Idaho Drone League (iDrone) to Stimulate STEM workforce

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Abstract

The Idaho Drone League (iDrone) was launched to inspire the next generation's workforce through engagement with STEM research and education. Idaho youth (middle/high school students) participated in four two-day drone workshops in locations across Idaho. Although drone applications are prevalent in many civil operations, including emergency response, hazard monitoring, delivery services, transportation, precision agriculture, public safety, and more, STEM workforce development programs are limited. The iDrone program, an informal STEM activity, was developed to introduce and apply STEM concepts packaged in a large dose of imagination, excitement, and teamwork sprit to inspire the future Idaho STEM workforce. The hands-on drone workshops integrated computer science, technology, engineering, and STEM career education. Students worked in groups to build, program, and fly drones and learned federal regulations and safety guidelines. The students also interacted with local professionals who use drones in their work and were introduced to a variety of drone research applications. Throughout the workshops, the students also shared and explored their own creative ideas for future drone applications and technologies. The preliminary results from student surveys demonstrate that iDrone can improve the preparedness of Idaho youth for college and careers in STEM fields. The developed iDrone curriculum module can be easily transferred and employed to promote a STEM pipeline broadly for K-12 education as well as for continuing education units (CEU) programs, undergraduate curriculums (iDrone X), and for graduate students and professionals (iDrone Pro) in years to come.

Introduction

Idaho is heading for a crisis in the workforce with sixty percent of projected jobs requiring postsecondary education by 2020 (Idaho STEM Action Center, 2016), mirroring an overall trend in the U.S (U.S. Bureau of Labor Statistics, 2014). Additionally, thirty-eight percent of U.S. jobs are likely to be lost to automation in the next fifteen years (PricewaterhouseCoopers, n.d.), which makes states with a range of manufacturing jobs, like Idaho, particularly vulnerable. These changes in the job market suggest that in addition to being prepared with academic courses for their educational careers, America's youth should also have an understanding of the changing landscape of jobs for the future.

A recent study by Hormel et al. (2013) demonstrated that many students in Idaho do not feel well prepared to make college or career decisions, such as what classes to choose and which careers to pursue. In addition, the STEM Access program at the University of Idaho (UI) has demonstrated that students who are interested in STEM do not necessarily see STEM as an important part of their careers, and their motivation toward a university major and/or career in STEM can be low, which is the current trend across the state of Idaho (Hamilton, Hormel, & Stauffer, 2016). This is particularly challenging for students underrepresented in STEM, as they often depend on the K-12 school system to provide that support. Such disadvantaged populations in Idaho include female students, rural students, potential first college generation students, students from low-income families, and Latino and Native American students. College and career decisions are often made by the information available to youth, such as social media, formal education, community, and out-of-school experiences.

Previous studies indicate that student engagement (Chen, 2013; Kober, 2015) and project-based learning increase student learning and improve retention for STEM majors (Raines, 2012). In addition, exposure of diverse populations to role models has been shown to have a positive effect on a STEM sense of belonging (Shin, Levy, & London, 2016). Hence, this project was designed to engage students in hands-on inquiry projects where they can lead with their own research questions, connect to real-world careers, and meet in-person with professionals engaged in STEM careers to increase their interest and understanding of applied STEM and STEM careers.

To maximize student interest in the STEM workshop, we applied the exciting and rapidly-developing technology of drones as a STEM learning tool. Drones (also known as unmanned aerial systems or UAS), are one of the current new driving forces for economic development, but education curriculums and courses stimulating future workforce are limited, both for professional drone operation and for youth to use drones as an easily accessible technology for STEM learning. Drone technologies are not military-centric businesses anymore in the sense that their broad applications are prevalent in many civil operations, including emergency response, hazard monitoring, delivery services, and public safety, so they draw a lot of attention from STEM communities. Thanks to technology improvements on smartphones and various sensor devices, the drone market will increase rapidly in the next decade. Thus, the number of civil operation drones will soon be larger than that of military operations. As of 2013, the global UAS market associated with research development on climate science, land and ocean management, aerial video photography, emergence response, and transportation was about $66 billion USD while it is estimated to increase to $114 billion USD in 2022 (Markets and Markets, 2015). However, domestic technology in the United States is not yet ready to be competitive in the global market due to slow core technology development, limited expertise, and incomplete infrastructure. Additionally, federal regulations and policy on UAS applications are still evolving to allow people to fly UAS safely and legally in the public domain.

We have therefore developed a drone education program, titled Idaho Drone League (iDrone), to educate and train Idaho youth (6th - 11th grade students) to become familiar with drone technologies in order to broaden and deepen students' interest in STEM fields and build competitivity for the future workforce (University of Idaho, 2018). Additionally, the hands-on drone workshop experience design also provides support for students already planning toward STEM careers to be successful in those pursuits. Other STEM programs have been designed that are weeks long (Kittur et al., 2017) and require time and resources that aren't necessarily available, especially when trying to reach underrepresented students in rural communities. Alternatively, iDrone has many elements needed to inspire STEM-interested students to enroll in college and seriously consider STEM as a major, while limiting the length to a two-day workshop format and keeping costs to a minimum.

Program Goals

The iDrone program is designed to provide mutual benefits to all participants. It aims to continually increase the awareness of STEM disciplines by attracting highly

motivated middle/high school students. The program staff, including advisors and graduate research assistants, have an opportunity to broaden their professional skill sets through mentorship and cohesive interactions with students. All other participants, including parents, legal guardians, and guest speakers share the goal of giving students the unique opportunity to experience fast-moving technologies, which leaves them well-informed for deciding on future academic and career paths.

The University of Idaho STEM Access project has identified seven critical elements for preparing high school students for college and STEM careers. These elements (listed below) were used as specific overall goals to guide iDrone development. Financial literacy/awareness was ultimately not explicitly included in the lesson plans. It would be useful to invite a speaker to discuss available scholarships and/or co-operative education opportunities for STEM students in the future.

1. Personal agency/responsibility: We design programming that fosters the ability of students to take charge of their personal and academic life. It includes the ability to balance academic schedules and free time, take charge of academic experiences, and show initiative in completing administrative tasks, such as college applications. This goal is assessed in the program experience survey by how well students were provided opportunities to make choices and be self-directed.

2. Financial literacy/awareness

Financial literacy includes an understanding of the monetary value associated with college, careers, and life in general. Students in the program should gain an awareness of costs and options available, fiscal decision-making, and personal financial management. Evaluation is focused on how well programs increased students' understanding of financial obligations and opportunities for college and future careers.

3. Academic and social preparation for college

This goal reflects support for students in their academic work and encouragement toward setting ambitious academic goals during secondary education. Out-of-school programs provide opportunities for students to advance their academic learning to better prepare them for college and careers. Programs are designed to give students opportunities to interact with peers, as well as professionals who can share career experiences and STEM expertise. Assessment of this goal focuses on how well students were provided content learning in STEM to increase students' academic preparation for college and careers.

4. Grit

Grit is defined as perseverance and passion for long-term goals. It entails working strenuously toward challenges, maintaining effort and interest over years despite failure, adversity, and plateaus in progress. Students who exhibit grit are aware of what kinds of challenges they will face in college and develop the skills necessary to overcome those challenges. Programs strive to provide students with challenges, as well as opportunities to fail and to overcome. Grit is assessed in the program experience survey by asking if the program increased students' ability to overcome obstacles and accomplish goals.

5. Experiential, hands-on learning

This goal reflects learning styles that utilize hands-on and experiential learning--i.e., learning by doing where each individual student is physically engaging with the tools and personally experiences the practices relevant in the subject matter. This also includes students' ability to connect their new-found knowledge to real-world applications in their daily lives and their ability, through this learning style, to improve their performance in a traditional classroom setting. Evaluation of this goal focuses on how well programs encouraged hands-on learning and provided opportunities for transfer of lessons to "real-world" applications.

6. Community building

Programming fosters the students' ability to strengthen existing communities and allows the students to build

DAY 1 - Drone Intro

Students explore the up-to-date technologies commonly used in industry and university research. Students will learn how existing technologies can be used to solve real-world problems using drones.

9:00am – 9:10am: Ice-breaker (10 min): Introductions in groups of ten teams and briefly discuss what students expect from the drone workshop. Each cohort team is formed with 2-3 students.

9:10am – 9:20am: Opener (10 min): Students can identify a question for information gathering in their environment. Students are asked to formulate questions, such as what would be interesting to explore with a drone or what is a question you have had about your environment? The questions are posted visibly to the whole group throughout the workshop.

9:20am – 10:00am: Safety Training (40 min): Students learn the basic safety precautions, laws and regulatory procedures of drone flying in an open airspace. A handout with safety measures and technical information about drones is passed out. Students are asked to discuss what's on the sheet in their groups and to write down at least 2 questions they have and then debrief and share what they've learned.

10:30am – 12:00pm: Technology of Drones - Jigsaw (90 min): Students learn about the engineering and technology of drones. Examples of sensor attachments to drones are presented. Handouts with information on how the tools work with the underlying scientific principles are available. Students work in groups to review how drones work; sharing with the whole group.

1:00pm – 5:00pm Research and discussion: Students finalize the research ideas and what data they will collect from drone flights. Students get back to brainstorming questions that they have about their environment. Students identify where they need to fly with which sensors and how they will process the data to address.

DAY 2 - Drone Building/Flight/Presentation

Students improve their flight skills to the point that they will be able to gather data (images) for their project in groups.

9:00am – 2:00pm Drone building/coding: Students are able to explain how a drone used by professionals is put together and what the individual technology pieces needed are. Students continue to gain experience with the process of drone operations in a coding environment.

2:00am – 5:00pm Drone flight/presentation: Students take a bus trip to an airstrip and have an opportunity to fly drones and present what they learn from iDrone in poster sessions.

Table 1. The iDrone workshop/Camp schedule and activities

<a. Hands-on drone building experience>

<b. Drone coding class>

<c. STEM is fun>

<d. Flight experience in the airfield>

Figure 1. STEM Activities (a – d) during Idaho Drone League (iDrone), March 2018.

their own network, supporting their career and life goals. The concept of community refers to social support networks at a range of scales. It includes interactions between students, as well as students' hometowns, high schools, and families. Overall, the "community" category should be thought of as an umbrella term encompassing the many facets of a student's social interactions. As the broadest of the categories, it speaks to the variety of connections the program provides and nurtures for its participants. Community also extends after the program, as students may also continue networking with the organizations and individuals they meet during the program. Assessment is focused on how well teacher, peer, and community connections were encouraged or developed during the program.

7. STEM skills/motivation/identity

Our curriculum develops STEM skills and STEM identity as a crucial element of the program. Students gain an understanding of what STEM degrees and careers entail and cultivate a personal desire to participate in them. The program seeks to supplement and support students' academic growth in STEM subjects, but also to build confidence to continue STEM education in the future. Science identity involves three dimensions: competence, performance, and recognition. Evaluation of this goal focuses on these three dimensions, as well as whether the students felt the program provided them with exposure to STEM fields and careers.

Program Administration

To accomplish the above goals, the iDrone program introduces students to basic concepts in automatic controls, robotics, and unmanned aerial systems in two-day workshops across the state. In addition to providing hands-on drone experience, iDrone attendees form groups to participate in social, academic, and STEM-related activities together.

The first iDrone program was conducted in three major cities, including Boise (South – 2018), Moscow (North - 2018), and Pocatello (East - 2018) in Idaho to engage sixth to eleventh graders in STEM education using drones (Idahonews, 2018; KBOI, 2018). Another workshop entitled "iDrone Summer Camp" was subsequently held in Boise, June 6-7, 2019 (KIVITV, 2019). Students built and flew drones with smartphones, learned to program and fly drones with software, reviewed federal regulations and safety guidelines, explored drone research applications, developed futuristic drone concepts, and interacted with local drone professionals who address real-world problems. **Table 1** summarizes the general iDrone workshop/camp schedule and activities and a discussion of each lesson is described below. **Figure 1** highlights some of the iDrone STEM activities.

UAS Hands-on building and coding

In order for the students to gain an in-depth understanding of how drones function, we put together a provided drone development kit that can be constructed by students. Building the kit allows the students to learn about the specific parts and their functions, such as the rotors, frame, motors, IC chip, Bluetooth functionality, battery, etc. The completed kits were pre-programmed to be operated through a mobile app, which was installed on a smartphone provided to the students for use at the workshop. Pedestals and mounts were also provided for the students so that they could test their drones without them flying freely.

On the second day of the workshops, the students were instructed through a programming session where they worked through basic coding exercises in the Arduino programming language to control their drone kits. The open-source Arduino Integrated Development Environment IDE software is available free for multiple platforms (Arduino, 2018). The drone kits can be connected to a computer with a USB/USB-C connector and using laptops provided by the workshops with Arduino preinstalled, the students were able to use and modify examples and create new code to transfer to the drone kits. Through these exercises, students learned how to modify the speed and timing of the rotors; how to control flight patterns, such as pitch, yaw, and roll; and how to develop methods for gentle take-offs and landings. As it was the first programming experience for the majority of the students, it was also an opportunity for them to learn basic programming concepts, such as algorithms, command line structures, variables, and loops. Overall, these sessions had the potential to cultivate interest in engineering, computer science, programming, mechatronics, robotics, and aviation.

Career Applications

This lesson stimulated interest in STEM fields of study and careers by directly connecting students with a variety of drone technologies, research applications, and the benefits to society. The students were asked to work in groups to select a research topic of interest from a predefined list of YouTube UAS research video links related to: Sea Level Rise, Dam Inspection, Poaching, Glaciers, Farming, Volcanoes, Fire Prevention, Disasters, Pipeline Inspections, and Marine Science. The students were then given sufficient time to view the videos multiple times to prepare brief presentations, consisting of a video summary (application, technology, research team, etc.), the benefits to society, possible technological improvements for the research, and other ideas that were developed for drones during the group work. The format of this session was intended to address the different learning styles of students: aural (videos and presentations), visual (videos), social

(collaborating in groups), and verbal (collaborating and presentations). When students with a more solitary learning style wanted to work individually, that option was also made available. As part of the first set of sessions on Day 1 of each workshop, this lesson provided some additional background and ideas for poster development and practice for the poster presentations. It also connected drone construction and flying to real-world uses and benefits to society through research.

Science-Fiction Research Poster Challenge

The students created a poster on a science-fiction drone, which they envisioned could be built in the future to address a current problem using a specialized drone. The students received a poster template, with pre-organized sections that they reflected upon and completed with their team throughout the workshop, using the internet as a source to find information and literature. At the end of the workshop, the students presented their poster to the whole group. The poster served as a tool for students to reflect upon the uses of drones in their potential career paths, to cross-connect societal needs to technology applications, and to deepen their understanding of related STEM careers that would be needed for the development of their respective drones. The sections in the poster had a title in each text box, with a description of the content to add as the final text. Due to limited resources and a smaller leadership team, the poster challenge was not included in the 2019 Boise iDrone camp. Two poster examples are provided in **Figure 2** below.

Expert Presentations

At each workshop various professionals using drones in their STEM careers came to showcase their drones or other unmanned aerial vehicles, talk about their application, and answer questions by students, including their career pathway, financing college, and any other recommendations they may have to support the student's trajectory to college. Many research applications in the field of agriculture, engineering, natural resources management, and hazard monitoring utilize satellite-based or airplane-based sensing for problem solving, but the availability of such products are often limited due to physical constraints (e.g., cloud cover) and/or production time. In addition, they are unable to provide very high-resolution data and do not provide flexibility to get up-close, underground, underwater, etc. Professionals discussed ways in which drones provide very effective ways to collect data and monitor areas. They also discussed various types of sensors that drones can use in many civil applications, such as the capacity for drones to carry physical objects (e.g., Amazon delivery services).

Federal regulations and safety guidelines

The Framework for 21st Century Learning (P21, 2009) has provided that three of the most important interdisciplinary themes are Global Awareness; Financial, Economic, Business, and Entrepreneurial Literacy; and Civic Literacy. Therefore, it is useful for students to begin learning the various ways that technologies are regulated, because of the tight interconnections between STEM careers and legal and economic arenas from local to global scales. For example, US and international standards, laws, and regulations are important considerations with respect to topics such as innovation, entrepreneurship, and intellectual property, as discussed by JD Claridge of xCraft Enterprises in the Moscow workshop. Perhaps more importantly, regarding drones and other automated robotic systems, the safety of the user and others is a major concern for a variety of government agencies, especially the Federal Aviation Administration (FAA).

Students at each location were given an overview of where drones fall under FAA regulations and what rules would apply for hobby, research, and professional uses of drone devices, depending on the size. These talks were given by experts in the field and included: Gary Austill of Austill Aviation (Pocatello), Dr. Jae Ryu (Moscow), and Steve Stroud of the US Department of the Interior (Boise). In addition, information about becoming a licensed UAS operator, the required reading, and testing details were provided for students that were interested in gaining the accreditation and/or had interest in using drones for more than hobby activities. Upon completion of these talks, the students also worked in teams to participate in a trivia challenge that was based on an online quiz provided by Popular Science (Popsci, 2018). The trivia challenge provided a change in teaching method and served as an assessment tool to verify that the content was learned. The student groups averaged around eighty percent or higher for correct responses, which is satisfactory.

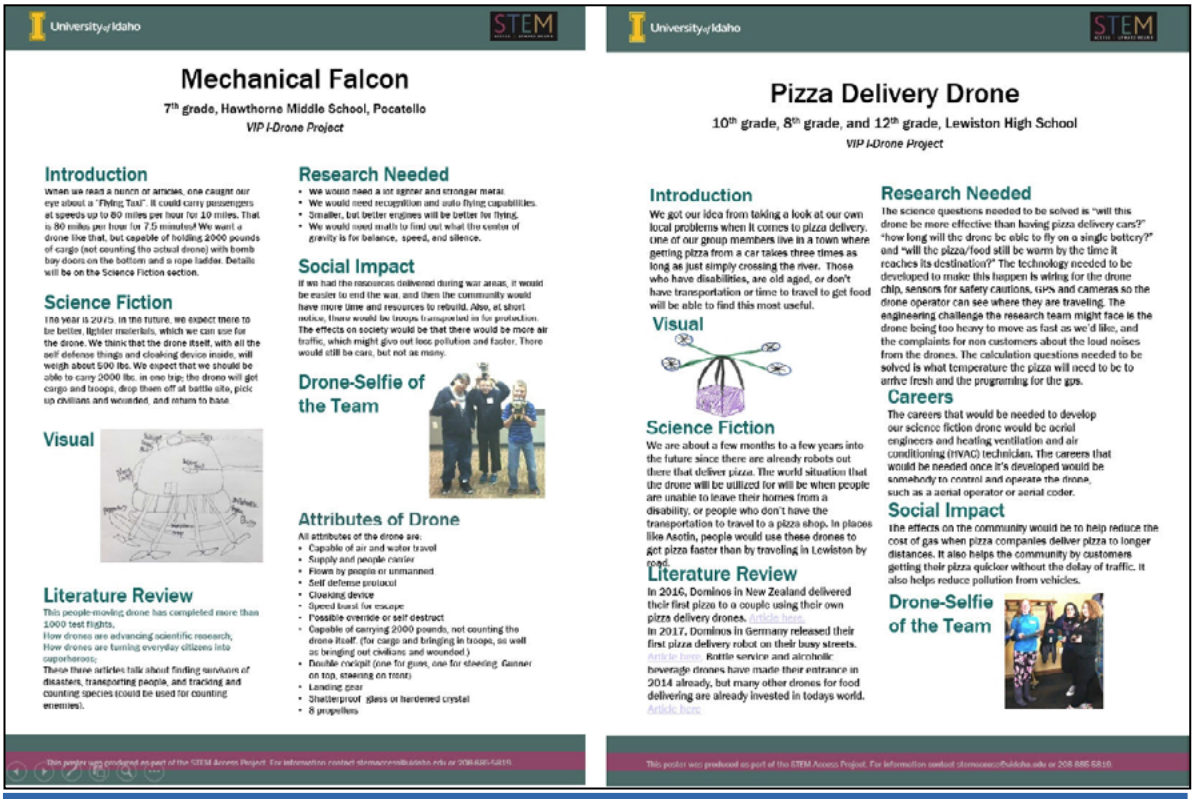
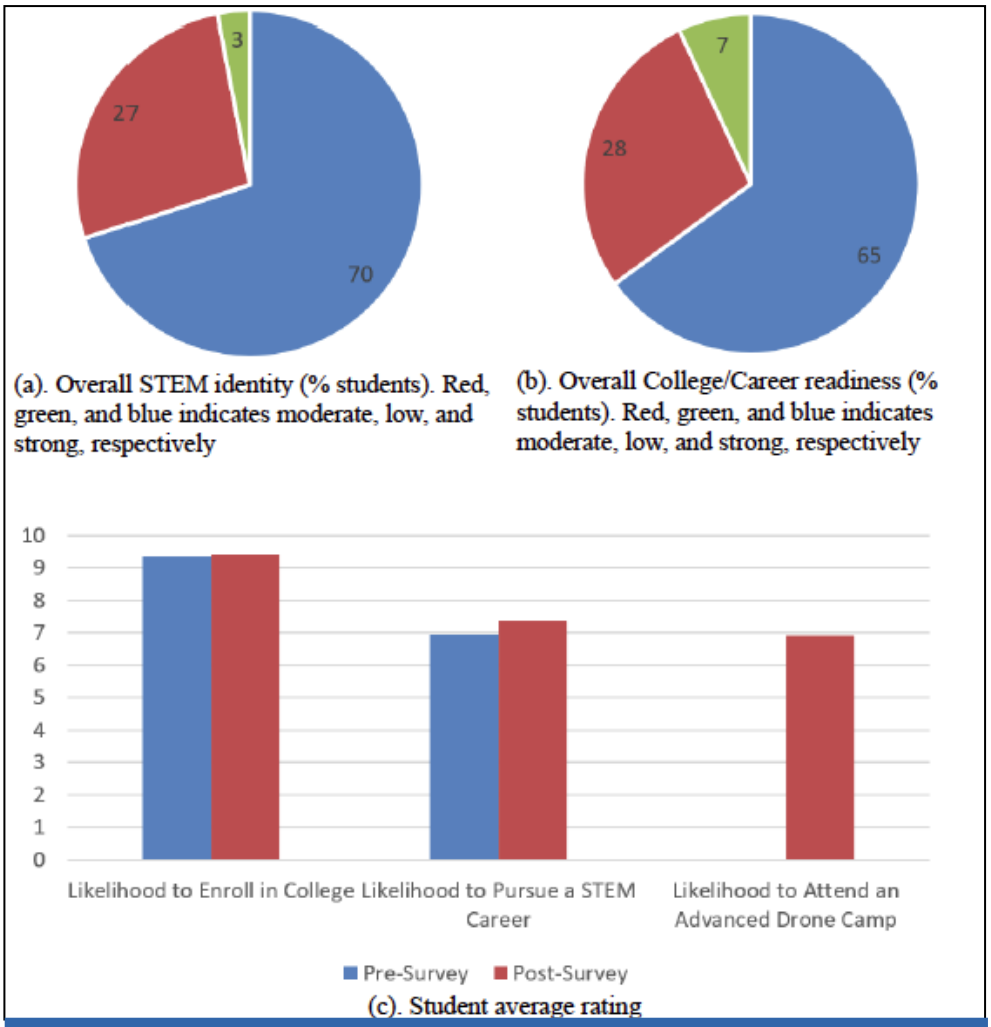


Figure 2. Examples of science-fiction research posters

Flight Stations

Students were challenged to learn how to fly medium and large drones in simulated real-world situations, including the DJI Spark, DJI Phantom, and the DJI Matrice 600. The sessions allowed the students to put into practice the same drone operations that were programmed in the Arduino coding session, including take-off, pitch, yaw, roll, and landing. The students also each took photographs from the air, which simulated the use of sensors that are attached to drones in various applications and can be controlled from the ground. These scenarios helped to encourage and promote learning with drone technology and provided opportunities for students to visualize potential future uses for drones.



(a). Overall STEM identity (% students). Red, green, and blue indicates moderate, low, and strong, respectively

(b). Overall College/Career readiness (% students). Red, green, and blue indicates moderate, low, and strong, respectively

(c). Student average rating

Figure 3. STEM identity and college/career survey results from iDrone participants

Evaluation Methods & Results

Overall, the iDrone program had the potential to cultivate interest in engineering, computer science, programming, mechatronics, robotics, and aviation. The lessons fell under various goals and objectives of the Idaho Content Standards (ISDOE, 2018), including Information and Communication Technology, Computer Science, Physical Sciences, Earth and Space Science, and Engineering and Technology Standards. Under the Three Dimensions (NRC, 2012), the lessons involved Scientific and Engineering Practices, including asking questions; defining problems; and obtaining, evaluating, and communicating information. All crosscutting concepts and Disciplinary Core Ideas for the Physical Sciences, Life Sciences, Earth and Space Sciences Engineering, Technology, and Applications of Science were also incorporated. The lessons also addressed all P21 (2009) 21st Century Framework skills: Learning and Innovation Skills, Information, Media and Technology Skills, and Life and Career Skills. The topics covered also align well with the 21st century interdisciplinary themes: Global Awareness. Financial, Economic, Business and Entrepreneurial Literacy, Civic Literacy, Health Literacy, and Environmental Literacy.

A pre- and post-survey was administered to evaluate the program. It measured STEM identity and STEM college and career readiness, change in likelihood to enroll in college and choose STEM careers, and overall satisfaction with the workshop by the students. Eighty-seven total students participated in the workshops, with eight in Pocatello (2018), twenty-nine in Moscow (2018), and fifty in Boise (2018 and 2019). Data was collected from the middle and high students before (n=87) and after (n=64) the program. Sixty-three percent of the students identified as male and thirty-seven identified as female, with no other gender categories selected. Only fourteen of the students reported their ethnicity in 2018, and twelve of the fourteen identified as Asian, with the other two identifying as White/Caucasian. Do to the low response rate, the question was not used in 2019.

STEM Identity of Participants. STEM Identity describes how competent students feel in STEM, how well they think they perform, and how much they feel recognized as a STEM person. To better understand the level to which students already have STEM identity coming into the workshop we measured this dimension by adapting Schon's (2016) survey for science identity. As shown in **Figure 3a**, 70% of the students demonstrated strong STEM identity, 27% moderate STEM identity, and 3% low STEM identity.

College & Career Readiness of Participants. To understand how well students are already prepared for college, we utilized the instrument published by Lombardi (2011) that measures the sub-dimensions for how well students feel prepared for college preparedness: goal-driven behaviors, persistence, study skills, and self-monitoring. As shown in **Figure 3b**, 65% of the students expressed strong college/career readiness, while twenty-eight percent expressed moderate readiness, and seven percent expressed low readiness.

Pre-Post Increase in Likelihood to go to College and Pursue a STEM Career

To assess if the workshop impacted students' likelihood to enroll in College or a STEM career, we also had students choose before and after the workshop with a slider from 0 to 10 (0 least likely, 10 most likely) how likely they are to pursue a STEM career. As shown in **Figure 3c**, the average ratings for likelihood to attend college were quite high at 9.35 and 9.41 out of ten for the pre- and post- surveys, respectively.

In line with the STEM Identity data, the average rating for intention for pursuing a STEM career was also moderately high (6.94) in the pre-survey, with a slight increase to (7.37) for the post-survey. Seven students did not return the second day and an additional sixteen did not complete the post-survey due to parents coming early to pick their children up, skewing the post-survey response. As adding a name was optional, pre-post responses could only be directly compared for thirty-five students and for those participants, the intention to pursue a STEM career only increased by an average of 2% between the pre- and post-surveys. **Figure 3c** also presents an additional question asked during the 2019 Boise iDrone, which was the likelihood of returning for an advanced iDrone camp in the future. The average response was seven out of ten, again indicating the strong interest in STEM among the participants, as well as an appreciation of the overall program and its merits (further discussed below).

Participant Satisfaction. The post survey asked about students' satisfaction with the activity and the program itself using both Likert-type scales (strongly agree to strongly disagree) and open-ended questions (2018 only). As shown in **Figure 4**, the majority of students were very or mostly satisfied with all aspects of the program and activity. Students especially liked the DJI drone-flying activity and the hands-on experience with STEM.

Open-ended responses showed that students had a lot of fun during the program. For example:

"I loved it, and it was a ton of fun learning about drones, how to fly them, how to code them, and learning about real world applications for them."

"We had an absolutely wonderful time learning about the

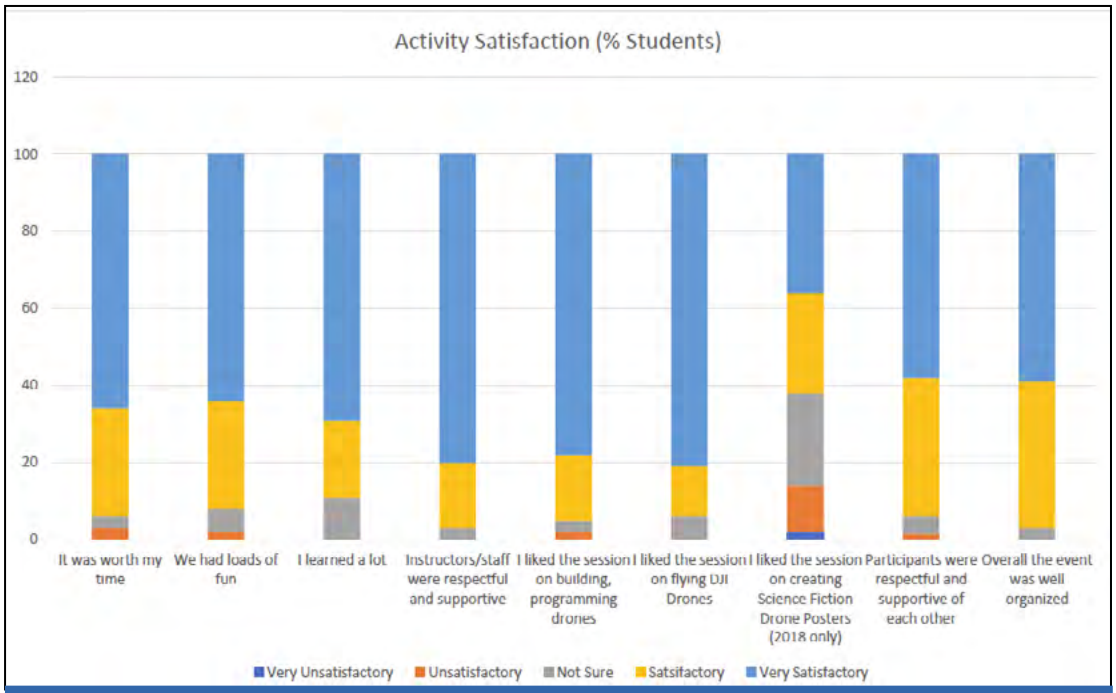


Figure 4. Activity Satisfaction survey results from iDrone participants

technology behind drones and having the hands-on experience that we can't get anywhere else."

"If you aren't sure of what career you want to choose then definitely go to a STEM camp and let your creative juices flow."

"I didn't like STEM before this."

Meeting STEM Education Goals

The survey also measured how well the Program Goals previously discussed were delivered in the workshop. The results of the Likert Scale questions (very unsatisfactory to very satisfactory) are provided in **Figure 5**. Overall, students felt they received information to further their learning on all of the goals to a high degree. As previously discussed, college finances were ultimately not explicitly part of the curriculum in 2018 and 2019, so it was expected that many of the students responded with "Not Sure". Other students asked questions to the leadership team or presenters related to finances and found the guidance to be useful.

Summary And Future Work

In summary, UAS technologies such as drones, are uniquely situated for STEM education since they are aligned with workforce needs, affordable, easy to manage and transport, programmable, and have a short learning curve for middle and high school-aged students. The outcome of this pilot project (iDrone) was a successful and rewarding program towards improving the go-on rate in for Idaho STEM pathways. The evaluation further informs how impactful the program is and can be leveraged to benefit more Idaho youth for their future STEM careers. In the near future, we will continue to apply the rapidly developing drone technology, along with imagination, excitement, and a teamwork spirit to inspire the future Idaho STEM workforce and beyond. Ultimately students will develop critical thinking and team-building skills through the research-oriented STEM iDrone experiences, while they brainstorm solutions in creative activities and demonstrate workability and feasibility based on development of science and engineering concepts and practices. The iDrone team is currently developing an advanced level of iDrone with school sports titled "iDrone 2 Soccer" for Gifted and Talented Education (GATE) program. The students and teachers in the GATE program will participate in STEM+Sports (STEMS) to experience digital-age sports and learning in their education platforms. The STEMS will be broadly implemented nationally and internationally through annual conventions by working with iDrone collaborators, including iDrone cohorts and alumni in years to come.

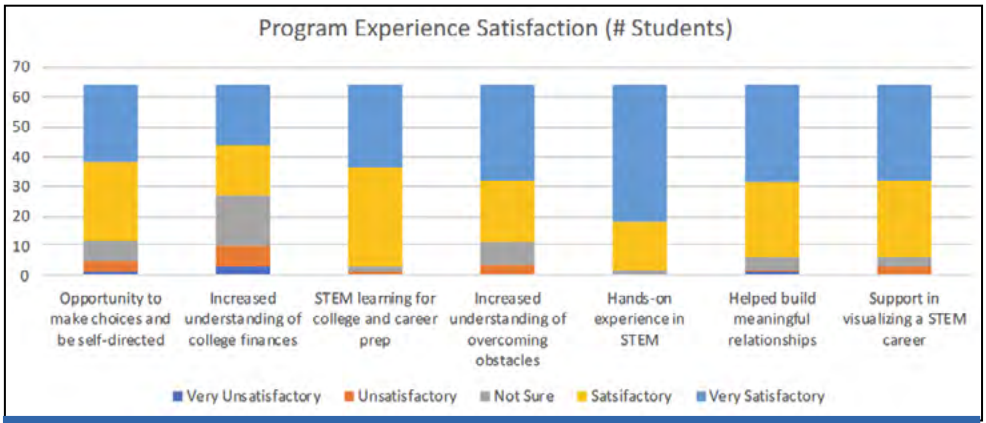


Figure 5. Program Experience survey results from iDrone participants

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Sonja Kirsten LaPaglia is the director of STEM Access, a University of Idaho TRIO-INSPIRE project. STEM Access experiences inspire transformation and personal empowerment in Idaho youth by providing supportive spaces and strengthening community. Kirsten and her team strive to deliver student-relevant STEM education by applying engineering design and math skills to authentic science problems and using technology as a tool to solve them. Kirsten has an MS in curriculum and instruction from the University of Idaho, an MS in biology from Nuremberg University in Germany, and an Idaho teaching certificate for German, earth science, and biology. Her areas of interest in research, teaching, and service include: adolescent STEM motivation, authentic, and student-relevant education.

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