DRONE PEDAGOGY IN PRACTICE: LESSONS FROM A PILOT STUDY IN LANDSCAPE ARCHITECTURE

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ABSTRACT
The use of drones in landscape architecture and related professions is increasing, along with the advancement of student training in this technology. However, drone technology is often inaccessible to students due to the expense of the equipment and licensing, as well as the need for maintenance and training support. At the University of Connecticut, a pilot study was initiated on the establishment of a college-wide fleet of drones for instructional purposes in the landscape architecture program. This study outlines the setup of the drone fleet, with a specific focus on the integration of drones in the undergraduate landscape architecture curriculum. During the pilot year, students gained hands-on experience with this technology, advancing their flight skills, as well as their data analysis and digital representation capabilities. Students showed a marked improvement in their flying abilities as well as a critical sensitivity to the extent to which drones can and should be used to inform the design process. This study contributes to design pedagogy informed by a mixed methods approach that incorporates direct and indirect documentation of student learning through participant observation, assignment deliverables, and a pre- and post-workshop survey. Outcomes from this pilot study provide a roadmap that highlights lessons learnt from this initial phase of drone integration into LA teaching and learning, and the establishment of a college-wide teaching resource.

Keywords
Drones, Landscape Architecture Curriculum, Educational Assessment

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1 INTRODUCTION

Remote sensing technologies are becoming more accessible, and drones are being used in research and practice in a variety of environmental disciplines including conservation, natural resource management, and construction[1]. Drone data including standard RGB imagery and videos, light detection and ranging (LiDAR), multispectral hyperspectral, thermal images, and sonar data are being used across the globe in a range of scenarios that advance landscape-scale analysis (Lee et al., 2016; Navia et al., 2016; Santangeli et al., 2020; Jensen and Cureton, 2024; Villarreal et al., 2025; IALE, 2025). Drones are also being used in landscape architecture (LA) research and practice in site analysis, monitoring, data development and digital visualization (Kullmann, 2017; George and Park, 2020; Cureton, 2020; Munck Petersen, 2020; Antelis, 2022; Cureton et al., 2022; Jensen and Cureton, 2024; Laursen and Hald, 2024). However, the use of drone technology and training is often out of reach for students, despite the need to understand their use and applications (George and Park, 2020). This study reports on the pilot phase of a drone module offered as part of the advanced computer graphics course in the undergraduate landscape architecture curriculum at the University of Connecticut (UConn). It aims to (1) demonstrate how drones were incorporated into an existing class, (2) share student assessment and learning outcomes, and (3) reflect on lessons learned to inform educators on approaches for applying similar methods in their own teaching. During this pilot year, students gained hands-on experience with drone technology, advancing their flight skills, as well as their data analysis and digital representation capabilities. Students showed marked improvement in their flying abilities as well as a critical sensitivity to the extent to which drones can and should be used to inform the design process. This study contributes to design pedagogy informed by a mixed methods approach that incorporated direct and indirect documentation and assessment of student learning through participant observation, assignment deliverables, and a pre- and post-workshop survey. Outcomes from this pilot study provide a roadmap that highlights lessons learnt from this initial phase of drone integration into LA teaching and learning, and the establishment of a college-wide teaching resource.

1.1 Drones and Landscape Architecture

In recent years, the use of drones has increased as drones have become *the sixth quantum leap in technology* (FAA, 2019)[2]. While aerial imagery had previously been obtained through satellite images and manned aircraft, drones have become popular as a means of acquiring multi-modal remote sensing datasets, such as multispectral, hyperspectral, thermal imagery and LiDAR point clouds. This data, in turn, informs site inventory and analysis, 3D modeling (Herrero et al., 2022), surveying (Burgett et al., 2021), and feature extraction (Crommelinck et al., 2016). The use of drones in LA has been recognized by the field's professional and academic organizations, with both the American Society of Landscape Architects (ASLA) and the Council of Educators in Landscape Architecture (CELA) offering drone workshops (ASLA 2021, 2023; CELA, 2023), and publications geared to landscape architects have emerged that introduce designers to the technology and workflow (Cureton, 2020; Tal and Altschuld, 2021; Cureton et al., 2022).

Drones in LA are being deployed to refine and extend data collection, enhance visualization and as educational tools, however, they also come with their own set of technical challenges and ethical considerations. In research and design, access to self-directed aerial imagery is giving designers greater control in the development of geospatial datasets (Dillon, 2020) while enhancing environmental modeling to inform design for more resilient climate futures (EMLAB, 2025) and for landscape performance (Antelis, 2022). In addition, video tracking between waypoints allows landscapes to be recorded and footage choreographed to enhance visualization (Kullmann, 2017) and create common land use understandings and collaboration amongst stakeholders (Kleinschroth et al., 2022). Piloting drones and working with this data has been shown to develop a human-technology interface with the landscape, shaping knowledge through interaction and perception (Kullmann, 2017; Milligan, 2019; Cureton, 2020; Munck Petersen, 2020) while offering new aerial views and points of cognition that differ from 2-dimensional mapping (Jensen, 2020; Laursen and Hald, 2024). Alongside their increased use, designers have been grappling with the "promise" of incorporating this technology along with other modes of environmental simulation in their work. For instance, drones raise questions of surveillance, data security, privacy, and access to knowledge (Sandbrook, 2015; Jensen, 2020; Cawthorne, 2024).

Universities are bringing drones into the classroom with Utah State University, North Carolina State University, Smith College, and the University of Arizona, to name a few, providing student education on

drones related to landscape architecture practice (George and Park, 2020; Antelis, 2022; CAPLA, 2025; Smith College, n.d.). In contributing knowledge on drone pedagogy in LA, this study builds from previous work that outlines the development and integration of drone programs in LA curriculum (George and Park, 2020; Antelis, 2022). It fills a critical gap in the literature on the adaptation and translation of this technology to LA by providing further insight into an iterative learning sequence with an emphasis on student perceptions and evaluation. The paper reflects on the connection to broader college resources, offers a detailed outline of drone workshop tasks, as well as lessons learnt from this pilot drone program. Due to the number of landscape architecture firms already using this technology, and the perceived increasing application of this tool in the discipline, the purpose of this study explores the development of this college resource and integration of drone theory and practice within the landscape architecture curriculum to better prepare our students to think critically about the use of drones, the data produced, and give them access to technology that connects to ways of working in the field.

1.2 University of Connecticut LA Drone Pilot Study

At the University of Connecticut, landscape architecture is situated within the Department of Plant Science and Landscape Architecture in the College of Agriculture, Health, and Natural Resources (CAHNR). We are a small accredited landscape architecture program with approximately 80 undergraduate students. Our recent class sizes range from 18 students in the graduating class of 2026 and 23 students in the graduating class of 2027. The UConn LA program's small class sizes enable instructor-student teaching ratios that allow for experimentation with new pedagogical approaches, and enable in-depth observation and assessment of teaching practices and learning outcomes. This study was supported through the College of Agriculture, Health, and Natural Resources (CAHNR) Teaching Enhancement Grant Competition with the purpose of establishing a college-wide fleet of drones for instructional purposes.

The experience of flying a drone and having access to this technology is intended to give our students confidence in their ability to work with aerial equipment. Both PIs on the grant have their Federal Aviation Administration (FAA) Remote Pilot Certificate and have prior experience working with drones. The development of a CAHNR Drone Fleet enables students to take advantage of facilities conducive to learning how to pilot drones, experiment with different image capture techniques, and fail in a safe environment. During this initial phase of the study, both direct and indirect assessments of student learning were conducted (Suskie, 2018) to give insight into student perceptions, skill development and content-related learning. The awarding of the CAHNR Drone Fleet provides a unique educational opportunity for LA students, and this paper reports on the development of teaching materials, learning strategies, student experiences and lessons learnt with the intent of providing a roadmap for others.

In fall 2024, drone-based teaching and learning activities were integrated into an existing junior-level landscape architecture graphics course. This class built student competencies in various representational media, with a focus on their research potential in the field of landscape architecture. Guiding design inquiry during the semester was the theme of visualizing forests as socio-ecological systems on UConn's campus. The class was comprised of 5 modules: (1) creative note-taking, (2) photographic inquiry, (3) critical mapping, (4) thematic analysis, and (5) a final exhibition. Learning objectives for the class aim to develop students' 2-dimensional as well as 3-dimensional drawing and representation skills, build familiarity with digital data sources, and develop design research skills with particular attention to methods in landscape architecture. The intent is to assist students in the development and articulation of the values that underpin their creative, representational, and analytical choices, while fostering a studio community that facilitates supportive peer learning.

The grant allowed for the purchase of six DJI Air 3 Drones and one DJI Mavic 3 Thermal Drone, both of which are lightweight, while also having a variety of advanced features that make them ideal for aerial imagery[3]. Drone teaching occurred in the third module of this class entitled "critical mapping" in mid-September and involved a 3-phased teaching method. Phase 1 consisted of a reading response and a lecture to introduce drone theory and practice. As well as a visit from the Advanced Remote Sensing Imaging and Analytics Lab (ARIAL), which featured a drone demonstration. Students then handled the DJI Mavic 3 drones for the first time and practiced assembling and disassembling the equipment (Figure 1).

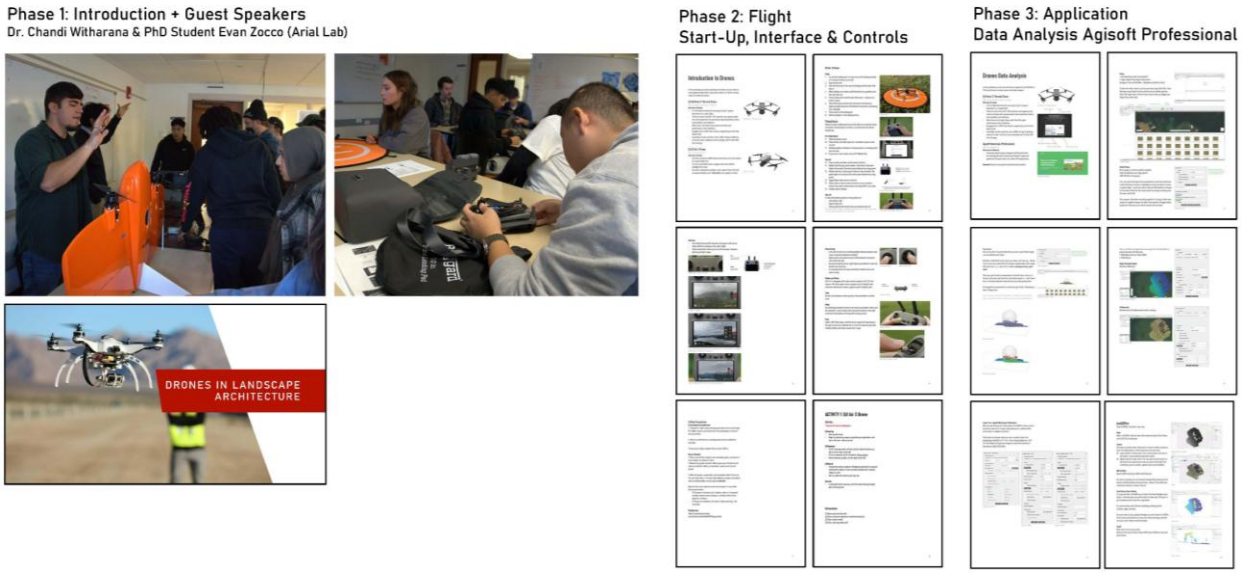

Figure 1. Three-Phase Drone Workshop Model (2024). Photos by Monika Mihok, labs by Julia Smachylo.

Phase 2 demonstrated and developed student flight skills and was comprised of 2 workshops (Figure 2). The goal of the first drone workshop “Introduction to Flying” was to introduce students to hands-on flying basics to improve their handling skills. Students were tasked with setting up the drone and the landing pad, taking off from the landing pad, flight management (moving the drone in different directions), camera management (photo and video), and returning the drone to the landing pad.

The aim of the second drone workshop “Advanced Drone Flying” was to improve student confidence and abilities (Figure 2). In this second flight session, students began by demonstrating an overview of the skills they had learnt previously before engaging in new maneuvers. Similar to the first workshop, students were required to set up and put away the drones at the beginning and end of their session. For this workshop, students were given specific navigation prompts while recording their progress through photo and video. They were tasked with bringing the drone to an altitude of 10 meters, taking an image of a previously determined object, and then recording a video with the object in the middle of the camera focus area. Students then increased the drone’s altitude to 20 meters while trying their best to keep the landmark in the center of the camera. Students then orbited the drone around an object with a relatively constant radius. The last task they completed before landing the drone was to experiment with the drone’s flight maneuverability or flight extent. Students tested out different shapes such as a figure eight or how far away (vertically or horizontally) the drone could go from its home base before they got a warning.

Phase 3 used the DJI Mavic 3 Thermal Drone to collect a series of overlapping aerial site photos. The demonstration showed students how to set up and run a flight route. The aerial photos were packaged and shared with students. Students were asked to download a 30-day free trial version of Agisoft Metshape Professional software, which was used to conduct photogrammetric processing of the aerial images to produce 3D spatial data. This software was used to stitch the aerial images together and create a 3D Photogrametric Point Cloud, Orthomosaic image, and Digital Elevation Model (DEM), which were then exported to ArcGIS Pro software. Students experimented with developing their own contours from the DEM and overlaying these on the Orthomosaic. Students also created a cross-section through the point cloud data using a local scene and the classification tool in ArcGIS Pro. The final deliverable for the module was a data processing and reflection assignment, and a final exhibition of student work where drone imagery and analysis were displayed in a gallery space in the main library at the university (Figure 3).

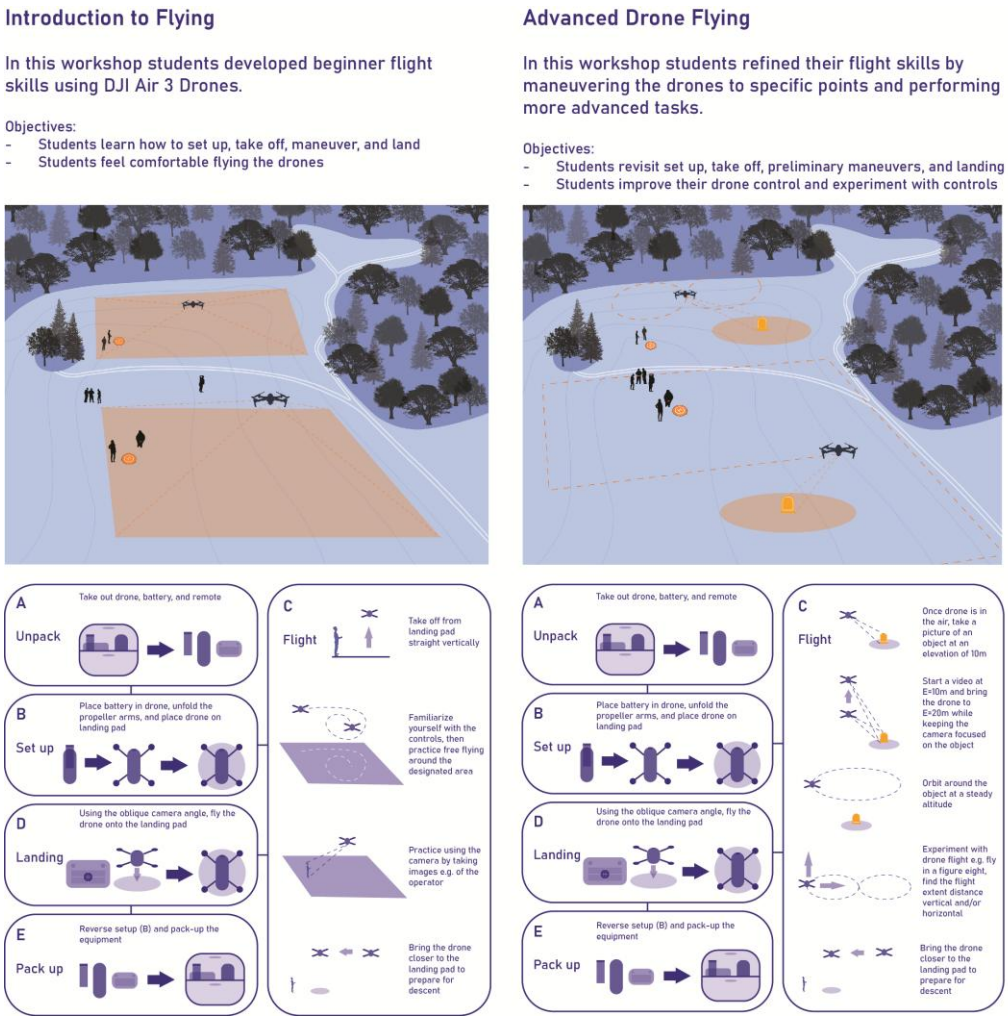

Figure 2. Workshop Flight Instructions (2025). Illustration by Andrew Simmons.

Figure 3. Workshops, Analysis and Exhibition (2024). Photos and Graphics by Sam Meyer, Eveleen Jiang, Matthew Enright, and Nick Jamrock.

1.3 Research Objectives

The purpose of this study is to contribute to knowledge and outline a particular approach to integrate drone teaching and learning in landscape architecture digital visualization curriculum with a focus on undergraduate student teaching and learning. The objectives are to (1) illustrate a particular example of how drones were integrated into a previously existing class through discussion of the set-up of the drone fleet and pilot study, (2) share student learning outcomes, and (3) reflect on lessons learnt and next steps. The intent is to provide educators with a pedagogical case study supported by specific materials, methods and lessons learnt that can be applied elsewhere. Through both qualitative and quantitative assessments, we were interested in how the integration of this technology developed relationships between students and the landscape and allowed them new interpretive lenses in a landscape architecture context.

2 METHODS

This mixed-methods study used assessment measures that incorporated direct and indirect observable documentation of student learning. Using a teaching learning assessment process (Suskie, 2018), the drone module aimed to: (1) establish clear learning goals, (2) allocate enough time for students to meet these goals, (3) incorporate evidence of how student learning met these goals, and (4) use this evidence to improve student learning. Direct assessment was gathered through student data analysis assignments and reflection papers, with indirect assessment collected through participant observation and self-reported survey data[4].

A pre- and post-survey instrument using the Qualtrics software platform was developed to understand the skill level and perception of drones in LA, both before and after the workshops. The survey combined measures of student perceived skill level, understandings of the use of drones in LA, and workshop expectations. The pre-workshop survey had 2 rating scale-style questions as well as 3 short-answer open questions. The post survey had 5 rating questions and 3 open short-answer questions. Both pre- and post-survey questions can be found below in Figures 4 and 5.

Participant observation can give a better understanding of the study context, insights into behavior, as well as build connections and integrate immediate feedback when assessing creativity in learning environments (Katz-Buonincontro and Anderson, 2018). This qualitative observation method was carried out in our study using a *participant-observer* and *observer as participant* approach (Merriam & Tisdell, 2016). The instructor and graduate student leading the drone module took a participant-observer role, where we engaged in leading the activities and wrote up our observations to gain a better understanding of the behaviors and dynamics of the workshop experience and learning outcomes. An additional graduate student attended the second flight skills workshop, where they recorded their observations rather than actively participating. These text-recorded field notes were used to better understand how students developed their skills, whether the skill level achieved was adequate to our objectives, and how we accommodated different student skill levels.

A reflexive thematic analysis method was undertaken by the primary investigator to code results from the qualitative observation and student reflections using NVivo software. This method does not use a pre-defined code book but instead emphasizes the outcome of the analysis as iterative (Braun and Clarke, 2021). The reflection paper asked students to write 300 words that reported their experience of the workshops, and their thoughts on the opportunities and constraints of working with drones. Data analysis of student observation and responses used the six-step method outlined in the literature (Braun and Clarke 2006, 2021; Byrne 2022)[5]. Analysis followed Braun and Clarke's (2006) recommendation to code for many different patterns at first that retain context, and Byrne's 2022 demonstration of coding specific extracts. In some cases, certain aspects of the data were coded into several different categories as they spoke to multiple aspects of the research. The next stage of analysis looked for patterns and sorted codes into broader themes. The approach relied on an analytic process (Braun and Clarke, 2021) where coding becomes part of the development of themes. Initial themes were assessed and were in some cases expanded, removed or broken down following Braun and Clarke's advice that data within each theme should be internally consistent and meaningful, with a clear difference between themes (2006). Lastly, the

primary investigator refined the definition and naming of themes and drafted the narrative related to the objectives of the study.

3 RESULTS

3.1 Student Survey

Qualtrics surveys were used to understand the skill level and perception of drones in the field both before and after the workshops (Figures 4 and 5). Responses were assessed using descriptive statistics built into the survey platform. Of the 22 student participants in the preliminary survey, the average experience of using drones was rated 1.8/5, indicating that many students had limited or no use of the technology before the workshop. Those with previous experience using drone-like devices had used small personal drones and RC planes for recreational use. Students' level of knowledge of how drones are used in the profession resulted in an average score of 3.9/5 with student perceptions highlighting their applicability to site analysis, video information, up-to-date aerial imagery, and topographic analysis. To get a sense of student expectations for the workshop, we asked students what they were hoping to learn. Responses included an interest in graphic visualization, drone licensure assistance, data collection and analysis, how to fly drones, and a better understanding of the technical and legal aspects associated with the technology.

Figure 4. Pre-Workshop Survey Results Graphic (2025). Illustration by Julia Smachylo.

The second survey was intended to assess student knowledge and skill levels after the workshops. This survey had 20 student participants. The average perspective of the importance of drones to landscape architecture students was 4.35/5, which showed an increase from the initial survey. Students responded that drones would be useful in providing up-to-date site inventory, survey imagery, as well as confirming and establishing current site conditions. The students finished the workshops with an average self-ranking of 3.45/5 for their drone flying skills and 3.2/5 for their drone data analysis skills. In the end, students said that they would have liked additional flight time as part of the workshops, as well as more analysis applications for the data that they collected. Overall, students ranked the workshops as an average of 4.6/5 for meeting their expectations. Of note is that the survey developed was intended to give insight into student skill level and their background understanding of the use of drones in design rather than measuring student knowledge against a standardized, quantifiable survey tool. Limitations to quantitative

student assessment in this study include the small sample size and single-institution focus. A longer-term goal is to develop more robust methods of quantitative assessment that provide more nuanced and comparable insight into students' motivational, performative and cognitive aspects of learning in this context.

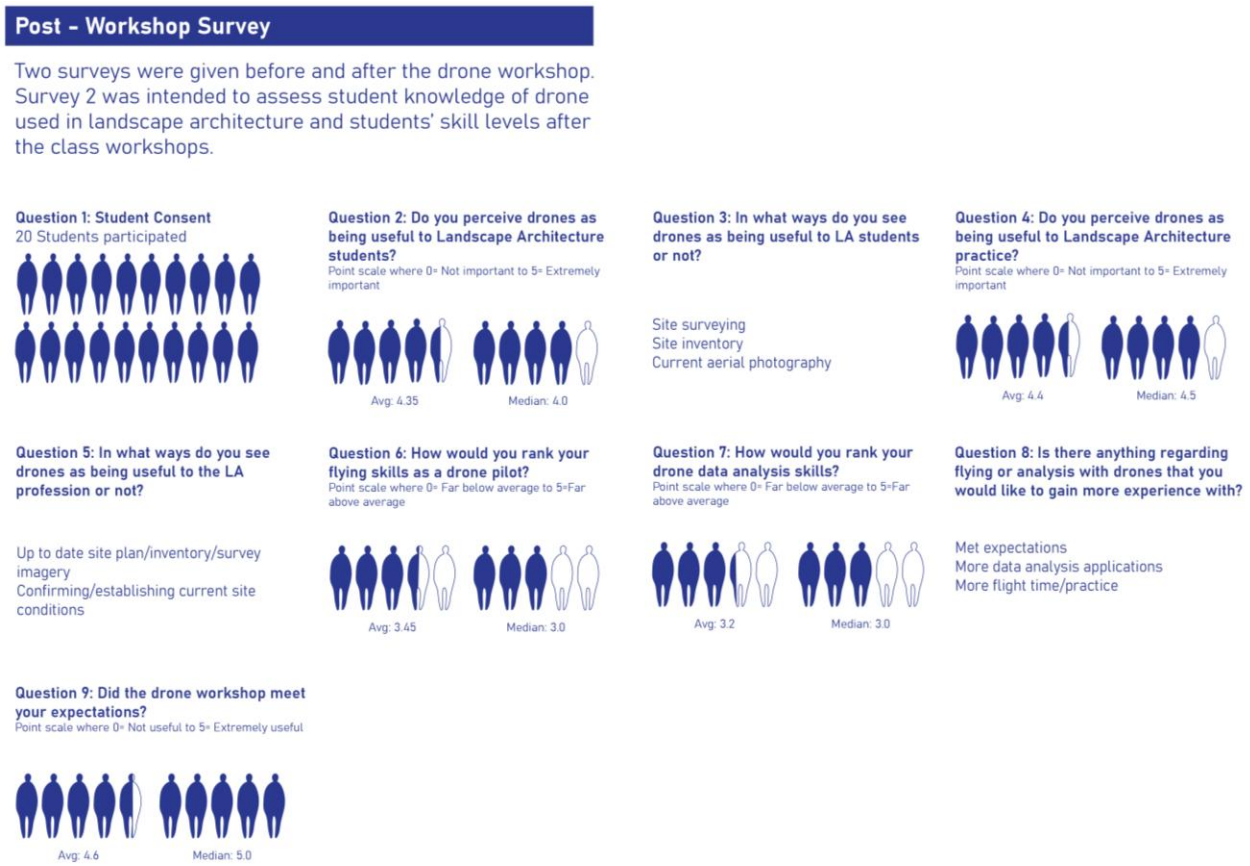

Figure 5. Post-Workshop Survey Results Graphic (2025). Illustration by Julia Smachylo.

3.2 Student Observation

Participant observation included both *participant-observer* and *observer as participant* approaches to assessing student learning (Merriam & Tisdell, 2016). Based on instructor and graduate student field note observations, four broad themes were identified through coding which included (1) an overall positive student sentiment, (2) flexibility in workshop requirements (3) student skill levels, and (4) workshop outcomes.

Positive student sentiment arose from the hands-on nature of the module, and it was observed that there was a high level of interest in the subject matter. Students were actively engaged in flying the drones and attendance was at an all-time high. They were active participants in the workshops and sought advice from instructors when they needed extra guidance. There was strong support from fellow students of their peers who were learning and experimenting with the capabilities of the technology.

The workshop requirements were noted by the observers in terms of their flexibility, which was intended to provide a base set of skills while aligning with each student's interest and abilities. Both the graduate assistant and instructor worked with each student to cater their flying time to their specific interests and needs, while also meeting the workshop prompts to ensure base-level skill requirements. The instructor made sure that those waiting for their turn to fly were engaged by supporting their peers by helping as spotters to follow the drone's trajectory to avoid collisions, or to have eyes in the sky to spot potential interference with wildlife.

The skill level of students was a common theme that surfaced in participant observation. Most students had very little experience handling or flying drones. Using an iterative approach, we ensured that tasks were built on one another to introduce drone flying skills aligned with student experience. The baseline starting level was thought to help put everyone on the same footing, but also allow students that had more experience to experiment and go beyond initial prompts. While the timeline was fast paced, observers felt that each student had the chance to master basic skills, while also being given the opportunity to test out more complex flight maneuvers.

Regarding workshop outcomes, generally it was observed that the most difficult skill for students during the workshop was the task of flying drones along a curved path. Generally, those students who had some previous flying experiences (2 students) were able to reach this level, while most students who had never flown before had a harder time understanding the controls to attain this flight pattern. One observer noted that while difficulties occurred during the skills workshops, these opened teaching moments that led to additional learning. For instance, *"one of the students ended up breaking one of the propellers of the drones when landing due to one of the landing pad stakes sticking out of the ground, but this opened up the opportunity to teach the students how to remove and replace the propellers as well as how to make sure the landing areas have no obstacles risking damage to the drones."* By the end of the two flying workshops, we saw students experimenting with the limits of these drones and showing increased confidence in their abilities. One observer noted, *"several students actively experimented with adjusting the drone's height and taking photos from different perspectives. They tested varying altitudes to capture detailed close-ups or wider landscape shots, which demonstrated a growing understanding of the drone capacities and camera functions."*

3.3 Student Reflections

Undergraduate students were asked to reflect on the drone module experience in a 300-word paper. Based on their observations, four broad themes were identified from detailed reflexive coding of their responses in NVivo by the primary investigator. These included (1) student experience (2) critical reflection on the use of drones (3) applicability to graphic representation, and, lastly, (4) relevance to design and future work in landscape architecture.

3.3.1 Student Experience

Similar to the participant observation above, students had an overwhelmingly positive experience in this workshop sequence, with most students referring to their enjoyment of this learning module. *"Using a drone to collect site data for the first time was an incredibly enjoyable and unique experience, one that marked an important milestone in my learning journey."* A deeper understanding of the theory and practice of using drones was noted, and students reflected on how this technology could be used to further their own research interests outside the scope of the class. *"Overall, I really appreciated this lab, and found it very helpful, and I am curious to see how I can use this technology for my own interests in urban tree canopies."* Students also commented on the ease of learning the drone skills where, *"when working with drones it came as a smooth and straightforward experience."* And, *"though I am not that skilled at flying yet, with more practice I think I'll do a lot better in the near future."*

Students liked the combination of structured and explorative workshop elements. Many students expressed positive feedback regarding the hands-on nature of the workshops and remarked on the benefits of learning practical skills. *"Using drones has not only improved my technical abilities but also deepened my appreciation for integrating innovative tools in creating sustainable, well-informed landscape solutions."* Students saw the development of these skills as serving them in the future, as well as during their remaining time in the LA program. Several students remarked that they would be interested in obtaining their drone license.

3.3.2 Critical Reflections

In their reflection papers, students were asked to expand on the opportunities and constraints of using drones. In their responses, they highlighted many limitations of using this technology citing issues of accessibility, privacy, the process of collecting data, the type of data produced, and the relative importance of this information when compared to other methods of data collection. Students mentioned accessibility as a key factor to consider regarding the drones themselves, and the software used to process the images. They pointed to the time needed to develop flying skills, to become proficient in the

software, the ability to access computers that have processing capabilities, and to obtain an FAA license. Students were cautiously optimistic, but highlighted concerns of relying too heavily on this form of inventory and analysis at the expense of developing other ways of knowing a site. Several of these sentiments are highlighted below: *"While the implementation of drones can bring a variety of benefits to students, it can also pose a threat when it comes to their ability to rely on their instincts and develop probing skills. If we use technology like this for our own convenience, we can stray away from traditional methods and prevent our minds from inquiring about important aspects of a site.*"

"While drones are useful tools to capture a wide range of data, they cannot replace our human senses. Therefore, we must continue to physically visit sites and collect our own data along with the drone's data, for we cannot solely rely on drones to pick up the same features humans can. It is important to find a balance between using this technology and our knowledge to conduct effective site analysis and create meaningful designs."

Other critical reflections on the integration of drones included safety and privacy concerns, the limitations of the drone itself in terms of battery, maintenance and performance, the need for adequate flight conditions (weather and airspace) and the maximum horizontal and vertical flight distance allowed by the DJI Air 3. While students approached the integration of drones in landscape architecture teaching and learning with caution, they also saw many benefits. The accuracy of this data and increased agency in its collection were overwhelmingly mentioned by students. The ability of this technology to access difficult terrain and site conditions, the quickness in which the data could be collected, the use of these drones for large sites, and the compatibility with other software such as GIS were seen as very useful by students. *"During this experiment, we were able to use the drones to explore the site we were on. This is a great opportunity because drones offer a powerful way to capture data in areas that may otherwise be inaccessible, enhancing the study of sites that are challenging to reach on foot."*

Students also saw particular relevance of using drones to enhance their understanding of topography and hydrology on site. *"Instead of relying only on ground measurements, students can see the whole landscape from above, helping them understand how elevation impacts things like water flow, erosion, and plant growth."* Interestingly, *"*time" was a theme that came up repeatedly. Students recognized the use of drones as providing a way of tracking changes in the landscape and monitoring site conditions ranging from design construction to environmental monitoring. *"This information can be invaluable in developing sustainable designs and better understanding environmental impacts over time."* And*, "not only could this data help us record current site conditions, but it could be a good tool to help record conditions during construction, after, and even the integrity several years later."*

3.3.3 Graphic Representation

Students appreciated the connection between the hands-on flying skills partnered with learning software workflows, analysis and alignment with systems that they were already familiar with such as GIS. Some students were less confident using Agisoft Metshape Professional and highlighted the need for more guidance in interpreting the data and visual outcomes. Some students were unclear on what the visualization of the data was depicting or questioned the usefulness of the resulting visual material. *"In my images you can see there is a lot of data including topography and vegetation in the area. However, I am not sure that the way these images are depicted is the best way to show the elements of the site."*

The aerial data collected and its interpretation through Agisoft and ArcGIS Pro were seen as beneficial for enhancing student understanding of the topographic elements of the site and giving them tools to enhance their understanding of the terrain. *"For example, detailed aerial images can highlight subtle elevation changes that might be missed otherwise, helping us plan more effectively for grading or drainage."* The use of drones and subsequent data processing was seen by many students as particularly relevant to site analysis and helpful in the development of different visuals. The ability to work between planar and sectional views to better understand patterns in the landscape and communicate their design ideas was also seen as valuable.

3.3.4 Relevance to Design and Future Work

Lastly, students noted how drones could be integrated into the design process as one of many tools. While students were wary of relying too much on this technology, they saw its relevance to the profession,

especially in having more control over the data they were using in the development of their design visuals and in site analysis to enhance their understanding of a site's strengths and weaknesses. *"The use of drones can facilitate both site analysis and the design phase at the same time by providing data that can't be as easily acquired otherwise."*

"This experience helped me recognize the evolving nature of tools in landscape architecture and how technology like drones can expand the possibilities of site analysis and design."

Students predicted the increasing use of drones in the LA program at UConn and saw the skills they learned in this class as relevant to other courses. However, they raised concerns regarding time, expense, support, and licensure. *"Drones and the sensors they carry are very expensive, and the licenses to programs like Agisoft and ArcGIS Pro can be very expensive."* Despite anticipating further use of drones in the future, students still recognized the importance of multiple approaches to understanding landscape. *"If drones are integrated in the classroom in the future, I think making sure to still emphasize good site analysis (physical data collection) along with drone usage is important."*

4 DISCUSSION

4.1 Teaching Drones in LA Undergraduate Curriculum: Lessons Learnt

Fall 2024 was the first year the LA program at UConn had access to the DJI drones as part of a learning module in the junior-level advanced graphics class. The development of the curriculum and the setup of this resource for students is the first step in establishing a college-level CAHNR drone fleet. This graphics class was an ideal test scenario, as the technology aligned with existing learning objectives for the course and provided students with hands-on experience outside of the computer lab. The partnering of hands-on analogue skills with digital software supported the pedagogical approach of the class which asked students to continually revisit a section of the UConn Forest throughout the fall semester. As a result, students flew the drones in a familiar location, in a large, secluded field, which was ideal for learning and practicing. Throughout the workshops, maintaining the safety of students and wildlife was important and the location chosen offered enough space for students to experiment away from other people, while maintaining continuous lines of sight. Students waiting for their turn to fly were expected to serve as visual observers to assist the student pilot in maintaining lines of site and in anticipating possible hazards to people and wildlife.

As evidenced by student reflections, there was a marked improvement in drone handling, data management, and visualization capabilities. However, student feedback pointed toward the need for more detailed instruction on how to interpret the data analysis which will be addressed in future workshops. All students attended the workshops and learnt the required flying skills. Iterative skill development allowed students to gain confidence with basic skills, building to more advanced maneuvers. Of note, there were moments when the instructional team ended up reassessing the requirements of the module *in situ*. For instance, during the first flight skills session, we quickly realized that time would be a limiting factor. After the first 30 minutes, we split the students into 2 groups, each led by an instructor who had their FAA Remote Pilot Certification to allow for more time for each student to fly the drones.

During this first outdoor workshop, we also realized the benefit of having multiple drones with us on site. While 6 drones seemed excessive on initial purchase, in the end, it meant that one student could set up while the other was packing away the drones. As battery and storage capacity were limited, having students in two groups, each with 3 drones allowed for an extended battery life and storage capacity to record student images and videos for each task. Another lesson learnt during this initial pilot phase occurred in the advanced flying workshop. After several students struggled with some of the more complicated maneuvers, we reassessed our objectives and were more flexible in student interpretation of the goals of the assessment. Rather than dictating exact flight paths, we gave them a prompt and let students choose to meet the objective in the way that felt most comfortable for them.

4.2 Limiting Factors

Developing a drone resource and integrating this technology into a pre-established LA curriculum comes with financial constraints, logistical hurdles, access issues, as well as sustainability and scalability challenges. Drones and associated software are expensive. This doesn't just refer to the initial purchase,

but also drone maintenance, the licensure of pilots, and subscriptions to software[6]. The drone workshops relied on at least two people with Remote Pilot FAA licenses to accomplish the tasks during class hours to give everyone time to fly and gain confidence. For the class instructor, depending on another licensed pilot to run the workshops with them adds uncertainty. In this case, the instructor's graduate student had funding and interest in this technology and co-instructed the flight workshops (Figure 6), which might not always be the case. The Agisoft Metashape software licenses are also expensive, and the computer lab portion of this drone module depended on students being able to download a 30-day free trial while also having access to ArcGIS Pro. While GIS is provided by the university, having access to the drones and software after students graduate is a limiting factor, and we are exploring open-source platforms for future workshops.

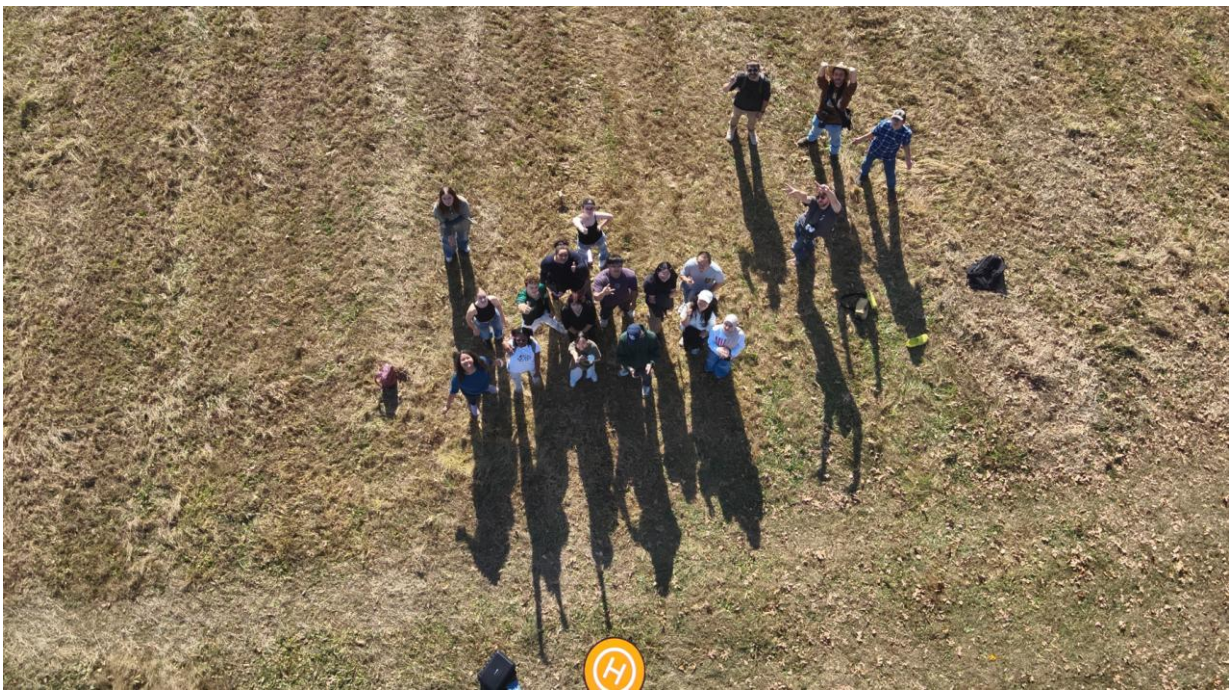

Figure 6. Third Drone Workshop. Graduate Student Coordinated Class Photo (2024). Photo by Andrew Simmons.

The broader ambition tied to the CAHNR Teaching Enhancement Grant was to expand drone access to other classes in the LA program and to connect with additional departments and programs within the college. Luckily, the college has faculty who have been involved with this pilot study, who are working with drones in different capacities and are helping to establish these connections. For instance, Chandi Witharana, an Assistant Professor in Natural Resources and director of the ARIAL Program at UConn, instructs a dedicated class on drones for students in the Department of Natural Resources and the Environment (NRE) and works with drone data in his research[7]. Evan Zocco, a PhD student in NRE, is using drones to monitor the conservation of beaver habitat in Connecticut. Several other graduate students in Witharana's lab use drones to monitor roadside trees and nutrient deficiencies in commercial fruit crops. Going forward, we will be continuing partnerships between these departments to enhance cross-disciplinary knowledge formation.

After completing the pilot phase, certain logistics of managing a communal resource of drones and expanding access to others at the college have raised issues. To comply with FAA regulations, we would need to have certified pilots accompanying anyone (faculty and students) who would like to use the drones. This would rely on dedicated funds to train people to support the program. In addition, the time and travel requirements involved in providing this service are a limiting factor. Weather conditions are also an issue. Most of the academic year takes place in the colder months when many are perhaps less inclined to spend time outside and the weather conditions (wind, snow, rain) limit flight. We recognize that

the LA program's collaboration with the ARIAL Lab is a resource that others won't have access to, and that our program benefits from this relationship in terms of drone storage and access to expertise. There is also a steep financial barrier to purchasing the drones, and while we were lucky to have had the opportunity to apply for a college-level grant to cover the costs, funding resources differ between LA programs across the country. Despite these constraints, we are looking for additional funding options to support expansion and other ways in which to increase access to this resource within the college.

5 CONCLUSION

The experience of piloting drones and the integration of data analysis and visualization into teaching will prepare students for practice and contribute to learning outcomes within the college. In supporting students to enhance their hands-on experience with this technology, the CAHNR Drone Fleet enables students to take advantage of facilities conducive to learning how to pilot drones, experiment with different image capture techniques, and fail in a safe environment. Providing access to drone technology and integrating these skills into the LA curriculum were the primary goals of this pilot study, along with the provision of a road map for creating college connections. Using qualitative and quantitative assessment measures, we saw student knowledge, analysis, visualization, and handling of drones increase during the semester. Next steps for our team include the integration of the results of this study into the next iteration of the module in the fall of 2025, and the continuation of student assessment to support multi-year data collection. While several limitations impacted the outcomes of the study such as the small sample size of participants and the single institution focus, this paper outlines outcomes and lessons learnt from the use of this technology in a landscape architecture context. Future research aims to develop a better understanding of the affective aspects of the use of drones in landscape architecture, partnered with a more in-depth study of the human-technology-landscape perspective to add greater insight into how students use drones in unanticipated ways related to site analysis, environmental management, and graphic visualization.

Endnotes

1 Unmanned Aerial Vehicles (UAVs) weigh less than 55 pounds inclusive of all attachments and are often also referred to as small, unmanned aircraft systems (Smal UAS) or drones (FAA, n.d.).

2 As per *Landscape Architecture Magazine*, drone usage by landscape firms as of 2019 was reported at 55% of firms utilizing drones in some capacity (George and Summerlin, 2019).

3 The DJI Air 3 drone captures complex and high-quality professional footage, incorporating a dual-camera system, with a wide-angle lens and 3x medium telephoto lenses for both focusing on subjects and capturing large-scale landscapes. DJI drones have a compact foldable design which enables it to travel well and allows for compact storage. Also included in this package is an Air 3 battery charging hub, two extra intelligent flight batteries, three extra pairs of low-noise propellers, and a shoulder bag. Two additional features which make this drone suitable for teaching undergraduate and graduate students is the: (1) obstacle avoidance built-in sensors which automatically detect obstacles in any direction during flight, and the (2) smart RTH which when triggered to come home, the Air 3 can automatically plot a flight route back to a set point, while using the obstacle avoidance system to keep it safe along the way (DJI, 2025).

4 The UConn-Storrs HRPP-IRB has made an exempt determination regarding this IRB submission.

5 The six step process of reflexive coding followed in this paper includes: (1) familiarization with the data (2) systematic coding (3) generation of themes (4) developing and reviewing themes (5) refining and naming themes (6) writing the report (Braun and Clarke, 2006; 2021).

6 To fly a drone under the FAA's Small UAS Rule (Part 107) a FAA Remote Pilot Certificate is required. The test costs $175, must be taken at a FAA approved Knowledge Testing Center Facility (FAA, n.d.).

7 See ARIAL (Advanced Remote sensing Imaging and Analytics Lab) *Eyes in the Sky StoryMap* https://storymaps.arcgis.com/stories/1da6df61b62b484fa40b7a3854c79e82 (ARIAL, n.d.)

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