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A Comparative Analysis of Learning Outcomes in Introductory Unmanned Aircraft Systems Education Across Three Instructional Modalities

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During the COVID-19 pandemic, educational institutions transitioned traditional face-to-face classes to online or remote modalities to maintain academic continuity and revenue. This shift has persisted in some cases due to reduced overhead and increased flexibility. Compressed or accelerated courses have become popular for students seeking expedited degree completion. Previous research, including studies by Miller and Bliss (2023, 2024), indicated no significant difference in learning outcomes between traditional and compressed classes based on final exam scores and Student Learning Objectives (SLOs). In 2010, the FAA emphasized the importance of identifying effective educational methods to enhance aviation safety. This study aims to determine whether traditional face-to-face instruction is the most effective modality compared to accelerated and online options for Unmanned Aircraft Systems (UAS) education. Given the rising popularity and certification of UAS, understanding the optimal instructional modality is crucial. This quantitative study examines students' performance outcomes in a Part 107 Remote Pilot Certification preparatory course delivered via three modalities: traditional 16-week face-to-face, 7-week accelerated face-to-face, and 16-week asynchronous online. The study analyzed two classes per modality over six years, using the same content and instructor. Performance was measured by quiz scores and the FAA UAG knowledge exam scores. Findings from this research will inform best practices for UAS education, contributing to the broader discourse on instructional modalities in aviation training. The results could have significant implications for the design and delivery of all aviation courses, potentially influencing curriculum development and instructional strategies in collegiate aviation programs.

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Introduction

In 2010, the Federal Aviation Administration (FAA) issued a 200-page document entitled *Answering the Call to Action on Airline Safety and Pilot Training* which stated in its opening paragraph the most important role of the Department of Transportation and Federal Aviation Administration (FAA) is "to protect the safety of the traveling public" (FAA, 1). One of the ways recommended in this document was to identify and implement the educational methods that prove most effective. This research, although not airline pilot training specific, asks the question of whether the traditional face-to-face instructional methods are truly the most effective modality of instruction when compared to the more contemporary options of accelerated or online classes.

During the COVID-19 pandemic, many institutions sought to convert traditional face-to-face classes to online or remote instructional modalities to maintain students' progress through their respective academic programs and a tuition revenue stream. Many institutions retained some of these non-traditional classes due to the reduced overhead and increased flexibility these modes of instruction offer. In addition to online or remote instructional delivery options, several institutions offer a "compressed" or accelerated version of a traditional 16-week semester class. This option benefits students who want to complete their degrees as soon as possible due to either a career change or other motivation. Miller and Bliss (2023) found that using final exam scores showed no significant difference between the two modalities of compressed and traditional classes when using the final exam as the metric for comparison. In another study, Miller and Bliss (2024) noted that using Student Learning Objectives (SLOs) also showed no significance between a traditional mode of instruction and its compressed counterpart.

Our research, although not airline-specific, seeks to identify if the traditional in-person modality is the most effective when compared to accelerated and online modalities. Is it possible that students, when presented with the same material by the same instructor, perform significantly better in a different instructional modality?

Significance of the Research

The FAA's "Call to Action" paper acknowledges that the one-size-fits-all approach to pilot training may no longer be sufficient in today's aviation environment, and potentially dangerous gaps in knowledge and skills may exist after formal learning (FAA, 2010). While there has been much focus on researching instructional modalities of manned aircraft operations (FAA, 2010; Miller & Bliss, 2023; Miller & Bliss, 2024), there is a lack of literature on instructional modalities for Unmanned Aircraft Systems (UAS). UAS Operators are unique in the industry in many facets. These individuals are required to know much of the knowledge necessary for operating a manned aircraft in addition to the specific regulations surrounding remote operations. Situational awareness for UAS operators requires not just a mental picture surrounding themselves but also the displaced vehicle they control. Many UAS courses include complex electronics, technical repair, critical thinking, and a variety of other aspects, making the results of a UAS-focused study of instructional modalities potentially different from previous research.

Research in this area is crucial because of the popularity of UAS. In August of 2024, the FAA (2024) reported over 780,000 drones registered in the U.S., which far exceeds the number of manned aircraft registrations. Additionally, the same report indicates there were over 400,000 remote pilots certified at that time. While this number is smaller than the total number of manned certificated pilots, the Part 107 (UAS) certification has only been active since 2016. Collegiate aviation programs have developed UAS courses and curricula to keep up with the increased popularity and demand for UAS. Thus, research in instructional methods for UAS courses could provide beneficial insight into future educational methods in these classes.

Literature Review

A search for research in UAS modalities did not yield any results. However, significant research has been conducted in interdisciplinary fields of education on this topic. McGee et al. (2014) found that students completing a remedial math class performed better when the class was administered online and utilized an adaptive classroom setting. This allowed students to focus on the material they did not understand rather than review simple concepts they did understand. McGee also found through questionnaires that some students believed the 3-week online class lent itself to short-term memorization of the material to pass the exams. This research, however, focused on a remedial class rather than one dedicated to the presentation of new material, as would be the case with the UAS classes in the authors' research.

Bannier (2017) focuses on the instruction of new material for Chemistry and Biology students at a community college who completed a compressed 8-week online lab course versus a 16-week online version. Bannier's analysis indicates that there was a statistical significance between the two, with higher final grades coming from students in the 8-week course (p = .0004). Additionally, the study tested whether students' performance varied by semester (fall, spring, and summer) and found students who took the introductory Chemistry class during the summer (a shorter term) had a strong correlation to their final exam scores (p = .0063). This study would indicate that online education was a viable option for laboratory courses at community colleges.

Though positive learning outcomes have been illustrated in these two limited studies, there are other considerations concerning remote and accelerated classes. In a 2021 study, Troutt found that students in the aviation science program at Utah Valley University thought the shift to online and remote was acceptable for combatting the pandemic. However, they also found through mixed methods surveys that students believed the quality of their instruction decreased and the lack of face-to-face contact was negative. Troutt notes this frustration was very much connected to the unpreparedness of faculty to deal with remote operations due to the nature of the shift from in-person to remote or online instruction in response to the COVID-19 pandemic. While this was a variable during the initial pandemic shift, research removed from that time does indicate online or accelerated classwork to be a viable option across a variety of fields (Almquist, 2015; Choudhury, 2017; Williamson, 2017; Miller & Bliss, 2024).

In addition to student's perspectives, faculty perspectives can provide valuable insight into modalities of instruction. Tombaga (2022) administered a Likert scale survey to instructors at an international secondary school to determine students' preparedness level in computer

literacy competency, self-directed learning, and motivational learning when compared to the numerical scores in the class. Tombaga found that during the shift to online in COVID-19, instructors found students readily able to succeed in STEM fields, and computer literacy was not an issue.

While a plethora of research shows the positive components of a variety of educational modalities, very little of it is specific to aerospace and none to Unmanned Aircraft Systems. As such, the authors sought to identify data that agrees with the aforementioned interdisciplinary studies through a quantitative study.

Purpose of the Research:

The United States has seen a mass increase in the number of Part 107 (UAS) certificates issued since the certification process began in 2016. As of August 2024, over 400,000 Remote Pilots Certificates have been issued. With industry operations increasing every year, it is imperative that these UAS operators be effectively trained. Many organizations utilize a variety of modalities of instruction, including online, book, self-paced, and in-person training. This explosive growth in the industry, coupled with the lack of published research on the topic, is the premise for the curiosity that prompted the authors to evaluate these three modalities of instruction.

Considering the benefits and challenges of instructional modalities, the authors sought to understand how students in UAS Remote Pilot Certification classes at a medium-sized university in the southeastern region performed when offered the same topic in varying instructional modalities. Students in this university's UAS Operations Program must obtain their Federal Aviation Administration (FAA) Unmanned Aircraft Systems (UAS) Remote Pilot Certificate as part of the program requirement. The FAA Unmanned Aircraft General (UAG) written examination is administered through a third-party vendor. The knowledge test consists of 60 randomly selected, three-option multiple-choice questions. UAS topics and percentage of items on the knowledge test are outlined in the Remote Pilot – Small Unmanned Aircraft Systems: Airman Certification Standards (FAA-S-ACS-10A) (2018). Students must obtain a 70% (42 correct answer out of 60 questions) or greater to pass the test.

While research into the topic of instructional modalities has been completed in other fields of study and even in other aspects of aviation, no such research has specifically focused on Unmanned Aircraft Systems (UAS) programs like those at a collegiate university. In addition, very little research focuses on comparing the three modalities of traditional, accelerated, and online instruction using the same content and material. For this study, the online instruction was asynchronous rather than synchronous. The purpose of this quantitative study was to determine whether students had significantly different performance outcomes when taking a Part 107 Remote Pilot Certification preparatory course via a traditional face-to-face 16-week semester, face-to-face 7-week accelerated semester, or 16-week asynchronous online course. The study compared two classes from each of these three modalities during the Fall 2018 to Fall 2023 semesters. The courses utilized the same content and were led by the same facilitator. Ultimately, this information could be used to inform educators of viable options for future versions of this class.

Operational Definitions

Many universities use a variety of instructional delivery methodologies. To prevent the potential variance of operations from causing the reader to infer an incorrect view of the differences in the presentation methods, the researchers define instructional modalities used in this study in the following manner:

1) Traditional 16-week semester: this constituted an in-person, traditionally scheduled class that meets at a specific day/hour schedule routinely through a 16-week semester, which includes one week designated for final exams. The instructor utilized PowerPoints, lecturing, and demonstrations as necessary during the course of the class to achieve the desired learning outcomes.

2) Accelerated Classes: these are classes that were still held in-person but at a much faster pace. An example of this would be a traditional 16-week fall semester, which contains two accelerated semesters of 7.5 weeks each within the traditional semester. Students receive the same content and contact hours as a traditional semester, just in a shorter period of time requiring longer classes or more class periods.

3) Online Classes: Online classes refer to classes administered remotely using the university's Learning Management System (LMS). These classes can be offered as synchronous or asynchronous. For the purposes of this study, the classes were asynchronous.

Course assessment consists of five quizzes and the FAA UAG exam, which is the course's final exam. Quizzes are grouped around five major topics: (1) regulation, (2) airspace classification and operating requirements, (3) weather, (4) loading and performance, and (5) operations. Assessment methods are consistent across all course offerings. Quiz questions are similar to questions students may encounter on the FAA UAG exam. Students accessed quizzes using Brightspace D2L Learning Management System (LMS) and the FAA UAG knowledge exam proctored at an approved FAA testing center.

Research Question

There are three methods of measuring student performance in these classes: students FAA's Unmanned Aircraft General (UAG) knowledge exam test results, UAG national average test results, and routinely administered quizzes during the class. The UAG knowledge exam is utilized as a final exam for this class, allowing the researchers to compare UAS classes used in this study to the national average. The additional metric of routinely administered quizzes provides more data points to attempt to compare these modalities to one another quantitatively. The three research questions below were posed:

RQ1. Is there any statistically significant difference between students' scores on the FAA UAG exam and on the quizzes when compared across the three instructional modalities?

a) **Null Hypothesis (H_{01}) –** There is no statistically significant difference between students' UAG test scores and quizzes when compared across the modalities of a traditional 16-week semester, accelerated, or online classes.

b) **Alternate Hypothesis (H_{A1})** – There is a statistically significant difference between students' UAG test scores and quizzes when compared across the modalities of a traditional 16-week semester, accelerated, or online classes.

RQ2. Is there any statistically significant difference between students' FAA UAG exam scores in each modality and the national average?

a) **Null Hypothesis (H_{02}) –** There is no statistically significant difference between students' FAA UAG exam scores in each modality (traditional 16-week semester, accelerated, or online classes) and the national average.

b) **Alternate Hypothesis (H_{A2})** – There is a statistically significant difference between students' FAA UAG exam scores in each modality (traditional 16-week semester, accelerated, or online classes) and the national average.

RQ3. Can the quizzes in this course be used as a predictor for the students' FAA UAG exam scores?

a) **Null Hypothesis (H_{03}) –** The quizzes applied in this course do not adequately predict the students' FAA UAG exam scores.

b) **Alternate Hypothesis (H_{A3})** – The quizzes in this course adequately predict the students' FAA UAG exam scores.

RQ1 and RQ2 directly are designed to address the modality of instruction being used. RQ3 verifies that the content of the class can be directly applied across the industry, accurately preparing students for the UAG exam. All three questions compare the instructional methods both internally (through the quiz scores) and externally (through the UAG exam scores), allowing a better perspective of these data points.

Limitations

This study is limited, considering the data collected was from only UAS classes taught through the university used in the research project. There were two classes for each modality used in this study. Additional classes or multiple universities being incorporated into the data could potentially provide more insight. In an attempt to minimize external factors in the research, no additional preparation software for the UAG exam was included in the class, and the textbook was the same for all sections regardless of modality. Although the same instructor led each of the six classes that are being evaluated, the years of these evaluations range from 2018 through 2023. This class is limited to only individuals who have not attained their private pilot certificate or remote pilot certificate, separating those students who have the knowledge, skills, and abilities obtained pursuing either of these items. Additionally, student aptitude, previous class content prior to this Sophomore-level class, and dedication to success are uncontrollable limiting variables.

Methodology

Student assessment data was downloaded from the Learning Management System (LMS) and combined into one file for data analysis. Quiz scores for each student were averaged for the analysis. Data analysis was performed using *R*. Statistical tests selected for this study were *t*-test, ANOVA, and linear regression, and these tests were used to identify what if any, method of instruction resulted in statistically significant differences in FAA UAG exam scores and quiz grades across the various modalities. Students' scores on the FAA UAG exam were compared against the FAA-published, publicly available national averages for the FAA UAG exam. Additionally, students' performance on quizzes was compared to the scores of the FAA UAG exam to determine if the quizzes were effective in preparing students for the final assessment. This study was approved by MTSU's IRB under protocol IRB-FY2024-80.

Student assessment records of the UAS course from 2018 to 2023 were utilized for this study. As previously noted, this course has been delivered through various modalities in the past six years—accelerated, online asynchronous, and traditional—and the data were grouped by modality. Though the schedule and modality differed, the instructor, course materials, and assessment materials were all the same. Additionally, students in all sections were required to take the FAA Part 107 exam at the conclusion of the course. See Table 1 for the key details of each modality.

Table 1
Key Details of Various Modalities

	Traditional	Online Asynchronous	Accelerated
Enrollment	43	46	21
Schedule	16 weeks	16 weeks	7.5 weeks
Years Offered	2018, 2019	2020, 2021	2022, 2023

Course assessment consists of five quizzes and the FAA Unmanned Aircraft General (UAG) knowledge exam. Quizzes are grouped around five major topics: (1) regulation, (2) airspace classification and operating requirements, (3) weather, (4) loading and performance, and (5) operations. Assessment methods are also consistent across all sections. Quizzes are taken online in the D2L LMS, and the FAA UAG exam is proctored at an FAA-approved testing center.

Results

A total of 110 sets of scores were analyzed. Of the 110, there were 16 missing FAA UAG exam scores and were excluded from any analysis pertaining to FAA UAG exam scores. Two reasons caused these missing UAG exam scores. During the 2018 and 2019 Traditional classes, the UAG exam was required to pass, but the score was not documented as part of the student's grades. This required the facilitator to retroactively retrieve students' scores, of which 11 were unavailable. For the 2020 and 2021 Online sections, the five missing UAG exams were directly caused by students' lack of attendance and ultimately not completing the final component of the

class – the UAG exam. All students completed the Accelerated sections and UAG exams as indicated below. See Table 2 for the number of records used for this study.

Table 2
Number of Students per Modality of Instruction and UAG Exam Completions

Year/Modality	Number of Students	Number of Completed FAA UAG exams
2023 Accelerated	13	13
2022 Accelerated	8	8
Total Accelerated	**21**	**21**
2021 Online	24	21
2020 Online	22	20
Total Online	**46**	**41**
2019 Traditional	20	19
2018 Traditional	23	13
Total Traditional	**43**	**32**
Overall Total	**110**	**94**

Statistical Analysis for Research Question 1

Is there any statistically significant difference between students' scores on the FAA UAG exam scores and on the quizzes when compared across the three modalities?

A one-way ANOVA showed no statistically significant difference in the mean quiz scores and the modalities; $F(2, 107) = .608$, $p = .546$. The mean quiz score for the traditional sections was 82.8 ($SD = 6.95$), the mean quiz score for the online sections was 83.2 ($SD = 9.92$), and the mean quiz score for the accelerated sections was 85.2 ($SD = 7.09$). We failed to reject the null hypothesis (H_{01}) at the 5% significance level.

A second one-way ANOVA was conducted on the scores of the FAA UAG exam and the three modalities. The results showed no statistically significant difference in the FAA UAG scores and the modalities: $F(2, 91) = 1.07$, $p = .348$. The mean FAA UAG exam score for the traditional sections was 84.0 ($SD = 6.03$), the mean FAA UAGF exam score for the online sections was 86.0 ($SD = 7.26$), and the mean FAA Part 107 exam score for the accelerated sections was 83.95 ($SD = 6.23$). We failed to reject the null hypothesis (H_{01}) at the 5% significance level. Table 3 shows the scores for each section and the accompanying national averages.

Table 3
Mean Scores by Modality with National Averages

Modality	Mean Score	National Average	*p*
Accelerated	83.95	80.77	< .05
Online	86.00	82.38	< .05
Traditional	84.00	83.02	.37

Statistical Analysis for Research Question 2

Is there any statistically significant difference between students' FAA Part 107 exam scores in each modality and the national average?

A *t*-test compared the mean FAA Part 107 exam score for the traditional sections (M = 84.0, SD = 6.03) and the national average for 2018 and 2019 (M = 83.02). There was no statistically significant difference between the traditional sections' mean FAA Part 107 exam score and the national average; $t(31) = .92$, $p = .37$. We failed to reject the null hypothesis (H_{02}) at the 5% significance level.

For the online sections, the mean FAA Part 107 exam score (M = 86.0, SD = 7.26) was significantly higher than the national average for 2020 and 2021 (M = 82.38); $t(40) = 3.19$, $p < .05$. We reject the null hypothesis at the 5% significance level. Similarly, for the accelerated sections, the mean FAA Part 107 exam score (M = 83.95, SD = 6.23) was significantly higher than the national average for 2022 and 2023 (M = 80.77); $t(20) = 2.34$, $p < .05$. We reject the null hypothesis (H_{02}) at the 5% significance level and accept the alternate hypothesis (H_{A2}).

Statistical Analysis for Research Question 3

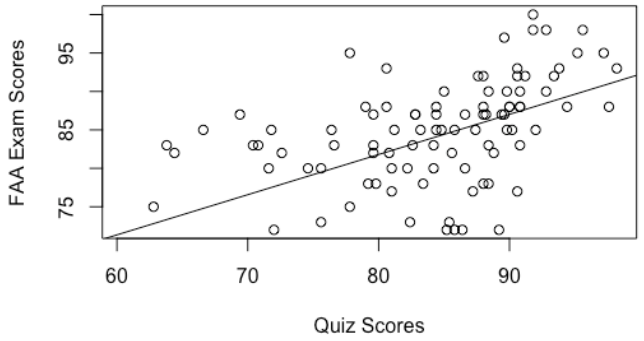
Can the quizzes in this course be used as a predictor for the students' FAA UAG exam scores?

A linear regression was conducted to test if mean quiz scores significantly predicted the FAA Part 107 exam. The fitted regression model was:

$$FAA\ Part\ 107\ Exam\ score = 52.78 + 0.38 \times mean\ quiz\ score$$

The regression was statistically significant; $R^2 = .20$, $F(1, 92) = 22.82$, $p < .05$. The results indicate that the mean quiz score significantly predicted the FAA Part 107 exam score (ß = .38, $p < .05$). We reject the null hypothesis (H_{03}) and accept the alternate hypothesis (H_{A3}). See Figure 1.

Figure 1
Mean Quiz Scores as a Predictor of FAA Part 107 Exam Score



Discussion

Overall, students in the accelerated and online sections performed on par with those enrolled in the traditional section, and the results from this study suggest that there is no negative effect of employing an accelerated or online delivery method for the UAS course, nor are accelerated or online sections inferior to the traditional learning modality. When comparing student performance to those outside the university, the results reveal that students enrolled in the accelerated and online sections performed better than the national average. In this case, accelerated and online modalities produced better outcomes than the traditional method.

Furthermore, the linear regression demonstrates that the quiz scores are a significant predictor of the FAA UAG Exam score. The quizzes that cover five broad UAS topic categories are effective in preparing the students for the final assessment.

While the FAA's 2010 *Answering the Call to Action on Airline Safety and Pilot Training* recommended identifying if a particular modality is best in our current education methods, this study indicates that any of these three modalities is an equally viable option for training. This research can be utilized to help universities select the modality that best suits their needs and infrastructure.

Future Research

The research presented leads the authors to consider future components of UAS and aviation education in general connected to this study. Many aerospace classes incorporate hands-on assignments (such as Aircraft Maintenance Technician classes) or projects (such as an application of aerodynamics project in theory classes). The author's future research seeks to explore the value of these types of components when incorporated into a class.

In addition to this, the authors plan on employing mixed-method surveying in future research to understand students' perceptions of how instructional methods benefit or hinder their performance in class. By combining qualitative data from surveys administered during future research and quantitative data of the surveyed student's UAG exam scores, the authors hope to gain a better understanding of the benefits and limitations of the various modalities.

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