Interstate Drone League (iDrone National) to promote hands-on remote STEM learning using cloud-based virtual meeting platforms in the global pandemic (COVID-19)

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Abstract

The global pandemic (COVID-19) has devastated tens of millions of people suffering from separation anxiety among family members, economic crisis, health issues in sensitive groups, and even education landscapes. In response to COVID-19, a hands-on, virtual STEM camp is proposed to stimulate American youth for the future workforce. The project aims to inspire the next generation of the STEM workforce by encouraging 6th – 12th grade students to enter STEM-related careers. This hands-on, online program utilizes a series of educational modules involving drone design, code, fly, mission plan, poster session, and preparation for the Part 107 pilot license to introduce participating students to basic concepts in automatic control, robotics, and unmanned aircraft systems (UAS, also known as drones). Furthermore, pre- and post-camp surveys were conducted to collect comments and feedback from participants to assess academic learning in three dimensions of the Next Generation Science Standards. Survey results from both on- and off-line iDrone workshops yielded similar results in the sense that most participants demonstrated strong STEM identities, college/career readiness, as well as likelihood to pursue higher education or careers in STEM disciplines.

Keywords: iDrone, Interstate Drone League, STEM, Online STEM camp, E-learning Cloud

Introduction

The global pandemic (COVID-19) continues to impact billions of people around the world, while also impacting STEM learning landscapes at large. During school lockdowns, many educational institutions are still debating in-class versus online learning environments. In line with this transition effort, we demonstrate how hands-on remote learning can leverage the existing STEM program known as "Idaho Drone League (iDrone)" to benefit more youth (6th – 12th grade students) during these unforeseen, challenging times.

The goal of the iDrone program is to inspire the next generation's workforce through engagement with STEM research and education, which has been successfully implemented across the state of Idaho (Ryu et al., 2020). The hands-on drone workshops included in the iDrone program have integrated computer science, technology, engineering, as well as STEM career education and practices. In addition to building, coding, and programming drones, students have also gained experience learning federal regulations and safety guidelines set by the Federal Aviation Administration (FAA) to fly drones in the public domain.

As a result of technological improvements, e-learning platforms are rapidly evolving and becoming a fundamental tool for many educational activities worldwide to gain a competitive edge (Sanchez, R. & Hueros, A., 2010). Many previous studies have demonstrated different e-learning platforms to achieve their educational goals and objectives via virtual meetings. Different types of virtual environments adopted for e-learning platforms include commercial systems, free research and collaboration, and Web-based learning systems, such as Moodle (Moodle, 2020; Clark, T. & Hermens, A., 2001; Sanchez, R. & Hueros, A., 2010). More recently, high-speed internet connections and cloud-based learning platforms (Riahi, G., 2015) are becoming more prevalent as they also provide user-friendly Learning Management Systems (LMS) with all-possible virtual meeting tools, including but not limited to: YouTube/video-based learning, forum-based learning, and social e-learning (Siddiqui et al., 2019). To implement the existing hands-on STEM camp online, we utilized a combination of e-learning platforms, including Google Sites (for the course website), YouTube (for video-based asynchronous learning modules), Zoom (for forum-based online meetups), and Padlet (for social and collaborative e-learning).

The main advantage of Google Sites (Google Sites, 2020) is the versatility to develop a course website using the existing templates. Thus, a user can build their own project hubs, team sites, and public-facing websites by dragging content where needed. Additionally, the end user can easily link other files stored in Google Drive to their website so that file updates are taking place on a real-time basis. The embedded security function to set shareable links is another avenue for restricting permissions for safe access within groups. YouTube is an excellent e-learning platform for sharing educational videos asynchronously among online participants. More recently, YouTube users have also been able to edit their video prior to uploading it in the public domain in order to save time and effort in video production. However, preparing YouTube-based educational modules for iDrone Online requires additional video editing software, such as Windows Movie Maker (Microsoft, 2020), Adobe Premiere (Adobe Creative Cloud, 2020), or Corel VideoStudio (Corel VideoStudio, 2020). These programs are necessary to create more effective educational e-learning modules, as described later. The Zoom virtual meeting (Zoom, 2020) was also used to virtually convene during the camp. Zoom's video-first, unified communication platform is an excellent alternative to hosting an in-person event during the global pandemic (COVID-19). Since Zoom offers a solution tailored to fit our planned online camp, we took full advantage of the existing technology to maximize our impactful digital event, iDrone Online. Host control tools, including mute/unmute functions for all participants, waiting room capability, breakout room assignments, and group poll options were great additions for the meeting host to run digital events smoothly and effectively. Additionally, the real-time chat box is an excellent communication tool that benefits all program participants, including the iDrone host, students, coordinators, and observers. Note that Zoom's online chat box allows everyone to send a message to all participants or a private individual. Lastly, Padlet (Padlet, 2020) serves as an effective online collaboration board being used by students and teachers alike to post and share ideas on a common page. During this camp, Padlet was used for a meet-and-greet session during icebreakers, as described further below. Fig 1. illustrates the overall framework used to host iDrone Online on Zoom, the cloud-based e-learning platform (Zoom, 2020).

According to the survey results, about 70% of participants from both in-person (offline) and virtual (online) camps classified themselves as having a strong STEM identity. Despite the global pandemic, the 2020 camp illustrated students' substantial connections to STEM careers, college readiness, and persistence. Although the prior in-person 2018/2019 workshops yielded slight differences in the likelihood to enroll in college or pursue a STEM career, the 2020 online camp surveys largely indicated equally positive feedback from both programs.

This paper is organized as follows: the first section provides a brief description of the project design to give an

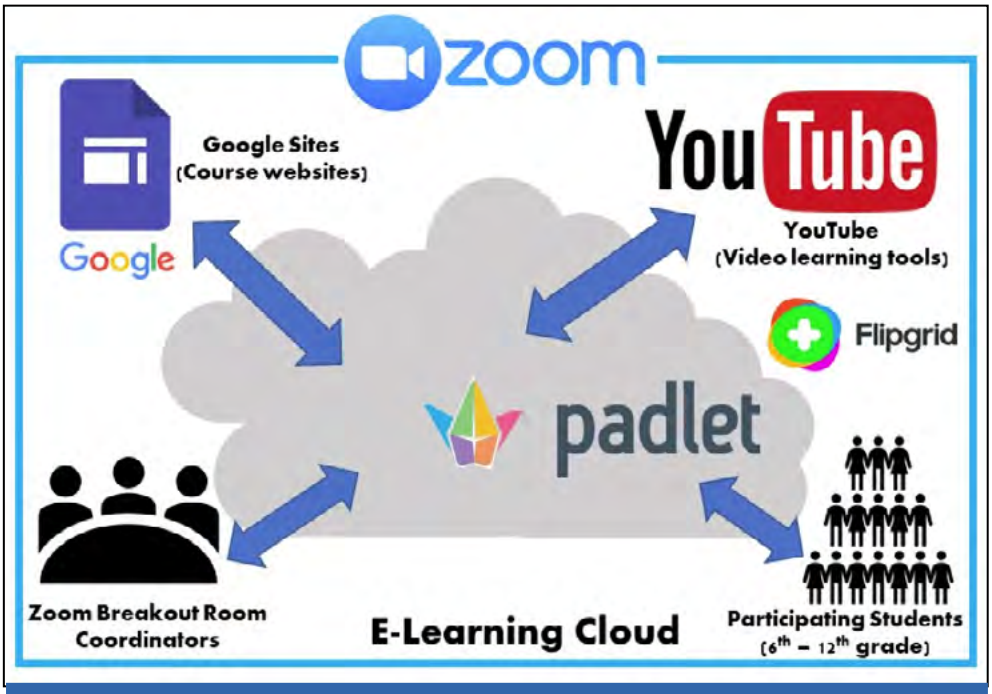

Fig 1. Example of cloud-based e-learning platform

understanding of the iDrone program, its operations, educational modules, and the associated e-learning platforms utilized to facilitate the camp. The second section presents findings regarding participants' STEM-related identities, college readiness, likeliness to pursue STEM careers, and activity satisfaction with the iDrone program overall. The third section examines constructive feedback from iDrone coordinators following the online camp. Finally, the last section offers a brief summary and discusses directions for future work and advancement of the iDrone program.

Program Design

The Idaho Drone League (iDrone) program was initially designed to provide mutual benefits to all participants across the state of Idaho by increasing awareness of STEM disciplines for highly motivated secondary students (Ryu et al., 2020). Over the past few years, the iDrone program was conducted offline in Idaho's major cities, including Boise (South – 2018 and 2019), Moscow (North – 2018), and Pocatello (East – 2018) to engage 6th – 12th graders in STEM education using drones (Idahonews, 2018; KBOI, 2018; Ryu et., 2020). Since early 2020, however, the landscape of STEM education has changed due to the global pandemic (COVID-19). To respond to such a change, we decided to offer this program online via the e-learning cloud platforms described above. We developed a series of educational modules to better assist students to achieve the designated learning objectives, including building, coding, programing, and flying drones via virtual meeting platforms (See Fig 2). Following the first successful iDrone online camp held on October 19, 2020, we decided to expand this program to benefit more students and to promote broader impacts at the national scale using the e-learning platforms shown in Fig 1.

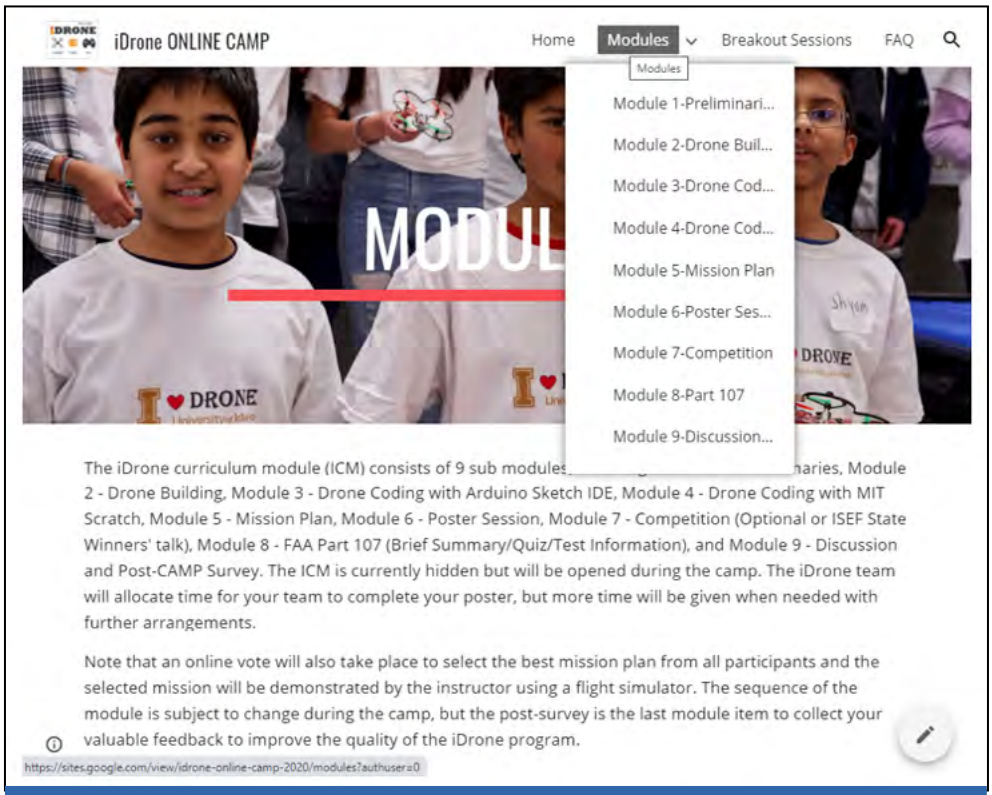

Fig 2. iDrone e-learning modules during the 2020 iDrone Online Camp held on October 10, 2020

On Saturday, November 14, 2020, we broadcasted the first Interstate Drone League (iDrone National) in real time (live streaming) in partnership with the Korean-American Scientists and Engineers Association (KSEA). The program targeted multiple states, including Alabama, California, Idaho, Illinois, Georgia, North Carolina, and Texas. Note that about 100 people used the Eventbrite registration platform (Eventbrite, 2020) to participate in this virtual meeting as shown in Fig 3.

Ice Breaker: A meet-and-greet with participants (ice-breaker) is first organized by a camp facilitator. The goal of this icebreaker is to help students break down barriers, learn about other participants, understand group dynamics, and most of all, have fun. We adopted a storytelling icebreaker format by asking a series of questions on the Padlet online board. For example, students got started by introducing their name, school year, hometown, summer plans, hobbies, reasons for participating, etc.

Zoom Breakout Rooms (BRs): A total of 14 breakout rooms (BRs) were created to accommodate students in teams of three to six by state. For example, two BRs (six students in each room) were created for students from Texas, while only one BR was needed to accommodate five students from Alabama. As soon as students join the Zoom meeting, they are asked to identify themselves by associating their breakout room number with their name. Thus, each student's Zoom identity (Zoom ID) starts with their BR number followed by last name, first name, and state abbreviation. Thus, if John Doe joins the meeting from Alabama and is assigned to breakout room 1 (BR01), his Zoom ID becomes "BR01: Doe, John-AB." We provided an information card to help participants rename their Zoom ID according to the aforementioned virtual meetings.

Drone Building: A low-cost drone development kit (IDK 2018), including all necessary parts such as motors, propellers, flight controllers, body frames, and batteries, are

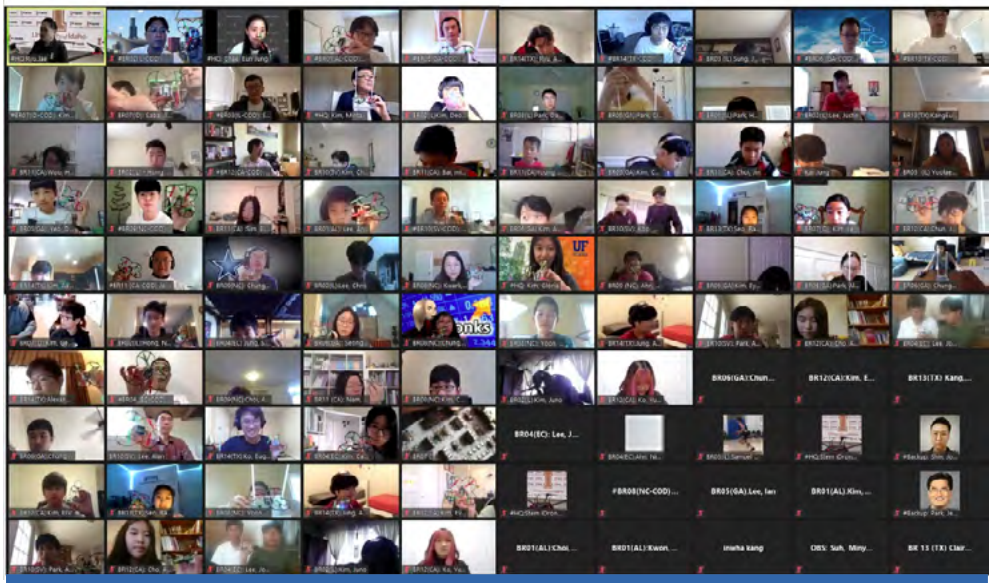

Fig 3. iDrone KSEA online camp (about 100 participants) held in November 14, 2020.

delivered to individual homes two weeks in advance. The provided kit allows students to construct the drones in order to gain an in-depth understanding of drone mechanics. The completed kits were pre-programmed to be operated through a mobile app, which can be installed on a smartphone for use during the online camp. Pedestals and mounts were also included in the shipping package so that the students could test their drones without them flying freely at home.

Drone Coding: Two drone-coding platforms, Arduino Integrated Development Environment (IDE) (Arduino, 2021) and Scratch Program Language developed by MIT (Scratch, 2021) were used to help students better understand autonomous technology. The participating students learned how to approach various real-world problems using logical and computational thinking in coding blocks, ultimately exploring optimal solutions that mitigate impacts on their community, society, world, and even space. For example, during iDrone 2020 online camps, all participating students were asked to develop their own code that would allow drones to take off slowly and land gently after hovering for ten seconds, which is similar to NASA's Ingenuity drone mission on Mars (NASA, 2021).

Mission Plan: A ground control station (GCS) software is required to fly drones autonomously. There are many GCS tools, including Litchi (Litchi, 2021), Autopilot (Autopilot, 2021), Pix4Dcapture (pix4Dcapture, 2021), and Mission Planner (2021). The Litchi software, in particular, is a highly versatile online hub that allows editing and sharing waypoint missions near-real time with team members quickly and easily. All students are required to watch an instructional YouTube video prior to developing their own missions as they meet the predefined requirements for safe drone flights in the national airspace (iDrone MP, 2020). Once complete, each team submitted their final mission to their respective coordinators to enter a Zoom online poll. All participants voted on the best mission plan, which was selected to be demonstrated in a flight simulation. Overall, this mission plan module increased all students' awareness of safety protocols and federal regulations for drone flight.

Poster Session/Presentation: During the poster session, students explored the latest technology commonly used in industries and researched how existing drone technologies can be used to solve real-world problems. Once each team, composed of four to five students, had brainstormed and finalized a research question, students created a poster presentation based on their research. One of the outcomes from this poster session included highlighting leadership roles based on cooperative, team-based leadership principles to aid in the process of group collaboration.

Troubleshooting: A separate troubleshooting model was also created to help students resolve any technical issues they had during the camp. Some students often face challenges when building and coding drones, especially when required to skillfully handle tiny parts and compile codes. The step-by-step, instructional YouTube videos are readily available for them to resolve most issues during the building and coding modules. The uploading error, for example, commonly occurs when the communication ports between the drone and computer are not well established. It appeared that the designated troubleshooting was critical for students to resolve these issues as soon as possible so that they could move on to the next module.

FAA Part 107: Under the Federal Aviation Administration (FAA)'s small unmanned aircraft systems (UAS) rule, known as Part 107, every pilot-in-command (PIC) must have a remote pilot certificate. For older students (at least 16 years old) who were interested in obtaining this Part 107 certificate, a FAA-certified pilot was invited to provide informational guidelines and procedures for Part 107 exams. Students interacted with the instructor to learn more about federal regulations and safety guidelines to become a drone pilot in the near future. The presentation was followed by a Part 107 pop quiz that formatively assessed students' understanding and leveraged their motivation toward future STEM workforces.

Survey Results

The surveys administered before and after the 2020 iDrone Online camps as well as the 2018/2019 in-person

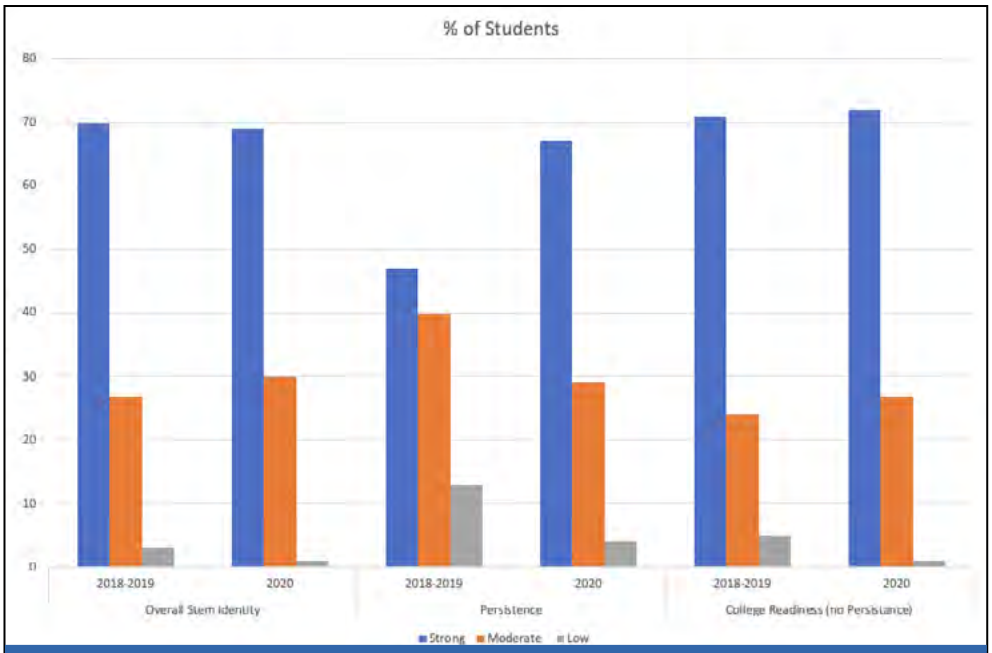

Fig 4. Comparison of STEM identity, persistence, and college readiness between offline camp (2018-2019) and online camp (2020).

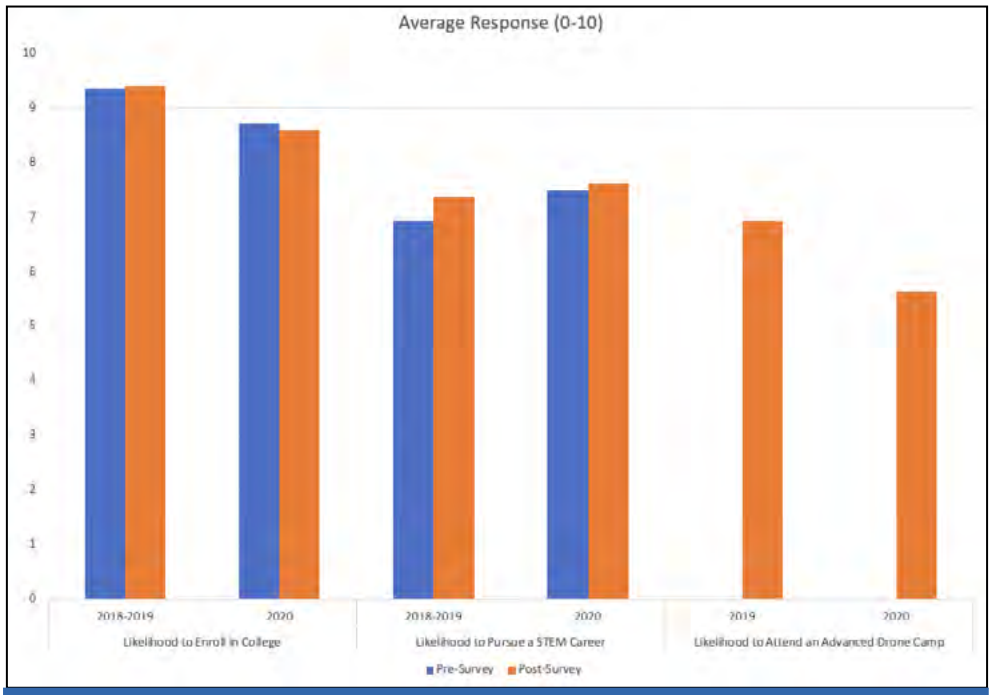

Fig 5. Average response to their STEM career in the future

workshops (Ryu et al., 2020) suggest that the online camp was just as successful as the former in-person sessions. The major findings are discussed below.

STEM Identity: Using the same methods as the previous in-person camps, the 2020 participants overall had similar STEM identification, with 69% strong, 30% moderate, and just 1% low, compared to 70%, 27%, and 3% from 2018/2019, respectively. We initially expected the 2020 participants to have stronger STEM identities, since most were specifically associated with KSEA. However, the similar survey results conclude that the topic itself tends to primarily attract strong STEM-identifying students in general. For those students, the camps can connect their interests with specific STEM fields that they might pursue in the future (See Fig 4). For the other approximately 30% that are moderate to low STEM-identifying, the workshops can serve to enhance their interest and connection with STEM overall.

Overall College/Career Readiness: Again, the results of the 2020 program were very similar to the 2018/2019 camps for three of the four categories used to calculate this metric. Both used the same survey methods as discussed in Ryu et al. (2020). However, the "Persistence" category yielded quite different results in 2020. As seen by the questions below, the stronger responses can easily be explained by the fact that most students were taking school courses online during the 2020 camps. Thus, they were often using course websites (i.e., Blackboard, Moodle, etc.) and communicating with their teacher via features of the platform or email. In addition, the virtual format of assignments may allow or require multiple drafts more frequently.

Perception Questions (survey responses rated strongly agree to strongly disagree – Likert scale):

1. I allow enough time to complete multiple drafts of an assignment if necessary.
2. I ask my teachers for help outside of class.
3. I refer to the syllabus or class website to prepare for and complete course assignments.

The results of this section are provided below.

Likelihood to Enroll in College/Pursue a STEM Career

As shown in Fig 5., the data reflects that the average response of students was very high with respect to the likelihood of enrolling in college, as was the likelihood of pursuing a career in STEM. Given the virtual nature of the camps, it was more difficult to ensure that students completed the post-program survey. Half of all attendees in the two sessions only completed the pre-camp survey. Thus, the slight increases or decreases between pre- and post-program responses may be biased. Nonetheless, despite a slight decrease in the average likelihood of attending college in the 2020 post-camp survey, there was still a slight increase in the likelihood of pursuing a STEM career.

As shown in the next section, the response to both the activities and the program were quite positive overall. However, there were some aspects of the in-person drone camp, such as allowing the students to fly professional drones, that were not able to be included. Therefore, it may have been difficult for the older students (e.g., 11th – 12th grade students) to imagine a more advanced camp, decreasing the likelihood of attending for the 2020 participants when compared to those from 2019.

Satisfaction with the Activities and Program Overall

The next two figures (Fig 6 and Fig 7) demonstrate that the camp was well-received overall. Less than 5% of students responded that aspects were unsatisfactory or very unsatisfactory. One exception was related to information on college finances, which is also discussed by Ryu et al. (2020) related to prior camps. We plan to incorporate some additional information on scholarship opportunities and technical co-op programs in future workshops, as time allows. Another exception was that approximately 10% of students responded that building meaningful relationships with other students was unsatisfactory, which

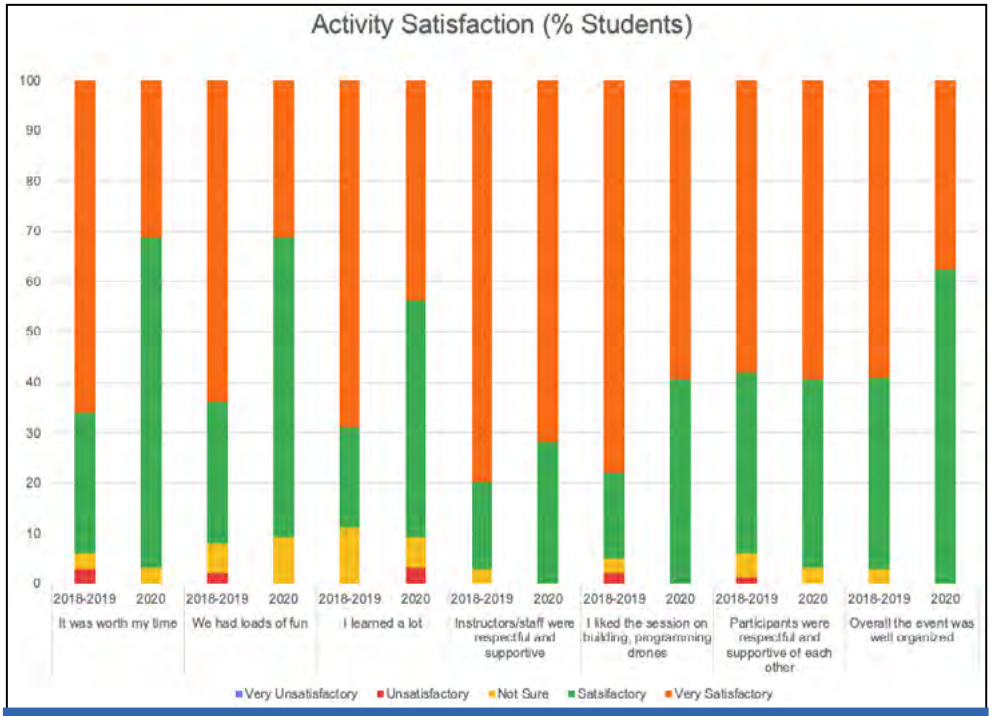

Fig 6. Comparison of activity stultification between offline camp (2018-2019) and online camp (2020)

was an increase from the prior years. However, we view this number as actually quite impressive for a short virtual workshop experience, given the difficulty of developing virtual relationships. All leaders worked hard to facilitate conversation within the breakout rooms during ice breakers, building, and programming sessions. In addition, the students worked together in these smaller groups to formulate ideas in the poster session.

Related to the mix between satisfactory and very satisfactory, the only decrease that stands out related to the program was about a 20% shift toward satisfactory for the "hands-on experience in STEM." As discussed earlier, previous in-person participants had the opportunity to fly both professional quadcopters and a hexacopter in an outdoor environment, which was not possible for the virtual program. We would certainly attribute the decrease in very satisfactory responses to a lesser hands-on experience. Nonetheless, with a 95% or above satisfactory rate, including over 50% responding very satisfactory, the survey is still fully demonstrative that the virtual version of the iDrone camp meets the needs and goals set out for both programs. The activity satisfaction responses, when combining very satisfactory and satisfactory, were also almost identical to the in-person classes. There was a clear 25% to 35% drop from very satisfactory to satisfactory between the on- and off-line programs for the first few categories. However, some of the fun, learning, and overall experiences were clearly enhanced when the students had the opportunity to go outside and fly larger drones. Despite this omission, we were still able to earn a 90% or above rating of satisfactory, with 30% to 70% very satisfactory, across the board for the virtual camp.

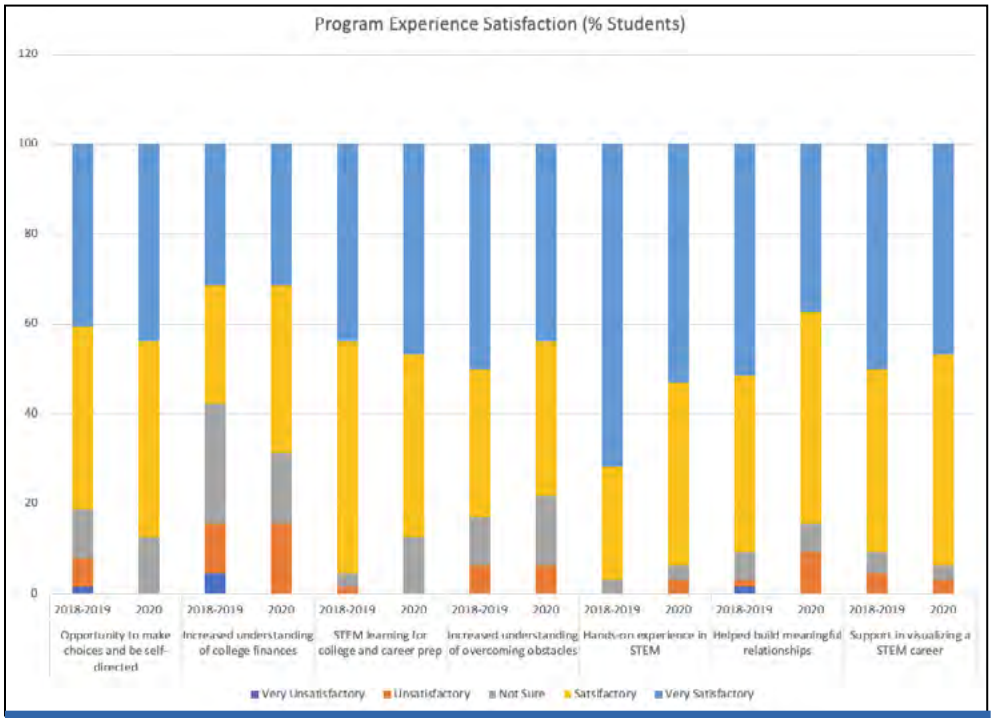

Fig 7. Comparison of program experience satisfaction between offline camp (2018-2019) and online camp (2020)

Feedback from iDrone Coordinators

The Interstate Drone League (iDrone National) coordinators (CODs) offered constructive feedback during the debrief following the iDrone online camp. Unequivocally, the CODs acknowledged that the camp operated better than expected. They largely agreed that participants were deeply invested and academically engaged with the drone-building and coding exercises despite lacking previous online, hands-on STEM camp experiences. CODs were also impressed by the overall seamless transition between these activities. However, CODs emphasized the need to resolve existing time constraints in addition to challenges associated with the coding exercises. The camp's pacing was generally appropriate for all learners of varying STEM skill sets; nonetheless, many participants experienced technical or communicative barriers that resulted in prolonged troubleshooting. To prevent such unexpected delays, CODs proposed to schedule a combined session of drone building and coding on the first day, rather than delaying the coding exercises until the second day. Furthermore, the camp could also offer an optional troubleshooting session for students requiring assistance before the official program resumes on the second day.

According to the CODs, the fundamental challenge involved maintaining active student engagement throughout the entire duration of the online session. Thus, a strategic implementation of frequent, yet timely, breaks may prevent participants from losing focus. A few CODs also necessitated an expanded time frame to work on mission plans and poster sessions. These activities should justifiably serve as the culminating learning experience, as the creativity, critical-thinking, and real-life application skills intellectually appeal to many students. In general, CODs acknowledged the need to break up and chunk tasks strategically and appropriately to keep participants actively engaged throughout the two-day camp. In the near future, perhaps implementing a week-long, or even month-long, virtual camp would significantly improve time constraints as well as continuous student engagement. In addition, the CODs suggested the potential implementation of an advanced iDrone program in the future, such as iDrone 2, that emphasizes coding challenges and peer competition for highly motivated students in STEM fields.

Summary and Future Direction

The Interstate Drone League (iDrone National) broadcasted via Zoom virtual meeting platforms and other e-learning tools across multiple states, including Alabama, California, Idaho, Illinois, Georgia, North Carolina, and Texas. A combination of asynchronous and synchronous STEM e-learning modules was well adapted to maximize online content delivery. More than 100 participants virtually interacted with each other to advance the informal STEM learning experience, focusing on drone design, coding, and building from scratch. Additionally, the team-based poster session and mission plan served as other avenues to increase leadership and to accomplish goals together by respecting the spirit of teamwork. The path to obtaining a remote pilot license administrated by FAA (also known as FAA Part 107) was also presented for the older students (16 years and older) to explore the initial aeronautical knowledge test covering diverse topics, including but not limited to: emergency procedures, crew resource management, radio communication procedures, aviation weather, and airport operations. Overall, the survey outcome indicated that the majority of the participants were satisfied with iDrone program and e-learning experience, indicating the success of iDrone Online.

As the global pandemic (COVID-19) lingers, we will continue to host iDrone Online in the near future. Unlike the iDrone 2020 online camp, the future iDrone workshop will adopt a hybrid approach (both online and offline) to maximize broader impacts. Thus, we will host a three-day online session for the general public, tentatively scheduled for the summer 2022. For example, students will have more time to complete drone-building on Thursday evening, followed by coding Friday evening, as well as mission planning via the aforementioned virtual e-learning platforms. On Saturday, selected teams will be invited to a national venue, such as the US-Korea Conference on Science, Technology, and Entrepreneurship (UKC, 2021) to accomplish their research goals according to the theme and poster presentation guidelines set by the iDrone program. Basically, the selected teams from the online camp will compete against each other for the advanced, offline championship, in which students are challenged with a coding-enabled drone obstacle course, Part 107

pop quiz competition via YouTube Live, and a poster presentation. We anticipate that the proposed hybrid iDrone will improve STEM pipelines across the states and beyond without limiting physical boundaries and educational constraints during the difficult times we are in today. Furthermore, advancing STEM education through a combination of drone technology with artificial intelligence (AI) will serve as another avenue to leverage the ongoing iDrone program for future implementation in this hybrid format, ultimately increasing future STEM workforces.

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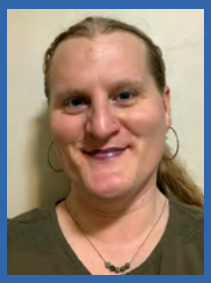
Riveraine Walters, PhD, PE, is an interdisciplinary environmental specialist with strong backgrounds in both engineering and social science. Her current work considers the role of belief systems in adaptation to climate and socio-natural change. Riveraine has participated in many STEM and environmental education programs over the past two decades, including workshops, training, and course instruction for youth and adult learners.



Hannah Ziegler is a secondary science and math teacher at Canyon Ridge High School located in Twin Falls, Idaho. She holds a B.A. in Liberal Arts from Pepperdine University and an M.A. in Science Education from Teachers College, Columbia University. She previously researched the impact of volcanic eruptions on global climate as a graduate research associate at the NASA Goddard Institute for Space Studies. Most recently, she has collaborated with the iDrone program to research and facilitate engaging drone-based teaching and learning. Her research interests largely involve: developing teachers' TPACK (technological pedagogical content knowledge), analyzing students' retention and perceptions of science, and ensuring equitable STEM learning for all.