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The Extent of Drone Education Being Taught in ASC Schools to 4-Year Construction Students

Cheran Teja Dumpati
cdumpat@clemson.edu

THE EXTENT OF DRONE EDUCATION BEING TAUGHT IN ASC SCHOOLS TO 4-YEAR CONSTRUCTION STUDENTS

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Cheran Teja Dumpati
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Dr. Joseph Michael Burgett, Committee Chair
Dr. Jason Lucas
Dr. Ehsan Mousavi

ABSTRACT

The technology of Unmanned Aircraft Systems (UAS) is growing rapidly in many fields and has become one of the skills in demand in the industry. Universities are one of the primary sources of teaching drone technology with a career-oriented approach. The goal of this study is to investigate the content of the drone curriculum being taught in Associated Schools of Construction (ASC) schools. This includes the topics covered, practical training offered, and the key deliverables taught. This information serves as a foundation for the schools that are looking forward to start drone courses in their department. The research found that there are only 50% ASC schools that teach any drone course in one of their departments. The analysis of syllabi collected from the Universities offering a UAS course show that Part 107, flight training, photogrammetry, and data collection are the common topics being offered which resonate with the curriculum in the schools of the FAA CTI group. The interviews with universities with well-developed courses mentioned that the UAS course needs a champion and the curriculum can be created from a wide range of resources. Part 107 is one of the primary topics covered by the universities with a focus on at least one deliverable aimed toward a career path. The local regulations, waivers, weather conditions, and privacy concerns should be made well aware to the students. Starting the course small with a basic budget is the most vocal advice by the faculty. Funding and administrational support are mentioned to be the predominant barriers to the implementation of the course and the new faculty should work closely towards addressing them.

ACKNOWLEDGMENTS

I want to express my sincere gratitude to Dr. Joseph Michael Burgett for his prolonged support. I am forever thankful for his support during each phase of the research. Additionally, I want to thank my friends and family for their encouragement throughout this journey.

I was able to make this journey thanks to the rich knowledge and suggestions provided by the defense committee. Clemson University's librarians, research assistants, and study participants played a vital role with their thorough support at different phases of the research.

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CHAPTER ONE

INTRODUCTION

Drones are an emerging technology in many fields. The necessity to use drones in the construction industry has been growing due to many factors, such as reducing human risk, improving logistics, and reducing cost (Sanchez, 2021). The trend of technological growth in the industry demands that students acquire such skills when stepping into the sector (Harper et al., 2022). Among such technologies, unmanned aircraft systems (UAS), commonly called "drones," is an emerging technology that can be taught with widespread usage. Owing to its various benefits, education on drones has become one of the prominent skills a student should possess (Williamson et al., 2019). To promote drone usage development, FAA issued specific guidelines for UAS in 2016 with the release of Title 14 CFR Part 107, which aided in opening the national airspace for commercial UAS operations in various fields.

The utilizations for various applications have been studied in many previous studies. In stable weather conditions, UASs can deliver products from online retailers, medical supplies, food, and medications to remote or disaster-affected locations (Radzki G. et al., 2021). UAS surveillance in farming and agriculture enables farmers to remotely monitor crops and vegetation to avoid damage by pest infestation, monitor frost damage, and optimize output (Luo, S. e. al., 2021). UAS is used to spray pesticides, which is considered safer and more accurate than manual spraying. With UAS image processing, fruit farms, and orchard management produce superior results (Zhang, C. et al. 2021). UASs measure air pollution and survey forests, wildlife, and other natural resources (Ivanova S. et al., 2022).

UASs are increasingly used in science, technology, engineering, and mathematics (STEM) fields. Multiple skills can be garnered to achieve various tasks in many disciplines, as shown in Figure 1.1. For example, research and data analysis is vital in Agriculture—similarly, problem-solving and critical thinking aid in assessing the statistics about forestry. Thus, the capabilities of drone technology in carrying out various activities reflect the advantages of incorporating UAS instruction within STEM education. Students in many STEM subjects would benefit from UAS instruction, given the broad range of UAS uses in STEM professions. (Bolick et al.,2022).

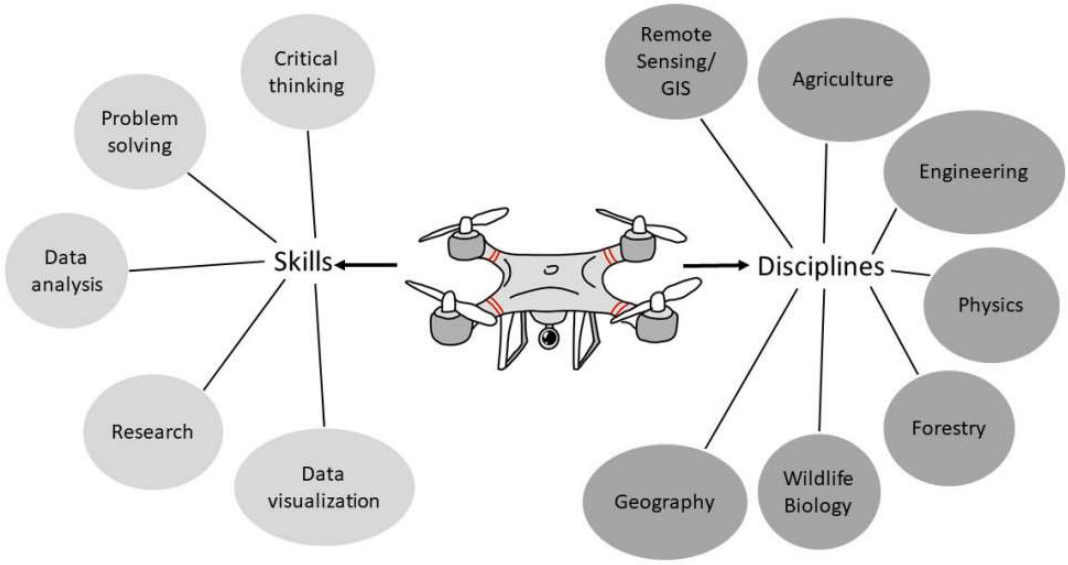


Fig.1.1: Examples of UAS skills in various educational disciplines. Adapted from Madeleine Bolick, 2022.

Over the past few years, UAS has attracted much attention as a platform for surveying and mapping, opening up a new range of potential for surveying, orthophoto generation, 3D modeling, and feature extraction(Remondino, F 2011). UASs offer a practical and

low-cost alternative to airborne and space-based sensors for medium- to large-scale mapping.

On the other hand, the FAA holds the authority to lay down regulations related to the operation of UAS. Drones are sophisticated machines that need special education and authorization to use safely. The FAA's CFR Title 14 Part 107 (Part 107) largely governs the use of drones for commercial purposes. Any missions connected to businesses that make money, even if the pilot is unpaid, are considered commercial operations. Commercial pilots are required by Part 107 to complete a knowledge test and obtain a remote pilot certificate. As mentioned in the FAA website, the knowledge of applicable federal regulations, such as airspace classification, weather, UAS performance, loading factors, and general operating best practices, are needed to learn to attain the part 107 license. Although an FAA license is necessary, it only theoretically evaluates the abilities required to operate safely in the national airspace.

The construction industry is one of the world's primary industries dealing with inspection, safety, survey, material logistics, etc. Drones can aid engineers in most of them(Naylor, B. 2015). The limited literature suggests that most universities teaching construction management and engineering still need to begin incorporating drone instruction courses into their curricula (Harper et al., 2022). As their utilization has also been growing owing to the needs, technology stands out as one of the key skills that can be taught to the students to meet the demands of the industry.

Research Question

This research aims to help faculty desiring to create a new drone class(es) at 4-year institutions by guiding the faculty with seasoned programs. To that end, the primary research question of this study is as follows.

- What standard practices and curriculum topics should be included in well-developed UAS classes at 4-year universities?

Research Objectives

To help answer the research question, this study aims to collect data from the affiliated universities of Associated Schools of Construction (ASC) to understand the level of inclusion of drone technology into their curriculum. A systematic way is adopted to complete the research to enhance the clarity of the collected data. The chronology of the study is formulated in the steps below.

- Assess the frequency of drone technology taught at ASC schools to find out the status of ASC schools
- Identifying the common topic in the curriculum of ASC schools
- Understanding the specific learning outcomes intended by the faculty from a "well-developed" course

For this study, "well developed" is defined (by assessing the syllabi received in further stages of this research) as a course that offer Part 107 exam preparation, any mode of practical training, and teaching students to provide at least one UAS-specific deliverable.

CHAPTER TWO

LITERATURE REVIEW

Unmanned Aircraft Vehicle (drone)

The utilization of drones has a long history. When the Austrians used hot air balloons to transport explosives to the Venetians in 1839, drones were first deployed (Sanson 2019). What we think of as modern small UAS were initially used for recreation. However, they are now used for a wide range of practical applications. One such application includes providing efficient medical support. Using drones to increase healthcare and health-related service accessibility for people in hard-to-reach places may be financially viable (Hiebert et al., 2020). For isolated and rural indigenous communities, drones have the potential to provide quick, on-demand access to health care, easing or eliminating the strain of travel to major urban areas and possibly enhancing patient outcomes in both routine and emergency healthcare scenarios (Flemons, K. et al., 2022). Additionally, there are growing research trends with the advanced usage of drone technology for tracking wild animals, especially in protected regions (Vas et al., 2015). Many businesses deploy UAS on their premises, with most applications substituting conventional still photography and video collection (Tatum M. C. et al., 2017).

Applications of Drones in Construction

Drones have become an integral part of modern technologies in many fields. One of the significant developments is observed in the construction industry. The construction industry started using three-dimensional modeling of extended objects created by multi-dimensional scanning produced by drones equipped with laser scanning systems and

automatic positioning systems (Zaychenko, I. et al., 2018). The most common uses of drones in the construction industry are marketing, video production, inspections, and 3-D modeling (Burgett 2021).

Over the last two decades, there has been tremendous scientific advancement in adopting technology such as UAS in the construction industry. Elghaish et al., 2021 mentioned that the existing UAS uses include automated surveying, information management and visualization, construction inspection, monitoring, and safety management. However, the paper states that the implementation process of the UAS needs to be addressed. One example is the study by Golizadeh et al. (2019), which focused on the need for more technical experience among construction practitioners in using UAS in construction activities. These studies show how the existing research has focused on the technical aspects of UAS applications rather than the implementation process for UAS in the construction industry. Yoo, S. (2021) discussed the limiting factors and improvement plans for using drones to operate drone technology at construction sites. From a technological standpoint, businesses must recognize and discuss competent people and infrastructure for systematic management. To extend the drone service to different fields, the management should possess adequate capabilities such as employing drones with better safety, strengthened on-site education, and better management of personal information.

Experimental Drone Curriculum as 4-year Universities

Many institutions have started implementing drone courses to experiment with understanding the students' benefits. Professors at Colorado State University authored a vital paper, Harper, C. M. et al. 2022, discussing the inclusion of the UAS curriculum

in higher education in the AEC programs offered by different universities. Harper et al., 2022 sent a questionnaire to the ASEE and ASC Universities faculty teaching AEC programs to understand their opinions regarding including drones in their curriculum and the different skill sets taught using UAS. The expectations of the construction industry from freshly graduated engineers were discussed, which demands the inclusion of drones' theoretical/practical experience. The questionnaire questions were divided based on the demographics, implementation, and skill set. Although the responses were low (6.7%), the survey results indicate that many schools are interested in adopting drone courses into their curriculum. However, many of them need clarification regarding the guidelines to follow and the requirements that must be fulfilled. A survey conducted on the students of Texas A&M University collected drone usage statistics and analyzed the growth trend (Williamson et al., 2019). An initial curriculum was created, which included the practical use of drones such as volume calculation, topography heat maps, linear measurements, and site photography. With less time for preparation and application for the students, it was mentioned to be a great learning experience. Still, the author emphasized the need for Part 107 certified tutors for the course. The university looks forward to further developments in the course and eventually develops the curriculum that can be implemented for the eleven colleges that share the same curriculum. In Malaysia, the implementation of a drone curriculum for students has been studied, including student's opinions (Phang et al., 2021). As part of the service-learning design, "Drone Tech for Edu-IR" is adopted for 31 students as part of the experiment over 14 weeks. The contents of the course include an introduction to drones, components of drones, application of drones, etc., for three weeks. The remaining weeks are allotted for practical applications such as the construction of

drones, operation of drones, starting and finishing a project with the help of drones, etc. After the course, a survey was conducted to collect the opinions of the students pursuing the course. The survey found that almost all the students were optimistic about the system and were satisfied with the learning process. Although the curriculum is not directly related to construction applications, the usage of drones has been discussed in a generalized way.

Irizarry, J. 2019 studied the use of Small Unmanned Aerial Systems (sUAS) in a graduate course in a construction education program (BC6005) that included the U.S. Federal Aviation Administration (FAA) regulations. The drone applications in the construction industry were reviewed while framing the course structure, such as Introduction to sUAS, sUAS selection, sUAS operations, sUAS applications in the construction environment, legal and regulatory considerations, etc. In addition, the FAA pilot certificate exam was conducted for the students willing to pay the additional fee. This study has offered a road map to help researchers and professionals better understand the demands of the industry and direct them as they investigate potential application areas and roadblocks that might have the most significant positive impacts on the U.S. construction industry.

Williamson et al., 2017 studied the extent of the construction surveying course being taught to the students. This research is limited to comparing the 10-day mini-mester period and the 15-week course. Students were divided into groups, with one group pursuing a mini-master course and the other seeking a traditional course in construction surveying. An online TOLT(Test of Logical Thinking) test was conducted for the students, and the results were assessed using the ANOVA method. This test requires

the students to choose the correct answer and the right reason to score the points allotted for each question. Although the results based on the topics such as laboratory activities, readings, and quizzes by the mini-mester students are predominating, the overall results are not satisfactory compared to the full-course students. This research stated that the teaching course curriculum in an elaborated way enhances the skills of students since long-term memory plays a vital role in the learning capabilities of the students. Sanson, J. 2019 cites the need to include UAS in the curriculum of construction engineering students through research at Youngstown State University (YSU). The University has started working on including a drone curriculum for the construction industry students. The expenses involved, regulations to be studied, and permits to be acquired are being evaluated. Their department is working on finding a faculty who is a certified drone pilot under the FAA and also brought a couple of drones. Al-Tahir 2015 mentioned a three-tiered method to include UAS-based technology in teaching geomatics and geomatics engineering at the undergraduate level. The three levels are assigning individual projects, teaching a small session, and teaching a significant component of a complete course. The amount of expected dependence on technical support and allotted time vary between the three levels of UAS instruction.

Demand for skills in Construction

Many firms are working towards offering drone jobs to pilots in a locality. They generally work similar to Uber, with drone pilots registered in different localities. When a customer posts a drone job in a locality, the firm will alert the pilots in that area. The responding pilot's information is sent to the customer so that he can choose among the viable options depending on the pricing, available timings, etc. The advantage of such

jobs is that they can be pursued part-time, do not consume much time, and hence be considered second income. Table 2.1 discusses some of the firms offering such opportunities in various fields.

Table 2.1 Firms offering jobs to drone pilots

Company \ Service	Agriculture	Civil Engineering /Construction	Environmental	Forestry	Event Photography	Property Inspections	Maritime	Mining	Marketing	Real Estate
DroneHive	✓	✓	✓			✓		✓		✓
SoldByAIr		✓	✓		✓	✓				✓
DroneUp		✓					✓			✓
Droners.io	✓	✓			✓	✓				✓
ConnexiCore	✓	✓			✓	✓			✓	
Drone Base						✓				✓
Drone Dispatch		✓								✓
Droneegenuity		✓							✓	✓
Mile High Drones	✓	✓								✓
Skycam production					✓					✓
Job for drones		✓			✓	✓				✓
Drone Safe		✓			✓	✓				
Aerial Drone Scan	✓	✓			✓	✓				

Gaps in the literature review

Despite the above advancements in the industry, many institutions have not taken the initiative to include a well-developed drone course. In the papers reviewed above, many of them have come up with surveys/questionnaires to the institutions/industry, experimental analysis of usage of drones, including primary curriculum of drones to test students' results, etc., they did not address the curriculum's learning objectives. In addition, there is a lack of clarity among the institutions regarding what needs to be included in a well-developed course. The schools must make such decisions based on specific parameters that vary from each institute. It is a significant concern that inadequate guidelines discourage schools from initiating the course. The level of practical training required for the industry has not been mentioned in any papers. Thus, the voids in the research papers have left the institutions in a considerable dilemma. There is a significant need to research the intent of the schools and their approach toward it. This explains the status of the universities in terms of drone education and a

platform for the remaining universities to assess the parameters for the inclusion of the UAS curriculum.

CHAPTER THREE

METHODOLOGY

The association of construction educators and industry professionals working together to grow and improve construction education is the Associated Schools of Construction (ASC). The ASC comprises eight regions, including one European and seven American areas. ASC is chosen as the sample because the Universities encourage information exchange which enhances the possibility of having a drone curriculum in more schools. The main idea of the research is to determine the extent of drone education being taught in ASC schools and suggest a recommended set of student learning objectives related to the UAS curriculum. Figure-3.1 shows a graphical representation of the methodology adopted for this study.

The first stage of the research involves identifying the ASC schools teaching UAS courses. A probe into the catalogs of ASC schools served as a base to identify the ASC schools teaching drone curriculum. The emails from such schools are used to request syllabi about the UAS courses. The common topics taught in the universities are assessed, and well-developed courses are identified. In the next phase, a structured framework is prepared to understand the learning outcomes, teaching practices, and content. The faculty teaching well-developed courses are requested for an interview. The data collected from the interactions serve as a further probe to learn the intended outcomes and the practices adopted, concluding the research. These quantitative and qualitative phases are discussed elaborately in the following sections.

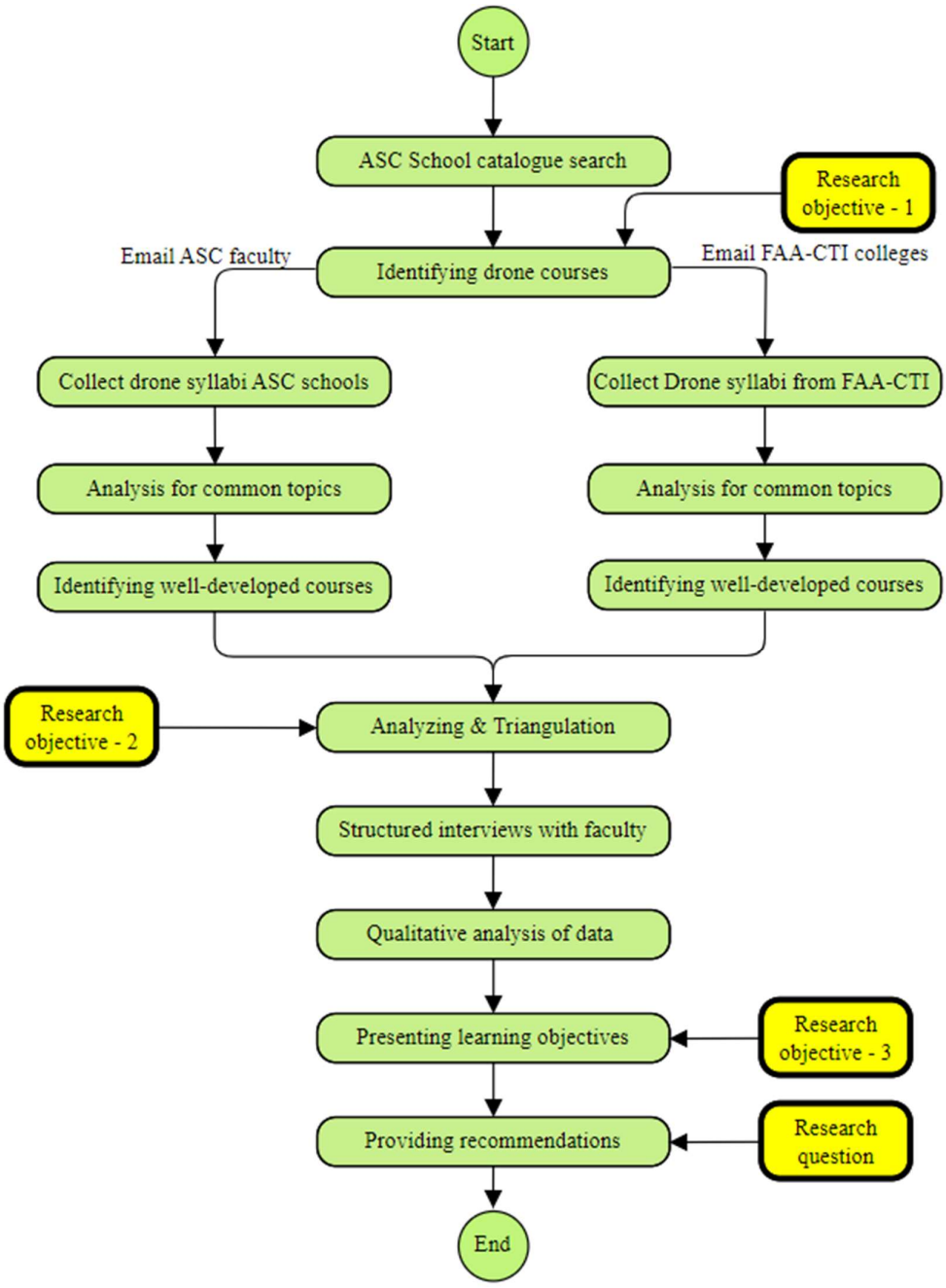


Fig. 3.1: Step-wise representation of the stages involved in the methodology

A mixed methods approach was adopted to achieve the study's goals. Phase-wise research was conducted where each phase provided the data to continue the next phase.

A deductive approach was undertaken in this research to understand how the drone curriculum has been started in the university and how the contents of the syllabi are being taught.

Quantitative Analysis

ASC schools' teaching UAS curriculum

A list of ASC schools was gathered from their website. The catalog of the ASC schools was searched using the keywords drone, UAS, UAS, and Unmanned. The search results are gathered from all the departments in the school. The data collected from the curriculum included the courses and their descriptions. This provided insight into the institutes' courses regarding what is being offered to the students. The information collected from the catalogs includes drone topics from civil engineering and other disciplines. The contacts of the instructors of record and the head of the department were collected from the college's directory. Owing to the statistics of the ASC schools on offering the course, the frequency of the UAS curriculum is studied. In addition to the construction programs, a few other departments offer the course as part of the curriculum. Table 3.1 displays the statistics collected from the school website catalog regarding UAS technology as part of their syllabus. Appendix-A displays the list of ASC schools teaching at least one drone course, as mentioned in their catalogue.

It is observed that almost 50% of the universities are offering drone courses in one of their departments. However, only six schools (3.7%) have a drone course in their CM department.

Table 3.1. Schools offering Drone courses in their curriculum

	Total ASC schools (162)	Percentage (%)
Schools offering drone course in any department	80	49.4
Schools with drone course in the CM department	6	3.7

UAS topics taught in drone courses

As the catalog only contains the course description, the topics being taught as part of the course during the semester are not available. The course faculty were contacted through email to facilitate such data, requesting complete syllabi. The research often required going through the school staff directory to gain the concerned faculty's email I.D. Thus, the course instructors are contacted through email, requesting the syllabus data for the offered course. Table 3.2 provides the statistics of reaching out to the universities and the responses received for the abovementioned process. The data of all the syllabi collected along with the typical topics identified is being attached as appendix-B.

Table 3.2. Schools sharing syllabi pertaining to their Drone course

	ASC Schools with drone course (80)	Percentage (%)
No. of emails sent to the faculty	100	-
No. of responses received for the syllabi	59	73.8
No. of syllabi with Well developed course	3	3.8

Once the research team received the data, it was reviewed and organized with the aid of a subject matter expert to filter out the typical topics from the syllabi. From this data,

well-developed courses were identified. A "well-developed course" is recognized as preparing students for the Part 107 exam, providing flight training in a simulator or in-person, and teaching at least one deliverable such as 3D Mapping/Thermal Inspection/LiDAR point cloud, etc. The information obtained from the professors' syllabi is summarized in Table 3.3.

Table 3.3. List of topics taught in the syllabi of ASC Schools

Topics included in the syllabus	No. of Schools (60 total)	Percentage (%)
Part 107 review	22	36.7
Part 107 exam	3	5.0
Flight training	20	33.3
Collect drone data	20	33.3
Air Traffic Control (ATC) authorization / LAANC authorization	1	1.7
Mapping / Modelling / Photogrammetry / Pix4D / DroneDeploy / ContextCapture	26	43.3
ArcGIS/GIS	6	10.0
Building information modeling / BIM	1	1.7
Thermography / infrared / Thermal imagery	3	5.0
LiDAR	6	10.0
Multispectral / NDVI / Plant Health	2	3.3
Other common topics	22	36.7
UAS minor	1	1.7

It can be observed that many syllabi focus on essential topics such as mapping, photogrammetry, etc. On the other hand, considerably fewer universities included the part 107 exam.

Syllabi from FAA-CTI

Additional data on universities offering well-developed drone courses are collected from different sources. The drone simulator software Zephyr has few connections with the universities where it is being extensively used. They have provided information

related to one school offering a well-developed course. The syllabi from the school have been collected, as mentioned by the software firm. FAA has undertaken an initiative known as CTI (Collegiate Training Initiative) to recognize the institutes that offer UAS courses to create career opportunities in unmanned aircraft systems. Through FAA's contacts, syllabi from seven colleges of the CTI group have been collected. This data has been collected to understand how the CTI group offers the course in a career-oriented path. However, all the universities providing the syllabi were 2-year community colleges.

Triangulation of syllabi

The topics such as Part 107 preparation, data collection aided by drones, flight training, and photogrammetry are the topics that are being taught extensively in the CTI group. This data resonates with the popular topics taught at ASC Schools. Thus, it can be inferred that the curriculum taught by ASC schools follows a similar path as that of CTI in teaching career-making skills. The validity of the data collected from ASC institutes is supported by the syllabus shared by the CTI group. Table 3.4 shows a comparison of the similar topics taught at CTI group that strengthens the priority of syllabi taught by the ASC schools

Table 3.4. Comparison of Syllabi taught at the ASC & CTI Schools

	ASC Schools		CTI Group	
Topics included in the syllabus	No. of Schools (60 total)	Percentage (%)	No. of Schools (48 total)	Percentage (%)
Part 107 review	22	36.7	16	33.3
Part 107 Knowledge Test	3	5.0	13	27.1
Flight training	20	33.3	26	54.2
Collect drone data	20	33.3	19	39.6
Air Traffic Control (ATC) authorization / LAANC authorization	1	1.7	16	33.3
Mapping / Modelling / Photogrammetry / Pix4D / DroneDeploy / ContextCapture	26	43.3	14	29.2
ArcGIS/GIS	6	10.0	8	16.7
Building information modeling / BIM	1	1.7	0	0.0
Thermography / infrared / Thermal imagery	3	5.0	9	18.8
LiDAR	6	10.0	5	10.4
Multispectral / NDVI / Plant Health	2	3.3	4	8.3

Qualitative Analysis

Mixed Methodology

The information collected from the syllabi has been analyzed to filter the universities offering well-developed courses. Such faculty possess adequate knowledge in successfully implementing the course in their schools. Those universities are chosen as subjects for a further probe to learn how the course has been initiated in their school and how the topics in the syllabi are being taught. Thus, the syllabi collected in the quantitative data served as a foundation for the qualitative part in achieving the objectives of this research.

The quantitative data collected above addresses the first two research objectives of analyzing the frequency and topics of UAS courses taught at ASC schools. It did not shed light on the further probe of the learning objectives and practices adopted by the

universities offering Well developed courses. A clear understanding of the curriculum's learning objectives can be achieved only through back-and-forth conversations with the faculty which can be facilitated by conducting interviews. The research team has identified ten faculty members that would make suitable candidates to interview. The course's learning outcomes and other pertinent details, such as the teaching methodology, practical training process, significant barriers in introducing the course, etc., need thorough research. This part summarizes the information collected above and fulfills the information required for in-depth research analysis.

Subjects of the Interview

The schools with well-developed courses are chosen as subjects of the Interview. The sample selection is because they offer most topics, giving them ample experience addressing the questions.

Interview Questionnaire

The study utilizes a questionnaire developed by the champion of the UAS program at their University in addition to the expertise of other UAS champions, and the information found in the ASC syllabi was used to influence the questionnaire development. To validate the instrument, the questionnaire has been sent to the professors of other universities who are subject matter experts in the research on drone curriculum. The additional inputs from the pilot testing are being incorporated into the final questionnaire. The study's objectives are used to frame the themes and sub-themes, which aided in formulating the questionnaire for this research. The Copy of the questionnaire has been attached to this thesis at the end as Appendix-A.

Process of Interview

The course faculty were contacted via email explaining the study's details. They were requested to participate in the study by contributing their valuable time. The interviews were held using the Zoom app by the research team, with the former being the primary interviewer.

IRB Approval

To attain information for the objective through interviews, approval is requested from the Institute Review Board (IRB) for the intended methodology. The request has been approved recently with the reference numbers below.

IRB Number: IRB00000481

FWA Number: FWA00004497

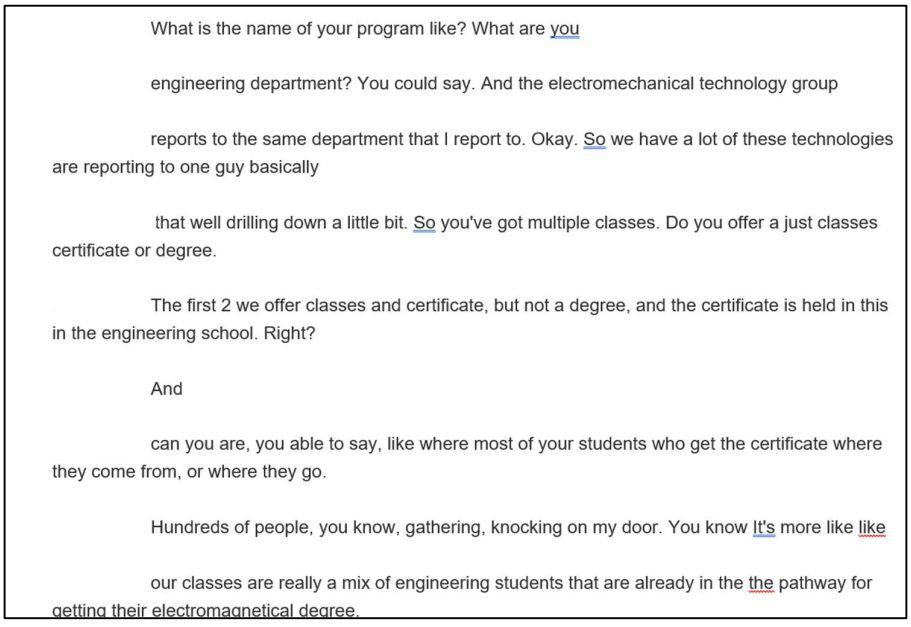
Interview Process

Only four faculty responded positively to the ASC Universities interview session. As the sample is inadequate, additional sources have been contacted to find the other universities, but those attempts were unsuccessful. Thus, the faculty from the CTI group were also contacted to collect more information for the research. Fortunately, seven instructors from the CTI group agreed to the Interview. Thus, eleven interviews were conducted where four faculty were from the 4-university college, and the remaining seven were teaching in 2-year community colleges. Each session lasted for around an hour, ensuring the responses to all the questions intended for the interviewee were collected. All the interviews have been recorded in Zoom to ensure they can be reviewed multiple times.

Post Interview clean up

The responses collected were not in order, and there were instances that they answered the other questions as part of the current one. After the interviews, the transcripts from the recording were converted to a Word format, as shown in Figure 3.2. Then, each interview was reviewed together with the transcripts. It is observed that the recording software couldn't catch all the speech in the recording. Thus, the missing sentences are transcribed accordingly for the whole interview. Figure 3.3 depicts this modification of transcripts. After this, all the documents were deidentified, and the text was formatted to remove bridging words interfering with the answers. The final format of questions and answers can be observed in Figure 3.4, where blue text belongs to the interviewer's speech, and the text in black indicates that of the interviewee.

Stage -1: Collecting the transcripts



What is the name of your program like? What are you

engineering department? You could say. And the electromechanical technology group

reports to the same department that I report to. Okay. So we have a lot of these technologies are reporting to one guy basically

that well drilling down a little bit. So you've got multiple classes. Do you offer a just classes certificate or degree.

The first 2 we offer classes and certificate, but not a degree, and the certificate is held in this in the engineering school. Right?

And

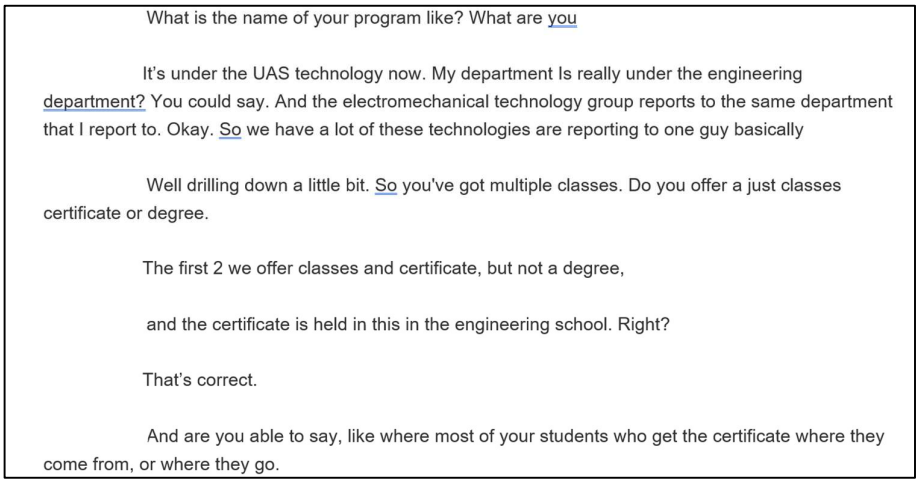
can you are, you able to say, like where most of your students who get the certificate where they come from, or where they go.

Hundreds of people, you know, gathering, knocking on my door. You know It's more like like

our classes are really a mix of engineering students that are already in the the pathway for getting their electromagnetical degree.

Fig 3.2: Image of uncleaned transcripts from the Interview

Stage -2: Cross verifying with the recording and cleaning up



What is the name of your program like? What are you

It's under the UAS technology now. My department Is really under the engineering department? You could say. And the electromechanical technology group reports to the same department that I report to. Okay. So we have a lot of these technologies are reporting to one guy basically

Well drilling down a little bit. So you've got multiple classes. Do you offer a just classes certificate or degree.

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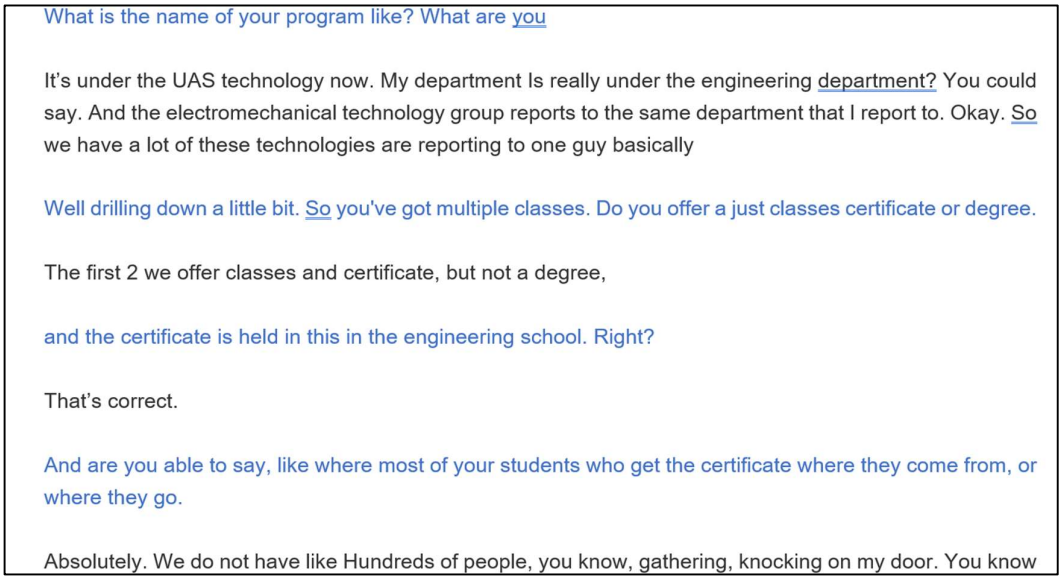
and the certificate is held in this in the engineering school. Right?

That's correct.

And are you able to say, like where most of your students who get the certificate where they come from, or where they go.

Fig 3.3: Image of cleaned transcripts after verifying with the recording

Stage -3: Deidentifying the data and formatting it to question and answers



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and the certificate is held in this in the engineering school. Right?

That's correct.

And are you able to say, like where most of your students who get the certificate where they come from, or where they go.

Absolutely. We do not have like Hundreds of people, you know, gathering, knocking on my door. You know

Fig 3.4: Image of deidentified and formatted transcripts

The information received has been analyzed separately for 4-year universities and 2-year community colleges. For reference, the university interviewees are called U1, U2,

U3 & U4. The faculty from the community college are termed C1, C2, C3, C4, C5, C6, C7. Among them, C1 is not the actual instructor but from the department that has attended the meeting on behalf of the faculty. Thus, C1 did not contribute all the relevant information. The data is uploaded to QDA Miner Lite software as individual files in each case. After that, the data from each document is reviewed, and codes are assigned for the relevant information. The codes are grouped under different subheadings when the data is observed to be spoken in terms of particular topics. This process has been repeated for each document, and codes have been assigned/created based on the content specified.

Figure 3.5 shows an image showing the interface of QDA software. The text has been assigned codes that can be observed to the right. On the left side, we have three palettes showing the list of cases, variables, and subthemes/codes. Figure 6 below displays an interface of QDA Miner lite software which involves the codes and themes at the left.

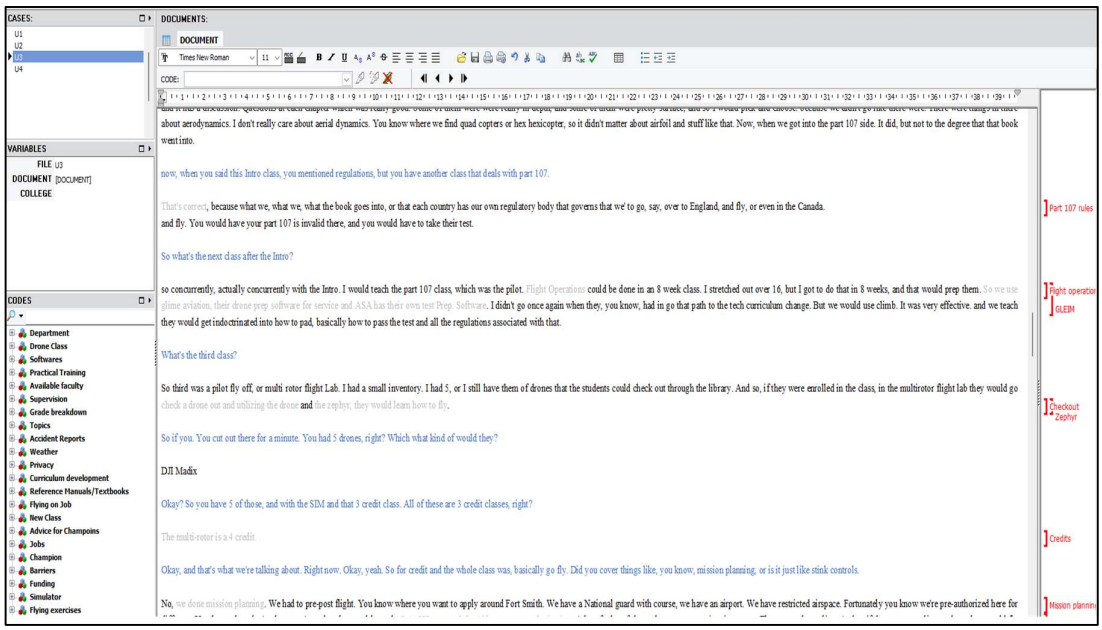

Fig 3.5: Image of the interface of QDA Miner Lite software used for analysis

Content analysis

A thorough review of the codes and their respective subheadings is performed to categorize the subheadings into a few sub-themes based on the focus of the response. Such sub-themes formed a foundation for a general theme that follows a pattern. This is the framework utilized for this analysis. A representation of the framework, from the objectives to the generation of themes, can be observed in Figure 3.6.

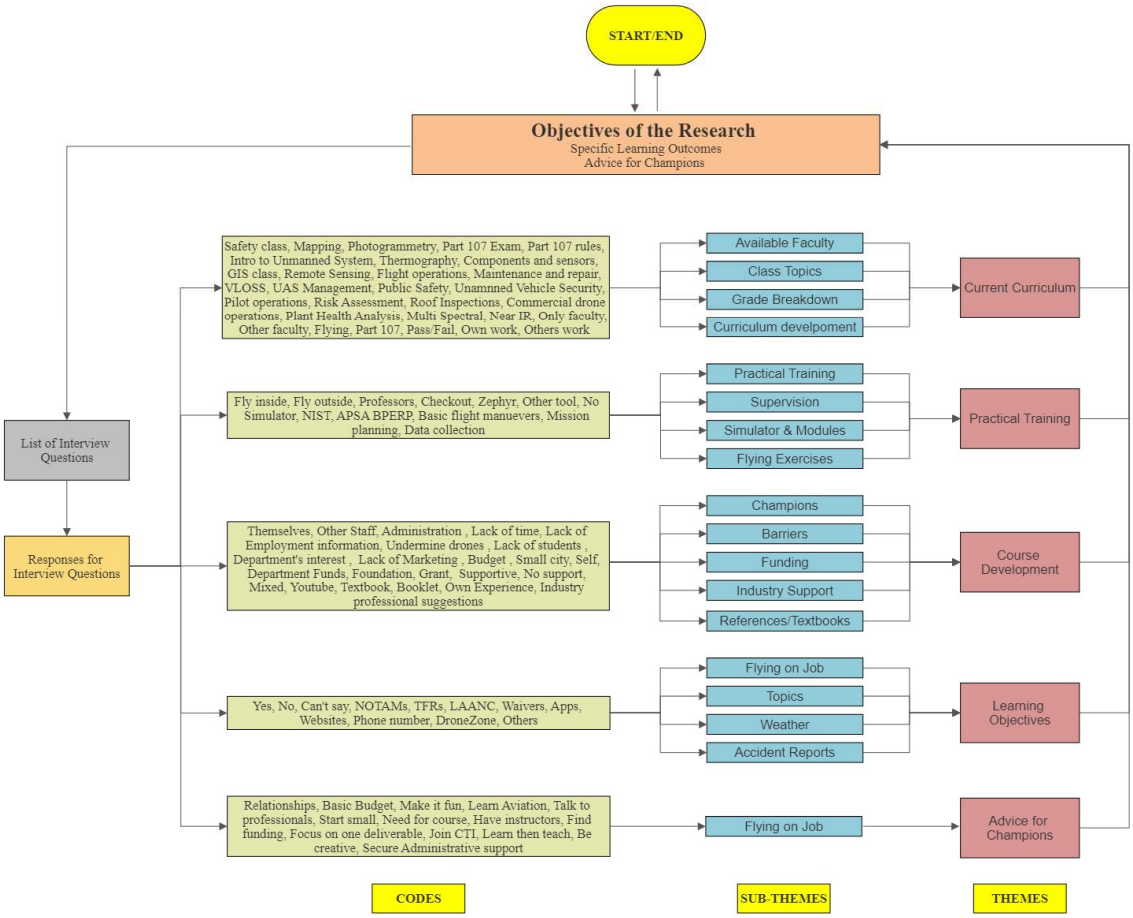

Fig 3.6: Content analysis for the research and its phase-wise procedure

CHAPTER FOUR

RESULTS

Classes & Credits

The interviewees of this research are a diverse sample in terms of the number of classes being taught. The 4-year colleges have several courses varying from one class to four UAS courses. Table 4.1 depicts the list of classes and credits offered for the course by the universities. As mentioned by the interviewees, Part 107, Introduction to unmanned systems, is the standard class taught by all the universities in the curriculum. Part 107 is being focused so the students can gain adequate knowledge to clear the FAA test and achieve a Part 107 license. However, none of them are making the test mandatory for students because they must pay for it out of their pocket. Instead, the faculty are conducting mock 107 tests at the university and are willing to replace their part 107 test grades with the actual test if they get a good score in the real exam. The Introduction to unmanned systems class is taught in terms of history, general usage, industry applications, etc. The other topics include surveying, GIS, and Geography. The 4-year colleges provide three credits for each of their class (theory and/or lab). U3 is the only university offering a 4-credit for a multi-rotor lab.

The 2-year community colleges are teaching the courses more department oriented. The departments include Agriculture, Aviation, Continued education, Public works, etc. The classes are framed to teach technical skills in a particular field. Multiple courses vary from one class to five classes. They all agreed to have been teaching Part 107 rules similar to 4-year colleges. The credits of the classes for the 2-year community vary from 1 credit to 4 credits depending on the content and focus related to drones.

Some universities teach a single class, including class and lab, and offer four credits for the course.

Table 4.1. List of classes taught at 4-year Universities

University	List of classes	Credits
U1	Surveying class (Partial)	3
	Intro 100 level class (Partial)	
	Safety class (Partial)	
U2	Introduction to unmanned system	3
U3	Intro to unmanned systems	3
	Part 107 and flight operations	3
	Multi-rotor Fly Lab	4
	Intro to GIS	3
U4	Advanced Drone Mapping & Model	3

Textbooks

The 4-year Universities use different sources for teaching the UAS curriculum. U1 mentioned using YouTube and other online resources to teach the class. The other textbooks mentioned by the interviewees are ASA study guides and Introduction to Unmanned Aircraft Systems by Barnhart. There are different reasons for the authors not recommending a textbook to the students.

In community colleges, not all universities teach drones out of textbooks, and there are instances of professors leading them out of their own experience for various reasons. C7 said, "I don't require the students to buy it. So every couple of years, I'll buy a new one, and you know, it's easier to have a class copy that I can pay for through NSF funds than to require students to buy books that you know. Right. I went through a lot of my education, not buying any books because I'd buy a book and use it for two

things, and then I'd be pissed out because I spent $400 on a book that I read two chapters of".

Current Curriculum

All the professors from 4-year colleges agreed that they developed a curriculum independently for the UAS classes. In contrast, the 2-year has a couple of colleges where other faculty from the same department contributed towards developing the curriculum.

Regarding teaching the drone course, U3 & U4 mentioned that they are the only faculty in the university to teach it, whereas U1 & U2 said their colleges have additional faculty available. The topics taught by the faculty in the drone class are safety class, mapping, photogrammetry, part 107 rules, intro to Unmanned Systems, thermography, GIS class, remote sensing, and flight operations. The responses specified some software tools used to teach a few classes. Photogrammetry is prepared using Dronedeploy and Agisoft, whereas DJI Thermal Analysis Tool is used in thermography. Based on the intensity of the topics taught at the universities, Table 4.2 represents the generalized level of learning in terms of the levels specified in Bloom's Taxonomy.

The 2-year colleges have a similar mix of opinions on faculty available for teaching the course, with two colleges having themselves and five possessing other instructors. The topics taught by the faculty in the drone class are Safety class, Mapping, Photogrammetry, Part 107 rules, Intro to Unmanned Systems, Thermography, Components and sensors, GIS class, Remote Sensing, Flight Operations, Maintenance and repair, VLOSS, UAS Management, Public Safety, Unmanned Vehicle Security, Pilot operations, Risk Assessment, Roof Inspections, Commercial drone operations,

Plant Health Analysis, Multi Spectral, Near I.R. The responses included some software tools used to teach a few classes. Photogrammetry is prepared using Dronedeploy, Pix4D, and Agisoft. Thermography is introduced using DJI and EDSB. Similarly, for the GIS class, ArcGIS is used. Dronesense is used in Flight risk assessment. GLIEM software is utilized to teach Part 107 regulations.

Table 4.2. Level of learning concerning Bloom's Taxonomy

Topic	Level of learning - Blooms Taxonomy			
	U1	U2	U3	U4
Part 107 Regulations	Un/Re	Ap/Un/Re	Ap/Un/Re	Ap/Un/Re
Flight training	Understand	Apply	Apply	Apply
ATC/LAANC authorization	-	Apply	Apply	Apply
NOTAM/TFR	Understand	Understand	Apply	Apply
Waivers	Remember	Remember	Remember	Understand
Accident Reports	-	Remember	Remember	Understand
Photogrammetry	Create	Understand	Create	Create
Thermography	Remember	Remember	-	Analyze

Un-Understand; Re-Remember; Ap-Apply

In 4-year schools, the grades are distributed among Part 107 & flying missions as stated by all the faculty, with a pass/fail on a few specific modules of practical missions. Similarly, in 2-year colleges, the grades are observed to pass/fail in five universities, and the percentage of grading for Part 107 & flying activities.

Practical Training

All the professors said they made the students fly the drones in the field. The locations they have chosen for the same are private properties, agricultural lands, open areas, and university grounds. In addition, U1 mentioned they have long halls inside the college to fly drones. While the students operate drones, all the instructors stated that they

supervise the operation of drones the students after handing them over. Only U3 mentioned drones could be checked out by the students after a specific trust level, and do not supervise them. U4 stated they make Part 107 licenses mandatory for all the students using real-time drones. The common activities taught using real-time flying of drones are basic flight maneuvers, mission planning, and data collection.

Similarly, in the 2-year colleges, all the colleges offer the students to fly the drones outside. A mix of five colleges has confined places inside the college to facilitate basic training. Except for C4, all other instructors supervise the operation of drones by their students. They are carrying out the same activities as 4-year schools with real-time drones.

It was learned that the universities use simulators to teach different practical training tasks for the course. The modules included in the simulator are the basic flight maneuvers, NIST and APSA BPERP. Three instructors mentioned using Zephyr, whereas one mentioned not using a simulator. Among them, NIST is being taught by all the schools, whereas U4 teaches APSA BPERP, and the professor is a certified proctor for the test.

Along the same line, two-year colleges are using Zephyr and similar tools to simulate real-time drones, and NIST/APSA BPERP are the common tests conducted with the help of a simulator.

Course Development

Three university professors mentioned they are the champions of bringing drone courses into the department/university, whereas one said that the other faculty are the course champions. The professors stated different ways of funding the course, such as

utilizing department funds or securing the budget from a foundation or a grant. There are varying opinions on the industry support received by the universities for the drone course. A couple of them mentioned that the industry is supportive, whereas others had mixed views on this aspect, meaning the industry is not always supportive. Similarly, as learned from interacting with the faculty, the barriers the champions face are widespread, as listed in Table 4.3. The instructors mentioned various reasons, such as lack of support from the Administration, access to funds, not realizing the capability of drones, and lack of interest among students.

Table 4.3. List of barriers faced by 4-year Universities

Barriers Faced	U1	U2	U3	U4
Administration		✓		
Undermine Drones		✓	✓	
Lack of Students			✓	
Budget				✓

2-year colleges follow the same pattern regarding being champions of the course. Five of them are champions, and two colleges have others contributing as champions. Grants are the significant funding source for most 2-year schools, with other funding methods such as department funds or foundations. Five faculty mentioned they got good industry support, while others had mixed views. The barriers faced by the champions are similar to 4-year Universities with additional reasons such as inadequate time for the faculty, lack of marketing, and remote location of universities where there are no technical drone jobs available for the students to take the course readily.

Learning Objectives

Apart from one faculty, all other 4-year universities are confident that the students can use their drones on the first day of their job. The faculty who is not confident mentioned that the student may not have skills as he doesn't have an entire class, instead three partial classes. The opinions from 2-year community colleges resonate with the information, with only one professor stating that the student will confidently fly the drone if he has completed all the exercises in the class satisfactorily.

The 4-year colleges teach NOTAMs, Temporary Flight restrictions, LAANC, and Waivers as part of their curriculum, except for U1. Table 4.4 mentions The tools specified are Horizonsky, LAANC app, Aloft, and Dronezone. The universities briefly discuss them in class, but not everyone ensures the students can learn and apply them practically. The reason for this is that the universities are focusing on their locality, where they may not be any regulations in the airspace. This can be seen as a setback as it would be a primary concern when the students get jobs near military space or major airport classes. Weather is one of the primary aspects discussed by the faculty. Apps/websites like Aloft and UAS Forecast are tools for assessing current weather conditions. There is also a mobile option where the weather is learned through METAR or TAFT format by sending a text message. Regarding Privacy, three faculty specified that they just briefly discuss it in class and clarify students' questions. In contrast, one faculty has a specific lecture dedicated to Privacy which discusses the legal aspects of it too.

Table 4.4. Software used by ASC Schools to teach different topics

Topic	Software Used			
	U1	U2	U3	U4
LAANC	-	Horizon sky	LAANC App	Aloft
NOTAM/TFR	-	-	LAANC App	Aloft
Waiver	-	-	-	DroneZone
Accident Reports	-	-	-	DroneZone
Photogrammetry	Dronedeploy	Agisoft	ArcGIS	Dronedeploy
Thermography	-	-	-	DJI Thermal
Part 107	-	GLEIM	-	-
Weather	Regular app	NWA	NOAA	UAV Forecast
Flight Training	-	Zephyr	Zephyr	Zephyr

NWA-National Weather Association; NOAA-National Oceanic and Atmospheric Administration

The case is the same with 2-year colleges where all the interviewees acknowledged teaching NOTAMs, Temporary Flight restrictions, and Waivers except for C1, who is unsure. They use the software B4Ufly, Dronesup, and Airmap in addition to the software mentioned for 4-year colleges. Similarly, they use Spacelink for LAANC authorization for the intended task. For learning the current weather, they use Aircontrol NOA and 1800webex apart from the existing options. The same is valid with Privacy, where everyone just briefly discusses it.

Regarding filing accident reports on the DroneZone website, the Universities follow two protocols. Three of them discuss this in class and tell students they should file any accidents while flying drones. One instructor is making the students go through the website and get through all the information that needs to be filled in except for submitting the information. 2-year community colleges follow a similar trend where the instructors teach them where and how to file the reports if needed.

New Class

The faculty hold different opinions on the new classes they intend to introduce when given the opportunity. 4-year professors mentioned they want to include History, Privacy lecture, License, Safety, APSA, Data management, thermography, and Industry specifics. It is observed that the thoughts on new classes depend on various university-specific factors such as existing classes, the job market, the department where the new class is proposed to be introduced, etc.

2-Year faculty would want to introduce GIS, Dronedeploy, Maintenance, GVLoss, Electrical and Mechanical Aspects, and Photogrammetry/Mapping in addition to some of the 4-year topics mentioned.

Advice for Champions

There is a lot of advice for the new champions gathered from the interviews. Securing a basic and decent budget required for the course, understanding the need for the course, and talking to professionals in the field are the resonating thoughts of the faculty. The other advice includes the following.

- Start the program small.
- Make the course fun and exciting for the students
- Maintain good relationships with the college administration
- Learn the basics of Aviation
- Teach how to pass the FAA exam and basic flying skills
- Have a champion

CHAPTER FIVE

CONCLUSIONS

The knowledge of Drone technology has the potential to serve different tasks in the industry, as discussed in this research. However, the statistics from Table 3.1 mention that the frequency of UAS taught at the ASC schools is only about 50% of ASC per the data from the university course catalog. This study found that only 6% of the ASC schools had a construction-focused UAS course which does not appear to meet industry demand. After the review of syllabi collected from the faculty, as listed in Table 3.3, the common topics taught are mapping/photogrammetry, Part 107 review, flight training, and data collection strategies. Photogrammetry was the most common data collection/processing activity in the four-year universities and FAA-CTI schools. During the interviews with faculty teaching well-developed courses, it was learned that drone classes are offered in different departments at each university. Almost all the programs are observed to teach the Part 107 component in their classes. They acknowledged the value of it to the student's future professional. The only reason they didn't make the Part 107 exam required were external barriers such as department funding to pay for it, the burden on students to pay for it, and administrative restrictions on requiring an external exam to be included in a course grade. From the classes in Table 4.1, the minimum number of credits needed for a UAS course was observed to be 3 or 4, depending on whether a one-credit lab was necessary for flight training.

Most drone programs observed were developed by a single "Champion." This person is passionate about UAS and knows to create the course. In some four-year universities, the champion was not the only person qualified to teach the course, similar to the FAA-

CTI schools. This has the advantage of not shelving the course if the champion is unable to teach the course. A key takeaway is that if a university wants to develop a drone course or program, it only takes one faculty member with the support of their administration to create it. Faculty trying to establish a drone course should have access to some open space for flight training. This can be a park or green space on or off campus. If they are on campus, they need authorization from their university administration.

The area to fly was not shown to be a significant barrier to starting a drone program/class. However, a simulator was an option if schools wanted to supplement their in-person flight instruction or have a more robust online UAS program. A simulator gave faculty an easy way for students to learn basic flight skills and allowed instructors to assess flight skills using quantifiable grading metrics. Simulators are cost-effective compared to actual drones. However, the simulator software and controller cost can be a barrier. Among the tools utilized by ASC schools in Table 4.4, Zephyr was the most common software mentioned. The Zephyr software is approximately $75 per license. The controller (which can be reused) is roughly $70.

The importance of grant funding was mentioned in most of the interviews. Several interviewees indicated that a grant was initially used to purchase equipment and start their UAS program. Table 4.3 reflects the barriers faced by the 4-year faculty, such as administrative barriers and people not realizing the capabilities of drones. Having a sustainable UAS budget was another barrier that directly and indirectly affected the instructors in gaining support for the program implementation. In addition, the lack of marketing in the UAS program to students and employment was a predominant barrier

mentioned by several interviews in the CTI. The industry may not know the significance of the course and the number of students acquiring drone skills. The interviewees were asked what basic-level advice they would give to faculty willing to start a drone course. Administration support and funding were found to be the primary barriers to creating a UAS course. They also advised keeping the first course straightforward with the curriculum of Part 107 and at least one UAS-based deliverable.

The 2-year college has similar suggestions with the additional advice below.

- Understand the need for the course
- Try to find different sources of funding
- Learn the subject thoroughly before the course starts in the college
- Find the instructors capable of teaching the course
- Focus on one deliverable
- Join CTI
- Teach at least license-acquiring skills and flying skills

The 2-year colleges opined that the need for the course and finding instructors are the additional aspects for the faculty to focus on in addition to the suggestions from 4-year Universities. With all the information presented, the universities looking forward to starting a drone course gain insights into the learning objectives and relate to the advice from the faculty already implementing the course.

Recommendations

There are different approaches that a professor can utilize when seeking to develop a drone course(s). Creating an entire drone course in their department may not always be necessary. As adopted by one interviewee, the professors can start offering a specific

part of UAS in an existing course as an experiment to understand the student's interests and learning capabilities. Thus, the new faculty can feel flexible in offering the course as one credit or 3-4 credits depending on their choice. In addition, such courses can be made available to students across different departments, which aids in gathering an adequate head count for the course. Teaching Part 107 should be the first topic for any drone course as it provides the basic overview of drone usage, atmospheric factors to be considered, and the associated regulations. Part 107 should account for at least 25% of the grade to motivate students to study hard and make them confident enough to clear the real Part 107 exam. The advantages of such implementation are that the students learn the industrial applications of drones in the particular course and the theory. The disadvantages are that the students not interested in learning UAS will not consider registering for the courses. The faculty has various options for developing the classes depending on the budget. They can either buy a textbook or look for free online resources. This study found that most programs did not use formal books often. This has the advantage of removing the cost of the textbook as a barrier to student enrollment. However, if necessary, the suggested ones include the following:

- Introduction to Unmanned Systems by R. Kurt Barnhart
- ASA books for 107 Prep and Introduction to Unmanned Systems
- Fundamentals of Capturing and Processing Drone Imagery and Data by Amy Frazier and Kunwar Singh
- UAS Management: Fundamentals of sUAS management by Mike Davis
- GLEIM Aviation pack

The GLIEM aviation pack is a Part 107 study guide package that professors can use to develop an exam preparation curriculum. It comes with a tool that conducts a mock part

107 test for the students, which helps them assess their performance in the simulated test. It isn't available for free but has the advantage of having an "out of the box" curriculum that can be easily incorporated into a university's learning management system.

All interviewees expressed the importance of students earning their Part 107 license before using drones commercially. The universities should look into opportunities to collect funding for the Part 107 exam, encouraging the students to take it and attain their licenses. Some of the recommendations to achieve support include:

- Collaborating with FAA and utilizing their industry contacts to receive financial support
- Look into grants or foundations that sponsor the drone courses
- Pursuing drone projects for a fee for local industry helps financially and promotes the skill taught at the university.

The interviewees consistently said that teaching flight skills is essential for a comprehensive UAS course. The school should arrange an open space, a park, or a green space on or off campus. At least 30-40% of the grades should be allotted to the flying exercises, which are considered fun among the students. NIST or BPERP are the primary tests that can be conducted utilizing a simulator or real-time, which fetches a certification for the students. These tests can be promoted as a fascination among the students to feel encouraged to register for the course. Using a simulator to gain essential trust and handing over the real-time drones for further missions was helpful for the faculty interviewed.

The importance of grant funding was mentioned in most of the interviews. The faculty should seek financial assistance and have good grant-writing capabilities that increase the probability of fetching the grants. Teach the course so the student attains a specific skill, adding it to his existing capabilities. The topics such as NOTAM/TFR/Waiver/Accident Report/Privacy should be taught to enhance students' ability to attain the permits and know the conditions independently. In addition to the topics above, photogrammetry is one of the key skills that can be offered to students as it is used in various industrial applications. Software such as DroneDeploy, Pix4D, and Agisoft are common ones universities mention to teach photogrammetry skills.

By considering the common level of learning intended at the ASC schools, the recommendations on the level of teaching of the topics are discussed as follows. By the end of the course the student should display the following levels of confidence.

- Part 107: Obtain sufficient knowledge to pass the FAA Part 107 exam.
- Flight training: Demonstrate ability to safely pilot a UAS in the national airspace
- ATC/LAANC: Use any authorized tool to obtain air traffic control authorization for UAS operations in controlled airspace using the FAA's LAANC network.
- NOTAM/TFR: Use any authorized tool to identify the presence of NOTAMs and TFRs in a mission area
- Waivers: Define what a Part 107 wavier is and know the process for submitting them
- Accident Reports: Define what UAS accidents require reporting to the FAA and know the process for submitting an accident report.
- Photogrammetry: Develop a 3D photogrammetry model using UAS data and extract meaningful data from it
- Thermography: Examine thermograms and be able to identify legitimate

thermal anomalies worthy of additional investigation.

Shortcomings of the Research

The study hypothesizes that drone course exists in the curriculum once we find one in the catalog or college website. There is a possibility of missing out on the universities offering drone curricula. There could be many confounding factors, such as inadequate information on the college website and the course shown as an independent study. For the qualitative part, the research did not succeed in attaining consent from the majority of 4-year faculty. Thus, seven of the interviews were from 2-year community colleges and four from 4-year Universities. The faculty contacted regarding the syllabi have yet to respond to the interview request.

APPENDICES

Appendix-A

List of ASC schools

Sl.No.	School Name	Have a Drone Course?	Drone Courses in catalog	Drone Course in CM Program
1	Central Connecticut State University	Yes	TM 576 Autonomous Logistics	-
2	Community College of Beaver County	Yes	AVIP101 History of Aviation AVIP102 Introduction to Aviation Pathway	-
3	Drexel University	Yes	Robotics and Automation Technology Concentration	-
4	Farmingdale State College	Yes	AVN 128 Unmanned Aerial Systems (AVIATION)	-
5	Farmingdale State College	Yes	GIS 433 Mapping Applications of Drones (GEOGRAPHIC INFORMATION SYSTEMS)	-
6	Norwich University	Yes	GJ522 Contemporary Issues in CJ	-
7	Rochester Institute of Technology	Yes	POLS-370 Cyberwar, Robots, and the Future of Conflict POLS-215 Tech, Ethics and Global Politics	-
8	Roger Williams University	Yes	PPSS 200 - Introduction to Public Safety Technology	-
9	State University of New York/ESF	Yes	ERE 556 Unmanned Aerial Vehicle Photogrammetry and Remote Sensing	-
10	Stevens Institute of Technology	Yes		CM 532 Unmanned Aerial Systems-Technology and Applications CM 535 Cyber-Physical Security in Critical Infrastructure and the Built Environment CM 516 Automation in Construction OE 536 Cyber-Physical Security in Critical Infrastructure and the Built Environment CE 536 Cyber-Physical Security in Critical Infrastructure and the Built Environment
11	Stevens Institute of Technology	Yes	SYS 636 Space Launch and Transportation Systems	
12	University of Massachusetts Amherst	Yes	SPP 597B Unmanned Aerial Systems	-
13	University of Massachusetts Amherst	Yes	ECO 652 Safety Management for Unoccupied Aerial Systems	-
14	Utica College	Yes	CYB 670 - Cyber Ethics and Professional Responsibility CYB 671 - Open Source Cyber Surveillance	-
15	Vermont Technical College	Yes	AER 4060 Introduction to Unmanned Aerial Systems	-
16	Auburn University	Yes	AVMG 2050 Introduction to Unmanned Aircraft Systems	-
17	Auburn University	Yes	UAS (Drone) Remote Pilot Part 107 Workshop	-
18	Clemson University	Yes		CSM 4210 - Applied Drone Use in the Built Environment CSM 4211 - Applied Drone Use in the Built Environment Laboratory
19	Clemson University	Yes	Section 004: AI Unmanned Vehicles STS 1020 - Science and Technology in Society: The Ethics of Progress	
20	Georgia Institute of Technology	Yes	DEF 6007P. Introduction To Autonomous Unmanned Systems	-
21	Georgia Southern University	Yes		CENG 5436 - Introduction to Close-Range Photogrammetry CENG 5436G - Introduction to Close-Range Photogrammetry
22	Georgia Southern University	Yes	MENG 5333 - Robot Dynamics, Design and Analysis MENG 5333G - Robot Dynamics, Design and Analysis	
23	Kennesaw State University	Yes	SURV 3320:Photogrammetry and Drone Analysis	-
24	Middle Tennessee State University	Yes	AERO 3745 - Aerial Cinematography I VFP 3745 - Aerial Cinematography I	
25	Middle Tennessee State University	Yes		CCM 3500 - Land Surveying (CM)
26	Mississippi State University	Yes	ASE 4713 Introduction to Unmanned Aircraft Systems ASE 6713 Introduction to Unmanned Aircraft Systems	-
27	North Carolina State University	Yes	GIS 584 Mapping and Analysis Using UAS	-
28	North Carolina State University	Yes	MEA 584 Mapping and Analysis Using UAS	-
29	The University of Tennessee-Knoxville	Yes	GEOG 313 - Geospatial Field Methods of UAVs, LiDAR, and GPS	-
30	University of Florida	Yes	SUR 4501C Foundations of UAS Mapping 3 Credits SUR 4940C Practicum in UAS Mapping 3 Credits	-
31	University of Florida	Yes	MAPPING WITH SMALL UNMANNED AERIAL SYSTEMS	-
32	University of North Carolina at Charlotte	Yes	EMGT 6116 - System Identification and Reinforcement Learning	-
33	University of Puerto Rico	Yes	Center for Aerospace and Unmanned Systems Engineering (CAUSE)	-
34	University of North Florida	Yes		BCN6315: Advanced Construction Technology
35	University of North Florida	Yes	MAR3702: Principles of Digital Transformation in Business	
36	Western Carolina University	Yes	EDM 410 - Unmanned Aircraft Systems and Emergency and Disaster Management	-
37	Bowling Green State University	Yes	SEES 4500 Remote Sensing	-
38	Eastern Kentucky University	Yes	AGR 170 Application of Unmanned Aerial Systems (UASs) in Agriculture	-
39	Eastern Kentucky University	Yes	AVN 170 Introduction to Unmanned Aircraft Systems Airport Management I: Operations and Security	-
40	Fox Valley Technical College	Yes	10-006-159 Precision Agriculture Advanced	-
41	Indiana State University	Yes	UMS 491 - Advanced Unmanned Aerial Systems Operations	-
42	Indiana State University	Yes	AVT 335 - Airborne Law Enforcement Operations	-
43	Kent State University	Yes	AERN 25800 INTRODUCTION TO UNMANNED AIRCRAFT SYSTEMS	-
44	Michigan State University	Yes	GEO 829 Collection and Analysis of Drone Imagery	-
45	Michigan State University	Yes	FOR 260 Applied Forest Management	-
46	Michigan Technological University- Tech.	Yes	SU 4140 - Photogrammetry & UAV Mapping	-
47	Michigan Technological University- Tech.	Yes	SU 4140 - Photogrammetry & UAV Mapping	-
48	Michigan Technological University- Tech.	Yes	FW 5580 - UAS(Drone)Remote Sensing and Photogrammetry	-
49	Purdue University - CM	Yes	AT 10901 - Introduction To Unmanned Aerial System Operations	-
50	The Ohio State University	Yes	3580 UAS and Remote Sensing in Agriculture	-
51	University of Cincinnati	Yes	FST 3021 - Terrorism For Emergency Responders FST 3055 - Unmanned Aircraft & High Technologies For Emergency Responders	-
52	University of Wisconsin - Stout	Yes	GEOG-251 Introduction to Geospatial Technologies	-
53	University of Wisconsin - Stout	Yes	ETECH-333 Introduction to Unmanned Aerial Vehicles	-
54	Kansas State University	Yes	MC 469 - Drone Photography and Video UAS 270 - Introduction to Unmanned Aircraft Systems	-
55	Kansas State University	Yes	COT 680 - Unmanned Aircraft Systems and Risk Analysis	-
56	South Dakota State University	Yes	GEOG 387 - UAS Photography and Videography GEOG 583 - UAS Remote Sensing	-
57	Southeast Missouri State University	Yes	ET 381 Fundamentals of Aviation in Unmanned Aircraft Systems	-
58	University of Central Missouri	Yes	AVIA 1211 - UAS Regulations and Applications AVIA 5700 - Introduction to Unmanned Aircraft Systems	-
59	Collin College	Yes	SUAS 1371 Small Unmanned Aerial Systems (Drones)	-
60	Lamar University	Yes	GEOL 5301 - Drone Photogrammetry and Applications	-
61	Louisiana Tech University	Yes	ELEN 474: UAV Control ELEN 574: UAV Control	-
62	Oklahoma State University	Yes	MAE 5963 Unmanned Aerial Systems Design and Analysis MAE 5973 Unmanned Aerial Systems Propulsion	-
63	Oklahoma State University	Yes	GEOG 4333 Remote Sensing GEOG 5333 Remote Sensing	-
64	Texas A&M University	Yes	ESSM 446 DRONES FOR ENVIRONMENTAL REMOTE SENSING	[redacted]
65	Texas State University	Yes	MC 3113. 3D Drone Modeling	
66	Texas Tech University	Yes	ECE 4379 - Unmanned Aircraft Systems ECE 5379 - Unmanned Aircraft Systems	-
67	Texas Tech University	Yes	GIST 2300 - Digital Earth	-
68	University of Oklahoma	Yes	AVIA 1313 Introduction to Unmanned Aerial Systems LSTD 1603 Operation and Application of Small Unmanned Aerial Systems	-
69	Arizona State University	Yes	AMT 170 Introduction to Unmanned Aircraft Systems	-
70	Arizona State University	Yes	GIS 202 Drones to Satellites: Observing Earth from Above	-
71	Boise State University	Yes	COID483 - Federal Aviation Administration (FAA) Unoccupied Aerial Systems (UAS) Pilot Licensing Material	-
72	Brigham Young University	Yes	GEOG 414 - Low Altitude, Large-Scale Image Acquisition and Processing	-
73	Brigham Young University	Yes	ANTHR 406 - Archaeoinformatics	-

74	Colorado Mesa University	Yes	Pilot Small UAS, Unmanned Aircraft Systems	
75	Colorado State University	Yes	Drone Training Program	-
76	MontanaTech of the University of Montana	Yes	UAS Applications & Design, Certificate, UAS Development & Analytics, Graduate Certificate	-
77	Southern Utah University	Yes	AVTN 1130 - Unmanned Aerial Systems Basics Aviation - Unmanned Aircraft Operator Emphasis	-
78	University of Colorado Denver	Yes		CVEN 5392 Unmanned Aerial Systems CVEN 5397 Unmanned Aerial Systems Data processing (Civil Engineering)
79	University of Denver	Yes	GIS 4750 UAS for GIS GIS 4760 UAS PHOTOGRAMMETRY GIS 4770 UAS GROUND SCHOOL PRACTICAL	-
80	University of Denver	Yes	GIS 4750 UAS for GIS GIS 4760 UAS PHOTOGRAMMETRY GIS 4770 UAS GROUND SCHOOL PRACTICAL	-
81	University of Nevada, LasVegas	Yes	EGG 270 - Introduction to Unmanned Aircraft Systems EGG 370 - Unmanned Aircraft Systems Testing EGG 470 - Unmanned Aircraft Systems Applications	-
82	University of Nevada, Reno	Yes	AGSC 440 - Applied Remote Sensing of Dryland & Agricultural Resources REM 440 - Applied Remote Sensing of Dryland & Agricultural Resources	-
83	University of Nevada, Reno	Yes	GEOG 413 - Application of UAS technologies in Geography	-
84	University of Nevada, Reno	Yes	ENGR 471 - UAS FLIGHT COORDINATOR COURSE	-
85	University of Utah	Yes	GEOG3170 Geospatial Field Methods: GPS and Drones GEOGS170 Geospatial Field Methods: GPS and Drones MG EN5510 - Unmanned Aerial Vehicle Applications	-
86	University of Wyoming	Yes	GIST4450 - UAS Photogrammetry and Image Process GIST5450 - UAS Photogrammetry and Imagery Process REWM4600 - Drone-Based Remote Sensing	-
87	Utah Valley University	Yes	AVSC 1120 Introduction to Aircraft and Spacecraft Systems	-
88	Utah Valley University	Yes	SURV 3400 Surveying Applications and Field Techniques III SURV 2100 Mapping From Field to Finish	-
89	Weber State University	Yes	GEO 4200 - Geospatial Data Acquisition GEO 2200 - Geospatial Data Acquisition GEOG 1790 - Exploring Our World Through Geospatial Technology	-
90	California Baptist University	Yes	UAS 415 - Unmanned Aerial Systems Mission Planning	-
91	California Polytechnic State University-San Luis Obispo	Yes	BRAE 355. Drone Assisted Surveying	-
92	California Polytechnic State University-San Luis Obispo	Yes	NR 355. Drone Assisted Surveying	-
93	Oregon State University	Yes	AAE 415, UAV ENGINEERING HEST 415, UAV ENGINEERING	-
94	Oregon State University	Yes	FE 423, UNMANNED AIRCRAFT SYSTEM REMOTE SENSING FE 523, UNMANNED AIRCRAFT SYSTEM REMOTE SENSING	-
95	San Jose State University	Yes	AVIA 150 - Unmanned Aerial Systems	-
96	San Jose State University	Yes	AE 173 - Uncrewed Air Vehicle Design	-
97	Stanford University	Yes	AA122N - Dawn of the Drones: How Will Unmanned Aerial Systems Change Our World?	-
98	University of California Berkeley	Yes	ENGIN 253 Flying Robots: From Small Drones to Aerial Taxis ME 136 Introduction to Control of Unmanned Aerial Vehicles	
99	University of California, Davis	Yes	MAE 275 — Guidance & Control of Unmanned Aerial Systems	-
100	University of California, Davis	Yes	ABT 060 — Introduction to Unmanned Aerial Systems for Agriculture & Environmental Science	-
101	University of Southern California	Yes	SSCI 220L Spatial Data Collection Using Drones	-
102	Washington State University	Yes	Applied Remote Sensing: From Drones to Satellites	-
103	Liverpool John Moores University	Yes	MSc Wildlife Conservation Technology	-
104	Technological University Dublin	Yes	Geospatial Surveying	-

Appendix-B

ASC syllabi

S.No.	University name	Course Name	Course Number (hyperlink to the syllabi)	Discipline	Number of credits	Part 107 review	Part 107 exam	Flight training	Collect drone data	Air Traffic Control (ATC) authorization / LAANC authorization	Mapping / Modeling / Photogrammetry / Pix4D / DroneDeploy / ContextCapture	ArcGIS/GIS	Building information modeling / BIM	Thermography / infrared / Thermal imagery	LiDAR	Multispectral / NDVI / Plant Health	Other common topics
1	S1	Construction Surveying	COSC 301	Construction	3	Yes		Yes	Yes		Pix4D						
2	S2	Virtual Design & Construction	BCTM 217	Construction	3	Yes		Yes									
3	S3	Computer applications in Construction	CMGT201	Construction	3								Yes				Procore, HCSS, CMiC, SAGE
4	S4	Construction Surveying	CSTM 236	Construction	3	Yes	Yes	Yes									Autocad, Leveling, Surveying, EDM
5	S5	Intro to Close-Range Photogrammetry	CENG 5436	Construction	3				Yes		Modeling						
6	S6	Intro to Terrestrial LiDAR	CENG 5435	Construction	3				Yes		Modeling						
7	S7	Use and application of UAS (Drone) technologies in GIS	GEOG 413/613	GIS	4	Yes		Yes	Yes		Pix4D Desktop, Pix4D capture, Drone Deploy and Map Pilot	ArcGIS, QGIS (open source) and/or GRASS GIS software					
8	S8	Introduction to Autonomous Unmanned Systems	DEF 6007P	Defense Department	1.4												
9	S9	Introduction to Unmanned Aircraft Systems	AERN25800	Aeronautics	3	Yes		Yes									
10	S10	Unmanned Aerial Vehicles	ETECH-333	Engineering	3	Yes		Yes			Mapping						
11	S11	Anthropology	ANTHR 406	Archaeoinformatics	3				Yes		Mapping, Photogrammetry						
12	S12	Drone Storytelling	MC4345	MASS COMMUNICATION	3	Yes		Yes			Modeling, Photogrammetry						
13	S13	3D Drone Modeling	MC1100E	MASS COMMUNICATION	1			Yes			Modeling, Photogrammetry						
14	S14	Applied Drone Use in the Built EnvironmentCourse Outline & Requirements	CSM 4210	Construction	3	Yes	Yes	Yes	Yes	Yes	Mapping, Modeling, Photogrammetry			Thermography			
15	S15	Aerial Cinematography I (EXL)	AERO/VFP 3745	AeroSpace	3			Yes									3D Printed UAS fly
16	S16	Introduction to Public Safety Technology	PPSS200 91C	Law Enforcement Training	3												
17	S17	Surveying Applications and Field Techniques III	SURV3400	Land Surveying	3	Yes		Yes	Yes		Pix4D, Photogrammtery						
18	S18	Geospatial Field Methods	GEOG 3170/5170	Geography	3				Yes		Mapping, Photogrammetry						Analyzing Digital Surface Models
19	S19	The Ethics of Progress	STS 1020	Science and Technology	3												
20	S20	Remote Sensing	SEES 4500	Geography	3												
21	S21	Low-Altitude Image Acquisition & Processing	Geog 414	Geography	3	Yes	Yes	Yes	Yes		Pix4D, DroneDeploy					NDVI	Aeronautical Decision Making
22	S22	DRONE ASSISTED SURVEYING	BRAE 355	BioResource and Agricultural Engineering	3	Yes		Yes				GIS					Surveying, Precision Agriculture, and Inspection
23	S23	Introduction to Unmanned Aircraft Systems (UAS)	EGG 270	Unmanned Aircraft System Minor	3				Yes								
24	S24	Unmanned Aircraft Systems (UAS) Testing	EGG 370	Unmanned Aircraft System Minor	3			Yes	Yes								Pixhawk
25	S25	Unmanned Aircraft Systems (UAS) Applications	EGG 470	Unmanned Aircraft System Minor	3				Yes		Mapping						Construction management, surveying
26	S26	Unmanned Aircraft Systems	ECE 4379	Electrical and Computer Engineering	3	Yes		Yes									4D imaging, GPS
27	S27	Unmanned Aircraft Systems	ECE 5379	Electrical and Computer Engineering	3	Yes		Yes									4D imaging, GPS
28	S28	UAS Basics	CVEN 5392	Civil Engineering	3			Yes			Pix4D						
29	S29	UNMANNED SYSTEMS	CVEN 5392 Cozart	GEOMATICS &GIS	3				Yes		Mapping						
30	S30	Principles of Digital Transformation in Business	MAR3702	Marketing & Logistics	3												
31	S31	Unmanned Aircraft Systems and EDM	EDM 410-50	Emergency and Disaster Management	3	Yes											
32	S32	Unmanned Aircraft Systems and EDM	EDM 410	Emergency and Disaster Management	3	Yes											
33	S33	Unmanned Aircraft Systems and EDM	EDM-410	Emergency and Disaster Management	3	Yes											
34	S34	Unmanned Aircraft System Design	ET 383	Electronics Technology	3												
35	S35	Geospatial Applications for Unmanned Aerial Systems	Geog 4263	Geography	3				Yes		Photogrammetry	GIS					GPS, Structure from Motion
36	S36	UNMANNED SYSTEMS	MAE 5963	Mechanical and Aerospace Engineering	3												
37	S37	UAS PROPULSION	MAE 5973	Mechanical and Aerospace Engineering	3												
38	S38	Geospatial Field Methods of UAVs, LiDAR, and GPS	GEOG 313	Geographic Information Science and Technology	3				Yes			ArcGIS					
39	S39	Aerial Remote Sensing	GEOG 483/583	Geography and Geospatial Sciences	3						Photogrammetry, Pix4D	ArcGIS			LiDAR		Structure From Motion
40	S40	Unmanned Aircraft Systems Photography and Videography	GEOG 387	Geography and Geospatial Sciences	3						Mapping, Modeling			Infrared			Multi-spectral Imaging
41	S41	Wildlife Conservation Technology	Wildlife Conservation Technology								Pix4D						
42	S42	Guidance and Control of Unmanned Aerial Systems	MAE 275	Mechanical and Aerospace Engineering	4										LIDAR		GPS
43	S43	Introduction to Unmanned Aerial Systems for Agricultural & Environmental Science	ABT 60	Biological and Agricultural Engineering	4	Yes			Yes		Mapping			Thermal Imagery	LiDAR		Aerial imagery
44	S44	Applied remote sensing: from drones to satellites	SOE 486	Environment	3				Yes						LiDAR	Multispectral	
45	S45	CYBERWAR, ROBOTS, AND THE FUTURE OF CONFLICT	POLS 370	Political Science	3												
46	S46	Photogrammetry & UAV Mapping	SU4140	Surveying	4	Yes					Photogrammetry, Pix4D	ArcGIS, GIS					
47	S47	ADVANCED UNMANNED SYSTEM OPERATIONS	UMS 491	Technology	3												
48	S48	FAA Remote Pilot Certification Preparation	ECO650	Environmental Conservation		Yes											
49	S49	Piloting Unoccupied Aerial Vehicles	ECO651	Environmental Conservation	2			Yes									
50	S50	Safety Management for Unoccupied Aerial Systems	ECO652	Environmental Conservation	3												
51	S51	Applications in Unoccupied Aerial Systems	ECO653	Environmental Conservation	3				Yes		Photogrammetry						Aerial imagery
52	S52	Unmanned Air Vehicle (UAV) Design	AE173	Aerospace	3										LIDAR		GPS
53	S53	UAV Engineering	AAE 415	Aeronautical & Astronautical Engineering	4												
54	S54	Introduction to Unoccupied Aerial Systems (UAS) Flying	COID 481	Drone Operations for Visualization, Research, and Resource Management Certificate	1												
55	S55	Unoccupied Aerial Systems (UAS) Flight Planning and Operations	COID 482	Drone Operations for Visualization, Research, and Resource Management Certificate	2				Yes		Photogrammetry						
56	S56	Introduction to Control of Unmanned Aerial Vehicles	ME 136	Mechanical Engineering	3												
57	S57	Unmanned Aerial Vehicle (UAV) Photogrammetry	ERE556	Environmental Resources Engineering	3						Photogrammetry, Mapping, Pix4D				LiDAR		Structure from motion
58	S58	Small Unmanned Aircraft Systems Procedures and Regulations	GEOG 158	Geography	1	Yes											
59	S59	Mapping and Analytics Using UAS	GIS/MEA 584	Marine, Earth, & Atmospheric Sciences	3	Yes		Yes	Yes		Mapping						
60	S60					Yes		Yes			Pix4D						

Appendix-C

Interview Questionnaire

Structured Interview Questions for Faculty with Well Developed UAS Course(s)

1) Tell me about the department you teach in?

a. How many faculty.

b. How many students.

c. Where do the students find jobs?

2) Tell me about your drone class(s).

a. Do you have a single drone class or multiple classes?

b. Is the class an entire semester? How many weeks?

c. Is it three credits?

d. How many hours a week does it meet?

e. How frequently is it offered during an academic year?

f. How many students typically enroll?

3) Tell me about your facilities. Do you have a place to fly outside?

4) Tell me how a drone class in your department will be.

a. Who initiated the efforts to create the class?

b. Does your department have a "drone champion," and are you it?

5) What were the most significant barriers to developing and offering the class?

a. Are these barriers ongoing?

6) How did your department get the resources to develop, staff, and equip a drone class?

7) Tell me about the major topics you cover in your class.

a. Can you break them down by weeks and how long you spend on each topic?

8) Tell me about how you break down the grades? How are the topics graded by overall percentages?

9) Tell me how you address Part 107 rules. Are they required to take the exam?

a. If not, how are they incentivized to take it?

b. Who pays for the exam?

c. What percentage of their grade is the exam?

10) Tell me about how you teach how to fly a drone.

a. What is the first mission like in terms of preparation?

b. How are they supervised?

c. Are there any university-level concerns, barriers, rules, etc.?

d. How do you go about teaching them how to operate the controls?

e. Where do you fly?

f. Do you use a simulator?

g. How are they assessed on their flight skills?

h. Do you use the NIST open lane test run?

i. Do you allow them to earn certifications like the APSA BPERP?

j. What percentage of their grade is flight skills?

11) Photogrammetry/thermography / other specific use cases

a. Tell me how you teach XXXX use cases.

b. What software do you use?

c. What deliverable do they learn how to create?

12) Do you cover these topics:

a. How to confirm airspace, NOTAM, and TFR. Conceptually or do you use an application? Which one?

b. LAANC. Conceptually or do you use an application? Which one?

c. Waivers. Conceptually or do you fill out a mock waiver or something like that? Tell me what you do.

d. Accident Reports with FAA. Conceptually or do you fill out a mock waiver or something like that? Please tell me what you do.

e. Weather tools. Conceptually or do you use an application? Which one?

f. Privacy. Conceptually or do you go into details?

13) How did you develop the curriculum?

14) Do you have a reference manual, textbook, or other external resources you use in the class?

15) If your students are handed a drone on their first day at a new job, are they at a level where

they could safely use it to support their employer?

a. If not, what limitations in skills or knowledge do they have?

16) If you were given the resources to create a second drone class, what new topics would you

cover, or what topics would you expand on?

17) Does the Industry support your drone program? In what way?

18) What advice would you give to a faculty member wanting to champion a new drone class?

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