards for drone education and, in parallel, no extant conceptual knowledge surveys or affective domain inventories that systematically catalog and measure student outcomes. Measuring the effects on students and their teachers is a high priority research endeavor the STEM and technical education community desperately needs.

In much the same way that there currently exists no agreed upon goals or assessment instruments to measure student outcomes, there are as yet no validated research instruments to measure the impact on participating teachers' instructional skills or teaching confidence. Such measurement tools do exist to measure reformed teaching (e.g., *RTOP*, Sawada et al., 2002) and teaching confidence (e.g., *STEBI-B*, (Enochs, Scharmann, & Riggs, 1995)and could serve as departure points for future researchers. Similar work has also been done in robotics by Cross, Hamner, Zito, and Nourbakhsh (2017)and Burrows, Borowczak, Slater, and Haynes (2012)and these efforts could serve as a solid starting point for nascent drone education scholars.

Finally, this research uncovered in broad strokes the benefits afforded to the participating, collaborative partners. The scholarly literature would benefit greatly from a laser-focused research effort documenting the specific benefits partners gain by full and partial participation in drone education programs. Such research efforts would inform similar programs in the future so that other projects could achieve successful implementation more rapidly.

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