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OBJECTIVES

The University Aviation Association publishes the Collegiate Aviation Review International throughout each calendar year. Papers published in each volume and issue are selected from submissions that were subjected to a double-blind peer review process.

The University Aviation Association is the only professional organization representing all levels of the non-engineering/technology element in collegiate aviation education and research. Working through its officers, trustees, committees, and professional staff, the University Aviation Association plays a vital role in collegiate aviation and in the aerospace industry. The University Aviation Association accomplishes its goals through a number of objectives:

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- To provide a means of developing a cadre of aviation experts who make themselves available for such activities as consultation, aviation program evaluation, speaking assignment, and other professional contributions that stimulate and develop aviation education
- To furnish an international vehicle for the dissemination of knowledge relative to aviation among institutions of higher learning and governmental and industrial organizations in the aviation/aerospace field
- To foster the interchange of information among institutions that offer non-engineering oriented aviation programs including business technology, transportation, and education
- To actively support aviation/aerospace oriented teacher education with particular emphasis on the presentation of educational workshops and the development of educational materials covering all disciplines within the aviation and aerospace field

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Collegiate Aviation Review International

Volume 42 | Issue 2 Peer Reviewed Article #1

08-06-2024

Enhancing Insight into Air Traffic Controller Fatigue: A Dynamic Quantitative Examination through Biological Rhythms

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To scientifically and effectively predict fatigue risk among air traffic controllers, the authors developed a dynamic evaluation model tailored to the routine activities of traffic controllers. By considering biorhythms and workload, we identified causes of fatigue and quantitatively analyzed their impact. Our study involved 24-hour sleep deprivation experiments, collecting electroencephalogram (EEG) data to track fatigue over time. Expert scoring determined workload coefficients for different periods and positions. Using experimental data, we established and validated a mathematical model for dynamic fatigue risk assessment during various work periods. Results align with controllers' actual fatigue levels and self-assessment scores, indicating the proposed method's effectiveness in early fatigue detection and ensuring aviation safety.

Recommended Citation:
Fan, X., Ma, Y., & Lu, C-t. (2024). Enhancing insight into air traffic controller fatigue: A dynamic quantitative examination through biological rhythms. *Collegiate Aviation Review International*, *42*(2), 1–16. Retrieved from https://ojs.library.okstate.edu/osu/index.php/CARI/article/view/9767/8796

Introduction

As air traffic continues to surge, so does the strain on air traffic management, with human factors emerging as a pivotal concern for civil aviation safety. The rotating day-night shift system and relentless mental and physical workload have spotlighted controller fatigue as a critical issue in human factors research. The International Civil Aviation Organization (ICAO) defines fatigue as a physiological condition in which the ability to perform mental or physical activities is reduced due to lack of sleep, prolonged periods of wakefulness, or excessive physical activity (ICAO, 2016). In two recent studies conducted by Lu and his research team, fatigue emerged as a significant causal factor contributing to undesirable events in aviation, especially amidst the challenges posed by the unexpected pandemic (Lu et al., 2023; Lu et al., 2024). Fatigue compromises attention, alertness, judgment, and decision-making, culminating in cognitive and operational errors. According to the U.S. Federal Aviation Administration (FAA), approximately 21% of annual aviation accidents stem from controller fatigue (ICAO, 2016). Hence, establishing a scientifically robust and effective method for predicting controller fatigue and implementing corresponding preventive measures holds paramount importance in safeguarding aviation operations.

Present studies on assessing controller fatigue methods classify into subjective and objective evaluation techniques. Subjective methods involve fatigue scales completed by subjects to gauge their fatigue status and severity, such as the Multidimensional Fatigue Inventory developed by Professor Smets at the University of Amsterdam in the Netherlands (Smets et al., 1995) and the MFI-16 Multidimensional Fatigue Self-Rating Scale (Sun et al., 2016). The objective evaluation method employs a range of instruments and techniques to gather physiological, biochemical, behavioral, or human factors engineering indices associated with fatigue, forming a comprehensive fatigue evaluation system. Commonly utilized approaches involve collecting subjects' electroencephalogram (EEG), electrocardiograph (ECG), Electrodermal, and other indicators to delineate fatigue. Foreign scholars Lal and Craig (2001) believe that EEG signal is one of the most reasonable indicators for testing fatigue. Chen and Wang (2017) collected the EEG data of controllers and used EEG indicators to compare the fatigue differences of controllers under different shift systems. Some scholars also analyze fatigue by monitoring subjects' blinking, yawning, and other behaviors. Chen (2015) proposed controller fatigue status monitoring based on eye movement data. The fatigue state of controllers was evaluated by collecting the eye tracking data and analyzing the fixation state, pupil changes, blink time, and other indicators combined with PERCLOS (Chen, 2015). Based on facial recognition technology, Sun et al. (2014) used the OpenCV development platform to identify controller fatigue status through the eyelid opening and closing rate and mouth opening frequency.

While the aforementioned method accurately gauges controller fatigue, its implementation entails a complex measurement process, prolonged testing duration, and requires installing cameras in control positions, potentially amplifying the psychological burden on controllers. Moreover, fatigue is subject to biological rhythms, work content, and dynamic time variability. Consequently, existing research solely evaluates personnel's current fatigue status, lacking predictive capabilities for preemptive fatigue risk assessment and proactive control measures in response to dynamic fatigue fluctuations (Li et al., 2017).

Controller fatigue primarily stems from endogenous biological rhythms and exogenous workload and pressure. Biological rhythms, such as the 24-hour circadian rhythm, dictate inherent patterns in physiological states characterized by fluctuations between high and low periods. Shift workers often find themselves operating during these low periods, such as late afternoon and midnight, exacerbating fatigue. Consequently, fatigue prediction models for controllers must comprehensively account for the influence of biological rhythms. Many scholars in relevant research domains have thus developed mathematical models for fatigue prediction grounded in human sleep homeostasis, circadian rhythm, and working hours. For example, the Three Process Model of Alertness (TPMA) proposed by Akerstedt and Folkard (2004) calculates the alertness value through the start and end time of work/sleep; in 2001, the Sleep Research Center of the University of South Australia proposed the Fatigue Audit Inter Dyne (FAID) model, which calculated the output fatigue value through duty/rest time (Roach et al., 2004). Rosa (2004) proposed the CAS model, which calculated alertness through circadian rhythm and sleep homeostasis. Based on the above studies, Li (2019) established a fatigue prediction model aiming at the work characteristics of subway attendants, considering factors such as the time domain of personnel operation, working hours, work breaks, and shift patterns. However, all parameters in the model were determined by subjective methods, lacking objective accuracy. Wu (2018) collected PVT reaction time data of subjects through a sleep deprivation experiment, established the change function of quantified alertness value with wake time, and combined it with the controller's workload to calculate the fatigue prediction curve. Workload denotes the volume of work the human body can handle within a given timeframe. A higher workload accelerates fatigue accumulation, resulting in an earlier onset of fatigue (Wu, 2018). Arico et al. (2015) analyzed the EEG signals of twelve (12) school control students, established the mental load coefficient of control work, and proposed a workload model based on EEG. Shou and Lei (2013) found that the frontal theta wave of controllers changes sensitively and significantly with the working load and working time.

The aforementioned research acknowledges the influence of sleep and circadian rhythm on fatigue and establishes a quantitative fatigue prediction model through experimentation and mathematical analysis, providing a basis for the present study. Nonetheless, existing studies on dynamic quantification of fatigue often overlook the specific work characteristics of air traffic controllers. Thus, this paper aims to address these limitations by introducing enhancements and additions derived from a comprehensive examination of current research gaps:

1) Considering both endogenous biological rhythm and exogenous workload, this study identified factors influencing controller fatigue: circadian rhythm, work content, and work hours. Through experimentation and mathematical calculations, a quantitative fatigue prediction model was subsequently developed.

2) Perform a controlled simulator test under conditions of sleep deprivation. Collect EEG signals from the subjects during the test and process the data to derive EEG fatigue values. Utilize regression analysis to determine the changes in the fatigue value curve over the course of 24 hours with respect to awakening time.

3) Utilize the expert scoring method to ascertain the workload coefficient for each control seat

and working period. Compute the controller's workload implementation curve and determine the parameters of the fatigue quantitative assessment model through mathematical calculations.

Experimental Design

Experimental Materials and Contents

The experiment utilized the MFI-16 fatigue scale, a unique adaptation of the Multidimensional Fatigue Scale (MFI-20) developed by the University of Amsterdam in the Netherlands. This revised version, developed by the Safety Science Institute of the Civil Aviation University of China, is specifically tailored to the professional characteristics of controllers. The scale, comprising 16 items, yields a total score ranging from 16 to 80 points, and a higher score indicates a greater degree of fatigue (Lal. & Craig, 2001). The scale score is recorded and can be compared with subjective scale scores to validate the effectiveness of physiological index data in representing fatigue.

The equipment used to collect physiological data is the Manglod-10 multi-channel physiological instrument produced by Mind Media. This equipment is used for recording human physiological signals and consists of a multi-channel analog signal collector, a signal processing unit, and computer software. During the experiment, physiological sensors were installed on various parts of the subjects' bodies to capture up to 10 signals, including electrocardiogram (ECG), electroencephalogram (EEG), electromyogram (EMG), and electrodermal response (EDA). These signals were then collected by a multichannel analog signal collector and transmitted to the signal processing unit. Following amplification, filtering, and interference removal, the data was sent to the computer for further processing and analysis.

Experimental Process and Content

A total of 12 air traffic controller students from the Civil Aviation University of China were selected before and after the experiment. They were all male, with normal naked or corrected vision, no smoking or drinking, self-reported no sleep disorders, and no history of neurological or psychiatric medication or medical history. All subjects studied radar control-related courses and passed the assessment of subject scores. All subjects were informed in advance of the experiment's content, method, and purpose and participated in the experiment voluntarily.

In this experiment, the subjects were deprived of sleep for 24 hours under the supervision of the experimenter, who ensured that the subjects did not sleep throughout the study. They were regularly tested. In terms of good health, an adult is recommended to sleep for seven to eight hours per night (Healthy China Action Promotion Committee, 2019; Napoli, 2023). Therefore, all subjects were asked to sign a pledge to get eight hours of sleep the night before and set an alarm for 7 a.m. on the day of the experiment to ensure uniform sleep conditions (no analysis of the subject’s sleep status was involved) before the test. Testing commenced at 9 a.m. and occurred every two hours until 7 a.m. the following day, totaling 12 tests per individual, as outlined in Table 1. During the intervals between tests, under the supervision of the researchers, the participants refrained from engaging in strenuous activities that would deplete physical energy and were prohibited from consuming stimulating beverages like coffee or strong tea. Additionally, the staff provided the diet during the experiment to ensure that meals did not affect the participants' state.

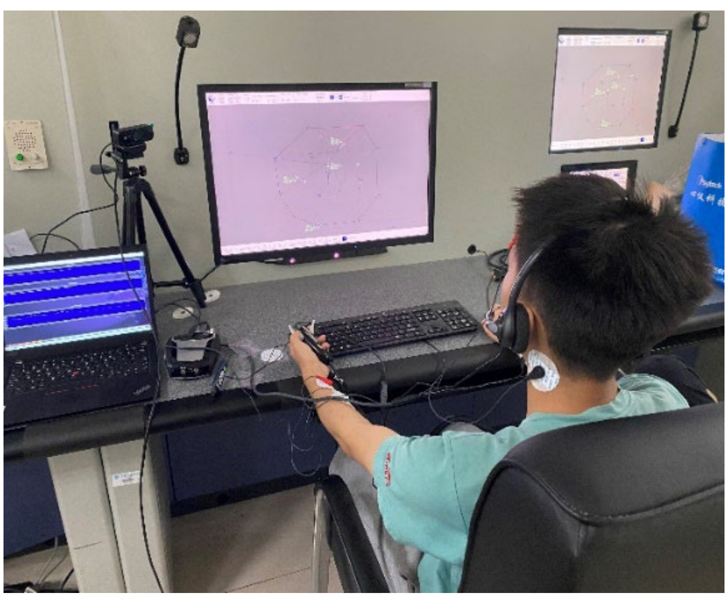
Table 1
Test Schedule

Number of Experiments	1	2	3	4	5	6	7	8	9	10	11	12
Time	09	11	13	15	17	19	21	23	01	03	05	07

The test contents include the approach radar simulator test and the MFI-16 fatigue scale filling (PVT test). Before conducting the radar simulator test, the subjects first filled out the fatigue scale to record their subjective fatigue value at the current moment. Each simulator test lasted 30 minutes.

The whole test process's EEG data were recorded. The multi-channel physiological instrument was connected to the controller's left forehead, wrist, ear, elbow joint inside, index finger, and middle finger through electrodes. The EEG unipolar lead method was used to record the EEG signals of the controller's left forehead during the simulation. Figure 1 shows the scenario during the test.

Figure 1
Experimental Scene Diagram



Workload Evaluation Indicators

Understanding the intricate relationship between workload and fatigue among air traffic controllers is crucial. The time between waking and sleeping represents a period of energy expenditure, where fatigue accumulates as energy is depleted. However, workload is also a key factor in this equation (Wu, 2018).

Given the inherent variations in workload and specific tasks, the accumulation of fatigue among controllers on duty varies significantly across different types of control, positions, and periods. These control types include airport control, approach control, and area control. Airport control oversees aircraft movements within the airport's jurisdiction, including taxiing, take-off, landing, and related maneuvers. Approach control manages aircraft approaches and departures. Area control provides air traffic control services for aircraft within a designated airspace. Control positions typically comprise director, coordinator, and supervisor roles. The director organizes air command and deployment, the coordinator facilitates coordination and handover, monitors flight dynamics, and oversees the director's commands for errors or omissions, while the supervisor manages on-site operations, coordinates with other units, and ensures overall operational efficiency (Li, 2000). Due to the workloads being different in different positions, general units will arrange for controllers to rotate positions for duty.

While the air traffic control industry operates continuously, controllers are mandated to be on duty around the clock. Flight volumes exhibit time-varying patterns, fluctuating throughout the day. Consequently, controllers contend with varying work pressures and loads as they manage different numbers of flights at different times. Ultimately, a controller's workload is shaped by the specific tasks and complexity of their position, as well as the workload during their designated working period.

Data Processing and Model Processing

EEG Data

The four fundamental rhythm waves of the EEG signal can be collected using a multichannel physiological instrument: fast waves α, β and slow waves θ, δ. According to scientific research in related fields, when a normal adult is clear-headed and alert, the brain waves are mainly α waves and β waves; on the contrary, when a person's alertness decreases, operational ability deteriorates, and fatigue increases, θ waves will appear in the brain, and δ waves will appear when a person is anesthetized or asleep (MOT, 2017). As adults shift from a normal to a fatigued state, the slow wave signal in the brain's electrical activity gradually intensifies while the fast wave signal weakens. Consequently, the energy ratio between slow waves and fast waves serves as an indicator to assess fatigue status (Chen, 2017), as illustrated in the following formula (1):

$$F_1 = \frac{E_\theta}{E_\alpha + E_\beta} \tag{1}$$

In the formula, F_1 is the fatigue value, E_α is the energy of α wave, E_β is the energy of β wave, and E_θ is the energy of θ wave. Since the subjects did not sleep during the experiment, δ waves were not considered in the formula.

During data processing, Biotrace+ software performs Fourier transform and filtering on the EEG rhythm, eliminating outliers greater than 50 μV in the data. The average power spectrum is used instead of the EEG energy value to calculate the F value, which is the EEG fatigue value (Chen,2017), as shown in formula (2).

$$F = \frac{P_\theta}{P_\alpha + P_\beta} \tag{2}$$

In the formula, F is the fatigue value, P_α is the power of α wave, P_β is the power of β wave, and P_θ is the power of θ wave.

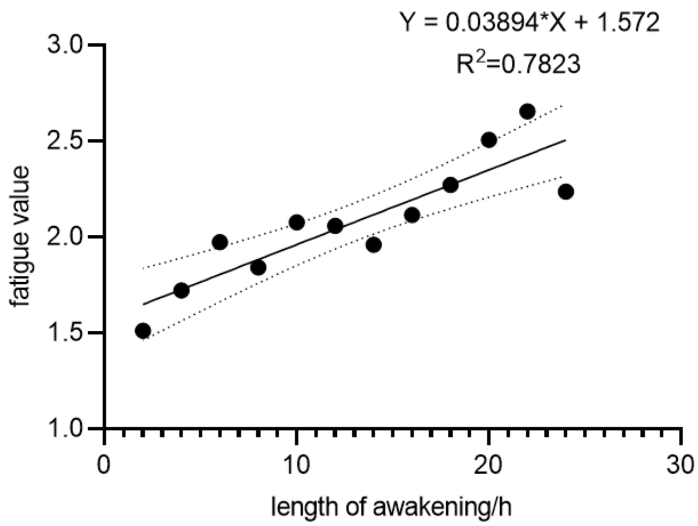
To verify the consistency of the fatigue value change curve with awakening time across subjects, correlation analysis was performed between the brain electrical fatigue data and the awakening duration of 12 subjects. Results revealed a significant correlation ($p<0.05$) between the EEG fatigue value and awakening time for most subjects. Table 2 below displays the correlation coefficients between the fatigue value and awakening duration, with letters representing the subject's fatigue value data number and awakening duration measured in hours.

Table 2
Results of Correlation Analysis between Fatigue Value and Awakening Time

Index		Subject A	Subject B	Subject C	Subject D	Subject E	Subject F
Wake time and EGG fatigue value	Pearson correlation	0.928**	0.694*	0.636*	0.748**	0.745**	0.736**
	Double tail sig. (p)	0.000	0.012	0.026	0.005	0.005	0.006
Index		Subject H	Subject I	Subject J	Subject K	Subject L	Subject M
Wake time and EGG fatigue value	Pearson correlation	0.686*	0.675*	0.738*	0.815**	0.740	0.791*
	Double tail sig. (p)	0.020	0.032	0.037	0.002	0.057	0.019

The table results demonstrate consistent changes in subjects' fatigue values with awakening time. Consequently, the average brain electrical fatigue value of all 12 subjects serves as a representative characteristic value to correlate with awakening time. Prior to computing the average, outliers are excluded at each time point to enhance the generalizability of the results. The fitting results are provided in Figure 2.

Figure 2
Fatigue Data Fitting Curve



The figure shows that the average EEG fatigue value of the subjects fluctuated and increased with the prolongation of awakening time. However, the fluctuation amplitude was small, and the overall correlation was strong. (R^2=0.7823). According to the trend line formula, the fatigue value prediction formula under the influence of biological rhythm can be obtained as Equation (3).

$$Y = 0.03894t + 1.572 \tag{3}$$

In the formula, Y represents the predicted value of fatigue changing with awakening time, and t represents the awakening duration, the difference between the current moment and the awakening moment of the day.

Model building

This article establishes a quantitative fatigue prediction model for air traffic controllers throughout the day. According to the regulations of the Civil Aviation Administration of China, radar controllers shall not be on duty continuously for more than 2 hours. They shall not have less than 0.5 hours off during work (MOT, 2017). On this basis, different control units have different requirements, and the general modes include 2 hours off for the upper 2 hours, 1 hour off for the upper 2 hours, 1 hour off for the upper 1 hour, and 0.5 hours off for the upper 1 hour. Controllers usually work from different positions at different times. Therefore, when considering the dynamic quantitative evaluation model of fatigue, the daily time is divided into different periods according to the work and rest patterns of the controller, and the fatigue values of the first and last nodes of each period are calculated.

Establish a segmented function based on the controller's scheduling schedule to predict dynamic fatigue. Propose a fatigue dynamic quantitative evaluation model, as shown in equation (4).

$$P(n) = Q + k(t_n - t_0) + \sum_{i=1}^{n}(C_{i-1}W_{i-1} - R_{i-1})(t_i - t_{i-1}) \tag{4}$$

In the formula, the independent variable n represents the number of time required, P(t) is the fatigue prediction value at time t ; $i \in \{1,2,\ldots,n\}$ is the time node number; t_i represents the time value of each time node during the duty process, such as t_0 represents the end of sleep and awakening time, t_1 represents the time when the first duty ends and the rest begins; t_m represents the moment requested; Q represents the initial fatigue value after sufficient rest; k represents the fatigue accumulation coefficient based on biological rhythm; C_i represents the fatigue value accumulation coefficient of the position that starts working at the i moment. If the rest starts at the i moment, C_i is 0; W_i represents the fatigue accumulation coefficient of the period when the work starts at the i moment. If the break starts at the i moment, W_i is 0; R_i represents the recovery coefficient of the period when the rest starts at the i moment. If the work starts at the i moment, R_i is 0. The parameter k in the formula has a value of 0.03894, and Q has a value of 1.572.

Case analysis

The authors conducted research at the regional control room of a specific Air Traffic Control Center, selecting several controllers as examples. The authors then calculated the fatigue quantification prediction values based on their scheduling information for a particular day, and the result of the model was verified and analyzed by the controller supervising the fatigue scale. In this control room, controller positions are categorized into director, coordinator, and supervisory roles. Controllers typically rotate between these positions according to a scheduling rule of 1.5 hours on duty followed by a half-hour rest period in the middle. The scheduling information of some controllers in the morning and evening shifts is shown in Table 3 and Table 4. The tables demonstrate the duty and corresponding duty positions of controllers at different times. The letter C stands for Coordinator, D stands for Director, and R stands for Rest.

Table 3
Schedule Information Sheet for Some Controllers (Morning Shift)

Controller number	0800-0830	0830-0900	0900-0930	0930-1000	1000-1030	1030-1100	1100-1130	1130-1200
A1	C	C	C	R	D	D	D	R
A2	D	D	D	R	C	C	C	R
B1	C	C	C	R	D	D	D	R
B2	D	D	D	R	C	C	C	R
C1	R	C	C	C	R	D	D	D
C2	R	D	D	D	R	C	C	C

Table 4
Schedule Information Sheet for Some Controllers (Night Shift)

Controller number	1800-1830	1830-1900	1900-1930	1930-2000	2000-2030	2030-2100	2100-2130	2130-2200
A1	C	C	C	R	D	D	D	R
A2	D	D	D	R	C	C	C	R
B1	C	C	R	Rt	D	D	D	R
B2	D	D	R	R	C	C	C	R
C1	C	R	D	D	D	R	C	C
C2	D	R	C	C	C	R	D	D

The six controllers are on duty during the morning and evening shifts, with morning shifts from 8:00 to 12:00, evening shifts from 18:00 to 22:00, and free breaks from 12:00 to 18:00 in the middle.

According to the questionnaire survey of the control room controllers and the surveyed scores, the specific position allocation of the unit and the load coefficient of each position is determined (Refer to Table 5, assuming that everyone in the same position has the same workload coefficient).

Table 5
Workload Coefficient of Each Position of An Approach Control Unit

Position Name	Director	Coordinator	Supervisory
Fatigue accumulation coefficient per hour	0.7	0.6	0.5

According to the change rule of actual flight flow, combined with the results of the questionnaire survey and expert scores, the duty-hours of controllers during the day shift were divided into four periods according to the degree of business, and the workload coefficients of each period were shown in Table 6.

Table 6
Working Load Coefficient of Each Period

Period	0800-1200	1200-1800	1800-2200	2200-2400
Fatigue accumulation coefficient per hour	2.0	1.5	2.0	1.4

The value of the controller's subjective fatigue degree was collected at the time node before the controller's middle rest and returned to work, that is, the value of the fatigue scale filled by the controller according to the current fatigue degree. The fatigue scale adopts the Stanford Sleepiness Scale, as shown in Table 7. The controller selects the most suitable state level according to the state description of the scale and records the current fatigue level value of the controller. The post-work fatigue scale value of controllers is correlated with the output value of the fatigue prediction model to verify the reliability of its application.

Table 7
Stanford Sleepiness Scale (SSS)

Degree of Sleepiness	**Scale Rating**
Felling active; Vital alert or wide awake	1
Functioning at high level but not at peak; Able to concentrate	2
Awake but relaxed; Responsive but not fully alert	3
Somewhat foggy; Lie down	4
Foggy; Lossing interest in remaining awake; Slowing down	5
Sleepy; Woozy; Fighting sleep; Prefer to lie down	6
No longer fighting sleep; Sleep onset soon; Having dream-like thoughts	7
Asleep	x

According to formula (4) and Table 3 through Table 6, fatigue prediction values of six controllers in morning and evening shifts were calculated. According to the survey results of the scale, the fatigue values of the six controllers were generally the same before starting work at 8:00 in the morning shift. They were relatively excited, and the self-rated fatigue level was 2 or 3. Therefore, it is considered that the initial fatigue state of controllers is the same, and the same Q value is taken. Since 12:00 to 18:00, between the morning and evening shifts, was free rest time, the controllers got sufficient sleep supplements and were in a relatively complete state of spirit before the 18:00 shift. The self-rated fatigue value was the same, and the same Q value was used for calculation.

Taking the early shift of controller A1 as an example, the parameters in the model are calculated. The controller wakes up at 6:00 that day, t_0 is 6, the start time is 8:00, t_1 is 8, and so on. Based on the working load coefficient of each position in each period, the values of each parameter are shown in Table 8. In the definition, C_0W_0 is the fatigue accumulation coefficient of commuting and preparation work, and the value is 0.5. In addition to working hours, the rest coefficient R_i equals 0.05. Any parameter equal to 0 is omitted from the table.

Table 8
Parameter Value Table

Parameter name	Value	Parameter name	Value
t_0	6	C_1	0.6
t_1	8	C_3	0.7
t_2	9.5	W_1	2.0
t_3	10	W_3	2.0
t_4	11.5	$R_{2,4}$	0.05
t_5	12	C_0W_0	0.5

The above parameter values were substituted into formula (4) to calculate the cumulative fatigue value and cumulative rest recovery value at each moment and obtain the fatigue prediction evaluation value at each moment, as shown in Table 9.

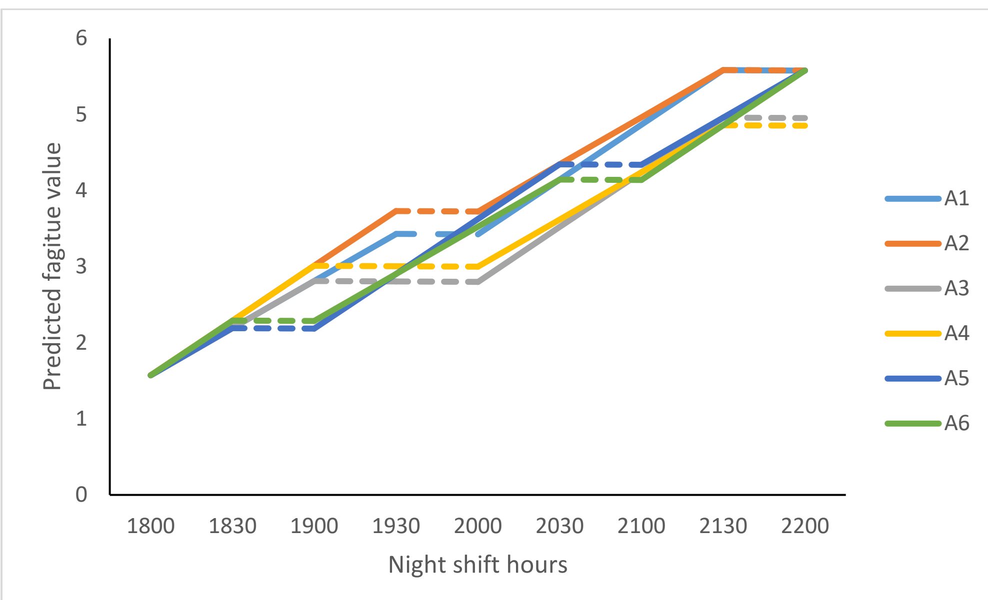
Table 9
Calculation Results of Controller A1 Morning Shift Fatigue Model

Start time	End time	Duration/h	Work or activity type	Fatigue value	Rest value	The end-time fatigue evaluation value
0600	0800	2.0	Commute and shift preparation	2.650	0	2.650
0800	0930	1.5	Coordinator	1.858	0	4.508
0930	1000	0.5	Rest	0.019	-0.025	4.502
1000	1130	1.0	Director	2.158	0	6.660
1130	1200	0.5	Rest	0.019	-0.025	6.654

The same method was used to calculate the fatigue prediction value of each node of the evening shift of the A1 controller and the morning and evening shifts of the remaining controllers. The fatigue prediction trend of six controllers in the morning and evening shifts was obtained, as shown in Fig. 3 and Fig. 4. The solid line in the chart represents the controller's work process, and the dotted line represents the rest of the controller.

Figure 3
The Trend of Fatigue Prediction of the Controller Early Shift

Figure 4
The Trend of Fatigue Prediction of the Controller Night Shift



Spearman correlation analysis was conducted between the predicted fatigue value of the controller at every moment, and the subjective fatigue scale value filled in, and the results are shown in Table 10. The results showed that the model output value strongly correlated with the subjective fatigue value, and the two results were consistent. This model can be used as a dynamic quantitative evaluation method for controller fatigue, providing a convenient and effective controller prediction.

Table 10
Correlation Analysis Result

		Model output value	Subjectivity fatigue value
Model output value	Correlation coefficient	1.000	0.681
	Sig. (double tail)		0.000

This paper introduces a biorhythm-based approach to predict the fatigue levels of controllers during duty. Through a carefully designed 24-hour sleep deprivation experiment, EEG fatigue changes of subjects were recorded continuously within the 24-hour period post-awakening. Data analysis and fitting techniques were then applied to derive a formula correlating EEG fatigue with wakefulness time. Subsequently, a dynamic quantitative evaluation model for fatigue was developed, integrating workload coefficients specific to each control position and working period. The reliability of the model for fatigue prediction was then confirmed through verification. The conclusions drawn are as follows:

1) The output value of the established fatigue quantitative evaluation model demonstrates a significant correlation with the subjective fatigue scale values reported by the subjects, indicating strong consistency. This model effectively predicts the fatigue experienced by controllers on duty, thereby providing a foundational framework for proposing optimal rest and scheduling strategies for personnel. Such measures are essential for mitigating safety risks associated with air traffic control operations.

2) The fatigue of controllers on duty was analyzed from two angles: biological rhythms and workload. We established a functional formula correlating fatigue with awakening time using objective EEG test data, and subjective workload coefficients were assigned for different positions and periods. By integrating these components, a comprehensive model was developed. This model allows for the quantitative evaluation of fatigue levels at any given moment of duty, with input derived from the controller scheduling table.

3) The participants in this experiment consisted of male control students with slight variations in age and health status, resulting in a limited sample size that may restrict the generalizability of the findings. To address this limitation, future experiments will involve in-service controllers of diverse genders and ages with an expanded sample size. These subsequent experiments aim to enhance the reliability and accuracy of the fatigue detection model by broadening the scope of experimental content.

Future Study

In the future, if the physiological data of controllers can be tracked for a long time, the physiological database of controllers can be established, and the fatigue prediction model of controllers can be established by using the method proposed in this paper.

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Analysis of VTOL Downwash and Outwash to Establish Vertiport Safety Standards: A Theoretical Approach

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VTOL aircraft are expected to play a crucial role in the air transportation sector, fulfilling various use cases similar to helicopters. However, they also present a significant safety hazard, downwash, which is the concentrated and powerful airflows generated by the rotors or propellers. To mitigate downwash risks, clear communication, proper training, and the establishment of safe operating zones are essential. The study suggests that existing FAA vertiport design criteria are insufficient as they lack minimum standards for downwash and outwash safety. This study identified the dangers of VTOL downwash and developed potential mitigation strategies and basic safety guidelines. The study used existing VTOL aircraft data to calculate theoretical airflow characteristics and then compared these to wind speed comfort and safety scales. Equations based on design dimension "D" as described in existing vertiport literature were provided. In addition, equations accounting for variations in VTOL design and propulsion configurations were developed. A resultant process for determining safety zones and buffer areas around vertiports is provided. The findings of this study can assist advanced air mobility stakeholders in the development of vertiport safety guidelines and protections.

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Introduction

Future vertical takeoff and landing (VTOL) aircraft are expected to play vital roles in the air transportation sector, fulfilling a variety of use cases similar to those of helicopters, including search and rescue, passenger transportation, and military operations. Also, similar to helicopters, VTOL aircraft present an often overlooked but significant safety hazard—downwash. Downwash refers to the concentrated and powerful air blast generated by the rotors or propellers of helicopters and VTOL aircraft as air is pushed downward to achieve lift. This invisible force can substantially threaten personnel and objects on the ground, particularly during maneuvers like hovering, takeoff, and landing. Downwash can cause individuals to lose balance and be knocked over, potentially leading to falls, injuries, or even being struck by loose objects. The strong winds can dislodge lightweight objects like debris, tools, or unsecured cargo, creating a projectile hazard. Additionally, downwash can cause structural damage to temporary shelters or fragile equipment. In dusty or loose soil environments, downwash can stir up significant amounts of dust, reducing visibility and creating a potentially hazardous situation for both personnel and the VTOL itself.

Although downwash is an inherent property of VTOL flight, measures must be taken to mitigate its dangers. Clear communication and signage are necessary to inform participating and non-participating personnel of the hazard. It is essential that ground personnel receive the proper training regarding downwash dangers and clear visual markers be available around the designated flight operations areas. Pilots should also undergo comprehensive training in downwash management techniques, including minimizing hover times and adjusting flight paths to minimize the impact on the ground. Establishing safe operating zones is one of the most effective ways to manage downwash risks. By implementing designated landing and takeoff areas with sufficient clearance from personnel and objects, the risk to persons and property can be minimized.

Due to the differences in downwash between VTOL aircraft and traditional helicopters, existing safety protocols may not be sufficient for the protection of persons and property from VTOL downwash. Very little data exists on the attributes and profiles of VTOL downwash, which is problematic considering the expected proliferation of VTOL aircraft operations. As such, a thorough understanding of VTOL downwash effects is crucial for further enhancing safety measures at vertiports. Research on quantifying the downwash force exerted at various distances and under different operating conditions for VTOLs is critical so that the data can then be used to refine existing safety zones and develop more precise downwash prediction models. Understanding downwash patterns can also inform the development of more effective training programs for ground personnel and pilots.

This study aimed to identify the dangers of VTOL downwash by analyzing its theoretical physical characteristics and impacts on personnel and objects. Further, potential mitigation strategies were sought to be developed. By fostering a comprehensive understanding of this phenomenon, logical standards such as safety zones or buffers can be developed to ensure a safer operating environment for those in the air and on the ground.

Literature Review

Background on Rotor Aerodynamics

The main rotor of a helicopter provides lift, propulsion, and control. It generates force by rotating through the air, creating a balance between lift and weight. Propulsion and control are achieved by tilting the rotor to orient this force in different directions. Basic rotorcraft design considers parameters such as the diameter of the rotor, the number of blades, the shape of the blades, and the airfoil shape.

While operating in hover out-of-ground effect (HOGE), Froude's theory indicates a connection between air speed at the rotor level squared and two parameters: the mass of the aircraft and the disc area. The speed depends directly on the mass and the rotor diameter; the heavier the helicopter, the higher the downwash speed; the larger the disc area, the lower the speed. Different helicopter designs will vary in this relationship, known as disc loading.
The induced velocity on the disc is not uniform, with more concentrated speed on the ends of the blade and as the airflow interacts with the fuselage. The unsteady airflow can form structures such as blade tip vortices, which are directly related to the hover effect of the rotor disc. Various factors, such as the size of the rotor disc, the wind direction, and the impact of the ground on the downwash, can influence wind speeds.

The Preston Model calculates the maximum speed at a given station as a function of distance in terms of rotor diameter; the further away from a reference point, the lower the speed. For an Airbus EC225 helicopter flying at an altitude equal to the distance of 1 rotor diameter above the ground, the maximum speed calculated with Froude's theory is approximately 70 mph. However, during hover, the rotor disc is not always perfectly horizontal and the axis symmetry in the diagram is not found in reality. To achieve hovering flight, the rotor must be tilted slightly due to the forces exerted on the helicopter (Airbus Helicopters, 2021).
A safety correction factor should be considered when the helicopter starts to move up vertically or stops its vertical descent, as asymmetric flows may temporarily modify the outwash. There is a minimum safety margin of 30% due to the lack of specific studies on this complex subject and the great variability of on-site conditions. Additional environmental conditions and obstacles (buildings) could also modify the outwash (Civil Aviation Safety Directorate, 2022).

The Australian Transportation Safety Board (ATSB) (2023) released a detailed report on safety risks from rotor downwash at hospital heliports. The report analyzed downwash occurrences from 2018 to 2022 to identify common factors, existing regulatory guidelines, and ways to mitigate the effects of rotor wash. Rotor wash has been shown to have a vertical component produced by the main rotor blades that support the helicopter in flight and a horizontal component due to the interaction of the outflow with the ground surface. Factors determining the strength of rotor wash include the weight of the helicopter, main rotor size, disc loading, wind, and flight path.

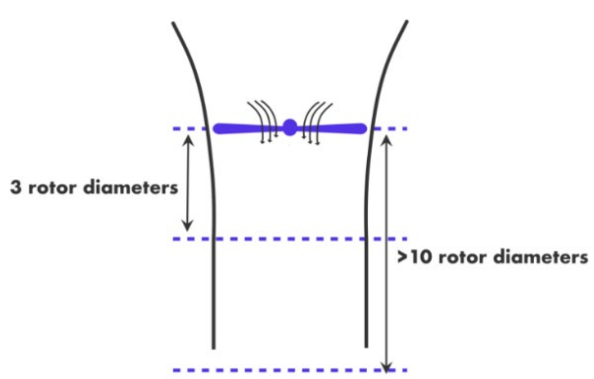
According to mathematical modeling by Airbus Helicopters (2021), the highest velocity of rotor wash occurs at altitudes equal to the length of 1 to 3 rotor diameters above the ground. Beyond this distance, high-velocity airflow dissipates due to turbulence. Researchers have also

determined that rotor wash effects are most pronounced during hover, takeoff, and landing, where they can produce localized wind strengths greater than 65 mph.
NASA researched the tuft patterns on the airframe of a full-scale UH-60L helicopter while it was hovering both within and outside the ground effect. The study revealed airframe tuft patterns at different heights above the ground, relative to the rotor, together with overlays that showed flow stability. As the helicopter descended into ground effect, the airflow grew more chaotic. The tuft patterns on the ground plane exhibited significant instability at all evaluated heights. Navier-Stokes computational fluid dynamics (CFD) simulations exposed the mechanism by which helicopter wake may induce brownout (creating a cloud of dust or dirt obstructing pilot visibility) behaviors (Wadcock et al., 2008).

Downwash generated by a helicopter hovering at four altitudes (16, 18, 20, and 25 feet AGL) was measured at two points within tree canopies. The effects of payload and hover altitude on downwash were significant, with the average downwash on the top section of canopies being significantly higher than in the middle sections at each hover altitude. Observations showed that tree branches, twigs, and leaves in canopies reduced rotor downwash. Flows varied significantly with different hover altitudes and payloads, which interactively affected the downwash. The hover altitude for generating the highest downwash for the tested helicopter was roughly 25 feet with a payload and 18 to 20 feet without a payload (Zhou et al., 2016).

Similar research has shown that downwash begins to impact the ground at a distance approximately equal to 10 times the diameter of the rotor. The maximum downwash occurs at or below a height approximately equal to 3 times the diameter of the rotor, while outwash reaches a maximum below 0.25 times the diameter of the rotor (see Figure 1) (Baculi et al., 2024; Seddon & Newman, 2011).

Figure 1
Key Rotor Diameter Heights



Helicopter wake can cause significant downwash, with velocities up to 100 feet per sec near the rotor, affecting the ground or water surfaces below and potentially leading to environmental disturbances or damage. Downwash can be estimated mathematically using Equation 1, where V_d is downwash velocity in feet per second, M is the mass of the aircraft, g is the gravitational constant, ρ is the air density, and A is rotor disc area (Baculi et al., 2024; Leishman & Bagai, 1998):

$$V_d = \sqrt{\frac{Mg}{2\rho A}} \qquad (1)$$

Due to the Bernoulli effects, there is an amplification of downwash and outwash velocities (George et al., 1968). Testing has shown that the actual flow speeds exceed V_d and can be calculated using an aircraft-specific geometric amplification factor correction. For downwash, the adjusted flow speed $V_{d(adj)}$ can be calculated with Equation 2 where k^c is the geometric amplification factor (function of all the specific aspects of the aircraft's configuration, such as the size and type of the aircraft's propulsors, their relative positioning, and the altitude of the aircraft above the ground).

$$V_{d(adj)} = V_d(k^c) \qquad (2)$$

To calculate outflow velocity, V_o requires the use of another formula, where k^c is the geometric amplification factor, r is the distance from the vehicle the flow is measured, and ψ is the azimuth of the flow (Civil Aviation Authority [CAA], 2023):

$$V_o = k^c(r, \psi)V_d \qquad (3)$$

Helicopter downwash and vortices from the rotor blades can create a significant, dangerous impact on proximate aircraft operations. Numerous small fixed-wing aircraft accidents have implicated helicopter wake encounters, emphasizing the danger posed by the highly turbulent wakes during takeoff, landing, and taxiing flights in ground effect. The vortex wakes generated by helicopters can persist and pose a rolling-moment hazard to other aircraft, similar in severity to that experienced during airport approach, although the hazard diminishes after several minutes. Helicopter wake can also pose significant dangers to persons and objects on the ground due to the powerful downwash and environmental disturbances they create (Sugiura et al., 2017).

Impact of Downwash on Heliport Operations

Helicopters are often used in confined areas near pedestrians, structures, equipment, ground vehicles, and other aircraft, leading to rotor-wash-related incidents. These incidents frequently occur when helicopters hover close to the ground during takeoff or landing. The flow field of the rotor can be described as a radial wall jet, exiting almost perpendicular to the plane of rotation of the rotor. Several incidents involving severe injury to personnel and significant damage to vehicles have occurred. The downwash of helicopters can also accelerate fine particles, damaging people's eyes, skin, and respiratory systems. Direct damage to structures can include doors being ripped off hinges, defacement and cracking of building facades and windowpanes due to deflection, and fatigue damage to structural elements (Bernardo et al., 2021).

A person's height, weight, training, and awareness directly influence the primary rotor wash risk to pedestrians. The downwash and outwash can lead to loss of balance or to being violently pushed. Urban authorities and councils are beginning to recognize the importance of pedestrian wind comfort and wind safety in city planning. Bernardo et al. (2021) recommended that stakeholders use a standardized measure, such as the Lawson Comfort Criteria, to evaluate pedestrian comfort and safety under different circumstances.

Using fluid modeling of a Bell UH-1 "Huey" helicopter, the researchers studied the downwash effect on pedestrian comfort. To ensure the most effective wake modeling, time-averaged data was used for calculations. The Blade Element Theory (BET) was used to estimate rotor forces, which are calculated based on a rotor being divided into two-dimensional sections. The fluid-modeling approach solved the Reynolds-averaged incompressible isothermal Newtonian form of the Navier-Stokes equations, including a momentum source term from the rotor disc. The "blade-tip effect" was included in the model rotor disc to account for the presence of a relatively strong secondary flow in the form of blade-tip vortices. The result is a variable, unstable flow experienced by persons as wind gusts or shear (Kidwell & Foster, 1966; Petrescu et al., 2017).

Hospital helicopter landing sites (HLSs) are often situated in built-up areas or existing hospital facilities, which exposes the public to the risk of being struck by rotor wash or objects propelled or dislodged by rotor wash. Studies have shown that 50 mph winds are unsuitable for walking, and 35 mph winds are considered the "threshold of danger" for the average population. In people over the age of 50, roughly half were displaced by a gust of 25 mph.

Between 2018 and 2022, nine of the eighteen reported rotor wash occurrences occurred near HLS. The incidents resulted in six injuries, three serious and three minor. In one incident, an elderly pedestrian was blown over by a helicopter. The pedestrian sustained minor injuries, and the pilot was unaware of the potential strength of the rotor wash. Most incident crews were unaware of the incident, and no references were found to exist for rotor wash danger or exclusion areas. Injured pedestrians were mostly 75 or older, and the locations were outside the HLS perimeter fence but within 100 feet of the final approach and takeoff area. Additionally, three events involved damage to third-party property due to debris (ATSB, 2023).

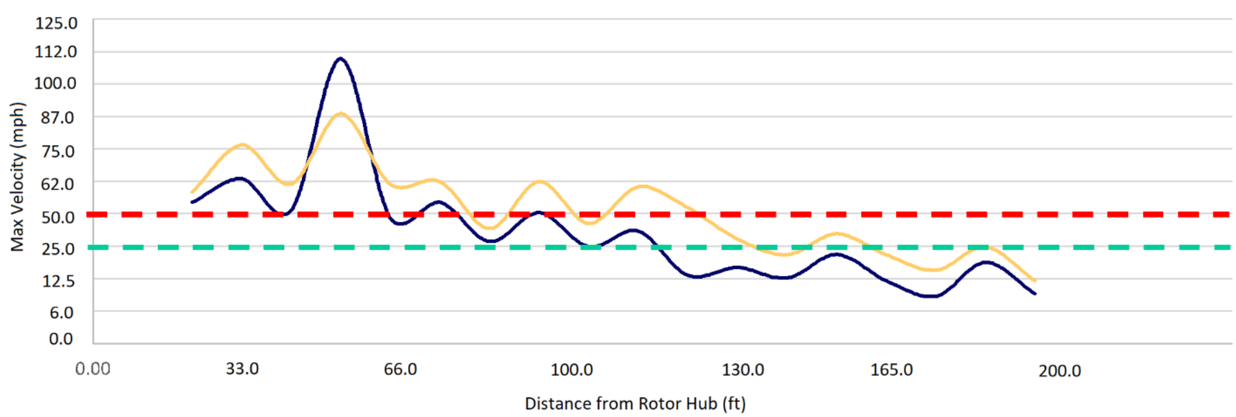
Extensive research has been conducted in the United States by the US Army to study the impact of helicopter downwash on the ground. Analysis of the effects of helicopter downwash on final approach and takeoff areas (FATOs) and hover-taxi sites can facilitate safer helicopter operations. By predicting regions with substantial wind velocity, both airports and helicopter operators can better protect people and property on and adjacent to the heliport. According to the Army's findings, it was recommended that objects and persons should be positioned at a distance equal to or greater than 2 to 3 times the diameter of the rotor (George et al., 1968). This distance allows the downwash velocity to decrease to acceptable levels. Figure 2 shows modeled data on helicopter downwash and outflow velocities. Note that the farthest distance for 50 mph was approximately 125 feet, and for 38 mph, it was approximately 158 feet (JJ Ryan Consulting, 2024). Additional data on peak helicopter rotor wash velocities was provided by ATSB (2023). On average, the range of distances where wind speeds are at or above 50 mph ranged from 26 to

125 feet; for 38 to 50 mph, the range was 72 to 167 feet, and for less than 38 mph, the distance ranged from 92 to 214 feet.

The oil industry is one of the largest users of helicopters, employing the vehicles for transportation between oil platforms and the mainland. The industry's vast experience with helicopters provides significant insights into the best practices associated with safe and efficient heliport operations. BP (2017) provides its offshore employees with training concerning the hazards of working in and around active helicopter operations. The warnings provided are noted to apply to all types of heliports. Several examples of how objects near the helipad can be damaged or cause damage were noted. One example was that a passenger exiting a running helicopter had a 10-pound bag ripped from their hands due to downwash. The bag was immediately sent flying, becoming a dangerous projectile. In another case, several 25-pound bags were blown out of a luggage holding rack adjacent to the helipad. Not only does downwash affect the helipad and its immediate surroundings, but it can also cause issues within passageways or in areas beneath the areas of operation. Moreover, if outwash is forced through tight spaces, such as a hallway, it can increase the speed of the flow due to venturi effects. Lastly, downwash and outwash have been known to violently knock people over. In some cases, persons have been pushed off of elevated structures or have been blown into objects, greatly increasing the severity of injuries (BP, 2017).

Figure 2

Modeled Downwash Velocity Versus Distance from Rotor Hub



Note. Adopted from JJ Ryan Consulting (2024).

Research on New VTOL Aircraft Downwash

Although there have been numerous studies on helicopter downwash and wake, there is limited research on more complex rotorcraft configurations, such as tilt rotors and tandem rotor helicopters. Many of the emerging VTOL aircraft have been designed to have far more complex configurations than has traditionally been assessed in aerodynamic studies. Many of these VTOL designs have four, six, eight, or even more rotors arranged in various locations along the wings and tail surfaces. This radical departure from conventional helicopter aerodynamics suggests that a more complete exploration of the characteristics of VTOL outwash fields is necessary (Brown, 2022a).

Unlike singular, isolated rotors used in helicopters, VTOLs have both more airfoil blades as well as a larger total number of propulsors. Unfortunately, research is limited on the applicability of conventional rotor blade aerodynamics to multiple propeller configurations, particularly in situations when the shared aerodynamic contact between objects plays a substantial role in determining the shape and dynamics of the wake that is produced. A simulation of the aerodynamics of a quadrotor VTOL aircraft out-of-ground effects and in-ground effects showed the complex flow field produced by the four rotors. When the aircraft is in an open environment, the wakes produced by four rotors drop into the airflow underneath the aircraft, creating a cylindrical shape. Nevertheless, the wakes are susceptible to inherent instability, which hinders the organized progression of the wakes and converts them into a chaotic arrangement of vorticity. As the aircraft approaches the ground, the vortices remain around the vehicle for an extended period of time due to their intrinsic instability and their interaction with each other and the ground (Misiorowski, 2019).

Brown (2022a) noted that VTOL aircraft have substantially higher disc loading than conventional helicopters of the same weight, leading to higher downwash velocities from the propulsors. Thus, there are potential risks to ground personnel and property due to VTOL aircraft downwash, which are smaller and lighter than conventional helicopters. The resulting augmentation in downwash velocity will lead to a corresponding increase in outwash velocity. However, this assertion is complicated by various factors, such as the impact of the overall vehicle size on the intensity of the outwash, as well as the influence of the propulsor arrangement on the structure of the outwash field surrounding the aircraft. Data indicated that typical eVTOL downwash velocities are 1.25 to 2.00 times that of conventional helicopters such as the Bell 206B and the R-22. Another challenge to the characterization of VTOL downwash is the lack of geometric amplification factor data for the new aircraft, which inhibits the characterization of the salient properties of the outwash field (Brown, 2022a).

Due to the potential for higher downwash/outwash speeds produced by VTOL aircraft, they may be more susceptible to disturbing ground sediments. Operators and manufacturers must be ready to implement necessary actions to offset the potential for brownout conditions when their aircraft is close to the ground, especially when there are people, passengers, and unsecured objects and structures nearby. This may require that vertiports be paved and regularly swept (Brown, 2022a, 2022b; Chang et al., 2022).

The interaction between the wakes of the several propellers significantly contributes to creating unique flow patterns on the ground below the vehicle, which are dissimilar to those observed among typical helicopters. A higher concentration of test sensors in the testing area is required to accurately measure the outwash produced by certain VTOL designs. This will enable a more precise estimation of the velocities in the outwash region (Brown, 2022a). Interactions among wakes of different motors generate a cumulatively chaotic downwash structure (Chang et al., 2022). Stokkermans et al. (2021) examined the impact of propeller interaction on thrust, power, in-plane forces, and out-of-plane moments in side-by-side and longitudinally aligned configurations on eVTOL vehicles. The study found that interaction effects depend on the propeller angle of attack, with a drop in thrust and power of up to 30% being possible. Detrimental flow interactions will especially be important to consider as the aircraft transitions to and from vertical to forward flight. Compensation for the lost thrust through increased rotational speed resulted in power penalties of 5% to 13%. The results also indicated that downwash streams can interact in ways that can make estimated airflow speeds and directions difficult to predict (Chang et al., 2022; Stokkermans et al., 2021).

Symmetry-breaking occurs within the flow of multi-rotor aircraft when interacting with the ground, leading to small perturbations that can cause the flow to lose its original form. This phenomenon is common in the flows created by multi-rotor aircraft when interacting with the ground. One result of these interactions is the formation of highly unsteady, jet-like structures along the ground plane, known as "ground jets." These jets are the result of secondary, hairpin-like vortical structures within the outwash field. The presence of these jets can cause damage to the surroundings and can be subject to considerable meandering over time. An effect of rotor rotation can be observed in the formation of these jet-like trains of vorticity. The helical nature of these vortices tends to favor the formation of a stronger jet to the sides of the rotors that rotate outward away from the vehicle (Brown, 2022a; Civil Aviation Authority [CAA], 2023).

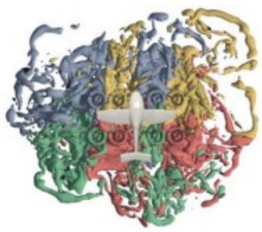
Research by CAA (2023) discovered that VTOLs in both quadcopter-type (e.g., EHang) and lift-jet (e.g., Lilium) configurations generate maximum velocities that were two times faster than those from conventional helicopters. For lift-cruise configurations (e.g., Archer), the difference was even greater, with VTOL outflow velocities of up to two and a half times that of helicopters (CAA, 2023). An example of lift-cruise configured VTOL downwash fields is shown in Figure 3. CAA (2023) also generated outwash hazard zones for different VTOL configurations based on their findings. These are shown in Figure 4.

Numerical estimates show that the mean speeds in the outwash field, at a distance of 2.5 times the system reference dimension (referenced as “D,” which is the largest overall dimension of a VTOL), are at most around 0.67 times the reference velocity. However, for the helicopter with a more standard disc loading, the mean velocities were reduced to about 0.57 times the reference velocity. The observed values align with what was anticipated, and the disparity in average and maximum speeds seen in the outwash underneath the two systems may be mostly attributed to the discrepancy in disc loading between the two aircraft. The impact of the aircraft's size compared to the radius of the cylinder on the outwash measurements seems to have little effect on the average and maximum velocities generated by these specific aircraft designs. This indicates that the impact of aircraft configuration on the geometric amplification factor is notably insignificant in this specific case. However, the unsteadiness in the velocity field does not quite follow the expected pattern – aircraft with high disc loading produces a far greater root mean square velocity than what would be predicted by simply scaling it based on the induced velocity (CAA, 2023).

Existing Guidelines

The Australian Civil Aviation Safety Authority (CASA) published *AC 91-29 v1.1*, which guides helicopter pilots and operators on suitable places to take off and land. It recommends clear final approach/takeoff (FATO) and touchdown/lift-off areas (TLOF) for hazard-free areas, no person within 100 feet (30 m) of the closest point of a hovering or taxiing helicopter, and obtaining appropriate information from owners and authorities. Rotor wash speeds can be expected at 25, 35, and 50 mph for common helicopter types, with strength increasing with increased helicopter weight. The AgustaWestland AW139, involved in nine incidents, shows that beyond the recommended 100 feet non-essential person exclusion area, rotor wash velocities can be between 35 and 50 mph (ATSB, 2023). Figure 5 shows an example of a rotor wash velocity region diagram for an AW139 aircraft.

Figure 3
Simulated Downwash/Outflow for Lift-Cruise eVTOL

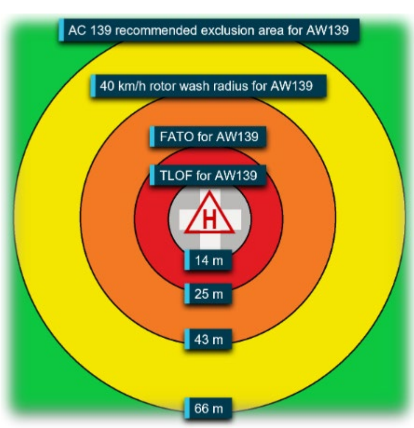


Note. From CAA (2023).

Figure 4
Outwash Hazard Zones

Note. Configurations from left to right: quadcopter, lift-jet, lift-cruise. From CAA (2023).

Figure 5
AW139 Rotor Wash Velocity Regions



Note. Color-coded where warmer colors depict the higher danger levels. From ATSB (2023).

The European Aviation Safety Agency (EASA) has developed a regulatory framework for helicopter downwash effects at facilities with scheduled commercial air. In EASA Member States, heliports with instrument approaches and VFR heliports at certified airports are subject to such regulations. Other public helicopter facilities are subject to individual national rules, which generally require that heliport operators maintain their facilities to applicable standards (private-use heliports are typically not regulated). The EASA has released prototype technical design specifications for vertiports that can accommodate manned VTOL-capable aircraft (Tauszig, 2023). In France, a 2009 regulation defined physical characteristics and visual aids for aviation facilities used exclusively by helicopters with one main rotor axis with an MTOW greater than 1,000 lbs. It also provides standards for obstacles to air navigation at and near these facilities (Civil Aviation Safety Directorate [CASD], 2022).

Per existing guidance, a vertiport Final Approach and Takeoff Area (FATO) is scaled based on the reference or controlling dimension "D." A vertiport should have at least one FATO, which need not be paved. The minimum dimensions of a FATO should be the length of the rejected takeoff distance required for VTOL aircraft (RTODV) for the required takeoff procedure prescribed in the aircraft flight manual or 1.5 x D, whichever is greater. Local conditions, such as elevation, temperature, and permitted maneuvering, may have to be considered when determining the size of a FATO in accordance with EASA standards (CASD, 2022; Crespillo et al., 2023; Tauszig, 2023).

To aid in determining appropriate FATO dimensions, existing guidance recommends that VTOL aircraft manufacturers should provide the downwash velocity measured on a 2 x D circle while the aircraft is hovering at three feet above the surface in no-wind conditions. FATO design ensures safety and minimizes the impact of the surrounding environment on VTOL-capable aircraft operations. It has been recommended that a FATO should be surrounded by a safety area (SA). The SA surrounding a FATO should extend outwards from the periphery for a distance of at least 10 feet or 0.25 x D, whichever is greater (Tauszig, 2023).

Tauszig (2023) suggested facility operators can use theoretical data to determine the recommended downwash and outwash protection, but a study should consider local conditions and personal wind comfort criteria (see Table 1). If the velocity of the downwash and outwash at or within a distance of 2 x D exceeds the recommended maximum, an additional downwash protection area should be created to reduce downwash at the boundaries. Jet blast fences positioned according to local standards can also be used. An extension beyond the 2 x D circle may be necessary to account for significant mean winds. EASA also provided a table of the recommended distance from the edge of the FATO to any adjacent runway or taxiway so as not to damage nearby aircraft. This could also provide a meaningful reference for the safe distance for persons and objects (see Table 2).

In the U.S., the FAA (2012) provided guidance on heliport design in *AC 150/5390-2D*. The design standards include a heliport protection zone (HPZ) for each approach/departure corridor (See Figure 6). The HPZ begins at the FATO boundary and runs horizontally under the flight path for a distance of 280 feet. The purpose of the HPZ is to augment the safeguarding of individuals and assets at ground level. To accomplish this, heliport owners should have jurisdiction over the HPZ footprint. Such control involves the removal and ongoing maintenance of incompatible structures and activities.

The FAA released Engineering Brief (EB) 105 *Vertiport Design,* which provides design guidance for public and private vertiports and vertistops, including modifications to existing helicopter and airplane landing facilities and the establishment of new sites. It was specifically written for VTOL aircraft powered by electric motors and distributed electric propulsion, i.e., eVTOLs. The FAA will update the EB over time to address new aircraft and technologies as more performance data becomes available. The document describes the Reference Aircraft as a VTOL aircraft that combines the performance and design features of nine aircraft that are currently being developed. In the future, the FAA will create a performance-based advisory circular (AC) that focuses on the design of vertiports. This AC will specifically cover advanced operations, autonomy, various propulsion sources, density, frequency, and the complexity of operations facilities. Future guidance will also include aircraft that do not currently comply with the Reference Aircraft mentioned in the EB. It will also address the instrument flight rules (IFR) capabilities and the utilization of multiple FATOs (FAA, 2022).

Table 1
Downwash Protection Standards

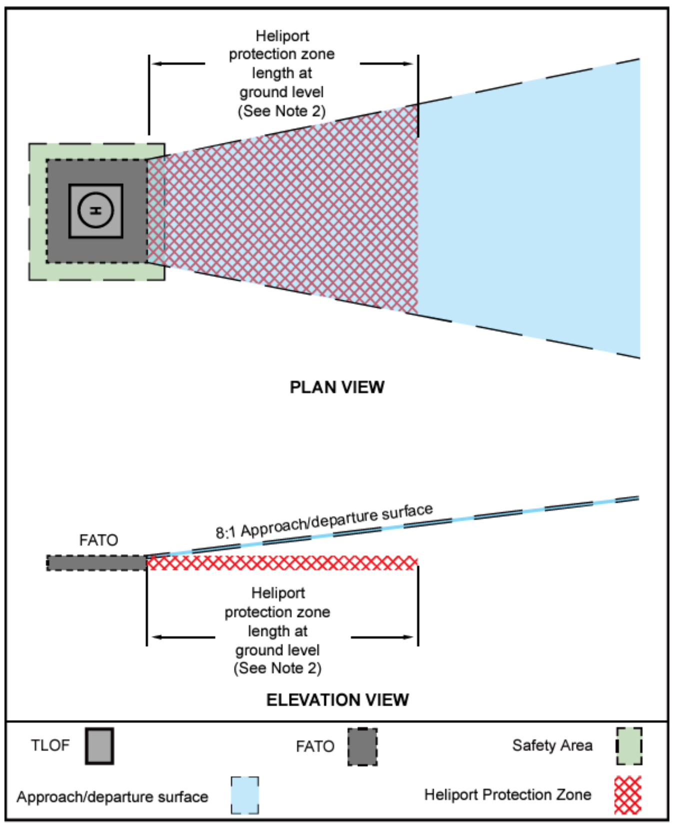
Maximum Downwash Velocity	Type of Area
35 mph	for areas of a vertiport traversed by flight crew or passengers, boarding or leaving an aircraft
35 mph	for public areas, within or outside the vertiport boundary, where passengers or members of the public are likely to walk or congregate
50 mph	for public areas where passengers or others are not likely to congregate
30 mph	for public roads where the vehicle speed is likely to be 50 mph or more
35 mph	for public roads where the vehicle speed is likely to be less than 50 mph
50 mph	for any personnel working near an aircraft
50 mph	for equipment on an apron
60 mph	for buildings and other structures

Note. Adopted from (2023).

Table 2
Recommended Distance Between FATO and Runways/Taxiways

eVTOL Mass	Distance from Edge of FATO
Up to but not including 7,000 lbs	200 feet
7,000 lbs up to but not including 12,700 lbs	400 feet
12,700 lbs up to but not including 22,050 lbs	600 feet
22,050 lbs and over	820 feet

Figure 6
Helicopter Protection Zone (HPZ)



Note. From *AC 150/5390-2D*

Additional Best Practices and Recommendations

Some additional best practices and recommendations are presented in the existing literature. Conservative heliport designers have historically planned for the worst-case downwash profile for the most likely helicopter traffic to make visits. For a surface-level heliport operating exclusively light air ambulance helicopters, a minimum 100-foot downwash zone should be established, keeping it clear of people, property, or parked vehicles. If heavy or extra-heavy helicopters are used at surface level, the downwash zone should be larger, typically between 165 feet and 215 feet for the largest helicopters. As a general rule, no one and nothing should be within three rotor widths of a helicopter when it is generating lift (CASD, 2022).

Vertiport design should take into account the inherent complexity of the outwash problem, especially when it comes to planning the areas for landing and takeoff. Furthermore, it is imperative to establish operating protocols for situations when these aircraft are flown in close proximity to the ground. Overly simplistic explanations of the impact of the outwash, such as creating a circular area around the aircraft where it is unsafe to be at the closest distance, do not align with numerical simulations that indicate certain new VTOL vehicles will create unevenness in the outwash field. The scenario becomes more intricate when a variety of VTOL aircraft, varying in size, weight, and configuration, are anticipated to operate from the same site. Both the shape and strength of the outwash field created below a multi-rotor aircraft, when operated close to the ground, are likely to be particularly sensitive to the details of the aircraft's configuration (Chen et al., 2021).

Offshore helicopter operations present unique challenges due to mission demands, oil and gas exploration and production facilities, and flight environments. Industry organizations like the Helicopter Safety Advisory Conference (HSAC) and the Offshore Committee of the Helicopter Association International (HAI) have developed guidelines to reduce risks in offshore operations. These practices provide aviation and oil and gas industry operators with useful information in developing procedures to avoid hazards in VTOL operations and at vertiports. Recommended practices for offshore helicopter operations include passenger management at heliport facilities, including a designated waiting area, unloading and clearing of passengers and cargo, and supervision of unloading and loading processes. A standardized visual signal on the vertipad/vertiport can help provide a positive indication to an approaching VTOL of the status of the landing area. Clear communication procedures should be in place to connect the pilot with the ground crew and passenger handling staff (FAA, 2024).

Scales Used to Describe the Safety and Tolerability of Wind Speeds

There are a variety of scales used to describe wind speeds and how certain velocities impact persons and objects. These scales can be used to identify wind speeds that may potentially be dangerous or harmful. The Lawson Comfort Criteria is a set of standards that quantify an individual's experience within a local wind microclimate. These criteria consider factors such as wind strength, clothing, environment, expectation, temperature, humidity, and sunshine. The criteria are based on the mean hourly wind speed, with green being acceptable, yellow being tolerable, and orange being unacceptable (see Table 3). The criteria depend on the mean hourly wind speed, with the threshold wind speed not exceeding more than 5% of the time (Bernardo et al., 2021).

Table 3

Lawson Comfort Criteria

Wind Effect	Threshold: MPH	Stationary	Walking	Transit (e.g., car)
Calm	0			
Felt on Face	<4			
Leaves Move	9			
Dust Raised	14			
Felt on Body	18			
Hard to Walk	22			
Trees Moving	33			
Dangerous	45			

Note. Adopted from Bernardo et al. (2021).

The Beaufort Scale was initially calibrated to British Navy commander Beaufort's assessment of wind effects on a full-rigged man-of-war, identifying thirteen states of wind force and ranking them from zero to twelve. While the scale does not directly indicate the precise wind speed, it is valuable for approximating wind properties across a wide region and may be employed to predict wind conditions in the absence of wind measuring devices. The Beaufort Scale can also be used to assess and depict the impact of various wind speeds on items on land or on the ocean. In addition, the scale has been adapted to determine at which point it becomes unsafe to walk (Meaden et al., 2007; National Parks Association of New South Wales, n.d.).

Method

In this study, investigators aimed to establish safety guidelines for the protection of people and property on the ground from VTOL downwash and outwash. The study used representative VTOL aircraft data to calculate the theoretical forces and characteristics of the airflow generated during the takeoff and landing phases. This data was then compared to established wind speed scales, which categorize wind speeds based on their potential hazardous impact. By carefully analyzing this information, the researchers were able to propose a process for determining safety zones and buffer areas around vertiports.

Data

Existing equations used to describe airflows around rotorcraft, along with data on how such flows dissipate under typical conditions, were amalgamated into formulas that theoretically describe induced flow velocities generated by VTOL aircraft. The formulas were then used to map estimated flow speeds on and around a landing site. Wind speed scales were also utilized to assist in determining speeds that are reasonable and safe for persons and property in proximity to a vertiport. In addition, an example based on the limited performance data available for an eVTOL prototype was calculated. Data for existing helicopters were also used to guide the outcomes of this study.

Procedure

First, a consensus was established from existing literature concerning the maximum wind speeds that might be reasonable, tolerable, and safe for pedestrians to experience when standing or walking in a vertiport operational area. The same was accomplished concerning the presence and location of objects. The distance at which flow speeds dropped below the aforementioned "safe" threshold was selected for placement of a protection zone border. Additional guidance on a potential buffer zone was determined by considering the altitude at which airflow exceeding "safe" speeds would begin to interact with the ground and at what distance this would occur from the vertipad assuming a specific VTOL approach glidepath.

Results

Maximum Safe Wind Speed

While the speeds determined to be safe for persons to stand and walk vary slightly across different scales, the variations provide general guidance on what may be acceptable. The most conservative and protective action would be to take the lowest indicated speed as the limit for passenger and ground crew operations. The most conservative is the Lawson scale value of 18 mph. Although the scale states that 22 mph is the limit for walking without trouble, the color scale indicates that 18 mph is the upper limit of the caution range when someone is physically walking. This conservative value provides additional protection for persons over the age of 50, as recommended by ATSB (2023).

Calculations to Determine Safety Areas at Vertiports

Using public data provided by various manufacturers, example dimensions were created to mimic one of the designs currently under flight testing. Using this data, the estimated downwash velocity for an individual rotor was calculated. The assumptions were:

- Rotor diameter = 9.5 feet
- Maximum gross weight = 4,000 lbs
- Density = Sea Level
- Number of lift rotors: 12
- Design dimension (D) = 39 feet

Under such conditions, an estimated downwash velocity was calculated to be 57 mph (using equation 1). Using a conservative outwash multiplier of 2x, the outwash velocity would approximate 114 mph ($V_{d(adj)}$). These calculations align with the findings by Brown (2022a; 2022b) and CAA (2023). As noted by Brown (2022a, 2022b), the interaction of outflows from the different rotors creates a complex airflow environment, which may result in jet-like flows in certain directions, as noted by the extensions in danger zones displayed in Figure 4. Thus, speeds in excess of 114 mph may be possible in the vicinity of these jet pathways and would be dependent on the geometric amplification factor.

The mean reduction in outwash velocity was estimated (based on Brown, 2022a, 2022b) to be 13.2% of the initial velocity for every dimension D equivalent distance or $V_{reduction} = 0.132(D)$. The new speed value is then calculated by equation 5.

$$V_{new} = V_{d(adj)} - V_{reduction} \qquad (5)$$

Therefore, for example, the estimated outflow velocity at a distance of 39 feet (1 x D) from the vehicle would be 99 mph. It should be noted that the outwash begins to expand laterally once the vehicle is within 1 x D in height and reaches a maximum when at or lower than 0.25 x D or around 10 feet. Although no guidance is yet available on how to calculate the impacts of jet flows, it was assumed that jet flows would carry further. A conservative assumed reduction of airflow speed was estimated to be at a rate of half that of normal conditions, calculated as $V_{reduction(jet)} = 0.066(D)$. These calculations and estimations provide some preliminary insight into the potential safety zone sizes for vertiports. Equations 6 and 7 can be used to determine the least conservative safe distance (D_{safe}). Note: The number “18” in the equation is the upper wind speed limit for pedestrians determined from the literature. Users can substitute alternative values as necessary.

$$D_{safe} = D[\frac{(V_{d(adj)} - 18)}{0.132(V_{d(adj)})}] \qquad (6)$$

$$D_{safe(jet)} = D[\frac{(V_{d(adj)} - 18)}{0.066(V_{d(adj)})}] \qquad (7)$$

As noted by Brown (personal communication, May 15, 2024), the dimension "D" is an arbitrary value and is not analogous to helicopter downwash and outwash speeds defined as functions of rotor diameter distances. Brown (2022a) recommended that downwash/outwash calculations consider variations in VTOL designs and be as conservative as possible due to the highly variable nature of VTOL wake. Brown (2022a) outlined an alternative means of estimating safe distances that consider the number and sizes of VTOL propellers. Thus, a D that takes these factors into account, D_{cc}, or dimension-conservative correction, should be used to calculate the most conservative safe distance. D_{cc} is defined as propeller radius (*p*) multiplied by the number of propellers (*n*) (equation 8).[1]

$$D_{cc} = p \; x \; n \qquad (8)$$

For the example aircraft used in this study, the most conservative estimated outflow velocity at a distance of 57 feet (1 x D_{cc}) from the vehicle would be 99 mph. It should be noted that the outwash begins to expand laterally once the vehicle is within 1 x D_{cc} in height and reaches a maximum when at or lower than 0.25 x D_{cc} or around 15 feet. Although no guidance is yet available on how to calculate the impacts of jet flows, the same formula for calculating jet-flow reduction rate was used, substituting D_{cc} for D: $V_{reduction(jet)} = 0.066(D_{cc})$. These calculations and estimations provide some preliminary insight into the potential safety zone sizes for vertiports. The most conservative safe distances for normal (D_{c_safe}) and jet flows ($D_{c\_safe(jet)}$) require the substitution of D_{cc} in place of D, yielding equations 9 and 10.

$$D_{c\_safe} = D_{cc}[\frac{(V_{d(adj)} - 18)}{0.132(V_{d(adj)})}] \qquad (9)$$

$$D_{c\_safe(jet)} = D_{cc}[\frac{(V_{d(adj)} - 18)}{0.066(V_{d(adj)})}] \qquad (10)$$

An approach or inner buffer area dimension formula is based upon the fact that downwash peaks begin at approximately three times the rotor diameter or D for eVTOLs represented by $3(D)$. A normal approach glideslope of 3:1 would mean that every 3 feet of distance is accompanied by a 1-foot change in height. Thus, the distance at which downwash increasingly becomes hazardous (D_{dwa}) would be three times the height of $3(D)$ or mathematically represented as $3(3(D))$. The distance at which downwash begins to impact the ground (D_{dwg}) is 10 x the height of $3(D)$ or mathematically represented as $3(10(D))$. Equations

[1] If propellers are stacked in tandem, such as on the EHang, use the number of propeller pairs instead of the total number of propellers.

11 and 12 show the least conservative approach to downwash and downwash buffer zone dimensions, respectively.

$$D_{dwa} = 3(3(D)) \qquad (11)$$

$$D_{dwg} = 3(10(D)) \qquad (12)$$

For more conservative height calculations, use D_{cc} in lieu of D in equations 11 and 12. Table 4 shows the current FAA guidance for vertiport dimensions based on dimension D. For comparison purposes, Table 5 shows the least and most conservative values based upon the equations presented in this study. Based on the calculations conducted in this study, existing FAA vertiport design criteria appear to be insufficient as they lack minimum standards for downwash and outwash safety.

Table 4
Vertiport Dimensions for Example Aircraft: Available FAA Standards

Element	Dimension (ft)
TLOF	39
FATO	78
Safety Area	117

Table 5
Additional Recommendations Vertiport Safety Areas Dimensions: Example Aircraft

Formula	Least Conservative Dimension (ft)	Most Conservative Dimension (ft)
Normal Flow	246	359
Approach Downwash	351	513
Jet Flow	492	720
Downwash Buffer Area	1,170	1,710

Note. All calculated dimensions exceed that of current FAA vertiport recommended distances.

Discussion

The emergence of new VTOL aircraft promises a revolution in urban transportation. However, ensuring the safety of people and property on the ground from the effects of VTOL downwash and outwash is paramount. A critical component of the vertiport development process is the thorough understanding of induced airflows as a result of VTOL operations and the potential impact these may have on persons, property, other aircraft, and structures on the ground. VTOL propellers generate powerful airflows downward (downwash) and outward (outwash) during takeoff, landing, and hovering. Downwash can create strong winds that can dislodge objects, damage structures, and potentially injure people. Outwash can also pose a hazard by pushing debris or loose objects into the path of the aircraft or nearby personnel.

Currently, vertiport design regulations regarding safety area dimensions are rapidly evolving. The Federal Aviation Administration (FAA) released initial guidelines in 2022, specifying minimum dimensions for the touchdown and liftoff (TLOF) area and the final approach and takeoff (FATO) area. The European Union Aviation Safety Agency (EASA) offers similar guidelines with slight variations. The areas outlined in FAA/EASA guidelines are crucial for safe aircraft operations but do not explicitly address the need for additional protections for ground personnel and objects. Moreover, the current dimensions do not take into account the type or size of VTOL that may operate at the vertiport, although, in all fairness, such information is likely to remain unknown or uncertain over the near term. However, considering that safety requirements appear to be dependent upon the configuration and size of VTOLs, there may need to be restrictions on the type and size of aircraft that can operate at a specific vertiport depending upon the sizes of the TOLF, FATO, Safety Areas, and other designated areas of protection.

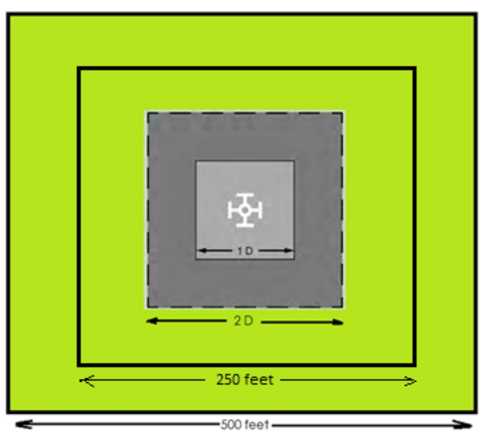
Safety areas extending beyond the FATO are vital for mitigating downwash and outwash effects. The most rational and responsible means of addressing this issue is to adopt a data-driven design approach. The dimensions of additional safety buffers should be determined based on a combination of factors. VTOL characteristics such as the size, power output, and propeller configuration of the specific eVTOL aircraft operating at the vertiport should be considered. Limits or standards for downwash and outwash should be set to help vertiport designers factor this important element into the planning process. Regulatory bodies ought to establish maximum allowable downwash velocities for different areas surrounding the vertiport, such as passenger walkways or public roads. Environmental factors should also be considered, as wind speed and direction, as well as obstructions and their geometries, can influence downwash effects, requiring adjustments to safety area size.

While safety is the paramount concern, it is also reasonable to expect that there be a balance between safety and efficiency. Larger safety areas undoubtedly enhance safety, but they come at a cost. Extensive land use can make vertiport development in urban areas challenging. Sizing can be optimized through computational modeling that can predict downwash and outwash patterns for specific eVTOL models, allowing for targeted safety area design. Wind mitigation structures such as strategically placed wind fences or deflectors can reduce the impact of downwash on surrounding areas. This simple design change could eliminate the need for larger vertipads and their surrounding buffers. Intelligent landscape design can also help dissipate airflows and provide additional protection for people and objects.

The findings of this study indicated that the current FAA (2022) standards may be inadequate for protecting persons and objects on and near vertiports. Moreover, the data shows that vertiport design should include downwash and outwash mitigation features. Also, designs that include means of segregating people and objects from areas influenced by airflow. This could include covered or enclosed walkways, walls, or tunnels. Areas influenced by airflow should be kept clear of unsecured objects, such as baggage and debris; items can easily become lethal projectiles if sent airborne by outwash or downwash. Consideration should also be given to the potential mix of aircraft that might operate at the vertiport because of potential differences in the characteristics of downwash and outwash. Perhaps a "worst case scenario" stance should be taken to maximize protection areas so as not to get into a situation where design features are inadequate for protecting passengers and property.

Although this study utilized theoretical data on airflows, it provides a foundation for assessing the altitudes and distances at which VTOL downwash and outwash may influence its surroundings. Available data indicated that the FAA safety area/zone dimensions are likely insufficient to adequately protect personnel and property on the ground. The least conservative safety zone dimensions (rounding up) could be defined as 250 feet for the inner safety zone, 500 feet for the outer safety zone, and 1,200 feet for a buffer zone. These values appear to be reasonable for a simple vertiport. For example, Volocopter (2024) suggested that a small vertiport could be approximately 6,700 square feet. The outer zone in this study would only occupy 2,500 square feet. A proposed basic vertiport design is shown in Figure 7. Calculating the most conservative safety zone dimensions, using Dcc could be defined as 360 feet for the inner safety zone, 720 feet for the outer safety zone, and 1,710 feet for a buffer zone. The outer safety zone would encompass just over 11 acres of land.

Figure 7
Proposed Vertiport Dimensions: Least Conservative



Note. The inner area is the TLOF (1 x D), the next box is the FATO (2 x D), the inner box is the inner safety area (ISA) (250 feet), and the outermost box is the outer safety area (OSA) (500 feet).

While this study provides some basic guidance on the effects of downwash and outwash on vertiports and surrounding areas, the question remains as to what types of activities or personnel would be allowed into the inner and outer safety areas. Furthermore, it must be determined when persons or objects can enter the safety areas. For example, service personnel may be permitted to begin handling the aircraft once it is on the ground and the motors turned off, but passengers will only be allowed in the areas if the propellers have stopped and the is no resulting airflow. If there are more than one vertipad, standards must be established on safe distances between pads as well as who or what might be allowed in the safety areas if an eVTOL is operating on an adjacent pad.

Another step that is necessary is to determine what land uses would be compatible with vertiports and the various distances from the vertiport that may be acceptable for such uses. This is particularly important for densely developed landscapes so as not to randomly place a vertiport that is surrounded by incompatible land uses. It is likely, however, that land use standards for vertiports will be less stringent than those for airports and will need to be flexible and customizable. For example, there could be a small buffer between the vertiport and development except in the area over which eVTOLs will approach and land at the vertipad. Land use restrictions may be applicable underneath the flight path but not in the other portions of the vicinity.

Conclusion

In summary, this study was able to provide theoretically based equations to identify the velocity of VTOL downwash and outwash on and around vertiports. The results provide a framework for predicting downwash and outwash characteristics of various VTOL types and configurations. This information can be used to define safety zones on vertiport surfaces and in the surrounding environment. These zones should account for minimum safe distances for personnel and ground infrastructure to mitigate the risk of injury or damage from high-velocity airflows. Also, the potential for dust and debris mobilization by the downwash should be considered. The study highlighted the importance of considering environmental factors, such as wind direction and speed, in determining safe zones for VTOL operations. By incorporating these variables into safety protocols, the risk of accidents or damage can be significantly reduced.

Coupled with the guidance of the FAA and other studies, the findings of this study can assist in the development of land use compatibility standards for vertiports. Overall, this research contributes valuable insights that can improve the safety and efficiency of VTOL operations in urban environments. Additionally, the research findings can aid in the establishment of regulations and policies for VTOL operations to ensure public safety. Collaborating with industry experts and policymakers can further enhance the integration of eVTOLs into urban airspace. By fostering collaboration between various stakeholders, including industry experts and policymakers, the integration of eVTOLs into urban airspace can be streamlined. This multi-faceted approach will not only enhance safety and efficiency but also pave the way for the future of air mobility.

Recommendations

The findings of this study logically lead to recommendations for future research. As more data becomes available on eVTOL downwash and outwash, such data should be included in standards and guidelines for vertiport design as well as local land use. This data may be sourced from simulation, but it is paramount to collect data directly from the aircraft whilst operating. By combining the findings of this study with those on vertiport safety, noise, and public sentiment, the foundation is laid to begin crafting land use compatibility guidelines and zoning standards. These are best developed under the consultation of industry experts, including manufacturers, airports, urban planners, aviation planners, and the public.

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Safety in Focus: Analyzing Aviation English Competency Among Ab-Initio Pilots

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The proficiency in Aviation English among ab-initio pilots raises significant concerns within the aviation industry, prompting the need for thorough research to explore the root causes, issues, and consequences. This investigation specifically concentrates on the competence of ab-initio pilots in Aviation English within a Turkish foundation university, utilizing a mixed-methods sequential explanatory design. The results obtained from the modified 'Competency in Aviation English' questionnaire, encompassing responses from 90 student pilots, along with focus group interviews involving 45 participants, highlight notable apprehensions, particularly in speaking and listening skills. The study aims to evaluate the competency of ab-initio pilots in Aviation English and shed light on existing issues by identifying root causes and their extensive impacts. Participants underscore challenges in maintaining fluent speech during emergency situations, comprehending diverse accents, and managing workload and noise. Root causes encompass language proficiency, cultural factors, fear of making mistakes, teaching styles, and a lack of practice materials. Adverse consequences involve stress, compromised flight performance, and safety concerns. The study advocates for tailored pedagogical approaches, proposing enhancements in proficiency exams, customized programs for ab-initio pilots' better integration of flight and language training. In addition, realistic fluency goals, stress management, and technology integration are crucial for effective training.

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Introduction

Safety, as defined by Aurino (2000), is primarily a mindset, with attitudes serving as its foundation despite the supportive role of formal structures and protocols. From a corporate perspective, safety is defined by the absence of accidents. The primary responsibility of safety management is accident prevention since accidents not only cause financial losses but also damage the company's reputation. To achieve this objective, safety measures are implemented to prevent accidents, including safety equipment, devices, and various behavioral activities (Li & Guldenmund, 2018). Managing safety effectively involves a comprehensive effort, requiring organizations to define safety requirements and establish a solid framework (Strutt et al., 2006). However, despite these efforts, tragic accidents persist in the aviation industry, often attributed to miscommunication.

Communication between pilots and air traffic controllers is a cornerstone of aviation safety, as highlighted by Kanki and Palmer (1993). The consensus among industry professionals, as articulated by Wulle and Zerr (1997), is that effective communication is just as crucial as technical proficiency for flight safety. Yet, communication errors remain a significant threat to aviation safety, influenced by factors such as language proficiency and adherence to standard phraseology, as observed by Molesworth and Estival (2015). Miscommunication has been a critical factor in over 2,000 aviation-related accidents that resulted in fatalities, particularly since the mid-1970s (Alharasees et al., 2023).

Examining 508 case studies from the National Transportation Safety Board's database on airplane crashes, it was revealed that 49 accidents were partially linked to various forms of miscommunication. This implies that around 10% of commercial aviation incidents involve critical miscommunication, significantly influencing the outcome of accidents (Hillis, 2019). Generally, pilots and ATCOs find it difficult to maintain efficient radiotelephonic communication, especially when they are not native English speakers. There are instances when radio communications between aircraft operators are not successfully completed, which could lead to dangerous circumstances(Alharasees et al., 2023). In noisy, high-pressure situations, non-native English-speaking pilots may struggle with language issues despite using standard terminology and having strong language skills. Additionally, varying accents can cause air traffic controllers to misinterpret pilots' readbacks or requests, and pilots might mishear controllers' instructions (Estival & Molesworth, 2012). In his study focusing on the obstacles non-native English speakers experience in aviation, Strugis (2018) found that non-native pilots face significant challenges in comprehending aviation content in English, particularly in mastering vocabulary and aviation acronyms, overcoming accent-related difficulties, and achieving fluency and comprehension for proper phraseology and radio communication. Similarly, Tiewtrakul and Fletcher (2010) investigated how 'non-native English' influences communication in pilot–air traffic control interactions. Their research focused on recordings from the approach phase at Bangkok International Airport. The findings indicate that communication errors, particularly those involving misunderstandings by pilots, are notably more frequent when both the pilot and the controller are non-native English speakers, especially when the messages are complex or involve numerical information.

Accidents in aviation history also demonstrate the vital importance of English proficiency for non-native pilots. For instance, in 1996, a mid-air collision in India resulted in 349 deaths when the Russian-speaking crew of the Kazakh Ilyushin misinterpreted instructions from an Indian air traffic controller due to poor English skills (Tajima, 2004). Similarly, in 1993, a commercial aircraft in China crashed during its final approach, killing 12 people because the pilot did not understand the English warning "pull up." (Wald, 1996). These tragic accidents highlight significant gaps in English proficiency among non-native pilots and display the critical role of English proficiency in aviation safety.

While some research has been conducted on various aspects of Aviation English (Cushing, 1997; Alderson, 2009; Cookson, 2009; Estival & Molesworth, 2012; Aiguo, 2008; Roberts & Orr, 2020; Kay, 2019; Bieswanger et al., 2020), there remains a notable gap concerning a specific examination of ab-initio pilots' competency in Aviation English and its implications for safety.

Roberts and Orr (2020) and Bieswanger et al. (2020) have contributed valuable insights into language education for ab-initio flight training. Additionally, Treadaway's study (2021) focuses on developing a reliable diagnostic language assessment for ab-initio pilots prior to their flight programs. In Turkey, there is one important study (Demirdoken,2019) that examines the needs of Aviation English learners at the tertiary level and another one (Dinçer & Demirdöken,2023) that focuses ab initio pilots' perspectives on the integration of simulation in Aviation English course. Nevertheless, there is no study specifically analyzing the competency of ab initio pilots in Aviation English, the issues they have, and the causes and consequences of the potential problems from a safety-centric point of view in literature. Considering the scarcity of studies focusing on ab-initio pilots, this research is significant since it is the first study to pave the way for understanding ab-initio pilots' perceptions about their competency in Aviation English, issues they have, and additionally, the causes and effects of these potential issues.

Accordingly, the primary aim of this research was to evaluate the proficiency of ab-initio pilots in Aviation English at a Turkish foundation university. This study sought to shed light on existing issues, identify root causes, and understand their extensive impacts. Secondly, it aimed to facilitate better learning programs, curriculum enhancements, and instructional approaches in training institutions to address communication-related issues more effectively. In line with these aims, the researchers investigated the following research questions to provide relevant answers.

Q1. What are the perceptions of ab-initio pilots at a foundation university in Turkey towards their competency in Aviation English?

Q2. What are the issues ab-initio pilots at a foundation university in Turkey have in Aviation English?

Q3. What do the ab-initio pilots at a foundation university in Turkey think about the causes and effects of the issues they have in Aviation English?

Literature Review: Competencies Required in Aviation English

Acquiring effective communication skills in a second language requires a comprehensive understanding of linguistic, sociolinguistic, and socio-cultural aspects (Saleh, 2013). In the aviation industry, safety is critical, and proficient communication can prevent disasters. In a study, Sexton and Helmreich (2000) found that over 70% of reports submitted to the Aviation Safety

Reporting System revealed major failures in interpersonal communication. Therefore, mastering Aviation English and navigational communication complexities is essential. In this context, three important competencies emerge: linguistic competence, communicative competence, and interactional competence.

Linguistic competence pertains to the innate ability of native speakers to construct "well-formed sentences" (Thornbury, 2006, p. 37). While crucial, linguistic competence alone does not ensure effective communication but sets the stage for standardizing communication protocols and fostering interoperability in the international aviation context. Engaging and active grammar instruction during ab-initio training can boost learners' motivation and language acquisition progress (Yoon et al., 2004). A strong grasp of grammar contributes to oral proficiency and speaking skills (Tuan, 2017; Wahyuni et al., 2015). Nevertheless, to ensure effective communication within specific contexts, grammar instruction must be supplemented with communicative competence to enable learners (Hymes, 1972; Canale & Swain, 1980).

Communicative competence is the ability to effectively convey messages and understand others within specific contexts, which involves real-world application and appropriate language usage beyond merely accurate grammar (Hymes, 1972). Canale and Swain (1980) expanded on this concept, highlighting grammatical, sociolinguistic, and strategic competencies essential for communication. Various instructional approaches, such as role-play, drama activities, task-based learning, and group work, have been shown to effectively enhance communicative competence among learners. The ICAO Manual (2010) stresses the importance of communicative competence in aviation, emphasizing the need for pilots and controllers to understand communication concepts for safe operations. Ultimately, developing strong communicative competence is crucial for ab-initio pilots to ensure effective communication in high-stakes aviation situations.

Interactional competence is the ability to collaboratively share communication responsibilities among all participants, adapt to various situations, and utilize diverse communicative resources effectively (Kim & Elder, 2009). Unlike communicative competence, which emphasizes individual speakers' abilities within a social setting, interactional competence focuses on collaborative efforts involving all participants. It also emphasizes the ability to infer each other's thoughts and intentions, extending beyond verbal communication to encompass written, digital, and non-verbal exchanges. Interactional competence can also be viewed as being engaged in social interactions and professional pursuits, emphasizing the strategic use of language resources, including aviation phraseology (Douglas, 2000). Studies by Kecskes et al. (2017) and Park (2017) highlight the importance of equipping learners with interactional competence from the outset of language learning, incorporating nonverbal communication elements, and providing ample opportunities for authentic practice. Xiao (2016) emphasizes the need for targeted instruction in interactional competence specific to the target language, which could prove useful in preparing learners for real-world language use scenarios during training.

The focal point is that combining linguistic, communicative, and interactional competencies in ab-initio training is important since they all prepare student pilots to confidently communicate in real-world aviation scenarios.

Methodology

A mixed-methods sequential explanatory design was employed to investigate the research question in this study. This approach combines both quantitative and qualitative methodologies, as it is widely acknowledged that the integration of these two approaches offers a more comprehensive understanding of research problems compared to using either approach alone (Creswell & Plano, 2007).

Data Collection and Analysis

In this research, two methods were utilized for data collection: a questionnaire assessing competency in Aviation English and semi-structured focus group interviews. To gather quantitative data, a Competency in Aviation English questionnaire based on Demirdöken's (2019) work was adapted and administered to participants. This questionnaire was the main instrument for data collection. It consisted of 18 items to assess learners' perceptions of their proficiency in Aviation English. Participants were asked to indicate their level of agreement using a 5-point Likert scale. The questionnaire was administered through Google Forms and reached 110 students online. In total, 90 students completed the survey. The quantitative data analysis for this study was conducted using Minitab 17. Initially, demographic and educational characteristics among participants were examined. Following this, an in-depth analysis was carried out on the data collected from the second part of the questionnaire, which specifically focused on learners' perceptions of their competency in Aviation English. This analysis included measures such as means, standard deviations, and percentages. Furthermore, a two-sample t-test was applied to differentiate between the responses of students whose English language proficiency was below the B2 level (the prerequisite for commencing undergraduate studies) and those who indicated proficiency at the B2 level or higher before undertaking the Aviation English course. The purpose of this statistical test was to determine whether there were any significant differences in perceptions of Aviation English competency between these two distinct groups.

Additionally, semi-structured individual interviews were conducted to gather qualitative insights. The focus group discussions were conducted online through Zoom meetings. With the aim of encouraging active participation in a comfortable environment, the learners were divided into nine separate groups, each consisting of five students. Each focus group meeting lasted approximately 25 minutes. The focus group discussions underwent complete transcription prior to entering the analysis phase. These transcripts were meticulously examined to explore keywords and identify recurring themes, aiming to reveal valuable insights into the perspectives and views of the participating students.

Respondents of the Study

Table 1.
Demographic Information Related to the Participants in the Study

	Variables	N	%
Age	19	2	2.2%
	20	10	11.1%
	21	21	23.3%
	22	27	30%
	23	20	22.2%
	24	7	7.8%
	25	2	2.2%
	26	1	1.1%
Nationality	Turkish	82	91.11%
	Azerbaijani	3	3.33%
	Spanish	1	1.11%
	Turkish-British	1	1.11%
	Uzbek	1	1.11%
	Pakistani	1	1.11%
	Egyptian	1	1.11%
Gender	Male	73	81.1%
	Female	17	18.9%
Flight Hours	10-60	39	43.33%
	60-110	25	27.28%
	110-160	9	10%
	160-210	2	2.22%
	210 and above	15	16.67%
License Type	Currently in the process of obtaining PPL	1	1.1%
	PPL	46	51.1%
	Holding a PPL and recently completed ATPL theoretical courses	29	32.2%
	ATPL	14	15.6%
Learning Experience	1-3 years	7	7.8%
	3-6 years	21	23.3%
	6-10 years	26	28.9%
	More than ten years	36	40%
Learning Circumstances	I have learned English in a language school in Turkey.	25	28.1%
	I have learned English as part of compulsory education.	50	56.2%
	I have learned English abroad.	11	12.4%
	I have learned English with a tutor.	3	3.4%

Note: N: Number of responses, %: Percentage of responses

As presented in the table, the age range varied, with the largest group falling between 21 and 22 years old, each comprising 23.3% of the sample. Most of the participants were Turkish (91.11%), with smaller percentages from various other nationalities. Gender distribution was predominantly male (81.1%). Flight hour experience ranged widely, with 43.33% reporting 10-60 hours and 51.1% holding a Private Pilot License. In terms of their English language learning experience, 40% had over ten years, while 56.2% learned English as part of compulsory education, and 28.1% learned it in a Turkish language school.

Findings and Discussion

Discussion of Findings Regarding Research Question 1

The first research question was designed to explore how ab-initio pilots at a foundation university in Turkey perceive their competence in Aviation English. To gain meaningful insights into this research question, the data collected from participants via a questionnaire was subjected to statistical analysis using Minitab software version 17.

Table 2.
Participants' Own Perceptions of their English Language Proficiency Level Prior to taking Aviation English Courses

	Variables	N	%
Speaking	A1 Beginner	0	0.00%
	A2 Elementary	7	7.78%
	B1 Intermediate	39	43.33%
	B2 Upper-Intermediate	27	30.00%
	C1 Advanced	16	17.78%
	C2 Proficient	1	1.11%
Listening	A1 Beginner	1	1.11%
	A2 Elementary	1	1.11%
	B1 Intermediate	37	41.11%
	B2 Upper-Intermediate	32	35.56%
	C1 Advanced	19	21.11%
	C2 Proficient	0	0.00%
Reading	A1 Beginner	0	0.00%
	A2 Elementary	4	4.44%
	B1 Intermediate	31	34.44%
	B2 Upper-Intermediate	35	38.89%
	C1 Advanced	19	21.11%
	C2 Proficient	1	1.11%
Writing	A1 Beginner	1	1.11%
	A2 Elementary	3	3.33%
	B1 Intermediate	37	41.11%
	B2 Upper-Intermediate	38	42.22%
	C1 Advanced	11	12.22%
	C2 Proficient	0	0.00%

Note: N: Number of responses, %: Percentage of responses

As shown in the table, a significant finding emerges regarding students' perceived proficiency levels in speaking and listening skills, which are highly crucial in Aviation English. Data reveals that 43.33% of participants assessed their speaking proficiency at the B1 level, with 7.78% at the A2 level before undertaking Aviation English courses. Similarly, a majority (41.11%) rated their listening skills at the B1 level, while only 2.2% rated them at A1 or A2 levels. These findings suggest potential gaps in linguistic competence, indicating that a notable portion of participants may not meet the necessary language proficiency standards for effective communication in aviation.

This finding aligns with feedback from focus groups, where many students, despite undergoing preparatory programs, felt they had not reached the B2 level, a prerequisite for undergraduate studies. Addressing this issue involves two critical considerations. Firstly, the institutional proficiency exam, while evaluating reading, writing, and listening, lacks a direct assessment of speaking skills. Incorporating a section focusing on speaking skills can provide a more comprehensive evaluation of students' proficiency levels. Secondly, although the exam aligns with Common European Framework levels, ensuring the curriculum and materials effectively establish a solid foundation for B2 level proficiency across all four skills is crucial.

Table 3.
Participants' Personal Thoughts on the Most Difficult Skill to Develop in English

	Variables	N	%
Skills	Listening	12	13.3%
	Speaking	43	47.8%
	Reading	5	5.6%
	Writing	30	33.3 %

Note: N: Number of responses, %: Percentage of responses

According to the data in Table 3, the majority of students (47.8%, n=43) identified speaking as their biggest challenge. Writing was noted as the primary difficulty by 33.3% of students (n=30), while 13.3% (n=12) found listening to be the most challenging skill. Only a small percentage (5.6%, n=5) viewed reading as the toughest skill to develop in English.

Considering the widely recognized difficulty of speaking in a foreign language and the time required for speaking proficiency to develop (Luama, 2004), it is not surprising that most learners (51.11%) perceived their speaking skills to be below B2 level. The second most prevalent challenge reported was writing, noted by 33.3% of students (n=30). As outlined by Dastgeer and Afzal (2015), students predominantly acquire English language skills in academic settings, often relying heavily on memorization and reproducing learned information during exams rather than practical application. Notably, the Aviation English program lacks emphasis on writing skills, compounding the challenge. Interestingly, only 13.3% (n=12) of participants identified listening as their most difficult skill, despite 42.21% rating their listening skills below B2. Focus group discussions revealed a perception among learners that listening skills improve through practice and experience, making it more manageable compared to speaking and writing. These insights underscore the complexities of linguistic competence, with speaking identified as particularly challenging and raising concerns about communicative competence. A T-test was performed to determine whether there existed a statistically significant distinction between the group who rated their speaking and listening skills below B2 and the group who rated these skills as B2 and above in the questionnaire. The outcomes of the test are outlined below.

Table 4.
Speaking Comparison of The Groups

	Students at B2 level and above (*n*=44)		Students below B2 (n=46)			
					t	*p*
	M	*SD*	*M*	*SD*		
Scores	4.128	0.731	3.594	0.702	3.53	0.001

Note: M: Mean, SD: Standard Deviation, t: T-Value, p: P-Value

Based on the table's analysis, the initial group comprising students at the B2 level and beyond consisted of 44 participants, with a mean of 4.128 and a standard deviation of 0.731. Conversely, the second group, consisting of students below B2, comprised 46 participants, with a mean of 3.594 and a standard deviation of 0.702. The two-sample t-test revealed a t-value of 3.53 and a p-value of 0.001.

Table 5.
Listening Comparison of the Groups

	Students at B2 level and above (*n=51*)		Students below B2 (n=39)			
	M	*SD*	*M*	*SD*	*t*	*p*
Scores	4.066	0.727	3.580	0.724	3.15	0.002

Note: M: Mean, SD: Standard Deviation, t: T-value, p: P-value

The same methodology was employed to evaluate participants' listening skills based on their self-reported levels. As indicated in the table, the initial group consisted of 51 participants reporting B2 level listening skills and above, with a mean of 4.066 and a standard deviation of 0.727. Conversely, the second group comprised 39 participants reporting listening skills below B2, with a mean of 3.580 and a standard deviation of 0.724. The two-sample t-test conducted for the listening skills produced a t-value of 3.15 and a p-value of 0.002.

Table 6.
Listening and Speaking Comparison of the Groups

Metric	**Value**
Regression Slope Speaking	0.010214218327170364
Regression Intercept Speaking	3.917429622907424
Regression Slope Listening	0.013325037168858371
Regression Intercept Listening	3.6949081188808672
Correlation Speaking	-0.026043866854448317
Correlation Listening	-0.09771011811935984
Covariance Speaking	-0.014220636839558601
Covariance Listening	-0.05264720079091682
Variance Speaking Above B2	0.5667468558984529
Variance Speaking Below B2	0.5024230982851549
Variance Listening Above B2	0.5113232424846037
Variance Listening Below B2	0.5422599346901111

Table 6 shows key metrics such as regression, correlation, covariance, and variance derived from the data analysis. For speaking proficiency above the B2 level, the regression slope is 0.010214, and the intercept is 3.917430. For listening proficiency, the regression slope is 0.013325, and the intercept is 3.694908. The correlation coefficient between students above and below the B2 level is -0.026044, showing a very weak negative relationship. For listening proficiency, the correlation coefficient is -0.097710, which also shows a very weak negative relationship. For speaking proficiency, the covariance between students' scores above and below the B2 level is -0.014221. For listening proficiency, the covariance is -0.052647. For speaking proficiency, the variance score above the B2 level is 0.566747, and for scores below the B2 level is 0.502423. For listening proficiency, the variance above the B2 level is 0.511323, and below the B2 level is 0.542260.

In brief, the analysis of both skills reveals a notable contrast, suggesting a statistically significant difference between the groups. These findings also emphasize the importance of language proficiency in skills development. Students with higher proficiency levels demonstrate greater competence in both areas, highlighting the need for interventions to support students with lower proficiency levels.

Table 7.
Frequencies of Participants' Responses, Mean Score, and Standard Deviation of Items in the Questionnaire

Item	1	2	3	4	5	Mean	Standard Deviation	N
1. I can speak Aviation English fluently.	1	5	25	46	13	3.72	0.816	90
2. I can pronounce Aviation English terms correctly.	0	0	18	54	18	4.00	0.632	90
3. My Aviation English accent is intelligible to other aviators.	0	9	16	44	21	3.85	0.888	90
4. I can have good control of sentence patterns in Aviation English.	0	3	27	51	9	3.73	0.679	90
5. My knowledge of Aviation English terms is enough to understand audio files related to Aviation English.	0	4	22	56	8	3.76	0.667	90
6. My knowledge of Aviation English terms is enough to express myself to other aviators.	0	3	17	52	18	3.94	0.720	90
7. My knowledge of Aviation English terms is enough to explain an emergency situation.	0	3	28	41	18	3.82	0.782	90
8. I can communicate with other aviators effectively.	0	4	16	52	18	3.93	0.742	90
9. I can maintain fluent speech even in emergency situations.	0	12	45	27	6	3.30	0.781	90
10. I am a fluent English speaker in terms of aviation.	0	8	29	42	11	3.62	0.810	90
11. I can respond to the questions of other aviators appropriately.	0	4	20	52	14	3.84	0.728	90
12. I can maintain effective communication when I speak Aviation English.	0	3	24	50	13	3.81	0.713	90
13. I can easily understand a speech related to aviation.	0	3	20	48	19	3.92	0.748	90
14. I can ask for clarification when I do not understand other	0	1	9	48	32	4.23	0.667	90

people in terms of Aviation English.								
15. I can easily inform other aviators on a topic related to aviation.	0	2	25	47	16	3.85	0.723	90
16. My knowledge of Aviation English terms is enough to explain a problem.	0	4	20	52	14	3.84	0.728	90
17. I can ask for confirmation when a misunderstanding occurs.	0	0	6	30	54	4.26	0.573	90
18. I can express myself in black and white easily.	0	4	19	47	20	3.92	0.777	90

Note: 1: Strongly Disagree, 2: Disagree, 3: Neither agree nor disagree, 4: Agree, 5: Strongly Agree, N: number of responses.

The respondents' perceptions of their competencies in Aviation English offer valuable insights into their strengths and areas for improvement. Notably, Item 17, concerning the ability to ask for confirmation during misunderstandings, received the highest mean score of 4.26. A significant majority, 30 individuals (33.33%), agreed, and 54 individuals (60.00%) strongly agreed with this statement, indicating a strong inclination among learners to address misunderstandings proactively. Similarly, Item 14, focusing on asking for clarification when encountering difficulties, received a high mean score of 4.23. Here, 48 participants (53.33%) agreed, and 32 participants (35.56%) strongly agreed, reaffirming learners' confidence in resolving issues through effective communication.

These findings are supported by feedback from focus group meetings, where participants emphasized the importance of effective communication and their readiness to seek clarification. As highlighted by Uplinger (1997), the absence of non-verbal cues in pilot-air traffic controller communication underscores the necessity of clarification techniques for effective communication. These results suggest that current training methods have equipped learners with essential coping strategies aligned with the demands of Aviation English, demonstrating a strong inclination toward interactional competence.

However, concerning fluency in emergency situations, the data presents a different picture. Item 9, regarding the ability to maintain fluent speech during emergencies, received the lowest mean score of 3.3. While 12 participants (13.33%) expressed disagreement, and 45 participants (50.00%) remained neutral, indicating a lower perceived ability among participants in maintaining fluency during critical moments. Focus group interviews further revealed concerns among participants regarding fluency, particularly when communicating with non-Turkish people, highlighting potential challenges in interactional competence during emergencies.

Similarly, Item 10, addressing proficiency as a fluent English speaker in aviation, received a mean score of 3.62, with diverse opinions among participants. While many agreed or strongly agreed, 8 participants (8.89%) disagreed, and 29 participants (32.22%) remained neutral. Focus group discussions revealed difficulties in maintaining fluency during Aviation English lessons, especially in activities such as describing pictures or participating in group discussions.

Discussion of Findings Regarding Research Question 2

The second research inquiry aimed to identify challenges faced by ab-initio pilots in Aviation English through a series of focus group interviews with 45 students.

Table 8.
Issues

Issue	Percentage of Participants Affected
Rate of Speech	66.67%
Fluency	71.11% (lesson fluency)
	86.67% (emergency scenarios)
Regional Accents	86.67%
Lack of Knowledge	22.2%

As presented in the table, the initial concern raised by participants pertained to the rate of speech. Among the 30 participants (66.67%), a predominant issue was encountered with the pace of speech, particularly during the initial phase of flight training. Participants expressed difficulty in comprehending transmissions due to the rapid delivery of a substantial amount of information. Despite ICAO's (2010) recommendation for a steady speech rate not exceeding 100 words per minute in radio communication, this challenge persists. Sayer (2013) suggests that miscommunication arises not from the absence of distinct breaks between words but from insufficient time allotted to recipients for processing and comprehending information. Therefore, in ab-initio pilot training, Air Traffic Controllers (ATCs) must exercise caution in allowing inexperienced pilot trainees adequate time to grasp information.

The second issue discussed was fluency. Participants reported fluency-related challenges in various contexts. A majority (71.11%) expressed concerns about sustaining fluent speech in Aviation English lessons, particularly during activities such as describing pictures, summarizing topics through self-recordings, and engaging in group discussions. This finding suggests that students may require more time to digest new input and more opportunities for practice before reaching the production stage. Additionally, participants may prioritize accuracy over fluency in these activities, hindering their speech flow. Concerning emergency scenarios, 86.67% of participants indicated potential challenges in sustaining fluent speech, particularly when communicating with non-Turkish people. As stress and time pressure in emergencies can negatively impact fluency and communication performance, there is a dire need for accurate and reliable assessment of communicative competence to meet language standards for student pilots.

The third issue raised was regional accents. Although accent was not a concern when communicating with Turkish ATCs, 86.67% of participants found transmission recordings with various regional accents difficult to understand in the Aviation English course. However, this challenge aided in improving their listening skills through extensive practice. Lightfoot (1982) noted that accents impact transmissions due to pronunciation variations across languages, influencing non-native English speakers' speech. Challenges in pilot-ATC transmissions escalate when both parties are non-native English speakers, substantially reducing comprehension when attempting to understand unfamiliar accents. Therefore, it is crucial to help students gain awareness of regional accents, study their common phonological features, and dedicate ample time to practice both inside and outside the classroom.

The final issue discussed was the lack of knowledge and experience. 22.2% of participants reported challenges in busier airfields due to only having basic knowledge of radio communication, leading to confusion and stress when encountering unfamiliar ATC phrases. Comprehensive training under supervision is essential in aviation (Wilpert & Thoralf, 2013). Ab-initio pilots should be equipped with necessary phrases, terminologies, and alternatives during theoretical training, followed by ample opportunities for practice through role plays and simulation exercises.

Discussion of Findings Regarding Research Question 3

The primary aim of the third research question was to investigate the root causes and resultant effects of challenges encountered by ab-initio pilots in mastering Aviation English. In the table below, the causes and effects are summarized with their percentages.

Table 9.
Causes and Effects

Causes	**Percentage**	**Effects**	**Percentage**
Language proficiency	66.67%	Stress	86.67%
Cultural factors	13.33%	Impact on flight performance	26.67%
Stress and fear of making mistakes	60.00%	Safety concerns	71.11%
Issues with teaching style	31.11%		
Lack of practice materials	22.22%		
Multitasking and workload	68.89%		
Noise	24.44%		

Causes

When participants were asked about the root causes behind their issues, they identified seven main factors: language proficiency, cultural influences, stress and fear of errors, teaching style, lack of practice materials, multitasking and workload, and noise.

The key discovery concerning language proficiency reveals that 66.67% of students acknowledged that language-related challenges impact their performance in Aviation English class, including activities like short presentations, discussions, self-recording, and ATC transmissions. Furthermore, the t-test results demonstrated a significant statistical contrast between students who assessed their speaking and listening skills below B2 level and those who rated them at B2 or above. These findings underscore two pivotal points that warrant attention. Firstly, it is imperative to reconsider the language proficiency criteria for undergraduate program admission. Rather than relying solely on institutional proficiency exams, which fail to evaluate speaking skills, institutions should mandate high scores on standardized exams. Research by Dusenbury and Bjerke (2013) indicates a positive correlation between higher English proficiency scores on standardized exams and student success in flight school, suggesting improved performance on oral exams and reduced training hours required.

Secondly, there is a need to reassess the design and content of preparatory programs. A study by Nishikawa and Nawata (2019) revealed that only 20% of ab initio flight students at a Japanese institution found intensive academic English preparation classes generally beneficial for flight training skills. These programs, focusing primarily on writing instruction, do not adequately prepare students for the linguistic demands of flight training, crucial for ab initio pilots. Hence, there is an urgent necessity to develop programs tailored specifically to address the language requirements of ab initio flight training.

Although these participants noted that language-related issues affected their in-class performance, they added that these challenges did not hinder their flight performance due to the straightforward nature of standard phraseology. However, when asked about the potential impact of their language background and linguistic issues during flight training in a different country with native English instructors and ATCs, 51.11% anticipated difficulties.

13.33% of participants mentioned cultural influences on their language learning and practice, highlighting the need for increased exposure to the target language through technology integration, cultural awareness components, and peer support groups.

Stress and fear of mistakes were cited by 60% of participants, emphasizing the importance of stress management workshops and opportunities for practical experience in simulated environments.

31.11% of participants identified issues with the teaching style, advocating for interactive learning approaches, constructive feedback, and the provision of ample practice materials outside the class.

22.22% mentioned a lack of practice materials and suggested that additional practice materials for studying radio communication outside of class would have been beneficial. They noted that this could have reduced their stress levels when encountering unfamiliar terms on the radio.

The most prevalent cause, multitasking and workload, was cited by 68.89% of participants, highlighting the need for guidance on task prioritization and realistic simulations to enhance multitasking skills.

Finally, 24.44% reported that engine noise and radio chatter negatively impacted their ability to use Aviation English, suggesting investment in quality headsets with noise-canceling features and exposure to authentic materials during training.

Effects

During the interviews, participants cited three adverse effects, with stress being the most prominent. A staggering 86.67% noted feeling stressed when unable to understand Air Traffic Control (ATC) instructions or readbacks correctly, particularly when faced with harsh criticism for mistakes. Additionally, 57.78% reported stress during Aviation English classes when grappling with practice ATC transmission recordings. Stress, a known contributor to accidents in civil aviation, particularly affects ab-initio pilots, who are more responsive to flight-related stressors compared to experienced instructors (Kilic & Ucler, 2019). Comprehension-related issues exacerbate this stress among students, necessitating targeted strategies for mitigation.

Furthermore, 26.67% mentioned that stress adversely affected their flight performance, aligning with historical records linking stress-ridden pilots to diminished performance. Instructors play a crucial role in providing support to manage stress levels, emphasizing a holistic approach to pilot training that encompasses technical skills, humanistic values, and psychological well-being.

Moreover, 71.11% expressed concerns about potential safety issues stemming from language-related challenges during international flights, particularly in emergency situations. While miscommunication is common in emergencies, the participants recognized the importance of comprehensive training strategies. These strategies should include scenario-based activities to simulate real-life emergencies and cross-cultural communication training to address diverse backgrounds and regional accents in the aviation industry.

Implications

The findings of this study not only highlight current issues, their underlying causes, and consequences but also offer valuable insights into the future trajectory of Aviation English training. As a result, there is a compelling need for deliberate actions in this specific domain. These significant implications are presented below.

Pedagogical Implications

- The institutional proficiency exam should undergo comprehensive evaluation to ensure a thorough assessment of all four language skills—listening, speaking, reading, and writing—aligned with the B2 level of the Common European Framework of Reference. Meticulous preparation for this exam is crucial.
- Rather than offering an English for Academic Purposes (EAP) program, which emphasizes academic reading, writing, and listening skills, ab-initio pilots could benefit from a program specifically tailored to the language skills needed during training.
- Collaboration between flight instructors and ground instructors teaching communication and Aviation English classes is essential to ensure alignment of content covered in both

flight training and language classes. This coordinated approach enhances learning experiences and supports practical application during flight training.

- Due to the scarcity of commercial textbooks dedicated to aviation English, a custom-designed program and materials developed in-house should prioritize learners' needs.
- Setting realistic objectives for language learning and improvement rather than prioritizing native-like fluency is crucial. Instructors can encourage learners to prioritize fluency to ensure meaningful engagement in language use (Brown, 2007) and enhance communicative competence.
- A multifaceted approach is necessary to help students develop fluency, including interactive multimedia resources, simulated scenarios, peer-to-peer communication activities, and role-plays. Additionally, tailored approaches to language training, with additional support mechanisms for weaker students, could prove beneficial in enhancing fluency levels across the board.
- Investment in high-quality headsets with noise-canceling features is essential, along with exposure to authentic materials in Aviation English classes to familiarize students with real-world conditions.
- Providing guidance on prioritizing tasks and gradually introducing and building up the complexity of tasks can assist students in managing workload. Realistic simulations can further enhance their ability to manage multiple tasks simultaneously.
- It is advisable to offer students abundant resources beyond class time to strengthen their skills through practice, thus laying a solid foundation. Extensive training materials, along with clear instructions, should be provided in accordance with ICAO guidelines.
- Since language anxiety can hinder effective communication in a second language, especially when engaging in radio communication or cockpit interactions (Sirin,2023), incorporating language anxiety awareness training and stress management workshops into the aviation program can empower learners with effective coping mechanisms under stressful conditions.
- Integration of technology, such as virtual reality simulations and online language exchange platforms, can bridge the gap in exposure to English-speaking environments. Peer support groups focusing on language practice can also be beneficial.
- Equipping ab-initio pilots with necessary phrases, terminologies, and ample opportunities for practice during theoretical training is essential. Role plays and simulation exercises can aid in practical application.
- Adopting a holistic approach to regional accents, including exploration of common phonological features and ample practice opportunities, is crucial.
- Tailored approaches to language training in mixed-ability groups, along with additional support mechanisms for weaker students, can enhance fluency.
- Ground and flight instructors should prioritize constructive feedback that fosters improvement without inducing unnecessary stress. Positive reinforcement fosters a culture that views mistakes as opportunities for growth.
- Integration of cultural awareness components into the curriculum can raise students' awareness of cultural issues.
- The absence of standardized assessment tools for non-native students poses challenges to safety. There is a clear necessity for official criteria and standardized testing methods designed specifically for admission into flight schools.

- Flight schools and universities must strictly adhere to language proficiency standards set by aviation regulatory bodies to maintain safety standards.

Limitations and Recommendations for Further Research

This study has certain limitations. First and foremost, it focuses on 90 ab-initio pilots from a university in Istanbul, Turkey, limiting its generalizability. Although this sample size is adequate for the context and Turkey, it is small compared to all ab-initio pilots in JAA Countries. Furthermore, the study leans towards qualitative methods despite a mixed approach, reducing its applicability. Also, the researcher's close relationship with participants as their Aviation English instructor may have influenced responses. Future research should involve a larger, diverse sample, employ longitudinal designs, mitigate researcher influence, explore additional variables, and encourage collaboration among Aviation English professionals in Turkey and other countries who are active in civil aviation.

Conclusion

The study revealed significant concerns that might cause safety issues, particularly in speaking and listening skills, with a substantial number of students falling below the B2 level, as presented in Table 2. Data revealed that 43.33% of participants assessed their speaking proficiency at the B1 level, with 7.78% at the A2 level before undertaking Aviation English courses. Similarly, a majority (41.11%) rated their listening skills at the B1 level, while only 2.2% rated them at A1 or A2 levels. These findings suggest potential gaps in linguistic competence, indicating that a notable portion of participants may not meet the necessary language proficiency standards for effective communication in aviation. Additionally, potential gaps in the current proficiency exam emphasized the necessity for a more comprehensive assessment of speaking skills and a reevaluation of the curriculum and materials to establish a solid foundation in all four language skills. Moreover, the majority of the participants (47.8%, n=43) identified speaking as their biggest challenge. These insights demonstrate the complexities of linguistic competence, with speaking identified as particularly challenging and raising concerns about communicative competence. The analysis of both speaking and listening skills also revealed a notable contrast, suggesting a statistically significant difference between the groups (P-value 0.001 for speaking skills and 0.002 for listening skills). On a positive note, participants demonstrated a strong inclination to proactively address misunderstandings, adhering to the requirements of effective radio communication. However, maintaining fluent speech in emergency situations received the lowest mean score, indicating a perceived challenge among participants. Fluency-related issues were reported in both aviation English lessons and radio communication. Concerns about understanding different accents, particularly in recordings, were evident. Lack of knowledge and experience posed challenges in radio communication, impacting flight performance and safety awareness. Focus group interviews supported this, revealing concerns about fluency and emphasizing the need for attention in training. Additionally, difficulties in the initial phases of flight training were noted, with those completing ATPL theoretical classes finding the issue less problematic but anticipating challenges in their professional careers. Root causes behind the reported issues included language proficiency, cultural factors, fear of mistakes, teaching style, lack of practice materials, multitasking, workload, and noise. Negative consequences of language-related issues included stress, negative effects on flight performance, and safety concerns. A significant majority of participants reported experiencing stress when unable to understand ATC or practice recordings, and some noted a subsequent impact on their flight performance and safety awareness.

In brief, the study highlights complex challenges faced by ab-initio pilots in Aviation English training, calling for tailored approaches. Pedagogically, it suggests improvements in proficiency exams, custom programs for ab-initio pilots, and better alignment of flight and language training. Emphasis on realistic fluency goals, stress management, and technology integration is also crucial. Consequently, there is a compelling need to put deliberate actions into operation in this specific domain.

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Effect of Integrated Method of Flight Instruction on Student Pilot Performance

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With the prevailing use of integrated cockpit displays in flight training, flight students have shown to have difficulty controlling the aircraft and maintaining situational awareness. The integrated method of flight instruction is a proven tool to help transfer the skills necessary from visual to instrument flying, but it may also distract the student and lead to the formation of dangerous habits. This research study looked at whether the integrated method of flight instruction helps or hinders a student at the beginning of flight training. A quantitative experimental research design was used to measure situational awareness, reaction time to a traffic conflict, and ability to maintain the altitude and heading of participants instructed with visual and instrumental cues. Participant scores were analyzed using independent samples t-tests to measure the expected results that students exposed to visual and instrumental cues have significantly different scores. The results showed that participants instructed with visual cues had a significantly higher level of situational awareness in the subcategory of orientation, an overall higher level of situational awareness, and a quicker reaction time to a potential mid-air collision. The results showed that the very onset of training may not be the appropriate time to introduce instrumental cues.

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Introduction

Flight training instruction is a relatively new field that has garnered significant attention in modern research. Government agencies, commercial organizations, and individual researchers have dedicated substantial hours and fiscal resources to ensure the routine and safe operation of aircraft. In pursuit of this goal, government transportation regulators have prioritized perfecting the training procedures and processes involved in learning to fly an aircraft. Much of the research into learning theories used in modern flight instruction techniques stems from foundational work by psychologists since the 19th century, who studied how people learn. These theories are thoroughly outlined in the Federal Aviation Administration's (FAA) *Aviation Instructor's Handbook* (FAA, 2020).

The integrated method of flight instruction has been subject to study since the development of instrument flight rules (IFR) flying. The FAA has sponsored several research studies on the integrated method of flight instruction to identify the optimal minimum hour requirements for a pilot to obtain an instrument rating (Childs, 1986). Additionally, Situational Awareness (SA) has been a focus for human factors researchers, the FAA, and major airlines (Wright & O'Hare, 2015). With the increasing complexity of aircraft displays and automation systems, concerns over pilots' SA have grown steadily.

Methods of Flight Instruction

For the purpose of this study, flight instruction methods refer to the techniques Certified Flight Instructors (CFI) use to communicate information about the aircraft's attitude in relation to the external environment, particularly the ground. These methods include the use of visual cues, instrumental cues such as Basic Attitude Instrument (BAI), the integrated method of flight instruction, and, more recently, Integrated Sensory Flying (ISF).

Visual Cues Based Flight Training

Visual, or "contact" cues are the first method used in teaching a student how to manipulate flight controls and manage an aircraft's attitude. CFI uses visual cues by guiding students to reference a "sight picture" or an "out-the-window" view to control the aircraft.

Instrument Based Flight Training

In contrast, Basic Attitude Instrument (BAI) training teaches students to manage an aircraft's attitude by solely relying on flight instruments, extracting information from various displays to understand the aircraft's conditions during flight. CFIs teach the BAI technique by guiding students to interpret and cross-reference flight instruments, enabling them to visualize the aircraft's orientation in space and apply the necessary flight controls based on this information. Research suggests that early integration of instrument training benefits students in attaining an instrument rating. However, other studies also suggest that early integration of instrument training can be difficult and potentially hazardous to student learning and overall flight safety.

Integrated Flight Instruction Method

The combination of visual cues and BAI training is known as the integrated method of flight instruction. The integrated method of flight instruction has been used to facilitate the learning and transference of piloting skills from visual to instrument flying. The integrated method of flight instruction was first shown to be an effective technique in flight training by the Boeing School of Aeronautics in 1935 (Childs, 1986). A later study conducted by Ritchie and Michael (1955) demonstrated that transferring skills from instrument flying to visual flying was easier than teaching visual skills from scratch. Further research by Ritchie and Hanes (1964) found that delaying the introduction of instrumental cues can hinder student pilots when pursuing an instrument rating later in their careers.

As the aviation industry evolved, the necessity of instrument flying increased due to growing air traffic and weather-related challenges, which demanded greater consistency from pilots regardless of external conditions. As a result of increased instrument flying, many studies looked to assess the performance of instrument-rated pilots based on when instrument training was introduced in their flight training curriculum. The results of these studies demonstrated that the early introduction of instrument cues benefits the student tremendously in achieving an instrument rating in the least amount of training time (Childs, 1986). Childs (1986) indicated that there are benefits of applying the integrated method of flight instruction early on during flight training. According to Childs, early instrument training can also improve overall pilot skills in the face of sensory illusions (1986).

The integrated method of flight instruction is a proven technique in accelerating the time required for training students who intend to continue to an instrument rating (Childs et al., 1981; Holmes & Childs, 1982). However, there remains limited research on the optimal timing for safely introducing and implementing this method during flight training. Introducing instrument training too early may pose risks related to Visual Situational Awareness (VSA), as pilots must still look outside beyond their instruments while flying (Childs, 1986; Lane, 2009). Due to the limitations of the integrated flight instruction method, the Integrated Sensory Flying (ISF) technique was developed to address visual and instrument flying in today's complex training environments. ISF encourages students to use sensory information—such as sight, sound, and feel—to analyze their flying environment, with instruments providing a secondary confirmation to visual cues. By keeping the student's focus outside the cockpit, ISF enhances VSA, ensuring that the early introduction of instrumental cues does not diminish their ability to maintain situational awareness.

Challenges of the Technologically Advanced Flight Deck

Advanced systems concepts adapted from military and airline operations are increasingly finding their way into General Aviation (GA) aircraft. The rapid development of new equipment and technologies has resulted in more complex GA flight decks (Lane, 2009). A new term has been developed to describe aircraft fitted with modern equipment: Technically Advanced Aircraft (TAA). TAAs are aircraft equipped with an IFR approved GPS, autopilot, and moving map displays (Lane, 2009). While these systems can greatly enhance safety and efficiency when used correctly, they have also been shown to negatively affect less experienced pilots, leading to distraction and proficiency gaps due to inadequate training standards (Lane, 2009).

Integrated cockpit displays, or glass cockpits, first emerged in the aviation industry at the end of the twentieth century. Glass cockpit technology quickly became the standard avionics package on newly built aircraft of all designs and purposes (National Transportation Safety Board [NTSB] 2010, as cited in Wright & O'Hare, 2015). Traditional flight instruments consisted of six electro-mechanical individual units: the airspeed indicator, altimeter, vertical speed indicator, attitude indicator, heading indicator, and rate-of-turn indicator. Unlike traditional flight instruments, the glass cockpit consolidates all of this information onto a single LCD screen, called the Primary Flight Display (PFD). The PFD is typically accompanied by a Multifunction Display (MFD), which can be used to display navigation maps and other information. However, studies have shown that operating an aircraft configured with a glass cockpit can be significantly more challenging and result in less situational awareness (SA) than a conventional round dial aircraft due to the increasing amount of information required to be interpreted by the pilot (Wright & O'Hare, 2015). While experienced pilots may find these glass cockpit advancements beneficial, they can pose greater challenges for novices and student pilots (Lane, 2009). One solution is to ensure pilots receive thorough ground training on the equipment before operating a TAA.

Situational Awareness (SA) in Glass Cockpit Based Flight Training

SA involves gathering information about the surrounding environment, combining it with knowledge and experience, and making complex decisions based on the pilot's objectives (Endsley, 1995). Endsley (1995) categorized SA into three levels: the perception of environmental elements, the comprehension of the current situation, and the projection of future status. Though SA measurement is most commonly applied in aviation, it is relevant to any field requiring dynamic decision-making.

Measuring SA performance in dynamic environments has the advantage of being both objective and nonintrusive. Simulations, combined with computer software, allow for data collection without disturbing the participant's situational awareness. External tasks, embedded tasks, and global measures can help create a comprehensive understanding of SA through measurement devices such as the Situational Awareness Global Assessment Technique (SAGAT) (Endsley, 1995). SAGAT measures SA by pausing a simulated flight, asking a series of questions, and scoring the participant's responses.

Although glass cockpits are generally perceived to enhance SA, research suggests that they may actually reduce situational awareness for GA pilots. (Adams et al., 2001, as cited in Wright & O'Hare, 2015). Wright and O'Hare (2015) found that participants trained in traditional round dial instrument aircraft achieved higher scores on the SAGAT test than those who trained in glass cockpit setups. Although there was no statistically significant difference in the groups' performance on the SAGAT test, the study highlights that integrated cockpit may can impact the situational awareness of novice student pilots.

Comparison of Visual and Instrumental Cues Based Flight Training

Flight instruction often occurs in complex training environments, requiring a multifaceted approach to effectively convey information to students. CFIs must choose whether to emphasize visual or instrumental cues during the initial stages of training. As seen in Figure 1, visual cues present the student feedback on the attitude of the aircraft using sight pictures in relation to the horizon, while instrumental cues (seen in Figure 2) provide the same information in the form of an artificial horizon or attitude indicator.

Figure 1
Visual Cue Based Flight Training

Figure 2
Instrumental Cue Based Flight Training

During the onset of flight training, CFIs typically choose between teaching students using visual cues or the integrated method of flight instruction. Initially, students must first become familiar with flying the airplane safely while looking outside of the cockpit to navigate and avoid traffic. However, as newer aircraft are often equipped with integrated cockpit displays, students can become overwhelmed by the complexity of these systems. The task saturation and demands of flying a glass cockpit aircraft led to students spending a lot of time looking inside the cockpit at the screens instead of outside for visual cues. This may impact students' situational awareness and overall safety of flight. One of the most significant problems is that novice student pilots who fly airplanes with complex flight displays spend too much time looking inside the cockpit and have a reduced amount of situational awareness as opposed to student pilots who fly airplanes with less complicated flight displays. Introducing the integrated method of flight instruction too early may inadvertently lead to negative flying habits.

Summary

Research supports the integrated method as a valuable tool, particularly for students pursuing an instrument rating, showing that skills learned in instrument flying transfer positively to visual flying. However, the complexity of integrated displays can hinder situational awareness, increasing the tendency for students to focus inside the cockpit. While experience is necessary to master instrument flying, visual techniques like Integrated Sensory Flying (ISF) are considered safer for beginners. Although research suggests that the integrated method and BAI should be introduced early in training, the optimal timing remains unclear.

This research study examined the effects of visual versus instrumental cues on beginner student pilots learning to fly aircraft with integrated cockpit displays. The purpose of this study is to identify whether the integrated method of flight instruction helps or hinders students' situational awareness and performance when flying aircraft with complex flight displays and highlight the advantages and disadvantages of each technique.

Methodology

This research study was conducted at Embry-Riddle Aeronautical University (ERAU) in the Advanced Flight Simulation Center. This study utilized an experimental research design by measuring the effects of instructional techniques on situational awareness. The experiment incorporated surveys, reaction time assessments in response to potential Near Mid-Air Collisions (NMAC), and evaluations of participants' ability to maintain aircraft orientation. The independent variable, instructional technique, had two levels: visual cues and instrumental cues. The dependent variables of this study were participant scores on a situational awareness test, reaction time to an NMAC, and scores on the ability to maintain altitude and heading.

Population/Sample

Participants were selected using convenience sampling from the population of graduate and undergraduate students at ERAU. In order to participate in the study, participants were required to have no prior flight training experience. The sample size of the study was 30 participants, with 15 randomly assigned to each group.

Procedures

At the start of the session, each participant was briefed on potential hazards, including possible discomfort from motion sickness and being in a confined cockpit. The informed consent form was then reviewed and signed by participants who agreed to proceed.

Before the simulated flight commenced, the participant was shown a pre-recorded PowerPoint presentation lecture covering the basic information necessary for operating an aircraft. The presentations for the two groups (Visual and Instrument) were identical except for the cues referenced to control the aircraft. The visual group was only shown external visual cues, and the instrument group was only shown in-cockpit instrumental cues necessary for flying an aircraft. A sample presentation slide is illustrated in Figure 3. After the ground training, the participant and researcher entered the flight simulator.

Figure 3
Sample Training Slide

Note. To perform a turn, turn the control wheel in the direction desired

Each participant was instructed to maintain situational awareness, scan for traffic during the simulated flight, and notify the researcher if any traffic was observed. Once the participants had learned to maintain level flight, execute turns in both directions and perform 90-degree turns to cardinal headings, they were tasked with maintaining a specific altitude and heading. They were then asked to perform 90-degree level turns to a cardinal direction and back again to ensure they were actively controlling the aircraft. Altitude and heading management data were collected for five minutes as the participant got situated with flying the aircraft. The simulation was then paused, and the screens were blanked to administer the first situational awareness test using the Task 1 SAGAT questionnaire (refer to Appendix A).

After the first SA test, the simulation then resumed, and the screens were restored. The participants were then presented with a traffic conflict to avoid, and their reaction time to identifying the traffic was measured. The traffic was another Cessna 172 aircraft programmed to fly directly towards the participant's aircraft and collide in 20 seconds if no intervention was made. Participants were asked to verbally identify if they saw the aircraft traffic or if they needed to manipulate the controls to avoid a collision. After the NMAC reaction time was measured, the simulation was paused, and the screens blanked. The researcher then administered the second situational awareness test using the Task 2 SAGAT questionnaire (refer to Appendix A). The study session was then concluded with a debriefing explaining the purpose of the study, and incentives were given to the participants.

Apparatus and Materials

The ground portion of this study was conducted in a small classroom with a computer to present the PowerPoint presentation. The simulation was conducted in a Frasca G1000 Cessna 172 flight simulator. The flight simulator used was a high-fidelity FAA approved level six Flight Training Device (FTD) that provides a realistic flight experience with a dome projection screen and fully enclosed and functional cockpit via the Garmin G1000 integrated cockpit display avionics package. The simulated flight was controlled by an iPad, which the researcher used to set conditions and prompt traffic conflicts and other scenarios.

SA data was collected using SAGAT questionnaires (refer to Appendix A; Endsley & Garland, 2000). All the SA tasks were totaled up to get a total SA score for each participant. Data on reaction time to an NMAC was collected during the simulated flight using a stopwatch to measure reaction time and an iPad to prompt the simulation to create a traffic condition. The simulated traffic appeared on the horizon and was set to collide with the participant's airplane in 20 seconds in each scenario. The researcher simultaneously created the traffic and started a stopwatch to measure reaction time. The researcher stopped the stopwatch if the participant verbally announced the sight of the airplane or clearly moved the flight controls to avoid collision. Data on participant performance on the ability to maintain altitude and heading were recorded, measured, and collected by the flight simulation software.

Data collection on reaction time was made reliable by prompting the participant to tell the researcher when there was traffic in sight at the beginning of the flight and measuring the time carefully.

Independent between groups *t*-tests were performed to test the following null hypotheses:

$H_0 1$: There is no significant difference in overall situational awareness scores on the first flight of students exposed to visual and instrumental cues.

$H_0 2$: There is no significant difference in aircraft attitude situational awareness scores on the first flight of students exposed to visual and instrumental cues.

$H_0 3$: There is no significant difference in traffic avoidance situational awareness scores on the first flight of students exposed to visual and instrumental cues.

$H_0 4$: There is no significant difference in orientational situational awareness scores on the first flight of students exposed to visual and instrumental cues.

$H_0$5: There is no significant difference in the reaction time to a potential mid-air collision on the first flight of students exposed to visual and instrumental cues.

$H_0$6: There is no significant difference in the altitude deviation scores on the first flight of students exposed to visual and instrumental cues.

$H_0$7: There is no significant difference in the heading deviation scores on the first flight of students exposed to visual and instrumental cues.

Results

Descriptive Statistics

The following data in Table 1 illustrates the descriptive statistics for the SA and performance metrics.

Table 1
Descriptive Statistics

Statistic Type	Group	Mean	Standard Deviation	Score Range
Aircraft Attitude Situational Awareness				
	Visual	10.27	4.30	0.00 - 15.00
	Instrumental	10.40	3.94	0.00 - 15.00
Traffic Avoidance Situational Awareness				
	Visual	5.33	1.63	0.00 - 6.00
	Instrumental	4.20	2.37	0.00 - 6.00
Orientational Situational Awareness				
	Visual	5.33	1.45	0.00 - 6.00
	Instrumental	3.00	1.85	0.00 - 6.00
NMAC Reaction Time				
	Visual	8.54 s	6.38 s	1.50 - 20.00 s
	Instrumental	10.69 s	6.50 s	2.00 - 20.00 s
Altitude Deviation Before Turns				
	Visual	54.99 ft	32.03 ft	13.99 - 105.49 ft
	Instrumental	38.16 ft	32.98 ft	3.29 - 106.92 ft
Altitude Deviation After Turns				
	Visual	149.51 ft	138.28 ft	9.26 - 479.22 ft
	Instrumental	122.79 ft	119.28 ft	10.70 - 426.00 ft
Heading Deviation Before Turns				
	Visual	11.91°	21.01°	2.11 - 84.11°
	Instrumental	6.91°	6.32°	0.99 - 21.56°
Heading Deviation After Turns				
	Visual	7.04°	8.63°	1.26 - 35.34°
	Instrumental	10.64°	25.57°	1.01 - 102.61°

Hypothesis Testing

$H_0$1: There is no significant difference in overall situational awareness scores on the first flight of students exposed to visual and instrumental cues.

An independent samples *t*-test was applied to test the null hypothesis that there is no significant difference in situational awareness on the first flight of students exposed to visual and instrumental cues. The assumption of equality of variance was tested. Levene's test of equality of variance was not significant ($p > .05$), which implies that variance across the different groups is equal.

The mean of the visual group ($M = 20.93$, $SD = 5.87$) was larger than the mean of the instrumental group ($M = 17.60$, $SD = 7.04$). An independent samples *t*-test was not significant at the alpha level of .05, $t(28) = 1.41$, $p = 0.17$; thus, the null hypothesis was retained.

$H_0$2: There is no significant difference in aircraft attitude situational awareness scores on the first flight of students exposed to visual and instrumental cues.

An independent samples *t*-test was run to test the null hypothesis that there is no significant difference in aircraft attitude situational awareness on the first flight of students exposed to visual and instrumental cues. Levene's test of equality of variance was not significant ($p > .05$). The mean of the visual group ($M = 10.27$, $SD = 4.30$) was smaller than the mean of the instrumental group ($M = 10.40$, $SD = 3.94$). An independent samples *t*-test was not significant at the alpha level of .05, $t(28) = -0.09$, $p = 0.93$; thus, the null hypothesis was retained.

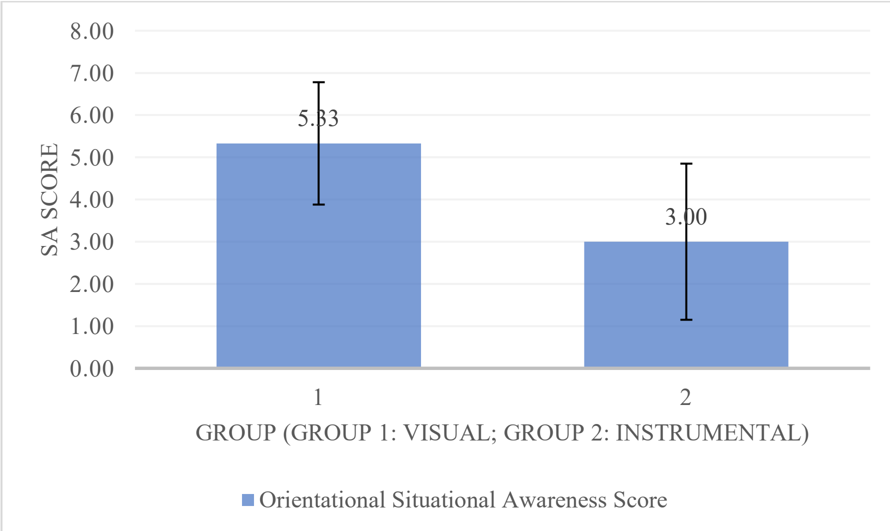
$H_0$3: There is no significant difference in traffic avoidance situational awareness scores on the first flight of students exposed to visual and instrumental cues.

An independent samples *t*-test was run to test the null hypothesis that there is no significant difference in traffic avoidance situational awareness on the first flight of students exposed to visual and instrumental cues. Levene's test of equality of variance was not significant ($p > .05$). The mean of the visual group ($M = 5.33$, $SD = 1.63$) was larger than the mean of the instrumental group ($M = 4.20$, $SD = 2.37$). An independent samples *t*-test was not significant at the alpha level of .05, $t(28) = 1.53$, $p = 0.14$; thus, the null hypothesis was retained.

$H_0$4: There is no significant difference in orientational situational awareness scores on the first flight of students exposed to visual and instrumental cues.

An independent samples *t*-test was run to test the null hypothesis that there is no significant difference in orientational situational awareness on the first flight of students exposed to visual and instrumental cues. Levene's test of equality of variance was not significant ($p > .05$). The mean of the visual group (Group 1; $M = 5.33$, $SD = 1.45$) was larger than the mean of the instrumental group (Group 2; $M = 3.00$, $SD = 1.85$). An independent samples *t*-test was significant at the alpha level of .05, $t(28) = 3.85$, $p = 0.001$; thus, the null hypothesis was rejected. Cohen's $d = 1.41$, which indicated a large effect. Figure 3 shows the difference between these two groups.

Figure 3
Orientational Situational Awareness Comparison



$H_0$5: There is no significant difference in the reaction time to a potential mid-air collision on the first flight of students exposed to visual and instrumental cues.

An independent samples *t*-test was run to test the null hypothesis that there is no significant difference in the reaction time to a potential mid-air collision on the first flight of students exposed to visual and instrumental cues. Levene's test of equality of variance was not significant ($p > .05$). The mean of the visual group ($M = 8.54$, $SD = 6.38$) was smaller than the mean of the instrumental group ($M = 10.69$, $SD = 6.66$). An independent samples *t*-test was not significant at the alpha level of .05, $t(28) = -0.90$, $p = 0.37$; thus, the null hypothesis was retained.

$H_0$6: There is no significant difference in the altitude deviation scores on the first flight of students exposed to visual and instrumental cues.

An independent samples *t*-test was run to test the null hypothesis that there is no significant difference in the altitude deviation scores on the first flight of students exposed to visual and instrumental cues. The data measured for this hypothesis test came from the first 30 seconds of in-flight measurement before the participant completed two 90 degree turns. Levene's test of equality of variance was not significant ($p > .05$). The mean of the visual group ($M = 54.99$, $SD = 32.03$) was larger than the mean of the instrumental group ($M = 38.16$, $SD = 32.98$). An independent samples *t*-test was not significant at the alpha level of .05, $t(28) = 1.42$, $p = 0.17$; thus, the null hypothesis was retained.

An independent samples *t*-test was run to evaluate the hypothesis during one minute of in-flight measurement after the participant completed two 90 degree turns. Levene's test of equality of variance was not significant ($p > .05$). The mean of the visual group ($M = 149.51$, $SD = 138.28$) was larger than the mean of the instrumental group ($M = 122.79$, $SD = 119.28$). An independent samples *t*-test was not significant at the alpha level of .05, $t(28) = 0.57$, $p = 0.58$; thus, the null hypothesis was retained.

$H_0$7: There is no significant difference in the heading deviation scores on the first flight of students exposed to visual and instrumental cues.

An independent samples *t*-test was run to test the null hypothesis that there is no significant difference in the heading deviation scores on the first flight of students exposed to visual and instrumental cues. The data measured for this hypothesis test came from the first 30 seconds of in-flight measurement. Levene's test of equality of variance was not significant ($p > .05$). The mean of the visual group ($M = 11.91$, $SD = 21.01$) was larger than the mean of the instrumental group ($M = 6.91$, $SD = 6.32$). An independent samples *t*-test was not significant at the alpha level of .05, $t(28) = 0.88$, $p = 0.39$. Therefore, the null hypothesis was retained.

An independent samples *t*-test was run to test the hypothesis during one minute of in-flight measurement after the participant completed two 90 degree turns. Levene's test of equality of variance was not significant ($p > .05$). The mean of the visual group ($M = 7.04$, $SD = 8.63$) was smaller than the mean of the instrumental group ($M = 10.64$, $SD = 25.57$). An independent samples t-test was not significant at the alpha level of .05, $t(28) = -0.52$, $p = 0.61$. Therefore, the null hypothesis was retained.

In the following section, these results are discussed.

Discussion

The results show a few key differences in the performance of the two groups (Visual and Instrumental). First, the visual group had a higher average score on situational awareness with significantly better SA in orientational awareness. Second, the visual group had a faster reaction time to a near-mid-air collision. However, the instrumental group performed slightly better at maintaining positive control of the aircraft.

Situational Awareness

The visual group scored better overall on the SAGAT test for situational awareness. Although the statistical analysis was not statistically significant, the differences in SAGAT scores still provide insightful information on student pilot situational awareness. The SAGAT test measured SA based on the student pilot's main goals of maintaining positive control of the aircraft, avoiding collisions, and maintaining aircraft orientation. Both groups were taught to maintain positive control of the aircraft based on their respective cues. The instrumental group scored high marks for the SA questions based on the goal of maintaining positive control of the aircraft but low marks on the SA questions based on maintaining orientation. The visual group tended to score high marks on all the SA questions, especially orientation and collision avoidance.

These results suggest that BAI or instrumental cues negatively impact student SA at the onset of training, especially in the subtasks of collision avoidance and orientation. Collision avoidance and orientation are very critical tasks to the safety of flight. Disorientation and loss of visual situational awareness can often result in further issues, such as airspace violations.

Instrumental cues did result in similar SA scores on awareness of the current state of the aircraft in space. This is most likely because of the participant's direct focus on the instruments, but these scores were on par with the visual group and not significant enough to maintain that instrumental cues are beneficial at the onset of training.

SA scores provide evidence that the very onset of training is not the appropriate time to introduce instrumental cues. The CFI needs to focus directly outside of the cockpit to develop the primacy effect of maintaining VSA.

Reaction time to NMAC

The visual group reacted faster on average to the traffic conflict. Although the statistical analysis was not statistically significant, the differences in reaction time measurements can still be analyzed from a qualitative perspective. Both groups were instructed to scan for traffic during the ground lecture, which covered how to scan for traffic and how to avoid colliding with traffic. Only one traffic conflict resulted in a mid-air collision, which occurred with a member of the instrumental group. These results show that initially teaching students instrumental cues, even when telling them to look outside the window, results in focus being shifted inside the cockpit. According to these results, one in 15 students taught by reference to instrumental cues at the onset of training will result in a catastrophic collision if an NMAC situation arises and is not caught by the CFI.

Orientation and Performance

The instrumental group outperformed the visual group in maintaining altitude. There was a significant statistical difference in orientation between the two groups, suggesting that different training methods enhance piloting accuracy. The instrumental group maintained a better heading prior to the turns, and the visual group maintained a better heading after the turns. In terms of task balance, both groups performed equally well in different areas. The visual group had a much higher deviation in altitude. This deviation would cause more safety of flight issues than the other performance factors. Therefore, it was weighted higher for analysis. The instrumental group appeared to have a higher level of control of the aircraft and were much more aware of altitude deviations than the visual group.

These results show that a proper understanding of the instruments will help the student tremendously in controlling the aircraft and maintaining altitude and heading. It is the CFI's responsibility to ensure the student understands that instruments are for verifying a condition exists that is already understood using visuals and ISF. Proper use of the instruments at the onset of training will benefit the student in both SA and performance.

Conclusion

This study investigated the potential outcomes, benefits, and disadvantages of using visual versus instrumental cues at the beginning of flight training. It is important for CFIs to be aware of the resulting effects of their chosen teaching techniques, as they can influence the safety of flight and the future habits of their students. CFIs should think carefully about how to present information to the students in the early phases of flight training to ensure optimal learning and safety.

This study further reinforces recommendations from previous research, suggesting that visual cues and integrated sensory flying techniques should be prioritized in initial flight instruction to help students maintain their focus outside the cockpit. CFIs can prevent students from developing hazardous habits by reinforcing the concept of interpreting the outside flight environment before referencing flight instruments. Beginning flight instruction with visual cues is the safest approach for new students learning to fly under VFR conditions, with instrument cues gradually introduced as their training progresses.

With regard to the BAI training, further research is required to understand the appropriate time in primary flight training for instrumental flying to be introduced. The responsibility of determining the appropriate time to introduce BAI lies with flight program curriculum designers, but it needs to be implemented carefully by the CFI, depending on the unique learning progression of each student. Ultimately, it is up to the CFI to interpret and teach the student based on the student's learning style. The CFI must demonstrate to the student that there are real consequences to mistakes made in flight, and actions must be taken to ensure the safety of the flight.

Limitations

Overall, flight instruction techniques and their impact on student situational awareness (SA), reaction time to Near Mid-Air Collisions (NMACs), and overall performance would benefit from further research. This research study can be improved and can also serve as a foundation for further research.

One of the limitations of this study is its limited sample size. A larger sample size might have yielded more data, potentially revealing statistically significant differences between the two groups. This study could also benefit from being conducted using a within-subjects design, allowing for more direct comparisons across conditions for each participant. The original pilot study for this experiment utilized a within-subjects design. However, the researcher ultimately decided against this approach due to concerns that potential testing bias inherent in within-subjects designs could confound the results of the SAGAT test. To mitigate this issue, a potential solution could be to implement a delay between the two measures, allowing sufficient time for participants' memories of the questions and traffic scenarios to fade.

This study could also be improved by using multiple measures of reaction time to the NMAC scenario. The SAGAT questionnaires could have been evaluated by multiple qualified CFIs, with the average scores taken to provide a less subjective and more reliable measure of situational awareness. Another limitation of this study is that it does not capture the full benefits of an integrated flight instruction method, where pilots utilize both visual and instrument cues. The study overlooks the real-world application of flight training, in which pilots must switch between these cues depending on conditions, and it does not account for holistic skill development. Consequently, it does not reflect how integrated flight instruction may enhance safety by preparing pilots for a broader range of scenarios. This study only focuses on the introductory flying lessons in an ab initio training context. Any observed differences in performance, particularly when comparing performance measures between the visual and instrumental cue groups, may primarily be attributed to students being task-saturated while looking at the instruments rather than true differences in flying skills/learning methods.

Using a *t*-test to compare the two groups also presents limitations, particularly when multiple dependent variables are involved. The *t*-test is designed to compare means between two groups on a single dependent variable and does not account for the potential correlations between multiple dependent variables. This simplification can lead to an increased risk of Type I errors due to multiple comparisons, and it overlooks the complex interactions between variables that might be better addressed with multivariate analysis techniques. Thus, the statistical analysis of this study may not fully capture the nuanced differences between visual and instrument approaches.

Further Study

Further research into this area would be beneficial to the field of flight instruction. Including eye-tracking technology to measure where the participants were looking and for how long could provide useful insights. During the debrief, when the purpose of the study was explained, most participants in the instrumental group acknowledged that they had focused inside the cockpit for much of the simulation. Collecting data on the duration of time participants spent focused inside the cockpit, along with their SA scores and reaction times to an NMAC, could provide valuable insights and enhance the findings of the study.

In future studies, it would be beneficial to include and report demographic information such as age, gender, and experience level. Including this data could help identify underlying demographic influences on the outcomes and ensure that findings are more generalizable. Additionally, understanding how these factors interact with visual and instrument approaches could provide deeper insights and enhance the design of flight training programs, making them more tailored and effective for the different ways students learn. This study could be integrated into a flight training course at a flight school, allowing new student pilots to participate in the research before proceeding with their regular flight training. Subsequent analysis of their performance could reveal whether the primacy effect influenced their progress during training. Future research could extend across multiple lessons and assess students in different phases of flight training to identify the most appropriate timing for introducing specific types of training, thereby optimizing the effectiveness of instructional techniques.

Continued research in this field will help make flight instruction safer. Identifying and optimizing instructional techniques that enhance flight safety will enable CFIs to adopt the most effective methods, ultimately producing safer and more aware pilots.

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Appendix A
SAGAT Questionnaires (Task 1 and Task 2)

SAGAT Questionnaire for Student Pilots – Task 1 – Participant:______________________

Desired altitude:	**Actual altitude:**
Desired airspeed:	**Actual airspeed:**
Desired heading:	**Actual heading:**

- *Is the aircraft at the desired altitude? (1)*
  - Yes
  - No
  - I don't know
- *How will you correct to achieve the desired altitude? (2)*
  - Climb
  - Descent
  - The aircraft is at the desired altitude
  - I don't know
- *If the aircraft is off the desired altitude, why? (3)*
  - Low power setting
  - Too much elevator pressure
  - Not enough elevator pressure
  - The aircraft is at the desired altitude
  - I don't know

- *Is the aircraft at the desired airspeed? (1)*
  - Yes
  - No
  - I don't know
- *How will you correct to achieve desired airspeed? (2)*
  - More power
  - Less power
  - The aircraft is at the desired airspeed
  - I don't know
- *If the aircraft if off the desired airspeed, why? (3)*
  - Power setting low
  - Power setting high
  - Inadvertent climb/descent
  - The aircraft is at the desired airspeed
  - I don't know

- *Is the aircraft on the desired heading? (1)*
  - Yes
  - No
  - I don't know

- *How will you correct to achieve the desired heading? (2)*
    - Yes, turn left
    - Yes, turn right
    - The aircraft is on the desired heading
    - I don't know
- *If the aircraft is off the desired heading, why? (3)*
    - Improper rudder usage
    - Inadvertent left turn
    - Inadvertent right turn
    - The aircraft is on the desired heading
    - I don't know

Pitch: up / level / down **Bank: left / level / right**

- *Is the aircraft in a level pitch attitude? (1)*
    - Yes
    - No
    - I don't know
- *Is the aircraft pitched up, down, or level? (2)*
    - Up
    - Down
    - Level
    - I don't know
- *Why is the aircraft at this pitch attitude? (3)*
    - Too much elevator pressure
    - Not enough elevator pressure
    - Improper trim
    - Proper elevator and trim
    - I don't know

- *Are the wings level? (1)*
    - Yes
    - No
    - I don't know
- *Are the wings banked left, right, or level? (2)*
    - Left
    - Right
    - Level
    - I don't know
- *Why are the wings at this attitude? (3)*
    - Right aileron
    - Left aileron
    - Rudder usage
    - Proper aileron usage
    - I don't know

SAGAT Questionnaire for Student Pilots – Task 2 – Participant:______________________

Vertical: above / same / below **Lateral: right / center / left**

Reaction time:

- *Is there traffic in sight? (1)*
  - Yes
  - No
  - I don't know
- *Is the traffic to the left or right of the aircraft? (2)*
  - Left
  - Right
  - Center
  - I don't know
- *Should you turn to avoid a collision, if so, which way? (3)*
  - No
  - Turn left
  - Turn right
  - I don't know

- *Are you aware of an airplane in the general vicinity? (1)*
  - Yes
  - No
  - I don't know
- *Is the airplane above or below the altitude of your aircraft? (2)*
  - Above
  - Below
  - Same altitude
  - I don't know
- *Should a climbing or descending evasive maneuver be performed to avoid a collision, if so, which one? (3)*
  - No
  - Climbing turn
  - Descending turn
  - I don't know

KDAB: left / right / front / behind **Shoreline: left / right / front / behind**

North / South / East / West **North / South / East / West**

- *Is Daytona Beach airport nearby? (1)*
  - Yes
  - No
  - I don't know
- *Which direction is Daytona Beach airport? (2)*
  - Left
  - Right
  - Front
  - Behind
  - I don't know
- *Which direction should we fly to get to get to Daytona Beach airport? (3)*
  - North
  - South
  - East
  - West
  - I don't know

- *Is the shoreline nearby? (1)*
  - Yes
  - No
  - I don't know
- *Which direction is the shoreline? (2)*
  - Left
  - Right
  - Front
  - Behind
  - I don't know
- *Which direction should we fly to get to the shoreline? (3)*
  - North
  - South
  - East
  - West
  - I don't know

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An Evaluation of Artificial Intelligence Chatbots Ethical Use, Attitudes Towards Technology, Behavioral Factors and Student Learning Outcomes in Collegiate Aviation Programs

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Despite the potential opportunities of Generative Artificial Intelligence (AI) Chatbots in higher education, ethical concerns surrounding their use, such as biased data assumptions and plagiarism, have been raised. Despite studies examining these concerns in higher education, there seems to be a gap in evaluating perceptions of constructs: ethical use, attitudes towards technology, behavioral factors, and student learning outcomes relating to Generative AI Chatbots in Collegiate Aviation Programs in the U.S. Using perceptions of aviation students from six universities in the U.S. (n=271), a modified Technology Acceptance Model (TAM) of the constructs fit the empirical data well; most hypothesized relationships were significantly supported. The most substantial direct relationship was between attitude towards AI Chatbot use and behavioral intention to use AI Chatbots. Despite deep concerns about the ethical use of AI Chatbots in collegiate aviation programs, the model could explain about 59% of the variances in user behavior, suggesting relatively good user behavior among respondents. Graduate respondents had higher user behavior than first—and second-year undergraduates, who had higher scores on ethical use concerns. Male respondents showed higher user behavior than female respondents. By understanding students' perceptions, administrators can create well-informed policy guidelines and strategies for the responsible and effective integration of AI Chatbot tools in collegiate aviation programs pedagogy.

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Adjekum, D.K., Waller, Z., & Keller, J.C. (2024). An evaluation of artificial intelligence chatbots ethical use, attitudes towards technology, behavioral factors and student learning outcomes in collegiate aviation programs. *Collegiate Aviation Review International*, *42*(2), 84-118. Retrieved from https://ojs.library.okstate.edu/osu/index.php/CARI/article/view/9949/8806.

Introduction

Artificial Intelligence (AI) has brought about a significant shift, revolutionizing the landscape of higher education (Zhai et al., 2021). This transformative technology has emerged as a catalyst, presenting thrilling prospects to elevate learning outcomes and educational efficiency within higher education (Xu & Ouyang, 2022; Yannier et al., 2020). AI, in its broadest sense, involves the development of computer systems capable of performing tasks that traditionally necessitate human intelligence, such as learning, reasoning, perception, and decision-making. It is a rapidly evolving field that encompasses a variety of techniques, including machine learning, deep learning, natural language processing, automatic speech recognition, computer vision, and robotics (Russell, 2010; Toumi, 2018).

Generative AI is a branch of AI that uses algorithms and models to create new and original content—such as text, images, video, audio, or software code—in response to a user's prompt or request (IBM, 2024). A Chatbot is a computer program designed to simulate conversation with human users, especially over the Internet, and a generative AI Chatbot is an open-domain chatbot program that generates original combinations of language rather than selecting from pre-defined responses (Adamopoulou & Moussiades, 2020; Codecademy.com., 2024). Generative AI Chatbots, like Open AI's Chat Generative Pre-Trained Transformer (ChatGPT), are not just theoretical concepts but practical tools actively used in higher education (McGrath et al., 2024; Open AI ChatGPT, n.d.). These Chatbots are trained using Reinforcement Learning from Human Feedback (RLHF), a process that involves training a model to make decisions and take action in an environment while receiving feedback from human experts through rewards, preferences, or demonstrations and helps guide the model's learning process (Jeyaraman et al., 2023; Open AI ChatGPT, n.d.).

Various iterations of Chat GPT have evolved, and they have the capability to assist with a wide range of tasks, such as providing personalized tutoring for students, reviewing resumes, helping researchers write grant applications, and assisting faculty with grading and feedback (OpenAI Platform, n.d.; Okonkwo & Ade-Ibijola, 2021). Gemini, formerly known as Bard, is another Generative AI Chatbot developed by Google that is natively multimodal. Gemini stands out with its unique ability to generalize and seamlessly understand, operate across, and combine different types of information, including text, code, audio, image, and video (Google Deep Mind, n.d.). Gemini is a Large Language Model (LLM) built on the more powerful Pathways Language Model (PaLM) 2 of the next-generation language model with improved multilingual, reasoning, and coding capabilities (Google Deep Mind, n.d.; Metz & Grant, 2024).

Windows Copilot, formerly Bing Chat, is another AI-powered virtual assistant developed by Microsoft and built on OpenAI's ChatGPT model. Window Copilot has features such as a conversational chat interface, image creation, and text generation that summarizes text and can write code in popular programming languages like JavaScript, C, and Python (Microsoft, n.d.). Claude is another Generative AI Chatbot developed by Anthropic that uses a different training method from GPT and Bard and aims to focus on safety and helpfulness (Anthropic, n.d.). Claude performs complex cognitive tasks beyond simple pattern recognition or text generation. Claude can transcribe and analyze almost any static image, generate codes, and provide multilingual processing (Anthropic, n.d.).

Within collegiate aviation programs, ground school academic courses and graduate-level aviation/aerospace research can benefit from the utility provided by AI-educational tools such as Generative AI Chatbots. Kasneci et al. (2023) suggest that these tools can enrich students' learning experiences, offering personalized support and potentially boosting academic performance With a high demand for extra-tutoring for large class sizes in some of the collegiate aviation programs in the U.S, these intelligent agents (Chatbots) can answer questions and replicate and process human communication, enabling individuals to interact with digital devices as if conversing with real people (Clarizia et al., 2018).

For professors and teaching assistants, Jafari and Keykha (2023) suggest that Generative AI Chatbots can enhance curricula design, teaching methods, and assessments in undergraduate and graduate collegiate aviation programs, leading to effective student learning outcomes (SLO). Other researchers like Cotton et al. (2023) suggest that Generative AI Chatbots can be used to assess various learning outcomes, such as knowledge, skills, and attitudes, as part of the ground school training course outline. In any academic pursuit, the ultimate goal for both professor and student is when both normative and objective assessments indicate a successful alignment of course objectives with student learning outcomes (SLOs). SLOs are statements that specify what students will know, be able to do, or be able to demonstrate when they have completed a course or program (UND, 2024). These outcomes are observable and measurable and demonstrate the knowledge, skills, attitudes, and habits of mind that students acquire from their learning experiences (Maki, 2011).

As part of any academic program of study, there should be evidence that individual students possess and demonstrate competencies required upon completing a learning experience or sequence of learning experiences (Eltabakh & Ahmed Ismail, 2019). Recent advances in flight deck technology, flight planning, and training tools may require collegiate aviation graduates to have AI-technological literacy and competencies (Pilon, 2023). AI tools leverage advanced algorithms and machine learning to process vast data and provide highly accurate route suggestions while accounting for real-time weather updates, air traffic congestion, and other crucial factors (Pilon, 2023). Introduction to AI tools at the collegiate levels and knowledge about Generative AI Chatbots can be helpful in better equipping aviation students with desirable technological competencies.

Despite the promising opportunities of Generative AI Chatbots in collegiate aviation programs, it is crucial to address the ethical use (EU) concerns surrounding them (Jeyaraman, 2023; Parson, 2021) and assess the levels of use among various demography of students. The ethical use of artificial intelligence involves optimizing its beneficial impact while reducing risks and adverse outcomes (IBM, n.d.). Hauer (2022) suggests that AI technologies should be developed, deployed, and used with an ethical purpose based on respect for fundamental rights and societal values. Ethical use concerns such as the need for informed consent, privacy breaches, biased data assumptions, fairness, and accountability are significant with the rapid use of AI educational tools in higher education (Sacharidis et al., 2020). User confidentiality and integrity (Zawacki-Richter et al., 2019) are also at stake. These EU concerns have also been suggested to impact attitudes and intentions to use AI-educational tools in higher education settings (Cotton et al., 2023; Dehouche, 2021; Kumar et al., 2024).

Literature Review

AI Chatbots and Collegiate Education

In a study on the effect of AI Chatbot-assisted learning on various components and how different moderator variables influenced its effectiveness, Deng and Yu (2023a) used a meta-analysis that reviewed 32 empirical studies with 2201 participants published between 2010 and 2022. The findings suggested that AI Chatbots could significantly improve explicit reasoning, learning achievement, knowledge retention, and learning interest despite negative findings in critical thinking, learning engagement, and motivation.

Labadze, Grigolia, and Machaidze (2023) found that students primarily gain from AI-powered Chatbots in three key areas: homework and study assistance, a personalized learning experience, and developing various skills. For educators, the main advantages are the time-saving assistance and improved pedagogy. However, the researchers also emphasize significant challenges and critical factors that educators must handle diligently. These include concerns about AI applications, such as reliability, accuracy, and ethical considerations.

Metcalfe (2017) suggests that timely formative feedback from a professor or instructor to students can help students learn. However, providing frequent quality feedback requires much time and effort from professors, and an AI Chatbot might help give students frequent, immediate, and adaptive feedback for academic tasks assigned to students. Tutoring is an essential part of effective pedagogy. It focuses on skill-building in small groups or one-on-one settings and can benefit learning (Robinson et al., 2021).

Effective tutors normally use questioning techniques, collaborative problem-solving, and personalized instruction to support their students (Robinson et al., 2021). Accessibility to a wider range of tutoring services in some universities that meet students' unique needs can also be a challenge, and this is where AI Chatbots can supplement tutoring services (OpenAI Platform., n.d.). In some collegiate aviation programs, one-on-one tutoring with a professor can present practical challenges necessitated by time constraints and the number of students in the class; hence, using such AI Chatbots can be beneficial to generate explanations and analogies for concepts in aviation or asking open-ended questions that stimulate further thinking (OpenAI Platform, n.d.).

Metacognitive skills can help students understand how learning works, increase awareness of gaps in their learning, and lead them to develop study techniques (Santascoy, 2021). Collegiate aviation students could use AI Chatbots to reflect on their experience working on a group project or to reflect on how to improve their study habits. A well-functioning team can leverage individual team members' skills, provide social support, and allow for different perspectives. This can improve performance and enhance the learning experience (Hackman, 2011). For example, in academic courses in aviation emphasizing team and scenario-based learning, such as Crew Resource Management, team members assigned can use an AI Chatbot to synthesize ideas, develop a timeline of action items, or provide differing perspectives or critiques of the team's ideas as suggested by Rahman and Watanobe (2023).

The process of organizing knowledge, teaching it to someone, and responding to that person reinforces one's own learning on that topic (Carey, 2015, p. 102). Carey (2015) further suggests that students can simulate or role-play how novice learners adapt to course materials by prompting AI Chat GPT for inputs on topics related to a course. This is also important in a student's ability to transfer skills and knowledge learned to a new situation, which usually involves abstract thinking, problem-solving, and self-awareness (Deng & Yu, 2023b).

Al-Zahrani (2023), in a study on the impact of generative AI Chatbots on researchers and research in higher education, suggested positive attitudes and a high level of awareness regarding these Chatbots in research. Respondents recognize the potential of these tools to revolutionize academic research and highly beneficial experiences using Generative AI Chatbots to expand project scope and improve efficiency. Positive attitudes toward Generative AI Chatbots in education have been suggested by Adeshola and Adepoju (2023).

Limitations and Challenges of AI Chatbot Use

Some challenges of using AI Chatbots in higher education need to be highlighted. AI Chatbots, primed from Large Language Models (LLMs), can produce incorrect yet plausible information confidently presented as factual. Mollick and Mollick (2023) suggest that this kind of hallucination or confabulation stems from how these systems work and the limits of their training data. AI Chatbots tend to make mistakes when prompted to provide quotes, citations, and specific detailed information. Different LLMs vary; most have become more sophisticated and less prone to making errors over time. Mollick and Mollick (2023) strongly suggest that users always fact-check the output of AI Chatbots with reliable external sources when using them to get information.

Developers train AI Chatbots on vast but still limited digital data sets, which can produce content that perpetuates harmful biases and stereotypes. Most training data comes from Western perspectives in the English language and is available online. With their inherent biases, human engineers also provide additional training for these tools. Individual users discuss their perspectives with a chatbot through prompts and queries. All these can result in subtle biases and stereotypes in the output of a chatbot. (OpenAI Platform, n.d.).

Like any technology, access to these tools may vary among categories of collegiate aviation students, and lack of access can perpetuate existing inequities. Concerns have been raised about the cost of subscriptions, access to computers and reliable connectivity, geographic restrictions, accessibility issues for people with disabilities, the user's preparation, and the tools' performance in other languages (Chan & Hu, 2023; Jafari & Keykha, 2023).

Ethical Use (EU) Issues with AI Chatbot Use in Collegiate Aviation Programs

One of the significant ethical use issues with AI Chatbots in higher education and research is the possibility of plagiarism (Loh, 2024). AI essay-writing systems are designed to generate essays based on parameters or prompts. This means that students could use these systems to cheat on their assignments by submitting essays that are not their own (Dehouche, 2021; Kumar et al., 2024). Fairness for class productive work is another assessment-related concern that impinges on learning outcomes, as Eke (2023) and Farazouli et al. (2023) suggested. Some students using

Chatbots can generate high-quality written assignments and have an unfair advantage over other students who do not have access to the tool, leading to inequities in the assessment process (Cotton et al., 2023). Other concerns are difficulty in adequately assessing a student's understanding of class materials when the student uses Chatbots to answer examination questions (Eke, 2023).

Other ethical concerns relate to privacy, bias, and transparency. Currently, privacy laws and regulations concerning AI Chatbots remain evolving and unclear in the U.S., and there is a likelihood that developers of AI Chatbots may use end-user data according to their terms of service (Parson, 2021; Williamson et al., 2020). That raises serious risk concerns about sensitive or private data inadvertently entered into an AI Chatbot by students (Popenici & Kerr, 2017; Hutson et al., 2022). Some studies have also highlighted the ethical risks associated with using AI in education, such as the risk of perpetuating biases and discriminating against marginalized groups (Yadav & Heath, 2022). Other studies have emphasized the necessity of ethical frameworks to guide AI implementation in education (Dwivedi et al., 2023). Breines and Gallagher (2020), in discussions on teacher bots, suggest AI is deceptive, implying that it intentionally undermines and competes with human agency.

As part of the phenomenon of "datafication" of higher education, which can be a by-product of Generative AI Chatbot use, Williamson et al. (2020, pg. 352) contend that "AI products and platforms can learn from experience to optimize their own functioning and become self-adaptive and further caution against trusting the 'magic' of digital quantification, algorithmic calculation, and machine learning." Interestingly, Kwet (2019) cautions against the datafication of higher education by associating it with technocratic control, data harvesting, and exploitation in controlling the digital ecosystem. Kwet (2019) further argues that big technological corporations control computer-mediated experiences, giving them direct power over political, economic, and cultural domains of life, and such datafication introduces vulnerabilities to the educational system.

The Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) conceptualized by Davis (1989) provides a framework to understand and evaluate how people accept and use technology. The initial TAM is based on the Theory of Reasoned Action (TRA), developed by Fishbein and Ajzen (1975), which predicts the attitudinal underpinnings of behaviors across a wide range of areas. TAM elucidates the technology determinant acceptance, which can explain the behavior while simultaneously justifying the theoretical and economic viewpoints (Davis, 1989). The TAM has five constructs, namely: perceived ease of use (PEU), perceived usefulness (PU), attitude towards use (ATU), behavioral intention (BI), and User Behavior (UB). These constructs are considered the primary determinants for users concerning application and technology acceptance (Ma & Lui, 2005; Venkatesh et al., 2003).

According to Davis (1989), ATU is an individual's negative or positive viewpoint toward conducting the intended behavior in applying a given system. The construct BI is the level at which particular technology users have shaped a plan of intent to continue utilizing or not a particular technology with their future behavior. UB is the degree of usage application of a specific technology in terms of frequency (how often) and the measured volume (how much) when using a given technology by users. TAM has been used to assess perceptions of technology in video gaming and family-life dynamics (Bassiouni, 2019), consumer perceptions of usefulness and attitude toward e-shopping and its adoption (Ha, 2009), internet banking (Yousafzai, 2010), online travel reviews and user-generated-content (UGC) adoption (Assaker, 2020), mobile phone technology, automated road transport (Madigan et al., 2017) and healthcare/medicine (Yetisen et al., 2018).

Some studies have used various underlying constructs of TAM to examine user behavior when teaching online and using Learning Management systems in higher educational settings (Wingo et al., 2017; Luo et al., 2021). Chumo & Kessio (2015) used a variant of TAM to assess Information Communication Technology (ICT) use among tertiary students in Kenyan Public Universities and found that the model explained 78.24% of the variance of the student's behavioral intention to use web-based information systems. A similar study was conducted by Aliaño et al. (2019) using a variant of TAM to examine the factors that determine the use of mobile learning in higher education contexts. The findings suggested a high predisposition for using mobile devices for learning, with a direct positive effect regarding the relationships between the TAM constructs.

Research Objectives

A comprehensive understanding of how ethical perceptions of AI Chatbots influence attitudes towards AI Chatbots, their impact on intentions to use, and ultimately perceived learning outcomes is essential for formulating policies and guidelines in higher education, specifically collegiate aviation programs. Despite all the studies that highlighted the effect of ethical use on AI chatbot useability in higher education, there seems to be a paucity of research that assesses the inter-relationships between ethical concerns of AI Chatbot use, user attitudes, behavioral intentions, user behavior, and student learning outcomes in collegiate aviation education.

Adopting constructs from the TAM, we examine the impact of ethical use (EU) concerns on ATU, BI, UB, and SLO and hypothesize relationships among these variables. Understanding collegiate aviation education respondents' perceptions of the strength of relationships between these factors can be instructive in formulating policies, processes, and procedures for effective teaching, learning, and research when using these tools.

Research Questions

In line with the research objectives, we posed the following research questions that will guide us to understand the research problem:

1. What are the strengths of relationships between AI Chatbot ethical concerns for use, attitudes towards use, behavioral intentions, user behavior, and student learning outcomes?
2. What are the differences in EU, ATU, BI, UB, and SLO perceptions among demographic variables, age, gender, majors, and academic levels?

Based on the TAM and supporting the research questions, we hypothesized the following relationships, which were explored in the study:

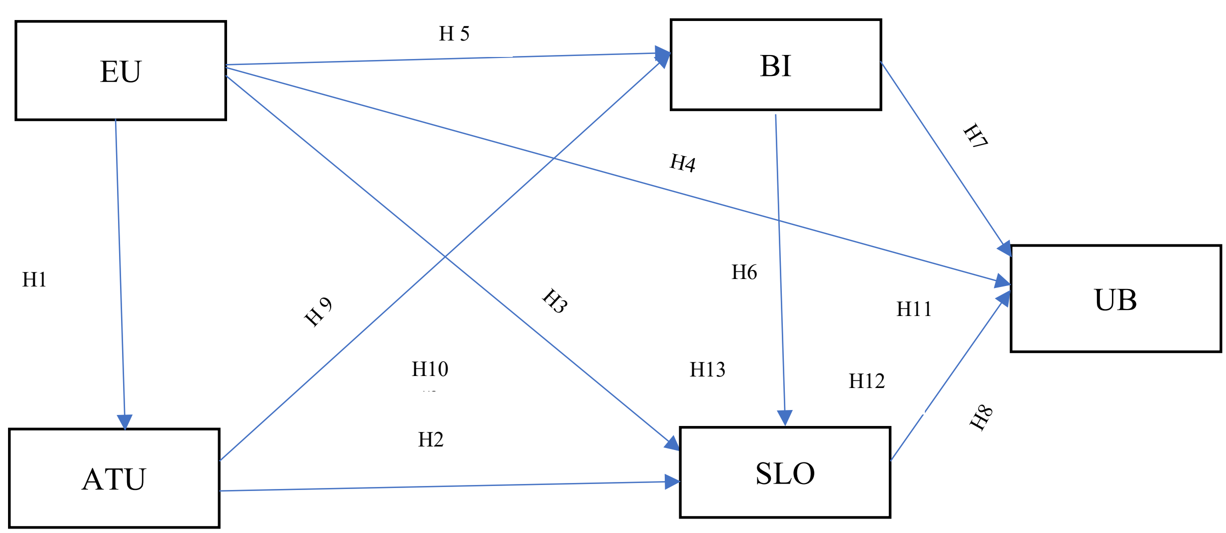
1. H1: EU has a direct relationship with ATU.

2. H2: ATU has a direct relationship with SLO.
3. H3: EU has a direct relationship with SLO.
4. H4: EU has a direct relationship with UB.
5. H5: EU has a direct relationship with BI.
6. H6: BI has a direct relationship with SLO.
7. H7: BI has a direct relationship with UB.
8. H8: UB has a direct relationship with SLO.
9. H9: ATU has a direct relationship with BI
10. H10: EU has an indirect relationship with SLO.
11. H11: EU has an indirect relationship with UB through SLO.
12. H12: BI has an indirect relationship with UB through SLO.
13. H13: ATU has an indirect relationship with SLO through BI.

We further provided a graphical representation of the hypothesized pathway for the relationships among the study constructs. Figure 1 shows these paths of relationships.

Figure 1

Path model showing the hypothesized relationships between constructs



Methods and Materials

We created an online and anonymous survey instrument to elicit respondents' perceptions of the strength of relationships between the study constructs. The survey items for the TAM constructs (ATU and BI) were derived from Venkatesh et al. (2003) and Lin and Yu (2023) and formed part of a broader research on AI Chatbot use in collegiate aviation. The items for ethical use (EU) were derived from Nguyen et al. (2023). The items for the student learning outcomes (SLO) were obtained from the Students' Evaluation of Learning and Instructions (SELFI), which is a validated instrument used by the University of North Dakota (UND) for evaluating students' learning outcomes (UND, 2024). The survey instrument was in English with a seven-point Likert-style scale (1= strongly disagree to 7 = strongly agree). The open-ended items elicited types of AI

Chatbots used by respondents and general opinions on AI Chatbot use in collegiate aviation programs. Table 1 provides examples of scale items.

Table 1
Study Construct Scale Item Examples and Sources

Study Construct (TAM)	Example of Scale Item	Source
Attitude Towards Technology Use (ATU)	I have a generally favorable attitude toward using AI Chat GPT.	(Venkatesh et al., 2003; Lin & Yu, 2023)
Behavioral Intention (BI)	I intend to use AI ChatGPT for my scholarly work frequently.	(Venkatesh et al., 2003; Lin & Yu , 2023)
User Behavior (UB)	I always prepare well for classes because of regular AI Chatbots use.	(UND, 2024; Venkatesh et al., 2003; Lin & Yu, 2023)
Student Learning Outcome (SLO)	AI Chat GPT use helps me develop in-depth knowledge of various aviation topics.	UND (2024)
Ethical Use (EU)	The use of AI ChatGPT can lead to cheating and plagiarism in scholarly works.	Nguyen et al. (2023)

Note: The entire survey is attached in Appendix A.

Sampling and Survey Administration

The study sample was purposefully drawn from a cross-section of undergraduate and graduate student populations enrolled in U.S. collegiate aviation programs with membership in the University Aviation Association (UAA). A University of North Dakota (UND) institutional review board (IRB) approved the protocols for the study. An anonymous online survey instrument was created via a Qualtrics® UND institutional account. Even though there are 2-year collegiate aviation programs in the U.S., we limited the scope of our sample by focusing on distributing the survey instrument to four-year degree-awarding collegiate aviation programs.

The anonymous survey link was sent to the respondents with the assistance of aviation program chairs at twelve UAA member institutions in the U.S., who facilitated the dissemination of the link via students' institutional emails and departmental listservs. The surveys also had QR barcodes that could be shared via phones and social media to enable easy sharing among the targeted respondents. The survey was also advertised through posters with scannable QR codes on various students' notice boards and electronic boards at various campuses. The survey link and QR codes were also sent to aviation student organizations at the various campuses for posting on their social media handles. For example, at UND, the digital poster was sent to the Students Aviation Advisory Council (SAAC) to be posted on various social media handles such as Facebook®, Twitter now X®, and Instagram®. The dissemination and collection period was from 20th January 2024 to 20th March 2024.

Results

Preliminary Data Collection and Analysis

At the end of the dissemination and collection period, two hundred and seventy-one (n=271) responses were obtained via the Qualtrics® data collection and analysis tool. About seven respondents did not disclose any demographic details. The quantitative data was downloaded from the Qualtrics site using an SPSS sav—file format for further analysis. The textual responses were analyzed using a Qualtrics tool and will be highlighted in detail. The details of the demographic variables are outlined in Tables 2 and 3.

Table 2
Academic Levels and Age of Respondents

Academic Level	n	Percentage
Undergraduate (1st & 2nd) Years	86	31.7
Undergraduate (3rd & 4th) Years	114	42.1
Graduate (Masters & Doctoral)	64	23.6
Undisclosed	7	2.6
Total	271	100
Age		
18-22	161	59.4
23-27	72	26.6
28-32	31	11.4
Undisclosed	7	2.6
Total	271	100

Table 3
Gender, Academic Majors, Chatbot Use Frequency

Gender	n	Percentages
Male	162	59.8
Female	102	37.6
Undisclosed	7	2.6
Total	271	100
Academic Majors		
Professional Flight/Commercial Aviation	161	59.3
Air Traffic Management	4	1.5
Aviation Technology	1	0.4
Uncrewed Aerial System (UAS)	17	6.3
Airport Management	20	7.4
Others	60	22.5
Undisclosed	8	2.6
Total	271	100
Chatbot Use Frequency in the Semester		
Never	93	34.4
Sometimes	118	43.5
About half of the time	15	5.5
Most of the time	1	0.4
Undisclosed	44	16.2
	271	100

Under the academic majors of Table 3, the "others" were primarily graduate students and some undergraduates with double majors. Some of the academic majors provided in the write-in space provided for other were aerospace sciences, atmospheric sciences, aviation safety and operations, computer science, aviation technician and maintenance, geography, and aviation public policy. Respondents were also asked to provide information on which AI Chatbots they usually use and any other comments.

Qualitative Analysis

We used a deductive approach for the open-ended responses provided by respondents since we had already outlined our research questions and keywords to align responses to specific questions. Qualtrics® Text iQ is a powerful text analytics tool integrated into the Qualtrics platform. It helps analyze open-text responses from surveys and uncover valuable insights. Text iQ can determine the sentiment (positive, negative, neutral) of the text, helping a researcher to understand the overall mood of respondents (Qualtrics, n.d). We used the Text iQ tool to identify and categorize common themes and topics within the 79 textual responses received (n =79). The tool allowed us to see what topics and words were frequently mentioned.

The utility of this TextiQ was that it automatically tagged and organized text responses, which helped align keywords/codes with specific textual responses. Using a dashboard, we visualize the analyzed data. One of the authors did the initial qualitative analysis of textual responses and produced the dashboard with keywords aligned with responses to form topics. The author's output was cross-verified by the other two authors, who independently reviewed the keywords, topics, and counts on the dashboard and their corresponding textual responses to ensure accuracy. We focused on using these qualitative responses to provide context during the discussion of the findings.

We assigned percentage frequencies based on each chatbot type's total number of mentions of all Chatbots identified. The output of the coding suggests that about 82% used Open AI's Chat GPT, 8% used BARD AI now Gemini, 4% used Quillbot, 2% used Snapchat AI, and 1% each for Claude, Grammarly, Bing AI, and Perplexity AI. Respondents were also asked to provide their institutions as an optional request. The qualitative results were collated and showed responses from participants enrolled in collegiate aviation programs at the University of North Dakota, Embry-Riddle Aeronautical University – Daytona, Purdue University, Dubuque University, Middle Tennessee State University, and Eastern Kentucky University.

Quantitative Analysis

Normality of Data and Descriptive Statistics

The IBM SPSS® Version 28 was used for descriptive and inferential computations as part of the preliminary analysis. The data was checked for normality to ensure that assumptions of linearity were not violated, and a visual inspection of Histograms for all the constructs was done. There were no indications of any abnormality, as evidenced by the skewness (.138 - 1.0) and kurtosis (-.035 – 1.8) values of the constructs being less than 3.000, which Kline (2016) recommends as a threshold for data to be considered normal.

Confirmatory Factors Analysis, Model Fit, Reliability Analysis, and Convergent Validity

We used Confirmatory Factors Analysis (CFA) to assess the fit of empirical data to the hypothesized model and the dimensionality of the various constructs. We used the IBM AMOS® version 26 for all model assessments. The chi-squared ($\chi 2$) index, the root mean square error of approximation (RMSEA), the comparative fit index (CFI), the Tucker-Lewis Index (TLI), incremental fit index (IFI), and the normed fit index (NFI) were used to assess model fit. According to Hu and Bentler (1999), implementing TLI and CFI cutoff values of 0.95 in conjunction with an RMSEA cutoff value close to 0.06 appears to result in lower Type II error rates at the cost of Type I error acceptable rates. An RMSEA of less than 0.05 is desirable, whereas values greater than 0.10 suggest problems with the model's fitness (Kline, 2016). The normed fit index (NFI) and the incremental fit index (IFI). NFI and IFI values should be greater than 0.90; otherwise, it indicates the need for model enhancements (Bentler & Bonett, 1980).

Due to low loading, we had to remove some items in various constructs to improve the model fit. The items removed were ATU_4, UB_3, EU_5, and EU_6. The removal was based on recommendations from the modification indices of AMOS and theoretical guidance for the parsimony of items underlying each construct. A final CFA structural model was obtained, which provided moderately acceptable fit indices [$\chi 2 = 223.649$, $p < .001$, PCMIN/DF = 1.804, NFI=.927, RFI =.901, IFI =.966, TLI = .953, CFI = .966, RMSEA =. 055 (.043 - .066)] for all the constructs.

The average variances extracted (AVE) approach was used to determine convergent validity, which refers to how closely a new scale is related to other variables and measures of the same construct. Fornell and Larcker (1981) recommend a value greater than 0.50. The AVE for all constructs was greater than the 0.50 threshold, suggesting acceptable convergent validity. Field (2018) and Hair et al. (2010) recommend a value of .70 or greater in determining survey item acceptability, reliability, or consistency. All the items had values greater than the .70 threshold. Table 4 shows the descriptive statistics of the study variables, the Cronbach's alpha, composite reliability, and AVE values.

Table 4

Descriptive Statistics of the Study Variables, Reliability Test, and Convergent Validity Test

	Number of Items	Mean		Cronbach's Alpha	Composite Reliability	Average Variance Extracted
Construct	Statistic	Statistic	Std. Error	Statistic	CR	AVE
ATU	3	4.10	.010	.92	.92	.79
BI	3	3.52	.069	.91	.90	.75
EU	4	5.28	.092	.82	.81	.54
SLO	4	3.80	.102	.91	.91	.71
UB	4	3.70	.148	.87	.85	.60

Note: All the α-vales for reliability were above the .70 threshold recommended. All constructs had AVE values ≥ .50 threshold recommended by Fornell and Larcker (1981) for evidence of convergent validity.

Discriminant Validity

The instrument's discriminant validity was found acceptable by comparing the square root of the AVE for constructs to the correlation coefficients for each variable. The square roots of the AVE on the diagonal line were greater than all other correlations in the corresponding columns and rows, as shown in Table 5. The results indicated that the covariates could be significantly distinguished from one another.

Table 5
Results of the Discriminant Validity Test

	ATU	EU	BI	SLO	UB
ATU	**.89**				
EU	-.529**	**.73**			
BI	.740**	-.347**	**.89**		
SLO	.731**	-.438**	.717**	**.84**	
UB	.715**	-.565**	.643**	.707**	**.77**

Note: Square roots of AVE are in bold on the diagonal. **. Correlation is significant at the 0.01 level (2-tailed).

After the preliminary data analysis, we assessed the strengths of relationships between AI chatbot ethical concerns for use, attitudes towards use, behavioral intentions, user behavior, and student learning outcomes. We also determine differences in the mean of respondents' perceptions of the study variables EU, ATU, BI, UB, and SLO based on demographic variables, age, gender, majors, and academic levels.

Research Question One

To answer the first research question, "*What are the strengths of relationships between AI chatbot ethical concerns for use, attitudes towards use, behavioral intentions, user behavior, and student learning outcomes?*" a hypothesized model was assessed using goodness-of-fit indices and squared multiple correlations derived from maximum-likelihood estimations. The IBM SPSS® AMOS 28 Graphics was used for all the structural equation model (SEM) path analysis, and bootstrapping was used (2000 bootstrap samples). Bootstrapping is a non-parametric method based on resampling with replacement, which is done many times, e.g., 2000 times (Bollen & Stine, 1990; Shrout & Bolger, 2002).

An initial measurement model with all the paths as proposed did not yield good fit indices [$\chi2$ = 13.842, p = .000, PCMIN/DF = 13.842, NFI=.983, RFI =.833, IFI =.984, TLI = .843, CFI = .984, RMSEA =. 218 (.126 - .326)]. The path between EU and BI was not significant, and the modification indices recommended for that path to be removed to improve the model. Removing that path improved the measurement model, resulting in good fit indices [$\chi2$ = 1.546, p = .214, PCMIN/DF = 1.546, NFI=.998, RFI =.981, IFI =.999, TLI = .993, CFI = .999, RMSEA =. 045 (.000 - .176)] was obtained. Table 6 shows the critical ratios, regression weights, p-value, squared multiple correlations, and hypothesis statements of the model with good fit indices.

Table 6
Table showing Maximum Likelihood Estimates, Standard Error, Critical Ratio, P-values, Regression Weight, and Hypothesis Statements

Path	**Estimate**	**S.E.**	**C.R.**	***P***	**β**	**Hypotheses**
ATU<---EU	-.757	.074	-10.207	***	-.528	Supported
BI<---ATU	.758	.042	18.053	***	.740	Supported
SLO<---ATU	.355	.056	6.282	***	.384	Supported
SLO<---BI	.358	.051	7.044	***	.398	Supported
SLO<---EU	-.128	.059	-2.166	.030	-.097	Supported
BI<---EU	-	-	-	-	-	Path removed.
UB<---BI	.432	.073	5.915	***	.484	Supported
UB<---EU	-.323	.057	-5.634	***	-.246	Supported
UB<---SLO	.306	.058	5.228	***	.308	Supported

Note: p-value *** is at the p < .001 level (2-tail).

The measurement model had significant explanatory powers measured by the squared multiple correlations (SMC) values of the endogenous variables (ATU, BI, UB, and SLO). The hypothesized model suggests that EU explained about 27.8 % variance of ATU. ATU explained about 54.7% of BI. EU, ATU, and BI explained 61 % of SLO. BI and SLO explained about 58.5% of UB. For the exogenous variable EU, the path coefficients provided a measure of the effect sizes (Kline, 2016), and the path with the largest effect size was ATU to BI. The path with the lowest effect size was EU to SLO. Table 7 shows the SMC values.

Table 7
Squared Multiple Correlations (R^2)

Construct	**SMC (R^2)**
ATU	.278
BI	.547
SLO	.610
UB	.585

Mediation Analyses

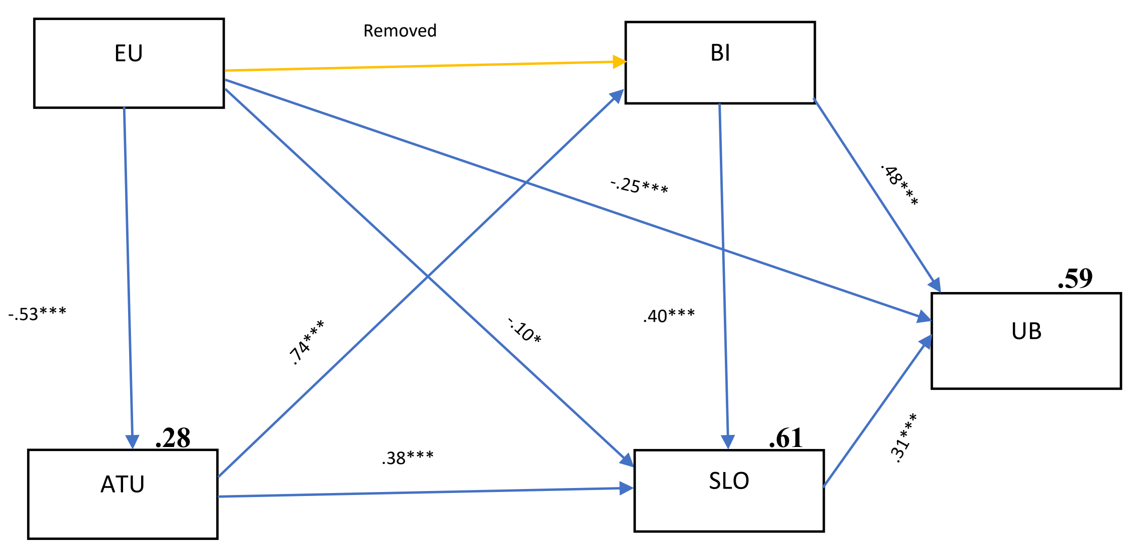
The check for mediation and the indirect effect was computed from these samples using the Hayes PROCESS® Version 4, which is an add-on to IBM SPSS Statistics® version 28, and a sampling distribution was empirically generated. According to Hayes (2022), a confidence interval is typically computed and checked to determine if zero is in the interval. If zero is not in the interval, then the researcher can be confident that the indirect effect differs from zero and that there is a mediation effect. Table 8 shows the mediation analysis outputs, and Figure 2 shows the hypothesized paths and mediation for the measurement model.

Table 8
Mediation Analysis

Pathways	*F (2,260)*	R^2	*P*	Stand. Indirect Effect	SE	95% Boot. CI LLCI - ULCI	Medn.	Hyp.
UB<-SLO<-EU	179.446	.550	***	-.249	.040	-.329 - -.173	Yes	Supported
SLO<-ATU<-EU	151.179	.538	***	-.365	.037	-.440 - -.294	Yes	Supported
SLO<-BI<-ATU	196.913	.602	***	.288	.068	.174 - .433	Yes	Supported
UB<-SLO<-BI	151,044	.537	***	.362	.043	. 277 - .447	Yes	Supported

Note: p-value *** is at the p < .001 level (2-tail). Boot. CI is the 95% Bootstrapped Confidence Interval with a lower limit (LL) and upper limit (UL). Medn. – Mediation; Hyp. – Hypothesis.

Figure 2
The final path analysis model shows the hypothesized relationships between constructs



Note: *** P < .001; *p< .05. The path between EU and BI (ns) was removed to improve the model.

Research Question Two

To answer research question two, "*What are the differences in EU, ATU, BI, UB, and SLO perceptions among demographic variables, age, gender, majors, and academic levels?*" a one-way analysis of variance (ANOVA) was conducted to determine if significant differences existed in the perceptions of the constructs among demographic variables (academic level, gender, and age groups). The Bonferroni test for post hoc analysis with a 95% percentile bootstrap confidence interval (BCI) was used since there were no violations of the homogeneity of variances, and 5000 bootstrap samples were used.

User behavior

For user behavior, only academic level showed significance. The ANOVA model, F(2,260) = 3.064, *p* = .048, eta-squared value = .023, suggested significant differences in the mean score for UB among the academic levels. A post hoc test using Bonferroni showed that the differences were between graduates [M = 4.10, SE= .167, 95% BCI (3.77 -4.44] with higher scores than the first and second-year undergraduates [M = 3.52, SE = .141, 95% BCI (3.26 – 3.80)]. There were no significant differences in the mean scores for SLO, BI, EU, and ATU among the academic levels.

Age Group

Another ANOVA model, F(2,260) = 2.913, *p* = .050, eta-squared value = .022, suggested significant differences in the mean score for UB for the age groups. A post hoc test using Bonferroni showed that the differences were between 28-32 [M = 4.28, SE = .276, 95% BCI (3.69 - 4.82] with higher scores than the 18-22 [M = 3.59, SE = .144, 95% BCI (3.37 – 3.81)]. A final ANOVA model, F(2,260) = 3.600, *p* = .029, eta-squared value = .027, suggested significant differences in the mean score for EU for the age groups. A post hoc test using Bonferroni showed that the differences were between 18-22 [M = 5.41, SE= .089, 95% BCI (5.41 – 5.59] with higher scores than the 28-32 [M = 4.48, SE = .200, 95% BCI (4.47 – 5.30)].

Gender

An independent T-test of means showed that there were significant differences in the mean scores on BI [t (261) = 2.417, p = .016, SE = .195, 95% BCI (.124 - .890)] among male respondents [M = 3.72, SE = .140, 95% BCI (3.44 – 3.97)] and the female respondents [M = 3.21, SE = .141, 95% BCI (2.93 – 3.49)]. All the other constructs did not show significance.

Discussions

Strength of Relationships Among Study Variables

The results from this study show the significant relationships between the ethical use of AI Chatbots and attitudes towards use, behavioral intentions, user behavior, and student learning outcomes among the respondents. The instrument used to evaluate the relationships had good reliability and construct/discriminant validity. A CFA model showed that the multi-dimensional structure of constructs and the interrelationships were consistent with the empirical data as observed by the fit indices, which were all acceptable. The path analysis model suggested that the hypothesized relationships among the study constructs were all supported, except for EU to BI, which was removed. The model could explain about 61% of the variances observed in SLO due to the predictive effects of EU, ATU, and BI. The model explained that about 59 % of variances observed in UB were due to the predictive effects of BI and SLO.

The results suggest that the hypothesized model significantly explained the relationships between ethical use and the other constructs: attitude towards use, student learning outcome, and user behavior. We found that these findings corroborate previous studies by Aliaño et al. (2019), Chumo & Kessio (2015), and Luo et al. (2021), where variants of the TAM were able to explain relatively higher variances in the underlying constructs. We also observed that the findings validate the utility and resilience of TAM in various disciplines. Ethical concerns had the highest mean score for respondents' perceptions of items compared to the scores for behavioral intentions, user behavior, and student learning outcomes. The findings suggest that the ethical concerns related to AI Chatbot use among this collegiate aviation sample adversely affect their behavioral intentions to use these tools, reflected in their actual user behavior, which aligns with previous findings by Ko and Leem (2021).

Regarding predictive relationships using the path analysis, the most significant effect size between EU and ATU suggested that ethical concerns negatively impact respondents' attitudes toward AI Chatbot use. Based on responses from the textual comments, which provided context and previous findings from Eke (2023), Farazouli et al. (2023), and Loh (2024), we surmise that some respondents are concerned about ethical issues such as plagiarism, fairness, and data privacy, and their potential impact on the value of university education, invariably influences their attitude towards using these AI-Chatbots. Other concerns related to the accuracy and transparency of information provided by AI Chatbots were noted in some of the textual comments and, as suggested by Parson et al. (2021), may be antithetical to a profession where professionalism and integrity are desired due to its safety-criticality. We think that these concerns can adversely influence attitudes towards AI Chatbot Use. These were some comments provided by respondents in the open-ended item, which aligned with topics/codes related to adverse ethical concerns:

> "*AI Chatbots in collegiate aviation education can lead to complacency in learning and understanding that's already faced with advancements in avionics/flight control systems. AI use for study can possibly cause complacency in studying/learning/and actually understanding material. Tied into the use of autopilot causing complacency amongst pilots, this could lead to complete reliance on automation, in terms of training*."

> "*I think it's good to keep it prohibited for plagiarism, so people actually learn the topics. It's a great tool for boosting your learning if you use it properly and not plagiarizing.*"

> "*I do not feel like they would be wise to use in a major that focuses on developing one's own critical thinking and problem skills and could lead to a loss of ADM if used excessively.*"

This finding is similar to that of Peres et al. (2023), who also found out that some higher education students expressed reservations about AI Chatbot accuracy, transparency, privacy, over-reliance on technology, and ethics and how it adversely impacts higher education. It is also in tandem with findings that sometimes it is challenging to assess the validity or identify falsehoods of information and suggestions proffered by AI Chatbots, thus necessitating human oversight (Lubowitz, 2023). Another statement that aligns with a code related to trustworthiness from a respondent highlights this point:

> "*AI Chatbots" are incredibly prone to spitting out garbage information, there is no true search function or way to properly curate the answers it provides. They have no place in higher education, espeacially in a field as complex and dangerous as commercial aviation*."

> "*it is a helpful tool but should not be considered to be trusted 100% you should look over what they provide*."

The findings suggest that even though the EU had a very weak predictive relationship with SLO, the mediatory effect of ATU was evident. Respondents' concerns about the ethical use of AI Chatbots adversely impacted their attitudes to using AI Chatbots, which influenced their perceptions of AI Chatbots on student learning outcomes, supporting findings by Nguyen et al. (2023).

The significant direct relationship between ATU, BI, and SLO agrees with previous findings by Habibi et al. (2023), who also found that attitudinal and behavioral perceptions of AI Chatbots significantly influence student learning approaches and outcomes among higher education students and must also be framed within the context of policies such as mandatory use, easy access and derived benefits of use. We proffer a potential reason for this finding in the collegiate aviation environment, especially within the undergraduate programs. Some respondents may be concerned about potential certificate revocations and other disciplinary actions for using AI Chatbots in ground school courses governed by stringent CFR Part 141 Training Course Outlines (TCO) with detailed student learning outcomes.

This is because TCOs demand strict compliance with testing standards, and eliciting solutions or suggestions from AI Chatbots other than those of FAA-approved test standards may be risky as these answers may not be accurate per the test standards. Most undergraduate flight-related courses have minimal essay-type assessments for the FAA ground school test, focusing on technical areas such as regulations, weather, airmanship, risk assessment, human factors, flight physiology, and aerodynamics before practical flight tests.

Since most of the assessments are in the multiple-choice format, which requires accurate answers, most collegiate aviation students rely on FAA-approved text for guidance and may not elicit answers or cues from AI Chatbots, which may be perceived as not transparent and sometimes unreliable; however, in courses where some elements of writing and research are required such as crew resource management (CRM), aviation safety management, aviation business, and economics, there may be opportunities to use these AI Chatbots. That can account for a proportion of undergraduate student respondents who indicated using AI Chatbots.

Regarding ethical use concerns and student learning outcomes, we suggest that some respondents' concern about plagiarism becomes paramount as they face difficulty determining the originality of work generated by AI Chatbots, which is corroborated by the findings of both Cotton et al. (2023) and Farazouli et al. (2023). This can adversely affect their perceptions of the value of AI Chatbots in students' learning outcomes. It is also possible that inconsistent policies on AI Chatbots in some of the collegiate aviation programs and the constant admonishment from some professors on plagiarism risk for using AI Chatbots in written assessments can influence some of the respondents to develop a natural aversion to its use, which can impact their perceptions on AI Chatbots risk-benefit to their learning outcomes.

Student learning outcomes also significantly mediated the relationships between EU and UB, suggesting that the policies guiding students' learning outcomes development and expectations invariably influence how respondents use AI Chatbots based on their ethical use perceptions. A scenario where SLO in syllabuses and course outlines expects respondents to demonstrate knowledge and use of AI tools such as Chatbots at the end of a course can positively impact respondents' use of AI Chatbots since they are intrinsically tied to expected outcomes.

The results also showed that the relationship between ATU and SLO is further explained by the behavioral intentions to use (BI). It suggests that when respondents develop either positive or negative attitudes towards AI chatbot use, their intentions to use the technology are framed with the expectation that it will impact the SLO. Interestingly, despite all these ethical use concerns, the variances explained by the model for user behavior were almost 59%, which is quite substantial and suggests that most respondents used these AI Chatbots in one way or another for academic work. Some comments from respondents that align with the user behavior code highlighted these conflicting phenomena:

> *"I have a negative view of AI, but it has helped me with questions that I thought were too specific for Google."*

> "*I feel as though AI in general has a long way to go until it can be used reliably in a professional or academic capacity. This, combined with a negative outlook on AI has caused me to be apprehensive about using it. AI should be used as a tool in academics to provide ideas or to reduce the busy work that people must do in their education, allowing them to develop better critical-thinking skills and more in-depth ideas. Overall, the way that AI works does require people to continue to use it for it to develop, however, that further adds to the unpredictability that comes with AI.*"

> "*I like using AI not for factual overview of topics but as a quick reference on something I'm not familiar with as well as organization. I condemn the use for cheating in academics or writing papers. For me, it is a tool and not a solution.*"

These findings agree with those of Chan and Hu (2023), who studied higher education students in Hong Kong, and Al-Zahrani (2023), who studied higher education students in Saudi Arabia. These researchers found that despite the ethical concerns over AI chatbot use in higher education, respondents were generally willing to use AI Chatbots for their studies and future work.

They found that students perceive AI Chatbots as beneficial for providing personalized learning support as they expect learning resources tailored to their needs.

Stöhr et al. (2024), in a study of AI chatbot use among Swedish university students, also found that more than half of the students expressed positive attitudes towards using Chatbots in education. However, almost as many expressed ethical concerns about future use. This concurrence suggests that ethical use concerns and impacts on attitudes to using AI, behavioral intentions, user behaviors, and learning outcomes may be similar in higher educational settings despite discipline-specificity and institutional and cultural context. It is also interesting that Stöhr et al. (2024) found that over a third of students regularly use AI ChatGPT in education and that using other AI Chatbots seemed minimal. This finding is similar to this study's findings and suggests Chat GPT's popularity compared to other Chatbots among university students.

Demographic Analyses

The demographic analysis suggested that graduates use AI Chatbots more than the first and second-year undergraduate students. This finding was consistent with recent findings by Stöhr et al. (2024), which suggested that undergraduate students generally were more negative than graduate students regarding overall positive attitude and the efficacy of Chatbots in improving their learning effectiveness, language ability, and study grades. Further, these students had stronger reservations about the role of Chatbots in education. They mostly perceived using Chatbots to complete assignments as cheating, which should be prohibited and goes against the purpose of education—some of the textual comments from undergraduate respondents in this study aligned with those from Stöhr et al. (2024). These were quotes from some undergraduate respondents:

> "*AI Chatbots should never be allowed in any college class, degree field, or master program. The use of AI Chatbots is cheating and plagiarism. Any college or university must have strict academic rules when it comes to cheating and plagiarism. AI Chatbots should fall under that. Giving credit where credit is due is one of the foundations of academics. AI Chatbots makes that foundation crumble, as credit is nowhere to be found in the sea of mass data pulled. Overall, AI Chatbots should never be allowed in any field, especially aviation education.*"

> "*I fundamentally agree with professors choosing to limit/ban the use of AI Chatbots for work in their courses; I believe they are detrimental to a college education*."

This observation is unsurprising since graduate students in most collegiate aviation programs engage in more research and written assignments as part of coursework and require extensive searches for literature and citations. It sounds logical since graduate coursework requires copious amounts of literature reviews and research writing for thesis and dissertations. For these graduate students, it is important to have efficient research and analysis support. That is where generative AI tools such as Chatbots facilitate literature searching and summarizing readings and may generate hypotheses based on data analysis, enabling them to stay up-to-date with the latest research trends and build upon initial insights for their own work, as Berg (2023) suggested.

These graduate students also find utilities with these Chatbots for search and academic writing, as suggested by Chan and Hu (2023), who found out that most students want feedback on how to improve writing skills, create and generate diverse and unpredictable ideas, and receive prompts beyond grammar checking and brainstorming. Despite the concerns about plagiarism and the potential for AI Chatbots to provide inaccurate information, these graduate students may possess the skillsets to screen AI Chatbots' suggestions and outputs using corroborative source checking and bibliographical indexing. These were some comments provided by respondents in the open-ended item that align with a code on usefulness:

> "*AI in general is useful when trying to find different resources for say a research paper. But it's also hard to tell if the student is only using AI for answers. But overall I have had a positive experience when using AI.*"

> "A*I is only telling us things that we have already told it, but more effectively. It is an extremely useful research and planning tool*."

> "*I think that AI Chatbots are great for research purposes. For me it acts as a search engine to where I am able to ask it a question and it is able to find information for me. This helps when I am stuck on something and am not quite able to figure it out*."

The primal fear of plagiarism experienced in early undergraduate coursework can be further exacerbated by some professors who are averse to using AI Chatbots, which may dissuade some early undergraduates from using AI Chatbots. That may not be similar in some aviation graduate courses with mostly adult learners. It is rather interesting that the graduate students being apt to use AI Chatbots seems at variance with findings from Deng and Yu (2023a), who suggest that graduate students may have some academic experience during their undergraduate study that does not require much use of such AI tools and may stick to traditional research and scholarly search tools such as printed materials and find challenges with using some of these AI applications. There were varying opinions from some undergraduate respondents about professors and programs allowing the use of AI Chatbots:

> "*I wasn't even aware that there were professors who were allowing and encouraging AI Chatbots.*"

> "*It should be made clear to us on its use. If we can use it I prefer to all do in class with the professor as a form of review that way the professor can see if the information listed is 100% correct.*"

On the other hand, this was an opinion from a graduate student:

> "*The use of AI Chatbots helps students stay engaged in their coursework, enabling them to persevere when faced with academic challenges and fostering a broader range of thinking. Since AI is utilized in the real world, it makes sense to leverage it as a valuable resource in academics as well. In the real world, you are allowed to use your resources, and academia should prepare us for this*."

As stated earlier, the apprehension of using Chatbots for ground school examinations or coursework seems realistic when there is currently no policy guidance by the FAA, and some collegiate aviation programs also have minimal guidance for use. These fears may be linked with the potential for certificate action (revocation of ground school assessment results). Currently, FAA ground school examinations are mostly multiple-choice options with standardized answers. AI Chatbots are not allowed, which may not incentivize their use since it may not benefit these young undergraduates seeking an FAA flight certificate. Graduate students are mostly engaged in non-flight certification-related courses in collegiate programs and have the flexibility to use AI Chatbots for their research work.

Based on the previous findings among the graduates and early undergraduates, It seemed logical for the 28-32-year-olds to have significantly higher scores than the 18-22. It is plausible that most of the 28-32-year-olds fall into the graduate group in most collegiate aviation programs. Bearman et al. (2022) suggested that AI chatbot user experience affects user behavior. The more positive experiences derived from Generative AI Chatbot use the more its value proposition function and tendency to use. Some older students may have family and work commitments that require the efficient use of time and effective apportionment. They may find using AI Chatbots functionally useful to get scholarly work, such as written assignments, done expeditiously to be able to attend to these other commitments. This was a comment from a 28-32-year-old respondent:

"*It takes my workload from 20+ hours to around 5 and allows me better mental health.*"

There were significant differences between male and female respondents regarding behavioral intentions. That was not surprising, as previous studies show that when there are no policies on the use of technology, and there seem to be ethical concerns about its use, female respondents tend to be more conservative in their intention to use such technology compared to males (Bearman et al., 2022). This finding was also consistent with Stöhr et al. (2024) study on students' adoption and perceptions of ChatGPT and other AI Chatbots in higher education. They found out that female respondents were ostensibly more concerned about the impact of AI on education, considered the use of Chatbots as potentially contrary to the purpose of education, and viewed the use of Chatbots in assignments and exams as cheating that should be prohibited. On the other hand, male respondents had an overall more positive attitude towards Chatbots and perceived them to a greater extent as tools that can improve their learning. From the findings, we suggest that as collegiate aviation programs develop policies on AI Chatbots, the gender context must be considered to ensure equitable access and use.

Implications for Policy

By understanding students' perceptions of these constructs, collegiate aviation program leadership can develop policy guidelines for AI Chatbots to address needs and concerns while promoting effective learning outcomes. Developing holistic policy guidelines for using these AI Chatbots that outline the scope, underlying benefits, and limitations is essential. The policy should also provide procedural guidelines for syllabi and class use, especially at the primacy levels in collegiate aviation programs. These policy guidelines must be developed with input from students, faculty, and technology resource persons in the program to ensure that data security and privacy issues are considered. Different policies and procedures should target graduates and undergraduates since this study suggests different user behaviors.

Our findings, which align with previous literature on AI Chatbot use in higher education (Al-Zahrani, 2023; Robinson et al., 2021), suggest that AI Chatbots have the potential to revolutionize traditional pedagogy in collegiate aviation programs. AI Chatbots and other AI educational tools can offer structured support for diverse learning needs, enhance efficiency, and promote self-directed learning, as Labadze, Grigolia, and Machaidze (2023) suggested. The successful integration of AI Chatbots in collegiate aviation programs may depend on how professors are educated through workshops to understand the utility, benefits, and limitations of the various AI Chatbots in higher education and how they develop their syllabi and SLO with that in mind.

Students must be well-informed about the benefits and potential pitfalls of using AI Chatbots for academic work. Professors play a key role in this by encouraging critical thinking and the need to cross-check information suggested by Generative AI Chatbots with other sources. These professors and teaching staff should set clear guidelines for using AI Chatbots and other resources appropriately and communicate them to students in their syllabi and course information. This could include guidelines on when and how AI Chatbots can be used and the proper citation and attribution of AI chatbot-generated text, as suggested by Chan and Yu (2023) and Bearman et al. (2022).

As the U.S. aviation regulator, the FAA can provide informational resources and advisory circulars highlighting advances in Generative AI Chatbots, their applicability in an aviation training environment, and the scope and limitations of their use. Institutions should consider providing educational resources and workshops to familiarize students with Generative AI Chatbot technologies and their ethical and societal implications.

This would enable students to make informed decisions when using these technologies in their academic endeavors. As extant research by Parson (2021) and Williamson et al. (2020) suggests, robust data protection policies and practices should be in place within collegiate aviation programs to safeguard users' privacy and to allay some of the fears associated with using AI Chatbots. We hope that based on some of the findings of this study, collegiate aviation programs will re-frame their policy, curricula, and teaching approaches to better prepare students for a future aviation industry where Generative AI Chatbots and technologies may become pervasive, bringing with them potential benefits such as enhanced operational experiences and efficiency.

Limitations

The sample size was relatively small for all collegiate aviation programs in the U.S., which should be considered. Collegiate aviation programs consist of two-year and 4-year undergraduate programs, but we did not have responses from any two-year programs, though we sent out the survey through UAA. We relied on self-reported data, which may also introduce potential biases, as participants could have been influenced by social desirability or inaccurate recall of their experiences with AI Chatbots. The data also suggested that the predominant AI Chatbot used by most respondents was the Open AI Chat GPT, which must be considered when interpreting the findings. We also limited our sample to 4-year collegiate aviation programs, even though there are some 2-year collegiate aviation programs.

Furthermore, the study's cross-sectional design does not allow for examining changes in students' perceptions over time as their exposure to and experiences with AI Chatbots evolve. Lastly, since some collegiate programs may not have a formal use policy in academic settings, students may have limited exposure to it. We also sampled our respondents early in the spring semester with minimal academic coursework. That could impact responses from fresh undergraduate students who may still be orienting themselves to the program's intricacies.

Conclusion

In conclusion, the perceptions of a sample of collegiate aviation program respondents were evaluated to determine the relationships between ethical use concerns of AI Chatbots, attitudes towards use, behavioral intentions, students' learning outcomes, and user behaviors. Some constructs from the technology acceptance model (TAM) were used to assess the strengths of relationships among these constructs. An SEM/PA measurement model fit the empirical data well; most of the hypothesized relationships were significantly supported. The most substantial direct relationship was between attitude towards AI Chatbot use and behavioral intention to use AI Chatbots.

Despite deep concerns about the ethical use of AI Chatbots in collegiate aviation programs stemming from cheating, plagiarism, loss of professor jobs, and data privacy, about 59% of the variances in user behavior could be explained by a model suggesting relatively good user behavior among respondents. Graduate respondents had higher user behavior than first—and second-year undergraduates, with higher scores on ethical use concerns. The 28-32-year-olds had relatively higher user behavior than the 18-22-year-olds. Male respondents showed higher user behavior than female respondents.

The insights gleaned from our study have the potential to significantly influence policy development around the integration of AI Chatbot technologies into higher education. By understanding students' perceptions and addressing their concerns, policymakers can develop well-informed guidelines and strategies for the responsible and effective implementation of AI tools, thereby enhancing teaching and learning experiences in higher education.

Future Direction

There is a need for further research as AI Chatbot use expands in higher education. Expanding our study to include other AI educational technologies, understanding how AI Chatbot technology is used among professors and collegiate aviation administrators, and probing the impact of AI Chatbots on future flight training and the AI-mediated aviation industry are all promising avenues for future investigation.

Ethical Disclosure: AI tools used were Qualtrics® TextiQ for coding and Grammarly® for editing and checking grammar and style.

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Appendix A

Sample of Survey Items

ATU_1: I generally have a favorable point of view toward using AI Chatbots.
ATU_2: I think using AI Chatbots for academic work is a good idea.
ATU_3: I am interested in learning about any new information related to the use of AI Chatbots in academic work.
ATU_4: How do you feel about the effect of AI Chatbots use on academic work? (removed)
BI_1: I plan to use AI Chatbots for my academic work in the future.
BI_2: I aim to use AI Chatbots for my academic work frequently.
BI_3: I hope to adapt AI Chatbots for academic work and professional development.
SLO_1: AI Chatbots help me to think analytically in aviation courses.
SLO_2: AI Chatbots help me deal with unfamiliar problems in aviation courses.
SLO_3: AI Chatbots use help me develop in-depth knowledge of various aviation topics.

SLO_4: How have AI Chatbots developed your critical thinking skills about aviation topics?
UB_1: The regular use of AI Chatbots in scholarly activities promote my active participation in academic activities.
UB_2: I am encouraged to ask questions and share ideas in classes where the professors regularly allow AI Chatbots as an academic tool.
UB_3: I regularly attend classes where professors regularly allow the use of AI Chatbots in their courses. (removed).
UB_4: I prepare well for classes because of regular AI Chatbots use.
UB_5: I put effort into my studies because of the regular use of AI Chatbots.
EU_1: The use of AI Chatbots can lead to cheating and plagiarism in academic works.
EU_2: Over-reliance on AI Chatbots can lead to students not developing critical thinking skills.
EU_3: The use of AI Chatbots can lead to a loss of human interaction and emotional connection among students.
EU_4: Accessibility to AI chatbot data should be transparent with informed consent and clarity of data ownership.
EU_5: AI Chatbots must ensure well-informed consent from the user and maintain the confidentiality of the user's information, both when they provide information and when the system collects information about them. (removed).
EU_6: AI Chatbots could lead to the loss of jobs for people working in academia and research fields. (removed).

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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

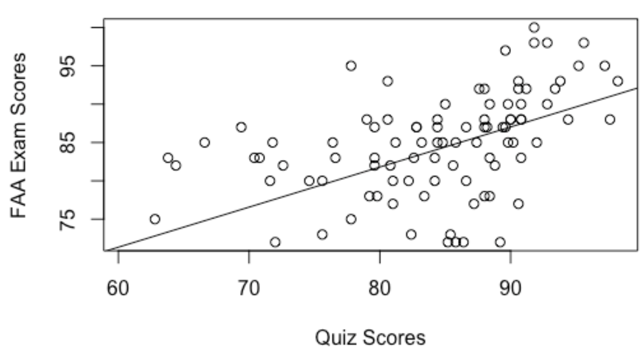
Can the quizzes in this course be used as a predictor for the students' FAA UAG exam scores?

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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An exploratory review of transfer policies for certified private pilots in collegiate flight programs

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Research problem: Universities often admit students who have already completed a portion of their flight training outside the collegiate environment and who want to transfer in their previous flight experience in fulfillment of a flight degree. There is no widely published standard by which to evaluate or successfully integrate transfer flight students into a collegiate flight training curriculum. This research aims to learn how common it is for students to enroll in a flight program with a Private Pilot Certificate, how university flight programs are evaluating and integrating these students into their existing curriculum, and whether or not there are any differences between ab-initio and transfer students in terms of graduation rates or other measures of success. Research questions: (1) What are common ways that flight programs award credit for private pilot certificates earned outside of the university? (2) What, if any, supplemental instruction or evaluation actions are transfer students required to complete before they start post-private training? (3) If supplemental instruction or evaluation actions are being completed, are those actions working as intended? (4) When considering two suggested measures of success, are universities finding any differences between ab-initio flight students and transfer flight students? Summary: This study explores why students may want to complete Private Pilot training before entering a collegiate program, shares how some collegiate flight programs are managing the flight transfer process, reports how successful these transfer processes are, and identifies additional areas of needed research in order to identify best practices.

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Introduction

The typical university flight curriculum requires the completion of multiple Federal Aviation Administration (FAA) certificates and ratings. These certificates and ratings most often include Private Pilot, Instrument Airplane, Commercial Pilot, Multi-engine, and sometimes Flight Instructor (CFI). These certifications are commonly completed along with academic coursework to fulfill degree requirements.

While not all universities allow students to complete a flight degree if they have completed some or all of their flight training elsewhere, many do, particularly if only the private pilot certificate has been completed. Despite a number of universities allowing for this type of transfer, there is no standardized method by which to evaluate the quality of a student's previous flight training or to ensure students will transition well into a university flight training environment.

This article discusses the factors that influence students' decisions to begin flight training prior to entering a university program and shares the findings of a survey that was designed to answer the following research questions.

1. What are common ways that flight programs award credit for private pilot certificates earned outside of the university?

2. What, if any, supplemental instruction or evaluation actions are transfer students required to complete before they start post-private training?

3. If supplemental instruction or evaluation actions are being completed, are those actions working as intended?

4. When considering two suggested measures of success, are universities finding any differences between ab-initio flight students and transfer flight students?

The theoretical framework of this exploratory review is based on the value of research-informed teaching and the belief there is a need for practitioners "to produce research that is more relevant to practice" (Sjolund, 2022). The findings of this research, then, are intended to inform educational practices among collegiate aviation educators by inviting flight department managers to consider how to more effectively integrate private pilot students into their own university's flight training curriculum.

Background and Literature Review

Understanding Aviation Degree Requirements

Universities offer a variety of aviation degrees, and not all include flight training. To get a sense of the different types of aviation programs at various universities, it is helpful to look at the classifications used by the Aviation Accreditation Board International (AABI), the only programmatic accrediting organization for aviation that is recognized by the Council for Higher Education Accreditation (CHEA, 2024).

AABI categorizes non-flying program offerings as Aviation Management, Aviation Maintenance, Aviation Electronics, Aviation Studies, Aviation Safety Science, Air Traffic Control, and Unmanned Aircraft Systems. The program category that *does* require flight training is referred to as "Flight Education," which AABI suggests includes degree offerings such as "Aircraft Systems Management, Flight Operations, Career Pilot, Professional Pilot, or Aeronautical Science." (AABI, 2024, p. 37- 44). The programs examined in this research include those that require flight training, which AABI categorizes as "Flight Education."

AABI clearly specifies that, for the Flight Education programs to be accredited, program goals "MUST lead to appropriate national certification," referring to FAA licensure and certifications for programs that operate in the United States (AABI, 2024, p. 40).

In the case of associate degree programs, the flight degree must include the Private Pilot certificate and the Commercial Pilot certificate with an instrument rating. In the case of Baccalaureate degree programs, the degree must also include either the multi-engine land rating or flight instructor certificate, in addition to the Commercial Pilot certificate with an instrument rating (AABI, 2024, p. 40).

Even if a flight program is not AABI-accredited, the logical purpose of any flight degree is to prepare graduates for employment in flying careers, all of which require some minimal level of certification. FAA regulations clearly outline the minimum experience and task requirements applicants must meet before certifications are issued; these standards are listed in the FAA Airmen Certification Standards (FAA, 2024a) and in Title 14, Code of Federal Regulations §61(Certification: Pilots, Flight Instructors and Ground Instructors, 2024). The FAA does not, however, dictate that flight training must take place at a university or college. That means there is a wide range of flight training options available to anyone who wants to learn how to fly, whether the goal is to fly recreationally or professionally.

Value of a College Degree

Sam Weigel, a professional airline pilot and author, explores the benefits of earning a four-year degree in an article published in a popular aviation magazine. He points out that even though a degree is currently no longer required for most major air carriers, a degree continues to be preferred due to the value of the academic curriculum that a student completes while earning the degree, and an aviation degree may allow graduates to qualify for hire at a regional airline with fewer hours of total flight time. Beyond these reasons, he also warns that, in times when airlines pause their hiring due to economic downturns or other reasons, "the majors will go right back to requiring (or strongly preferring) pilots with a 4-year degree when they start hiring again." He also notes that airline/university partnerships can be valuable benefits available to students who attend a university-affiliated aviation program (Weigel, 2022).

Costs Associated with Flight Training

In the same article, Weigel goes on to suggest that college attendance is an especially good idea for someone in the position to "get your PPL and a year's worth of college credits done in high school [so] you can decrease both the cost and time requirement of a degree." Saving money is a particularly compelling reason why someone might want to complete at least a portion of flight training before enrolling in a university curriculum. He reports, "...four years of tuition, flight fees, and room and board at Embry-Riddle Aeronautical University is now more than $260,000...and even smaller collegiate programs are pushing $200,000." He further notes that non-university training providers can provide flight training through MEI (Multi-engine instructor) for $90,000 (Weigel, 2022).

In validation of Weigel's assertions, anyone associated with aviation education is all too aware of the high costs of flight training. While it is difficult to make direct comparisons between university flight training costs and those found at a fixed-base operator (FBO), students can often save money by obtaining flight training at a non-collegiate provider. Two collegiate flight providers and their respective nearby FBOs are included here as generalized illustrations.

In one example, Southern Illinois University currently lists $16,603 as the minimum cost to obtain a private pilot certificate (Southern Illinois University, 2023). Enhanced Aero, an FBO located at the same airport, advertises an estimated private pilot training cost of $12,170. This represents savings of over $4000 (Enhanced Aero, n.d.).

In a second example, the University of North Dakota currently lists $19,778 as the cost to obtain a private pilot certificate (University of North Dakota, 2024). Comparable flight training at GFK Wings, LLC, a flight training provider that is located at the same training airport, could potentially save a student over $5000 if one calculates the listed hourly aircraft rates, instructor fees, and exam fees based on publicly available information on their website (GFK Wings, LLC, 2023). See Table 1 for details.

Table 1
Rough estimate cost to obtain a private pilot certificate at GFK Wings, LLC

GFK Wings	Cost	Qty	Totals
Cessna 172 (wet)	$135.00	63	$8,505.00
Instructor hourly	$56.00	100	$5,600.00
Written exam	$175.00	1	$175.00
			$ 14,280.00

Additional Factors and Considerations

Cost may be a driving factor for some students, but for others, a strong interest might be the primary motivation to learn how to fly as soon as they can. If they have the financial means and convenient access to a flight instructor and airplane, the goal of learning how to fly is much more attainable and doesn't require immediate enrollment in a collegiate program.

Whatever a student's motivation and ability to begin flight training before college, there are some important considerations they should be aware of before making a potentially consequential decision.

Age Considerations

While there are no restrictions on how old a person needs to be to start training, age restrictions on certain milestones do exist. Student pilots, for example, are permitted to solo an airplane if they are at least 16 years of age and complete the practical check ride for a private pilot certificate if they are at least 17. FAA regulations, however, require that commercial pilots be at least 18 years of age. These age restrictions make earning a private pilot certificate an attainable goal for those with the resources and opportunity while they are still in high school but may keep them from advancing further, depending on their age (Certification: Pilots, Flight Instructors, and Ground Instructors, 2024).

R-ATP Qualifications

In addition to age restrictions, students should be aware that to receive a Restricted Airline Transport (R-ATP) certificate at a reduced hour requirement, they must complete their instrument and commercial training in an FAA-approved part 141 program. These approved training programs allow students to complete the R-ATP in as few as 1000 flight hours of total flight time compared to 1500 hours (FAA 2024c).

As of July 2024, 104 collegiate flight programs were authorized by the FAA to certify their graduates as eligible to apply for a restricted privileges ATP certificate with reduced hour requirements (FAA, 2024b). Because the R-ATP has reduced hour flight time requirements compared to the unrestricted ATP certificate, completing a flight education at an approved program can save graduates a significant amount of money.

An Airline Transport Pilot certificate (ATP) or Restricted Airline Transport Pilot certificate is required before taking a pilot job at an air carrier certified under 14 CFR §121, such as commercial passenger air carriers or many cargo companies. While some students decide to complete all, or the majority, of their flight training outside a university environment, FAA regulations governing the eligibility of a reduced-hour R-ATP certificate give them compelling reasons to complete subsequent training beyond the private pilot certificate at an approved university instead of with an unapproved flight training provider such as an FBO (Certification: Pilots, Flight Instructors and Ground Instructors, 2021).

To qualify for an ATP, 1500 hours of total flight time and 500 hours of cross-country flight time are required. The different experience requirements for R-ATP options are illustrated in Table 2 (Certification: Pilots, Flight Instructors, and Ground Instructors, 2024).

Table 2
Required Experience to Apply for a R-ATP Certificate

Training required	Military	Bachelor's part 141	Associates part 141	No degree
Total Time	750	1000	1250	1500
Cross country time	200	200	200	200

Significance of Research

This research suggests that anywhere from 10 to 50% of students are entering college with previous flight experience, yet there is no standardized method for how to effectively evaluate and integrate these students into flight programs. Learning more about how universities manage incoming students who complete flight training outside of the collegiate environment allows flight programs to improve their integration strategies and determine how to best support all students.

Methodology

To help answer the stated research questions, a thirteen-question survey was designed using Survey Monkey. The survey link was sent via email by the University Aviation Association (UAA) on April 11, 2024, to all 130 UAA member schools. Instructions asked that respondents be the university or college's Chief Flight Instructor or their designee. The survey remained open for three weeks.

Fifteen institutional representatives completed the survey, but one was not part of a collegiate aviation program, so their survey responses were removed from the data set. That meant that 14 usable surveys were returned, representing 10.7% of all possible respondents. A summary of the survey responses follows.

Survey Results

Respondents' Titles

Six respondents indicated they were the Chief Flight Instructor of their institution. Other titles reported were "Chair," "Director," "Manager," or "Administrator" (5); "Assistant Chief" (1); and "Assistant or Associate Professor" (2).

Universities and Colleges Represented

Twelve respondents shared the name of their university or college. One responded, "State University," and one responded, "University." These answers confirmed that respondents represented a variety of public versus private institutions and represented institutions with both two-year and four-year flight education degrees. Several geographic locations within the United States were also represented. In terms of program sizes, three programs reported having over 500 students, five programs reported having 201-400 students, and six programs reported having 200 or fewer students.

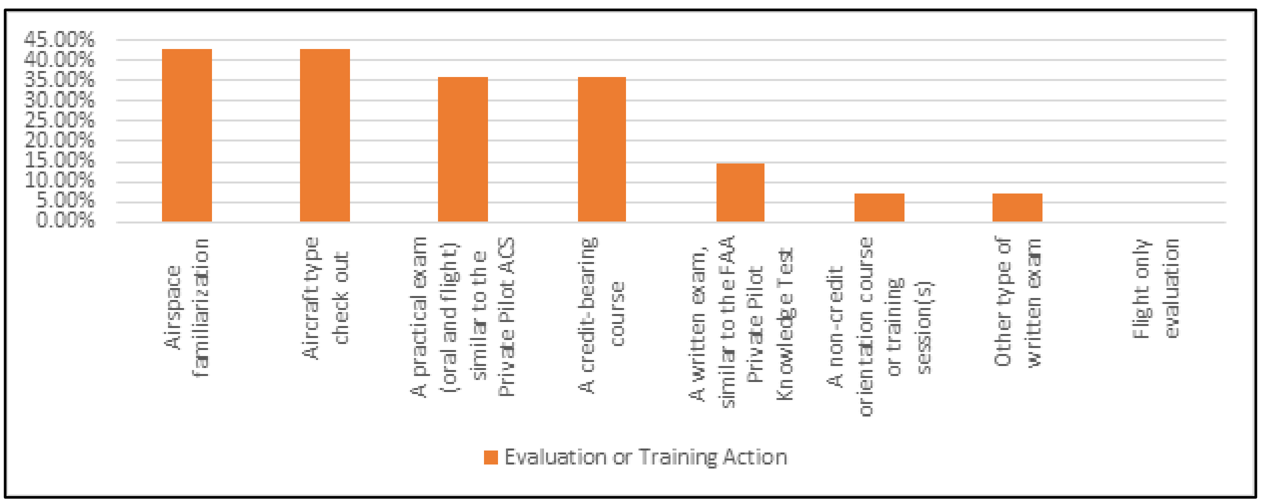
Acceptance of Outside Flight Training

All fourteen respondents reported that they allow students to begin post-private flight training and potentially complete a flight degree if they have completed the Private Pilot Certificate elsewhere. This article refers to these students as "transfer flight students." On the low end, three programs reported that an estimated 10-20% of their flight students are transfer flight students. On the high end, one program reported that as many as 40-50% of their flight students are transfer flight students. This information validated the assumption that learning more about transfer flight policies and sharing the findings could provide widespread benefits.

Evaluation and Integration

Despite all survey respondents reporting that their programs accept transfer flight students, there are many ways that programs evaluate and integrate them into their programs. Ten of the respondents (over 71%) say the transfer students receive additional evaluation or training prior to pursuing a post-private certificate, while four (almost 29%) said the transfer students are admitted into the flight training program without receiving additional evaluation or training before flying. The additional evaluation or training actions are detailed in Figure 1. Respondents were invited to select multiple responses if needed.

Figure 1
Additional Evaluation or Training Actions % of survey respondents



One respondent selected the "other" option but then went on to explain that they have transfer students take a credit-bearing course. To more accurately reflect their intended response, their response is included in the "credit-bearing course" category. Another respondent indicated they administer a written exam to transfer students for credit but did not say if it was modeled after the FAA Private Pilot knowledge exam. In this case, their response is included in an "other type of written exam" option.

An optional survey question asked respondents to describe their additional evaluation or training actions in more detail. These seven comments were submitted that further clarify and explain the initial responses.

- *"Students must complete a course in the [airplane type] to demonstrate Private Pilot skill in that airplane."* This comment supplements the "credit-bearing course" option.

- *"We find Part 61 PPLs have a lack of knowledge in several areas. We require them to take our PPL Ground I to ensure they have the base of knowledge for our program."* This comment supplements the "credit-bearing course," "airspace familiarization," and "aircraft type check out" options.

- *"Students with a PPL qualify to complete a written exam that, if passed, will grant them credit for our PPL lecture course. This course is normally taken by students who are working on their PPL with us. If the student passes, they receive credit and move on. If the student does not pass, they will be required to take the lecture course even though they already have a PPL."* This comment supplements the "written exam for course credit" option.

- *"They are given a written exam that is modeled after the FAA written. If a score of 80% or higher is achieved, they enter the next course. If a score of less than 80% is achieved, they are given 10 hours of remedial ground training on all areas of private pilot knowledge. All individuals are then given an evaluation ride; it is lesson 1 in the instrument syllabus (assuming they came to us with a PPL). That is conducted to ACS standards by a flight instructor."* This comment supplements the "written exam, modeled after the FAA Private Pilot Knowledge Test" option.

- *"Individual CFIs evaluate that students are up to Private ACS standards while putting those training sessions towards the instrument and commercial training requirements as appropriate. They are not allowed to go solo until the evaluation is complete."* This comment supplements the "Airspace familiarization," "Aircraft type check out," and "credit-bearing course" options.

- *"Student handbook, Safety Handbook, Make and Model, Airspace, Tracking software, enrollment certificate, and acknowledgment of risk."* This comment supplements the "Practical exam (oral and flight) adapted from or modeled after the Private Pilot ACS," "Airspace familiarization," and "Aircraft type check out" options.

- *"Students who come to [name of university] with their private pilot certificate obtained are required to go through a transitional course. This short course is a few flights and a few ground sessions to help students become familiar with airspace, aircraft, SOPs (ground and flight), etc."* This comment supplements the "Airspace familiarization," "Aircraft type check out," and "a non-credit-orientation course or training session(s)" options.

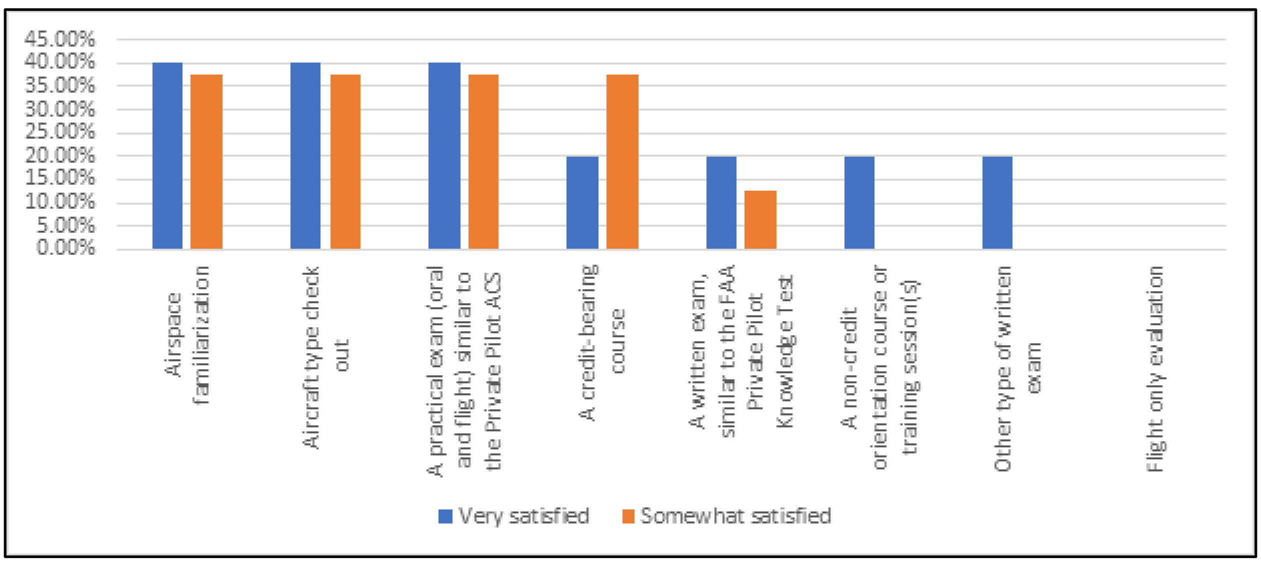
While there is no single method of incorporating students with Private Pilot certificates into collegiate flight programs, survey responses showed that the most common methods are airspace familiarization and aircraft checkouts. Practical exams modeled after the Private Pilot ACS and credit-bearing courses were each indicated by 36% of respondents. A written evaluation of some kind was indicated by 21% of respondents. One school indicated the use of a non-credit-bearing course to integrate flight students into their flight program.

Level of Satisfaction with the Evaluation and Training System

When respondents were asked how satisfied they were with the current system being used to evaluate and train transfer flight students, five (over 35%) selected the option "Very satisfied. Things are working as intended." Eight (over 57%) selected the option "Somewhat satisfied. Some minor changes in how we do things might be warranted, but overall, things are going well." No respondents chose options that indicated a neutral opinion or negative opinion. One respondent selected "prefer not to answer."

These responses provided an opportunity to determine what common elements the collegiate flight programs shared. Are the programs that report a high level of satisfaction in how they are evaluating and integrating transfer flight students into their programs doing anything different from the programs that report a lower level of satisfaction? Figure 2 shows what each of these two groups is doing to evaluate and integrate transfer flight students into their programs.

Figure 2
Comparing the "Very Satisfied" vs "Somewhat Satisfied" Respondents



Of the five respondents who indicated they were very satisfied with their school's system of integrating flight students effectively into their program, four (80%) require additional training or assessment for their transfer students. The one respondent who indicated being very satisfied with their transfer policy that does not use a formal assessment tool stated that "Students go directly into Instrument Rating training. They receive a "CR" (credit) on the transcript for Private Ground and Flight."

Out of the ten respondents who indicated they require additional training or evaluation for transfer students, four indicated they were very satisfied with the system used to integrate them successfully. Examining the four "Very satisfied" respondents, two respondents indicated using a practical exam modeled after the Private Pilot ACS; two indicated some sort of written exam.

In addition to identifying the many ways that transfer flight students are evaluated and integrated into collegiate programs, the survey included questions to determine if there were any discernible differences in terms of student success measures between ab-initio and transfer flight students. Survey question number 11 explained that for the purposes of this research, "ab-initio" was being defined as, "students who have done all of their flight training with your program from the beginning."

Program Completion

Program completion rates were identified as one important measure of student success, and survey respondents were asked to compare estimated program completion rates between ab-initio and transfer flight students. Six of the respondents (about 43%) said "there's little to no difference between the two groups." Three respondents (about 21%) indicated that "the ab-initio students are more likely to successfully complete their program," and one respondent (about 7%) said "the transfer students are more likely to successfully complete the program." Three respondents (about 21%) said, "I'm not sure which group is more likely to successfully complete the program." One respondent chose "prefer not to answer."

Interestingly, all three respondents who answered "I'm not sure" reported not using FAA-style knowledge tests and ACS-style practical exams when evaluating transfer flight students. Those respondents who reported using an ACS-style practical exam or an FAA-style knowledge test when evaluating transfer students reported program completion rates with more confidence.

Quality of Graduates

When asked to compare the overall quality of ab-initio and transfer students, at the time of graduation, the responses were nearly identical to those asking about graduation rates. Six (almost 43%) said, "there is little to no difference between the two groups; two (about 14%) said, "the ab-initio students are more likely to become flight instructors for us and do well in the industry;" and five (almost 36%) said, "I'm not sure which group would be considered generally more successful in terms of these measures." One respondent chose, "prefer not to answer."

Additional Comments

Two optional comments were offered by respondents at the end of the survey.

- "...Student retention is higher compared to incoming students without a PPL. We have significant retention problems among students at PPL. We actually encourage incoming student[s] to have a PPL before enrolling. The retention rate is much better after PPL."

- "When choosing our cohorts for each year, we consider non-PPLs in different groups."

Limitations of the study

Low Response Rate

While the survey's 10.7% response rate provided helpful foundational information in answering the research questions, a higher response rate would have improved the validity of this study. The resulting inability to fully assess nonresponsive error is acknowledged as a limitation. As suggested in an article by researchers in the information systems field, improving response rates might occur with email, letter, or telephone call reminders, and monetary incentives such as gift cards or opportunities to win a prize drawing. These researchers also point out that federally funded research requires an 80% response rate, and in other types of research, such as marketing and human resource management, response rates average around 50%. The average response rate in most of the information systems journals they reviewed averaged below 40% (Sivo, S. et al. 2006).

Low survey response rates in any type of research are unfortunate and might not be measurably improved with the efforts suggested. In the case of this survey, at least one reminder email about the survey might have prompted more responses, and perhaps other communication channels should have been included. Funding was not available to offer monetary or prize incentives.

Unexpected 100% Acceptance Response

Unexpectedly, 100% of all respondents indicated they accept transfer-fight students. That means either *all* collegiate aviation programs accept transfer flight students (unlikely), or the survey was designed in such a way to inadvertently discourage those who do not accept transfer students from completing the survey. The introductory message that accompanied the survey should be reviewed with this potential inadvertent messaging in mind if the survey is replicated in the future.

Despite not being able to learn more about collegiate aviation programs that do not accept transfer flight students, that was not a focus of this research, and the survey results still allowed us to address the intended research questions.

Survey Option Redundancy

Another potential survey design limitation relates to the multiple-choice options listed for the question asking about additional evaluation or training actions taken with transfer flight students. The options "airspace familiarization" and "aircraft checkout" were both chosen by the same respondents, indicating (logically) that an aircraft checkout flight would also include airspace familiarization.

Lack of Information about Areas of Needed Remediation

Finally, in terms of study limitations, this survey lacked questions that adequately explored the most common areas where transfer flight students struggle the most. Should this research be replicated or continued, more information should be collected to find out what areas of remediation, if any, are commonly needed to adequately integrate transfer flight students into collegiate aviation programs.

Discussion

Despite the limitations of this study, it answered the intended research questions and worked well as a foundational review of the ways colleges and universities are bringing transfer flight students into their flight programs. Knowing that, in some cases, nearly half of a program's flight students have completed their Private Pilot Certificate before coming to the university, this research shows that collegiate flight programs are managing transfer flight students with different levels of confidence and approaches.

Research Question 1

The first research question of this study asked about the common ways flight programs award credit for private pilot certificates earned outside of the university. Survey results showed that, in at least one case, academic course credit is awarded based on having the Private Pilot Certificate alone, with no evaluation or other actions required. Other survey responses described awarding credit to transfer flight students after they complete a course, successfully pass written and/or oral exams, or complete a flight checkout before academic credit is awarded. One survey respondent reported that their transfer flight students are required to take the Private Pilot Ground School in order "to ensure they have the base of knowledge for our program," even if they already hold the Private Pilot Certificate.

No two respondents described the same process whereby academic credit is awarded for previous flight experience, so there is no one "common" way this happens.

Research Question 2

The second research question of this study was designed to find out what if any, supplemental actions programs might take in terms of remediation or ensuring the readiness of transfer flight students to continue flying in subsequent courses.

Noteworthy is the finding that half of the respondents who said they were "very satisfied" with their procedures for evaluating and incorporating transfer flight students into their programs have in common the use of a written exam to initially evaluate the incoming student's Private Pilot knowledge that may or may not lead to remedial learning requirements either by having to take the Private Pilot "lecture course," or by having to complete ten hours of "remedial ground training on all areas of the private pilot knowledge."

Despite the small sample size, this approach may work well for other programs that want a relatively easy way to implement a structured process of evaluation in order to identify which students would benefit from supplemental instruction and then provide that supplemental instruction in either an existing course or a specified number of ground sessions, as needed.

Research Question 3

The third research question sought to find out how well additional evaluation or training measures are working for flight programs that choose to use them. Although it would have been nice to be able to identify the best method for integrating transfer students, the survey data yielded no clear consensus. Surprisingly, all the respondents who elected to answer this question (all but one) reported they were either very satisfied or mostly satisfied with their transfer process, even though there are several different processes being used.

Here, it is important to note the challenges of using a term like "satisfaction" in a survey. It measures the subjective feelings of the individual respondent, but it does not identify why the respondent feels satisfied or unsatisfied without the use of follow-up questions, which this survey did not include.

Definitions for satisfaction are likely heavily influenced by the respondent's personal viewpoint and by the values of the institution of higher learning and the individual program. Examples of satisfaction metrics, for example, might include things like economic outcomes for the institution, economic outcomes for the student, the effort required on the part of the student or the part of the institution, the student's perceived satisfaction, the impact of transfer policies on recruitment, how transfer policies impact resource availability, student success rates and student retention, and more.

Finally, despite the high level of satisfaction expressed, most respondents indicated there was room for improvement with their transfer practices. Without knowing exactly why they are not entirely satisfied, however, prevents clear recommendations from being suggested based on these survey results.

Research Question 4

An important goal of this study was to find out if collegiate flight programs saw differences in terms of student success outcomes between ab-initio and transfer flight students. "Student success" is defined in many ways, but for the purposes of this study, two characteristics were selected: 1) Program completion rates and 2) "Becoming a flight instructor for the program and/or doing well in the industry."

"Becoming a flight instructor for the program" was chosen as a measure because flight programs that hire flight instructors will presumably hire the best candidates and can be somewhat discerning when making hiring decisions. “Doing well in the industry” was selected as it allows survey respondents to answer quickly without requiring them to access data.

The primary finding related to this research question is that few programs closely track how well their ab-initio students are doing when compared to the transfer flight students. Some report that the ab-initio students do better, while others report the transfer students do better. A substantial number simply do not know.

A less clear but helpful finding is that those who reported using an ACS-style practical exam at least had an opinion about the difference in graduation rates between the two groups, saying there is little to no difference between them.

Conclusions and Recommendations

Students have compelling reasons to want to begin flight training outside the university environment related to cost and motivation; however, the impacts on universities in allowing students to begin flight training outside of the university are less clear. Do universities benefit from allowing students to transfer in with a private pilot certificate, or do they not? The answer to this question is not clear.

If these survey results are generalizable to the larger collegiate aviation community, ab-initio students are more likely to become flight instructors for their university’s flight program and be successful in the industry, while transfer students are not. At least one university manager reports that they actively encourage students to complete their Private Pilot training before enrolling at the university, based on the belief that they are more likely to be retained as students and complete the program. Data from this research, however, indicates that other university flight programs aren’t finding those same results.

As universities and students alike seek to make higher education more affordable, it is in everyone’s best interest to allow incoming students to complete Private Pilot training before flying at the college or university. Maintaining high training standards, however, is critical, and collegiate flight programs should be compelled to examine their own transfer policies and determine how to easily and efficiently bring transfer flight students into their programs.

Collegiate flight programs should also begin collecting data to measure program completion rates and other success measures between ab-initio and transfer flight students if they are not already doing so. Based on this survey's results, a significant number of aviation programs are generally not aware of how well their efforts to evaluate and integrate transfer students into their flight program are working. Overall, programs that do make an effort to evaluate and integrate transfer students into their flight program report feeling more satisfied with the results than the programs that do not, but this research failed to clearly identify which efforts on the part of the flight program yield the best results.

More feedback is needed from additional collegiate aviation programs if we are to identify best practices related to supporting transfer flight students in our flight programs and setting them up for long-term success as flight instructors and professional pilots in the industry;

if those are two measures we define as “success.” Another research gap is related to identifying the most common areas of deficiencies among transfer flight students. If collegiate aviation programs consistently see common areas of needed remediation, structured courses or training plans could be more easily built.

Finally, research that includes the perspectives of transfer flight students would also be valuable in terms of learning more about their decisions to begin flight training outside the university environment and whether they think their transfer experience into the collegiate flight education setting was well managed.

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Bridging the Gap: A SWOT Analysis Addressing Challenges in Hong Kong's Aviation English Training Industry

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This study examines the factors that could influence the growth of the aviation English training industry in Hong Kong (HK). A document analysis approach was employed, using the SWOT as the analytical framework. The analysis focused on 32 publicly available documents published between 2019 and 2024, which discussed the industry, particularly HK-headquartered passenger aviation companies. The findings of this study showed that the development of the industry was driven by the diversity of training providers tailored for HK students and the local aviation market, in compliance with International Civil Aviation Organization (ICAO) protocols, and the expansion of HK-based aviation companies. However, the sustainable development of the industry was hampered by several challenges. These challenges included the limited availability of customized courses for HK students and the local aviation industry, general talent shortages in the aviation sector, various institutional and operational constraints, and increasing competition from international online courses. The remaining sections of this paper provide recommendations for industry players and the HK government while also highlighting the academic contribution of this study.

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Introduction

The global aviation industry relies on English as its lingua franca and requires frontline employees to have a good command of the language. To ensure safe operations, the International Civil Aviation Organization (ICAO) has established standardized language proficiency requirements that have been widely adopted. The specific characteristics of aviation English, including specialized terminology and phrases, require targeted language training. As a result, governments and industry representatives are increasingly recognizing the importance of aviation English courses in maintaining safe and efficient air traffic operations.

As Hong Kong (HK) is solidifying its status as a major international aviation hub (Government of Hong Kong, 2021), the importance of effective English communication has become increasingly pronounced. The HK passenger industry has witnessed significant developments over the past five years, driven in part by key institutions such as Hong Kong International Airport (HKIA) and Cathay Pacific (Lam, 2019; Skytrax, 2023a). In tandem with these efforts, the need to enhance aviation English proficiency among in-service and aspiring aviation professionals in the HK passenger aviation industry has gained prominence. Despite growing recognition of this issue, the aviation English training industry in HK remains relatively understudied. This industry primarily encompasses HK-headquartered training providers, students and educators in HK, and the local regulatory authorities. The limited study of this industry could hinder a full understanding of its merits and caveats, thereby potentially hindering the development of effective strategies for its growth. This project aims to address this knowledge gap by conducting an in-depth examination of the industry. By exploring the favorable and unfavorable aspects of the HK market, this study will provide valuable insights for training providers, policymakers, and aviation English training instructors, ultimately informing strategies to support the continued growth and development of HK's aviation sector.

To address this research gap, we conducted a document analysis and integrated a SWOT analysis (examining strengths, weaknesses, opportunities, and threats) as the analytical framework. This approach was used to investigate the factors influencing the growth of HK's aviation English training industry. The key question guiding this analysis is: What key internal dynamics and external contextual factors are influencing the development of the aviation English training market in HK?

Theoretical Framework: SWOT Analysis

Document analysis is a qualitative research methodology that systematically evaluates documents to identify topics and themes, considering the social, historical, and business contexts in which they are situated (Bowen, 2009). It recognizes that documents are not merely static texts but are products of and contributors to their social environments. The document analysis procedure entails four key stages: data collection, code scheme design, topic annotation, and intercoder reliability. While subjectivity bias is a limitation, this qualitative method can facilitate an in-depth understanding of complicated social issues (Kutsyuruba, 2023). It has been widely used to examine policy, business, and economic documents, including annual reports and marketing files. In the field of economic/business document analysis, this method often integrates business frameworks such as SWOT that can investigate factors impacting market development (Asdal & Reinertsen, 2022). This study uses SWOT analysis to structure economic document analysis, exploring the factors that influence the aviation English training market in HK.

Wheelen et al. (2017) describe SWOT analysis as a framework for examining a regional industry. It identifies internal strengths that aid goal achievement, such as market expansion. It also pinpoints internal weaknesses that hinder desired outcomes, like poor financial performance. Additionally, the analysis considers external opportunities the industry can employ, such as supportive government policies. It also examines external threats that impede industry goals, such as market erosion by outside competitors. SWOT analysis thus allows researchers to explore both internal and external factors impacting the regional industry. It provides insights into institutional elements and broader contextual influences shaping industry performance and prospects.

SWOT analysis has been widely employed to examine the influencing factors impacting the development of the Asian aviation industry. Ellis (2020) applied the framework to examine favorable and unfavorable factors influencing efficient management in the Asian aviation industry. It was found that management efficiency is influenced by the geography of the airport, political issues, and the economic development of the industry. In the industry context, Nam et al. (2023) specifically compared the maintenance, overhaul, and repair industries in Northeast Asian countries. The findings showed that Japan has advantages in technology, China has advantages in cost, and Korea has advantages in human resources and quality.

Recent studies on the Chinese aviation industry have conducted SWOT analyses. Li (2020) identified several factors, such as the increase in e-commerce express deliveries, new technologies, and Chinese government policies, which mitigated the impact of COVID-19 on Chinese air cargo. Despite these mitigating factors, the industry was also threatened by trade tensions between the US and China and regional competition. In another study on Chinese aviation, Su and Zhao (2019) noted that Guangzhou Airport's growth is benefiting from government policies. In contrast, however, the facility also faces the threats of inefficient land supply, a lack of support facilities, and weak aviation production fundamentals. Hsu and Gu (2010) conducted a SWOT analysis of the aviation industry in HK. Their study highlights that the completion of the Hong Kong-Zhuhai-Macau Bridge makes it easier for passengers on long-haul flights to reach the airport.

Although Hsu and Gu (2010) have offered valuable insights into HK’s aviation industry, their study primarily focuses on the operational aspects, leaving a gap in the understanding of the aviation-related professional training sector. Continuous training, particularly in aviation English, plays a crucial role in ensuring that professionals in this field can effectively and safely perform their duties. It is thus essential to investigate the internal strengths and weaknesses, as well as the contextual opportunities and threats of HK’s aviation English training.

Methodology

A collection of 32 publicly available documents was compiled, spanning the period from 2019 to 2024, to examine the institutional and contextual factors influencing the HK aviation English training industry. The collection comprises texts that specifically address aviation English training in HK or discuss factors that may impact the industry's growth. These documents were authored by key stakeholders, including regulatory bodies, operators in HK-headquartered passenger aviation companies, aviation English training providers in HK, academic researchers, and journalists. They incorporate various discourse genres, such as course descriptions, corporate annual reports, press releases, government policies, academic journal articles, and news reports. By doing so, the collected documents provide a robust dataset that enables a systematic examination of the dynamics shaping the aviation English training industry.

This study employed document analysis as the overarching methodological approach, integrating the SWOT framework (Wheelen et al., 2017) to systematically evaluate and organize the findings. Using this analytical framework, this project explored the internal strengths and weaknesses of HK's aviation English training industry, as well as the external opportunities and threats to its growth. To investigate the industry's internal factors, a review of the official introductory materials for relevant training courses was conducted. This investigation focused on the number and specific features of available training courses, as well as the market's training providers. This project then investigated how opportunities and threats influence the growth of the aviation English training industry in HK. Examining multiple sources revealed these external variables, which include regulatory changes, talent supply, and the financial and operational position of HK-headquartered passenger aviation enterprises.

Findings

As shown in Figure 1 below, the development of HK's aviation English training industry was influenced by a combination of internal strengths and weaknesses, as well as external opportunities and threats. A key strength of the industry was the presence of diverse training providers and high-quality instructors. This diversity enabled the delivery of tailored aviation English instruction that met the varied needs of both individual students and different sectors within the aviation industry in the region. Conversely, a significant weakness was the limited number of these customized programs, which struggled to meet the demands of a growing population.

The industry was also impacted by various external factors. Opportunities contained the HK government's policies mandating English as the lingua franca in the aviation industry, as well as the recent expansion of HK-headquartered international aviation companies. In contrast, threats to the industry included a talent shortage across various sectors, such as aviation maintenance and piloting, operational challenges faced by some HK-headquartered passenger aviation companies, as well as the emergence of online aviation English training courses that directly compete with local providers. The following section will further discuss the impact of these internal and external factors on the development and progress of the aviation English training industry.

Figure 1
SWOT Results for the Development of HK's Aviation English Training Industry

Strengths and Weaknesses In HK's Aviation English Training

Based on SWOT analysis (Wheelen et al., 2017), strengths and weaknesses are internal aspects of HK's English training industry. In the context of HK's aviation English training industry, these factors respectively enhanced and hampered its growth. According to this theoretical framework, the primary strength of HK's aviation English training industry was the diversity of training providers and their experienced instructors. Conversely, the main weakness in the industry was the limited number of training programs offered by these professionals.

Diversified Training Providers And Quality Instructors

An analysis of HK's current aviation English training programs revealed they were managed by various types of providers. These programs not only adhered to international language policies but also were customized to HK's local aviation industry.

Professional training institutions, local public universities and passenger aviation companies all provided aviation English training. Professional training providers primarily offered language training for airline pilots, air traffic controllers, and airport staff. For instance, the Hong Kong Youth Aviation Academy (HKYAA) developed a course titled "ICAO English Training" designed to prepare aviation professionals for the ICAO Proficiency Test at Levels 4 and 6. The instructors at HKYAA, who included airline pilots, Civil Aviation Department technical officers, and air traffic controllers, brought substantial experience in teaching aviation communication in English (see Table 1 below). Moreover, public universities, such as the School of Professional and Continuing Education at Hong Kong University (HKU SPACE), offered a program aimed at students seeking to pass the ICAO English Proficiency Test at Level 4. HKU SPACE also incorporated aviation English into its aviation-related programs, such as the Higher Diploma in Aviation and Piloting (HKU SPACE, 2024). In addition to these external training providers, HK-headquartered passenger aviation companies provided internal training for new recruits and retraining of existing staff. For example, new hires at Cathay Pacific, including pilots and cabin crew, had to undergo aviation English training before assuming their duties. Existing staff were also commonly retrained to maintain the necessary proficiency.

HK's aviation English training industry could benefit from a diverse range of institutions offering programs tailored to various aviation roles and individual student needs. These programs demonstrate a nuanced understanding of the specific linguistic requirements across different aviation positions and student profiles. The involvement of industry experts as instructors brings real-world insights to the classroom, enhancing the practical relevance of the training. Furthermore, the localization of content to include HK-specific scenarios increases the practical applicability of the training. This approach not only ensures compliance with ICAO standards but also addresses the unique challenges of HK's aviation landscape. Consequently, these programs aim to equip personnel across multiple roles with the necessary language skills to perform their duties effectively in the regional aviation industry.

A Shortage Of Locally-adapted Training Programs In HK

Despite the presence of various course providers, the availability of aviation English training programs catering to the needs of students in HK and different roles in the regional aviation industry was limited. Only ten online/offline courses offered by HK-headquartered providers were found in the market, apart from corporate training. As shown in Table 1, HKU SPACE managed one of these courses, while professional training providers, such as HKYAA and Hong Kong International Aviation Academy (HKIAA), handled the others.

Table 1.
Aviation English training courses in HK

Name of the institutes	Course(s)	Official website
HKU SPACE	ICAO aviation English language proficiency training	https://hkuspace.hku.hk/prog/icao-aviation-eng-lang-proficiency-training
Aviation English Asia Ltd	ICAO Aviation English for cadet entry pilots ICAO Aviation English for commercial pilots, ICAO Aviation English for ATCOs or student ATCOs English for in-flight service and safety English for aircraft maintenance engineers, technicians, and mechanics English for airport customer service officers English for airport security officers Teacher training Rater training	https://aviationenglish.com/
HKYAA	ICAO English training	https://www.hkyaa.hk/about-us
Hong Kong Macau General Aviation Company Limited	Aviation English	https://hkmaviation.com/aviation-english/
HKIAA	Aviation English for air traffic controllers	https://www.hkiaacademy.com/en/air-traffic-management/professional-courses/atcs1963_aviation_english_for_air_traffic_controllers.html

The limited availability of aviation English courses that align with international language proficiency requirements while addressing HK's specific operational context may present challenges to the aviation English training market in the city. As passenger aviation companies continue to expand and the demand for new hires increases, the limited number of training programs and instructors may struggle to accommodate the influx of human capital. Furthermore, the insufficient number of such programs hinders the promotion of aviation English to the public in HK. While aviation English represents a specialized use of the language, offering courses to young people could attract their interest in pursuing aviation careers, thereby bringing more talents to HK's aviation industry and fostering the growth of aviation English training. To address these challenges, it is essential to expand the availability and accessibility of aviation

English training programs that comply with international standards and adapt to HK's specific context.

Opportunities For The Development Of Aviation English Training

As was previously reviewed, opportunities are the external contextual factors that institutes in an industry can use to realize a desirable outcome (Wheelen et al., 2017). Under this theory, this project analyzed the opportunities that aviation English training professionals could employ to develop the industry in HK.

Language Policies

The Civil Aviation Authority of Hong Kong (CAD) complies with ICAO standards in developing local language and training guidelines. One of these language policies requires individuals seeking the HK pilot license to pass the language proficiency test under the English Language Proficiency Assessment Program. Passing the language test demonstrates achievement of ICAO Operational Level (Level 4) (Civil Aviation Department, 2019a). In addition, following the ICAO Human Factor Training Manual, CAD also mandates that maintenance manuals must be written in a "simplified" form of English to enhance accessibility and understanding (Civil Aviation Department, 2023). Regarding training programs, CAD requires specific training modules in multi-crew cooperation courses, including upset prevention and recovery training. This requirement is aligned with the guidelines in ICAO Doc 10011 (Civil Aviation Department, 2019b).

This alignment ensures that HK's aviation professionals are well-trained through customized courses. Many professionals, including pilots, cabin crew, and air traffic controllers, are required to take aviation English courses and exams before they can assume their duties. As the English proficiency requirements for aviation professionals become more stringent, many of them need to be retrained to maintain their qualifications. Compliance with global language guidelines, therefore, increases the market demand for aviation English courses. Moreover, alignment with ICAO language guidelines encourages local programs to hire qualified instructors who strictly adhere to international standards and to develop teaching materials that meet ICAO requirements. In the long term, these measures are expected to improve the overall quality and effectiveness of aviation English courses in HK, ensuring that professionals are equipped with the necessary language skills to perform their duties safely and efficiently.

Corporate Development

Over the past five years, HK-headquartered passenger aviation institutions, such as HKIA and HK-based airlines, have attempted to strengthen their positions in the international markets. This was shown through increased institutional operational capacity and market share, enhancement of their global reputations, and the strengthening of intraregional connectivity. Such corporate ventures have driven the demand for a new workforce and are expected to attract students to aviation English training programs.

HKIA: Escalating Operational Service

The Three-Runway System (3RS) aimed to build a parallel runway to the north of the existing runway to meet the needs of the influx of international air passengers. From 2019 to 2020, the 3RS made solid progress in constructing the runway, completing sea filling and preparing the site for construction (Hong Kong International Airport, 2019). By 2021, major components of the runway – pavement works, parallel taxiways, runway grooves, and line markings – were completed (Hong Kong International Airport, 2021). In 2022, HKIA completed the installation of the major components of the runway, such as the air traffic control system and instrument landing system, enabling the runway to commence operations in July (Hong Kong International Airport, 2023). Additionally, the 3RS also incorporated the associated projects of a Terminal Two Concourse, an expanded Terminal Two, a new baggage handling system, and a new Automated People Movement system (Hong Kong International Airport, 2019; 2020). These projects were scheduled for completion in 2024 (Hong Kong International Airport, 2023).

The completion of these projects significantly boosted workforce demand. Once fully operational, HKIA was projected to require around 70,000 additional employees across various roles and departments. Roles like baggage handlers, cabin cleaners, and ground staff were in high demand to support the expanded operational ability and ensure the efficient functioning of the new facilities (South China Morning Post, 2023a). Consequently, this workforce expansion is driving a substantial need for aviation English training. Many positions, such as air traffic controllers and airport ground staff, required new hires to meet international language standards before beginning their duties. Thus, individuals interested in pursuing careers in this industry need to learn aviation English before applying for jobs.

HK-headquartered Airlines: Fleet Development and Market Expansion

The global ventures of HK-headquartered passenger airways varied based on company size. Cathay Pacific, a flag carrier, focused on fleet development, while other HK-headquartered airways emphasized establishing new routes in major Asian cities. These initiatives have increased the need for workforce and aviation English training.

Cathay Pacific's subsidiary, HK Express, focused on fleet development by purchasing 16 Airbus A321-220 neo aircraft (Cathay Pacific, 2020). The airline delivered the first aircraft in 2023 (Cathay Pacific, 2023a). When the fuel-efficient aircraft were fully delivered and operationalized, HK Express would increase its competitive edge in the Asian market. Cathay Pacific's development projects would help to enhance its competitive advantage against major rivals, such as Singapore Airlines, Shenzhen Airlines, and China Southern Airlines.

Other airlines have developed new routes in Asia in the past five years. Greater Bay Airlines, a low-cost airway founded in 2022, launched service from HK to five Asian cities – Bangkok, Taipei, Tokyo, Seoul, and Osaka – by 2023 (Greater Bay Airlines, 2023). Additionally, Hong Kong Airlines, a full-service international airway, opened new routes from HK to Phuket and Nagoya in 2023 (Hong Kong Airlines, 2023b, 2023a), expanding its network in Thailand and Japan. The new route development enhanced the competitive edge of Greater Bay Airlines and Hong Kong Airlines against major rivals. For instance, by launching the new routes, Hong Kong Airlines secured a significant market share in Southeast Asia. Essentially, new route development enabled these airlines to increase their visibility to a greater number of Asian aviation stakeholders. This visibility expansion in Asia could expand their brand awareness in the global market.

Fleet and market expansion prompted the recruitment of new staff. Cathay Pacific set a target to recruit more than 800 cadet pilots in 2023 and 2024 combined, in addition to the approximately 250 cadet pilots recruited in 2021. The airline also looked to recruit 4,000 frontline staff as it prepared for increased passenger numbers and aimed to fly at a third of pre-COVID passenger capacity by the end of 2024 (Cathay Pacific, 2023b). Hong Kong Airlines was expected to recruit 10% more pilots and 40% more cabin crew in 2024. Hundreds of employees from Hong Kong and Mainland China would join the airline (PR Newswire, 2024). While newly established, Greater Bay Airlines planned to recruit over 100 new pilots in 2024 (South China Morning Post, 2023b).

Such large-scale recruitment drives the need for aviation English training and enhances the teaching skills of professional instructors. While companies commonly offer internal training for new recruits, pre-employment training for roles such as pilots and cabin crew, covering aviation English, is also essential. This demand for training presents significant opportunities for the aviation English training industry in HK, particularly in attracting students and fostering collaboration with HK-headquartered airlines. Additionally, aviation English instructors working at carriers and external training schools may encounter increased teaching demands because of the influx of recruits. These instructors can further develop their teaching competencies by swiftly adapting their methods to accommodate the needs of a large student population.

Threats To The Development Of Aviation English Training

In this project, threats refer to adverse factors in HK's passenger aviation that would impede the development of the local aviation English training industry. As detailed in the following sections, the principal threats included a talent gap and the financial and operational troubles of HK passenger aviation entities.

A Talent Gap In HK's Aviation Industry

The talent deficiency in the HK aviation industry was notable. As reported by the airport authority, the workforce in the industry would rise from 53,000 to 69,000 by the end of 2024, leaving a gap of 16,000 personnel. While the government proposed employing 2,800 personnel from the non-local market, the industry still needed another 13,200 personnel to complete ongoing and new projects (HKSAR, 2023).

Demotivated aviation students further exacerbated talent deficiencies. The economic slowdown caused by COVID-19, as well as a growing unemployment rate, weakened many students' ambitions to learn. This was demonstrated by students' lack of passion for learning new things and their gloomy attitudes toward personal career advancement. If it was unsolved, the practice would lead to cultivating disqualified aviation professionals, which would undermine efforts to cultivate internationally qualified aviation professionals (Ng et al., 2023).

A lack of qualified aviation professionals in the industry would delay the growth of HK's aviation English training. Due to the current high demand for aviation professionals, as previously discussed, a struggle to retain talents may result in students with low motivation and/or English proficiency enrolling in aviation English training programs. This situation could challenge program leaders and instructors in managing and teaching such students effectively. Moreover, the talent gap may drive aviation English instructors to seek opportunities elsewhere or transition to other industries where their efforts are more valued. As a result, there could be a scarcity of experienced aviation English instructors. This shortage could adversely impact the quality and availability of the training programs, making it difficult to maintain high standards and meet the growing demand.

Financial/Operational Troubles Of Aviation Entities

The financial and operational troubles of passenger aviation entities posed significant threats to the development of aviation English training in HK. Over the past five years, HK passenger aviation entities have experienced a severe downturn characterized by decreased air traffic, reduced passenger numbers, contracted corporate revenues, and contracted international market size (Ng et al., 2023). This decline in financial and operational performance might lead to reduced efforts in (re)training new or existing employees. As an important soft skill for aviation practitioners, aviation English training could be deprioritized by companies during such challenging times.

COVID-19 severely impacted international passenger aviation, leading to a significant decline in passenger traffic, flight movements, and revenue at HKIA from 2020 to 2023. As shown in Table 2, annual passenger traffic dropped from 60.9 million in 2020 to 0.8 million in 2021. Flight movements and passenger revenue also declined similarly. In 2022, passenger traffic stagnated at 1.4 million, with 145,000 flight movements. Despite these challenges, HKIA served 12.4 million passengers and facilitated 161,000 flight movements in 2023, resulting in HK$8,217 in revenue. However, this represented only a partial recovery compared to 2019, with 2023 passenger traffic at just 16.5% of 2019 levels, far below IATA's projected recovery rate of 80% (IATA, 2022). Consequently, HKIA's financial performance was unlikely to fully recover to pre-COVID levels soon.

Table 2
Yearly Performance of HKIA (2019-2023)

	2019	**2020**	**2021**	**2022**	**2023**
Passenger volume (million)	75.1	60.9	0.8	1.4	12.4
Aircraft movements (thousand)	429	377	128	145	161
Revenue (million HKD)	19,470	17,106	5,936	5,798	8,217

(Hong Kong International Airport, 2019, 2020, 2021, 2022, 2023)

This financial shortfall could constrain HKIA's capability to support aviation English training for its new hires and existing staff. Although HKIA is likely to prioritize aviation English training, the financial shortfall might divert funds to more critical operational areas, thereby compromising investment in soft skills training. This reduction in funding would lower compensation for instructors, reduce their job security, and lessen the perceived value of their specialized expertise. Consequently, experienced and qualified instructors may be deterred from continuing their involvement in aviation English training both at HKIA and in the broader market.

Cathay Pacific faced mounting adversity, as reflected in key financial performance indicators such as passenger volume and passenger revenue. As detailed in Table 3 below, Cathay Pacific's passenger volume and passenger revenue declined severely from 2020 to 2022. The decline is driven by escalating COVID-19-related travel restrictions. Despite these challenges, the airline saw a notable increase in its financial status in 2023. Nevertheless, its passage volume only reached 22% of the volume in 2019, and the revenue only reached 34% of the amount in 2019. The numbers indicated that Cathay Pacific's financial recovery to its pre-COVID status would take considerably longer.

Table 3
Yearly Performance of Cathay Pacific (2019-2023)

	2019	**2020**	**2021**	**2022**	**2023**
Passage volume (million)	35.2	4.6	0.717	2.8	7.8
Passenger revenue (million HKD)	72,168	11,313	4,346	13,686	25,013

(Cathay Pacific, 2019,2020a, 2021,2022,2023)

Cathay Pacific also faced substantial operating issues. Despite strong demand in the American and European markets in 2019, Cathay Pacific's inefficient passenger capacity limited yield. The outbreak of COVID-19 in 2020 exacerbated the situation, resulting in travel restrictions and curtailed activities. To avoid insolvency, Cathay Pacific discontinued Cathay Dragon operations. Starting in the second quarter of 2020, Cathay Pacific launched ghostly passenger flights to a number of overseas destinations (Cathay Pacific, 2020). While essential, this choice resulted in lower passenger volume and income, as well as a lower international market share for the airline. In 2021, the HK government imposed new travel restrictions, resulting in the suspension of inbound foreign flights, substantially reducing the airline's worldwide market share (Cathay Pacific, 2021). Despite Cathay Pacific's slow expansion of foreign lines from 2022 to 2023, passenger traffic and revenue remained much lower than pre-pandemic levels.

Cathay Pacific's present financial and operational issues may demand transferring cash to fleet development in order to restore market share following COVID-19. This strategic shift in spending objectives will most certainly have an influence on the company's investment in (re)training its pilots and cabin personnel, notably in soft skills like aviation English. To save money, Cathay Pacific may explore cutting teacher salaries and numbers, as well as shortening the time of aviation English instruction. As a result, the quality of instruction may suffer as instructors struggle with job security and the need to offer good training in less time. Because Cathay Pacific is a major provider of aviation English instruction in HK, this issue may have ramifications for the advancement and general quality of aviation training in the local market.

The Rise Of Non-local Online Aviation English Training Programs

The emergence of online virtual aviation English training programs offered by non-local providers posed a potential threat to the market share of programs operated by HK-headquartered training institutes. As shown in Table 4, numerous online synchronous and asynchronous courses have been developed, catering to the needs of pilots, air traffic controllers (ATCs), flight attendants, and students seeking to attain ICAO levels 4, 5, and 6. Many of these courses were examination-oriented, focusing on ICAO English and IR English, but were not localized. These programs may effectively meet the requirements of aviation professionals and students, particularly those who must pass international English proficiency tests. Such tests, including the ICAO language proficiency test, evaluate participants' ability to comprehend language used in radiotelephony communication (ICAO, 2009), rather than emphasizing knowledge of regional aviation markets. Thus, students in HK may opt for these online courses to prepare for these aviation English proficiency tests. As a result, this could erode the market share of HK-headquartered training institutes and bring significant challenges to local training providers, including potential losses of revenue and the need to adapt to new market conditions.

Table 4
Typical Non-Local Online Virtual Aviation English Training Programs

Course type	Training provider	Official website
ICAO English	Practice ICAO English	https://practiceicaoenglish.net/
	Aero Language	https://language.aero/en
	Embry-Riddle Aeronautic University	https://www.captainpilot.com/post/how-to-prepare-for-icao-english-exam-with-captainpilot-training-model
	Latitude Aviation English Services	https://www.latitude-aes.aero/
	Aviation English Now	https://aviationenglishnow.com/products/
	AviaSpeak	https://aviaspeak.com/
	Udemy	https://www.udemy.com/course/icao-aviation-english-proficiency-for-aviation-test-prep/?couponCode=ST8MT101424
IR English	Aero Language	https://language.aero/en/checking/ir-english
Aviation English raters	Mayflower College	https://www.maycoll.co.uk/aviation-english/aviation_english_raters-ns.htm
English for flight attendants and aviation mechanics	Aviation English Now	https://aviationenglishnow.com/products/

Although these international online training courses pose a threat to HK's aviation English training industry, their impact is likely to be limited. First, HK’s aviation English training programs, which incorporate local operational knowledge and address specific student needs, offer a distinct advantage over examination-focused online courses. These programs provide a unique value proposition that online courses cannot match. Second, face-to-face aviation English training provides unique advantages such as real-time feedback, nonverbal communication practice, and authentic cockpit/tower interaction scenarios that online courses cannot fully replicate. As a result, a significant number of students in HK will probably continue to prefer in-person training programs over online alternatives for international aviation English proficiency tests. This distinct advantage not only mitigates the threats posed by international online training courses but also reinforces the effectiveness and appeal of in-person training programs offered by HK-headquartered providers.

Conclusions And Expected Contributions

The present study performed a document analysis that integrated the SWOT framework (Wheelen et al., 2017) to examine the development of HK's aviation English training industry. In addressing this research aim, the market strengths and weaknesses were identified based on the performance of relevant training programs over the past five years. Moreover, this project also showed opportunities and threats in the broader geo- and sociopolitical environment that either aided or impeded the growth of aviation English training.

HK's aviation English training industry harnessed considerable strengths and held the potential to use geo- and sociopolitical opportunities for substantial growth. Within HK's aviation English training industry, diversified training providers offered programs that catered to various aviation roles in the local market, addressed the specific needs of HK students, and complied with international standards. As for opportunities, adhering to the ICAO's language policies provided a standardized framework essential for effective teaching practices within the industry. Furthermore, the market expansion and fleet development of HK-headquartered passenger aviation companies may have significantly increased the number of students enrolling in aviation English training programs and enhanced teaching skills.

The aviation English training industry in HK faced both internal weaknesses and external threats that may impede its growth. A primary weakness was the shortage of suitable training programs that both addressed the specific needs of the local aviation industry and students and complied with international standards. This scarcity created a market gap and limited the industry's ability to adapt to new personnel needs, hindering workforce development. It also potentially undermined efforts to promote aviation careers among HK's younger generation. For external threats, the talent gap in the passenger aviation industry posed challenges for program managers, materials developers, and instructors, who were dealing with students with low motivation and limited English proficiency. Compounding this issue were the financial and operational difficulties faced by HK-headquartered aviation companies. This threat could lead to job insecurity, salary loss, and reduced teaching time for instructors, compromising the quality of aviation English education. Additionally, the emergence of examination-oriented online training courses also posed a threat to the industry, potentially diminishing the market share of HK's aviation English training providers.

Contributions To Industry Practice And Academic Research

In response to the challenges identified in the analysis, targeted suggestions are proposed to mitigate the talent shortage in the aviation industry. To attract individuals to the industry, the HK government may establish a series of support programs that would benefit not only the industry but also academic research on aviation English pedagogy in HK. As for contributions to the industry, by attracting students and motivating educators, these programs would enrich the talent pool of the industry and increase the motivation of educators. In the academic domain, government support offers an opportunity to examine the effectiveness of government intervention in aviation English education. This enables researchers to evaluate the interaction between government funds and aviation English training approaches and outcomes. In fact, the government has already allocated funds to encourage citizens to pursue careers in the aviation industry, with allocations for careers in the HK aviation industry, aviation companies, and public universities in the region (HKSAR, 2024).

To further increase student motivation, various institutes can incorporate innovative online activities, such as virtual tours (Ng et al., 2023). When developing these activities, educators and trainers should consider market needs and student characteristics to ensure a regular supply of qualified graduates that meet industry demands. These efforts not only address immediate industry needs but also have academic implications. They provide invaluable resources for researchers to gain deep insights into the students' unique requirements for learning aviation English.

One potential strategy to help HK-headquartered passenger aviation companies overcome challenges is strengthening collaborative relationships with the GBA (The Greater Bay Area of China)[1]-based airports and airlines. Enhancing collaboration with regional airports through information sharing and joint flight planning could reinforce the overall competitiveness of the GBA airports in the global market (Mo et al., 2022). This collaboration can improve the financial performance of HK-headquartered passenger aviation companies while securing the jobs and benefits of aviation English providers, teachers, and trainers. In addition, collaboration with the GBA-based airports and airlines can also have academic benefits. By working with HK-headquartered educators and providers, academic researchers can compare students from various areas of the GBA. This can lead to the development of more suitable teaching methods tailored to students with different learning habits, issues, and English proficiency levels. Thus, this approach can improve aviation English teaching in HK, making it more targeted and effective.

To counter the growing popularity of online language training courses, HK-headquartered training providers could develop online virtual ICAO tests training courses tailored to the needs of students in HK. Before designing these courses, providers ideally should conduct surveys to understand the specific language proficiency requirements of test participants in HK. During the course design process, more efforts must be made to address the unique questions and learning habits of local students. By doing so, HK-headquartered training providers can create online training courses that cater to the distinct needs of their ICAO test

[1] The Greater Bay Area (The GBA) is a newly established economic zone that combines the cities of Guangdong province in mainland China with the Special Administrative Regions of HK and Macau. Spanning eleven cities and regions, the GBA comprises major urban centers such as Guangzhou, Shenzhen, Zhuhai, as well as HK and Macau.

participants, thereby maintaining their market share and competitiveness. Additionally, it could contribute to academic research by providing deeper insights into online learning for ICAO English proficiency tests in HK. Researchers could analyze participants' learning habits, motivations, common errors, and difficulties encountered during test preparation. The findings could inform improvements in course design and delivery, ultimately enhancing the quality of ICAO English language testing training programs in the region.

For all other training programs, a blended-learning approach that combines online and offline activities such as workshops, seminars, and mentoring programs should be promoted. By using this approach, HK-headquartered aviation English training providers can enhance their reputation and maintain their market position amidst growing online competition. Additionally, these blended-learning courses present opportunities for academic research, potentially contributing to the global field of aviation English pedagogy. Additionally, these blended-learning courses provide a research opportunity to explore the interplay between online and offline learning components. By investigating how different combinations of delivery modes impact learning efficiency and skill retention, researchers can gain insights into the most effective design of aviation English training programs for students in HK. This research has the potential to establish new frameworks for creating integrated aviation English programs.

Limitations And Future Studies

This study has two major limitations. First, while the current document analysis provided valuable insights into the factors influencing HK's aviation English training industry, the absence of primary data, such as interviews or surveys, limited the depth of understanding. Second, the scope of this research was limited to HK's aviation English training industry, excluding broader regional markets. To address these constraints, future studies could integrate more research methods, such as interviews and surveys, and broaden the scope of investigation by encompassing aviation English training in other geographical areas (e.g., mainland China). Such projects could help training providers, instructors, and investors understand market changes and develop timely initiatives.

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The Underrated Value of Incremental Research in Aviation

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In the aviation industry, the excitement of groundbreaking discoveries often overshadows the significant impact of incremental research. This paper argues that small, continuous improvements are just as crucial as revolutionary innovations in advancing aviation research. First, we illustrate how incremental steps have collectively transformed aviation research—such as the evolution of jet engines, winglet technology, and composite materials. We further explore the role of incremental research in addressing modern aviation challenges while highlighting this approach's economic and practical benefits. Finally, we discuss how to establish a research agenda/platform that considers these issues while emphasizing the importance of maintaining a balanced focus on both incremental and revolutionary research. This approach provides a reliable path to continuous improvement while fostering a successful research future for aviation.

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Every few years, the world of aviation reports groundbreaking discoveries and revolutionary technologies. It's easy to get caught up in the excitement of these earthshaking findings that promise to transform the industry; however, while these major breakthroughs bring much value, it's crucial not to overlook the significant impact of incremental research—those more minor, continuous improvements that gradually enhance our technology and processes (Lindblom, 1959; Lindblom, 1979).

Aviation has a rich history of advancements that haven't necessarily made headlines. These incremental findings have collectively brought about profound changes in safety, efficiency, performance, and environmental concerns (Lee & Mo, 2011; Pereira et al., 2022). From refining the aerodynamics of winglets to improving the materials used in aircraft construction, these incremental steps have been the backbone of sustained progress in the field (Mowery, 2015).

In this paper, we'll explore why incremental research is just as vital as those significant leaps forward. We'll look at historical examples, present-day case studies, and discuss this approach's economic and practical advantages. By the end, we hope to demonstrate that incremental research isn't merely a stepping stone to bigger things—it's a crucial path to steady, reliable advancement in aviation.

Common Criticisms and Possible Disadvantages of Incremental Research in Aviation

Before discussing incremental research's value, we should highlight some of the common criticisms. While incremental research is valuable, it's not without its critics—frequently in academic circles. Understanding these criticisms can provide a more balanced view and highlight areas where incremental research can improve or be better communicated.

People criticizing incremental research often point out that it lacks the excitement and perceived value of revolutionary breakthroughs (Weiss & Woodhouse, 1992). In academia, where the pressure to publish novel findings is high, incremental improvements are often seen as less impactful. Scientists who focus on incremental research are frequently misjudged as unambitious and/or incapable of contributing significantly to the body of knowledge (Zdrazil et al., 2024).

Securing funding for incremental research is challenging compared to projects that promise groundbreaking results. Funding agencies and grant committees often prioritize innovative, high-risk projects that have the potential to make headlines (Bradley, 2016). This bias results in fewer resources allocated to incremental research despite its long history of delivering steady progress. Similarly, academic journals favor publishing studies with novel discoveries over those presenting incremental advancements (Bradley, 2016; Lai et al., 2022). This publication bias discourages researchers from pursuing—or even reporting—incremental findings, as they fear that their work won't be valued or rewarded.

Another criticism is that overemphasizing incremental research could lead to general stagnation in the field. Critics argue that if too much focus is placed on small, iterative changes, the field will fail to produce bold, visionary projects pushing the boundaries of what's possible

(Zdrazil et al., 2024). These critics contend that while incremental improvements are valuable, they should not come at the expense of pursuing revolutionary ideas that could lead to major leaps forward. Additionally, incremental research is often considered redundant when multiple groups work on similar small-scale improvements. This redundancy might lead to duplication of efforts and resources, which is perceived as inefficient in conducting science. Critics maintain that if incremental research is the only way forward, it should be pursued to maximize impact and avoid unnecessary repetition (Schöch, 2023).

We contend that criticisms of incremental research don't negate the value of this type of research but instead highlight the need for a more balanced approach in aviation. Both incremental and revolutionary research have their place, and each can benefit from the strengths of the other. While revolutionary research pushes the envelope and explores new frontiers, incremental research ensures continuous improvement with potentially less risk and cost. By integrating both approaches, the aviation industry and academia can foster a more holistic and sustainable path to innovation.

Historical Perspective

To appreciate the value of incremental research in aviation, it is helpful to look back at how the industry has evolved over the past decades. Many of the advancements we take for granted today didn't arrive in one fell swoop but rather through a series of gradual improvements that eventually produced the desired result (de Graaff, 2014; Lee & Berente, 2013; Pereira et al., 2022).

Take jet engines, for example. When they first emerged, they were a marvel of engineering. But it wasn't just one massive leap that made them what they are today—decades of fine-tuning and enhancements in materials, design, and efficiency turned nascent engines into the reliable powerhouses of today. Each slight improvement is built upon the latter, leading to better overall performance and greater fuel efficiency (Geels, 2006; Pereira et al., 2022). Similarly, developing avionics and flight control systems has been a journey of small steps (Thurber, 2024). Early aircraft relied on basic mechanical systems, but over the years, we've seen a steady stream of innovations—digital fly-by-wire systems, advanced autopilots, and sophisticated navigation aids, to name a few (Fielding, 2001). Each advancement might have seemed minor on its own, but collectively, they have improved flight safety and operational efficiency in ways unimaginable only a century before.

These historical examples highlight an important point: the cumulative impact of incremental research can be just as transformative as any single groundbreaking discovery. By continually refining and improving our existing technologies, we've made aviation faster, safer, more efficient, and significantly more reliable (FAA, 2024; Ney et al., 2023). This approach mitigates risk and ensures that we're constantly moving forward, even if the steps seem minor at the time.

Case Studies

To fully appreciate the power of incremental research, we will discuss three specific examples that illustrate how small, steady improvements can lead to significant advancements in aviation.

Winglet Technology. Winglets are those small, vertical extensions at the tips of airplane wings. They might not look like much, but their impact on fuel efficiency is substantial (Eguea et al., 2020; Gavrilović et al., 2015; Guerrero et al., 2020). The initial concept of winglets dates back to the 1970s (NASA, 2023); however, it took decades of incremental research and development to perfect the modern design. Engineers experimented with different shapes, sizes, and angles to improve performance gradually. Early winglet designs, dating back to the 1970s, focused on reducing drag and improving fuel efficiency. For instance, NASA's early concepts evolved over decades with adjustments in winglet shape, size, and angle. This gradual refinement led to modern winglets, which now yield a fuel efficiency improvement of approximately 6% per flight. Airlines have embraced these small, continuous gains due to their cost and environmental benefits, with models like the blended winglet on Boeing 737s and Airbus A320's sharklets highlighting this evolution.

Today, modern winglets reduce drag and enhance fuel efficiency, which translates to significant cost savings and environmental benefits in the world of aviation (Daniele et al., 2012; Eguea, Silva, & Catalano, 2020). While 6% may seem meager to the average consumer, airlines often scrutinize many aircraft items to reduce weight and save money on fuel costs (Mattos et al., 2003; Morris, 2018). A tiny savings on one aircraft translates into huge overall savings, considering that most airlines schedule hundreds of daily flights.

Composite Materials. The use of composite materials in aircraft construction has changed since a century ago; however, these changes didn't occur suddenly. Early airplanes were built with wood and metal, which were heavy and limited in performance (Schatzberg, 2002). The introduction of composites like fiberglass and carbon fiber represented big steps forward, but again, this didn't happen overnight (Trzepiecinski et al., 2022). It took decades of incremental research to develop strong, lightweight, and reliable composites for widespread use in aviation. Initial improvements involved simple fiberglass composites, but newer advancements in resin formulas and bonding techniques have led to stronger, lighter, and more resilient materials. These improvements make modern aircraft significantly lighter, resulting in reduced fuel consumption and enhanced safety due to greater durability against corrosion and fatigue. Each slight improvement in material science (e.g., better bonding techniques, new resin formulations, enhanced manufacturing processes, etc.) has improved aircraft performance and safety over time (Parveez et al., 2022; Williams & Starke, 2003).

Technological Flight Deck Enhancements. The increase of technology and automation within the flight deck has occurred through incremental advancements (Abbott et al., 1996). The technologically advanced aircraft of today did not develop overnight but rather through a series of innovations and the release of various components. Ground proximity warning systems and traffic collision avoidance systems are two technologies that have been developed and adapted over time (Dhami & Panthi, 2023). The resulting outcome from these continued advancements is a drastic reduction in controlled flight into terrain and mid-air collision accidents. The flight deck's evolution began with basic mechanical systems and has advanced through multiple smaller innovations, including digital fly-by-wire systems and, more recently, ground proximity and traffic collision avoidance systems. Each technology, developed and refined incrementally, now contributes to a drastic reduction in mid-air collision and terrain-related accidents. The gradual integration of these systems has enhanced flight safety and operational reliability without disrupting the established framework.

These case studies illustrate that incremental research isn't just about making minor tweaks; it's about a continuous improvement process that can lead to significant advancements over the long haul. By focusing on refining and optimizing existing technologies, the field has achieved significant benefits that might have been missed if researchers were only chasing after the next big thing. This steady progress ensures that we're continually enhancing aviation's safety, efficiency, and sustainability—one small step at a time.

The Role of Incremental Research in Modern Aviation

In today's fast-paced world, the aviation industry faces a multitude of emerging challenges. Incremental research plays a pivotal role in addressing these challenges by providing steady improvements that help the industry adapt and evolve. One of the most pressing issues is the need to comply with new environmental regulations. Incremental research has been vital in developing more fuel-efficient engines, lighter materials, and better aerodynamics, significantly reducing aviation's carbon footprint (de Graaff, 2014). Small engine design and fuel formulation improvements have gradually increased efficiency, helping airlines meet stringent emission targets without needing entirely new technologies (Lee et al., 2001).

Another challenge involves cybersecurity in avionics. As aircraft systems become more digital and interconnected, the potential for cyber threats becomes increasingly concerning (Ukwandu et al., 2022). Incremental research in this area focuses on enhancing security protocols and improving software resilience (Alsulami, 2021). These improvements help protect critical flight systems from cyber-attacks, which ensures safer skies for all.

Incremental research also facilitates the gradual integration of cutting-edge technologies in aviation. Take artificial intelligence (AI) and automation, for example. While the ultimate vision of fully autonomous flight might be years—or decades—away, incremental advancements have already begun making a difference. AI-driven systems for predictive maintenance and flight path optimization are being implemented step by step (Kim et al., 2022). Each new application is tested and refined before being widely adopted, ensuring long-term reliability and safety.

Similarly, improvements in aircraft systems—such as enhanced weather radar and collision avoidance systems—are often the result of incremental research (Sghairi et al., 2008). These technologies have evolved through several small enhancements, each building on the last. This approach allows for continuous upgrades and ensures that new systems are vetted and integrated smoothly into existing frameworks. Incremental research is indispensable for modern aviation. It enables the industry to address new challenges and integrate advanced technologies in a controlled, reliable manner. By focusing on continuous improvement, aviation can adapt to changing conditions and maintain its trajectory of progress while ensuring safer and more environmentally friendly skies.

Economic and Practical Considerations

Incremental research in aviation also offers significant economic and practical advantages beyond just the technical benefits (Richards, 2021). These often-overlooked aspects highlight why small, continuous improvements are beneficial and essential for the industry's sustainable growth. One of the most significant advantages of incremental research is cost. Developing entirely new technologies from scratch can be expensive and risky. In contrast, making smaller, iterative improvements to existing technologies usually involves lower costs and fewer resources, with much less risk (Pacific Research Laboratories, n.d.). An incremental failure doesn’t require starting over from scratch—it merely means redoing that one particular change. This incremental approach allows companies to spread their investments and makes it easier to allocate funds efficiently.

Incremental research excels in risk management. When changes are made in small, manageable steps, testing and validating each modification is easier (Tahera et al., 2019). This approach reduces the likelihood of unforeseen problems often arising with large-scale, revolutionary changes. By implementing and testing improvements incrementally, the aviation industry can ensure that each new advancement is safe and reliable before widespread adoption. This approach also allows for more effective troubleshooting. If an issue does arise, it’s typically easier to identify and address when changes have been made incrementally. This contrasts with the challenges of diagnosing problems in entirely new systems where multiple variables have changed simultaneously.

While each incremental improvement might seem minor on its own, their cumulative impact is profound. Small gains in fuel efficiency, slight weight reductions, or modest safety protocol enhancements all add up over time, leading to significant overall benefits (Bradley, 2016). These cumulative improvements contribute to lower operational costs, reduced environmental impact, enhanced passenger safety and comfort, and savings for companies and consumers. The economic and practical benefits of incremental research are undeniable. This approach provides a financially sustainable way to keep advancing aviation technology while minimizing risks associated with large-scale changes. Over time, this approach delivers substantial cumulative gains. By investing in incremental research, the aviation industry can continue to progress steadily in the future with lowered risk and a considerable upside. Future studies would provide value to the literature by completing a cost-benefit analysis to assess these differences.

Potential Future Incremental Research Opportunities

Looking ahead, the future of aviation will, as it has done in the past, continue to rely on a balance between incremental research and revolutionary breakthroughs. By focusing on incremental advancements, the industry will continue to ensure steady improvements that address current and emerging challenges.

One area ripe for ongoing incremental research is battery technology for electric aircraft (Schäfer et al., 2019). While electric propulsion represents a major shift, the path to fully electric commercial aviation has been and will continue to be, paved with numerous small improvements. This approach involves enhancing battery capacity, improving charging infrastructures, optimizing energy management systems, and improving safety throughout the system. These improvements contribute to making electric flight more likely to achieve long-term goals in sustainable aviation.

Noise reduction technology is another promising area of aviation (Grampella et al., 2017). Incremental research into quieter engines, insulation materials, more efficient flight paths, and training methods can reduce the noise impact on communities. By continually refining these aspects, the industry can address environmental concerns while maintaining high levels of performance and efficiency. To maximize the benefits of incremental research, it is critical to foster collaboration and knowledge sharing within the industry. Partnerships between academia, industry, and government agencies can accelerate the pace of innovation while ensuring that all parties benefit from the collaborations (Castaneda & Cuellar, 2020; Le et al., 2020). By sharing data and insights from incremental improvements, organizations can build on each other's work and avoid duplicating efforts.

Open research initiatives and collaborative platforms also play a pivotal role here. Encouraging transparency and the free exchange of information helps ensure that incremental advancements are published and disseminated widely, leading to quicker adoption. This collective approach not only speeds up innovation but also ensures that the benefits of incremental research are spread throughout the entire industry (Le et al., 2020; Lee & Jin, 2019). Recognizing the importance of continuous, small-scale improvements creates a more stable and predictable path of progress, and this balanced strategy ensures that while we strive for the next giant leap, we don’t lose sight of the steady gains that typically drive long-term success. The future of aviation depends on a sustained commitment to incremental research, and by focusing on continuous improvements and fostering collaboration, the industry can achieve significant advancements in a reliable and economically sustainable manner. This approach will ensure that aviation remains on a path of steady progress for years to come.

Establishing a Research Agenda that Embraces Incremental Advancements

For new aviation researchers, establishing a research agenda that values incremental advancements while navigating the associated challenges can be both challenging and rewarding (Foster, 2016). In light of this, we offer a guide to help build a research platform that balances the benefits of incremental research with the need for impactful, recognized contributions. A new research lab should start by identifying areas within aviation where incremental improvements can make a significant long-term difference. We recommend examining current technologies and processes to pinpoint opportunities for enhancement while focusing on topics where small advancements can lead to substantial benefits over time.

Researchers need to keep abreast of industry trends and needs (Xu et al., 2018). We should all engage with industry stakeholders, attend conferences, and participate in professional organizations to understand the pressing issues that face aviation today. We must align our research agenda with these needs to ensure that our work is relevant and valuable to academia and industry. Collaboration is vital to overcoming the challenges of incremental research. We want to establish partnerships with other researchers, students, industry experts, and academic institutions to take advantage of the shared knowledge. Collaborative projects can pool resources, share insights, and avoid redundancy, making our incremental research more impactful (Le et al., 2020). Networking also increases the visibility and credibility of our work and helps to counteract professional biases against this type of research.

When presenting our research, we want to emphasize the cumulative impact of incremental advancements. It is essential to highlight how each small step builds upon previous work and contributes to broader goals. Case studies and historical examples are valuable ways to illustrate the transformative power of continuous improvements (Baker, 2011). This approach can help convey the significance of our work to funding bodies and academic journals. Researchers should balance incremental research with exploratory or revolutionary projects. By diversifying our research portfolio, we can balance the reliability of incremental improvements with the innovation of groundbreaking studies. This mixed-method approach makes our research agenda more attractive to funding agencies and publishers and showcases our ability to contribute to both steady progress and novel insights.

Effective communication is crucial in overcoming the perception challenges of incremental research (Ghobadi & Mathiassen, 2016; Gui et al., 2022). Researchers should clearly articulate the significance of our findings, both in academic papers and public presentations. Data and real-world examples can demonstrate the practical benefits of our work, and engaging storytelling can make incremental advancements more compelling and accessible to a broader audience. Unless funding is plentiful—which is usually not for new researchers—labs should look for funding opportunities explicitly aimed at incremental research (Foster, 2016). Some grants and funding bodies recognize the value of continuous improvement and provide resources for such projects. Researchers should tailor grant applications to highlight the practical, long-term benefits of the research and emphasize how it addresses current industry challenges.

One should cultivate a culture that values continuous improvement within a research group or institution (Norman & Verganti, 2014). Principal investigators should encourage iterative testing, peer reviews, and ongoing learning for all their staff. They should create an environment where small advancements are celebrated and considered essential contributions to the larger body of knowledge. This cultural shift can help reinforce the importance of incremental research among peers and colleagues. Establishing a research agenda that embraces incremental advancements requires strategic planning, effective communication, and collaborative efforts. By focusing on relevant industry needs, emphasizing cumulative impact, and seeking supportive funding opportunities, new aviation researchers can build a platform that advances their careers and contributes meaningfully to the continuous improvement of aviation technology and safety.

Conclusions

In the field of aviation research, there is value in groundbreaking and revolutionary advancements. However, this paper has also expressed the value of incremental research in driving the aviation industry forward. Continuous, smaller-scale enhancements can achieve significant safety, efficiency, and sustainability advancements while minimizing the risks and costs that can come with major overhauls. The historical examples of jet engines and avionics—along with case studies on winglet technology, composite materials, and aircraft safety features like ground proximity and traffic collision warning systems—demonstrate the power of incremental steps. Though individually modest, these advancements collectively transform aviation in profound ways over the long haul. Incremental research addresses emerging challenges, integrates new technologies smoothly, and offers economic and practical benefits essential for sustainable growth.

As we look to the future, the importance of incremental research becomes even clearer. By maintaining a balanced approach that values incremental and revolutionary advancements, the aviation industry can continue innovating while managing risks and costs effectively. Collaborative efforts and knowledge sharing will further enhance this progress, ensuring that every small improvement builds on the last. The value of incremental research can be found in its ability to produce stable and reliable paths to progress. It keeps the aviation field adaptable, resilient, and forward-looking. Through investing in these continuous improvements, we remain committed to ensuring the skies remain safer, more efficient, and environmentally friendly.

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Women and Minorities in Collegiate Aviation: What Factors Lead to Enrollment and Persistence

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This project is focused on women and minorities in collegiate aviation. The purpose of this project is to determine the experiences that influence women and minorities to enroll in a collegiate aviation program and the factors that have helped them persist and succeed. According to the United States Bureau of Labor Statistics, the percentage of women and minorities working in the aviation industry is relatively low compared to their participation rates in the total workforce of the United States. Increasing the number of women and minorities working in the aviation industry must begin with increasing their numbers in the nation's flight schools and collegiate aviation programs. Participants will be interviewed about the experiences that influenced their decision to enroll in a collegiate aviation program and the factors that have helped them persist and succeed. The benefits of this project include information that will help increase the number of women and minorities working in the aviation industry by increasing their numbers in the nation's flight schools and collegiate aviation programs.

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Women and Minorities in Commercial Aviation

Increasing the number of women and minorities working in the aviation industry has long been a challenge with a small fraction of the workforce serving in roles such as pilots and maintenance technicians. The focus of this study will be on the factors that encourage and deter women and minorities from enrolling in and successfully completing collegiate aviation programs. Past studies have documented only marginal growth in the number of women and minorities working in these highly paid-occupations (Fowler et al., 2023). Understanding the unique challenges faced by these groups could lead to potential solutions and improved diversity in the aviation industry.

This research will be a qualitative phenomenological study that seeks to understand individual lived experiences through interviews, observations, and narrative interpretation rather than the numerical data that is generated and analyzed in a quantitative study. Quantitative social science researchers use various tools such as surveys and questionnaires to collect numerical data that is then statistically analyzed to test their research hypotheses. In qualitative research, the researcher serves as the primary data collection instrument by engaging with participants to gather insights that will reveal their motivations, support systems, and barriers to success. The qualitative approach captures an individual's personal experiences in the pursuit of a career in aviation that quantitative data alone may not reveal.

The goals of this research study include exploring the motivational factors that lead women and minorities to pursue and succeed in a collegiate, professional pilot program and understanding the support systems and the barriers that impact their retention. The results of this research will have significant implications for educational institutions, policymakers, and industry stakeholders who seek to improve inclusivity in aviation.

Research Questions

This study will be guided by two research questions: What factors lead women and minorities to enroll and persist in a collegiate professional pilot program? How do the experiences and support systems within a collegiate professional pilot program influence enrollment and persistence?

Literature Review

There are recurring themes that emerge from the existing literature concerning the challenges faced by women and minorities who pursue careers in the commercial aviation industry.

According to Opengart and Ison (2016), a lack of role models and mentors is a serious barrier to women who enroll in professional pilot programs. The lack of female representation leaves many female students feeling uncertain about their place in commercial aviation. There are very few female role models who provide guidance and advice to aspiring female professional pilots.

Turney (2018) found that gender stereotypes and cultural sexism was a significant issue that women face in pursuit of aviation careers. Also, women lack confidence in math and science due to societal expectations. As a result, women have fewer role models and mentors to help guide them to success. The traditional masculine image of commercial aviation discourages many women from pursuing a career in aviation.

Perceptions of intelligence and competency were the focus of research by Evans and Feagin (2012), who found that members of minority groups face stereotypes and report feeling the need to suppress emotions and prove themselves to be competent due to the biases they face from colleagues. This not only affects their work lives but also influences their personal lives. The emotional strain created by this bias has a negative effect on job performance and motivation.

Although Bureau of Labor Statistics (BLS) data over the last 20 years demonstrates a slow increase in the number of women pilots and technicians, the ratio of these individuals remains stubbornly low. If the current rate of growth continues, there will only be moderate growth in women's participation rates over the next 10 years. The same is true for Black, Asian, and Hispanic participation rates. These groups will remain proportionately smaller compared to White participation rates over the next 10 years (BLS, 2021).

Many women and minorities lack important networking opportunities that are usually available to their white male colleagues. Networks are critical in commercial aviation for career growth and success. Existing research demonstrates the need to create more networking and mentorship opportunities for women and minorities in the aviation industry.

Preliminary Data Analysis and Findings

Several themes were revealed that reflect the experiences of women and minorities who participate in collegiate aviation programs:

Financial challenges were a common theme among interview participants. Many relied on student loans, scholarships, and support from family members to pay for their education. The need to work part-time jobs was also common, and this combined with the demands of flight training and college course work created significant stress. Without financial support, many of these students indicated that they would not be able to continue.

Another common theme involved the emotional impact of subtle bias which also contributed to feelings of isolation. Women and minorities reported often feeling out of place and described interactions with instructors and other students that felt uncomfortable and dismissive, but not overtly discriminatory. One participant said that an instructor talked to him "weirdly," giving him the feeling that he didn't belong in the program.

Support from family, friends and mentors was cited frequently by participants as critical for success. Encouragement and advice from role models in the aviation industry who share similar backgrounds were especially important for success in a collegiate aviation program. In addition to role models and mentors, students who participated in study groups and student organizations indicated that the sense of community created by these groups had a positive impact.

Key Themes from the First Phase In Vivo Coding

Using In Vivo coding, the qualitative data was categorized as follows:

- **Financial Barriers:** Finances were mentioned by most of the participants as an issue that causes significant emotional stress. Many students have to work part-time jobs to make ends meet. Statements like "My parents help me out" and "I work part-time" both emphasize the reliance on different sources of financial support.

- **Gender and Racial Challenges:** Subtle and indirect exclusion due to gender and racial biases was often described as a source of emotional stress. Feelings of isolation and discrimination were reflected in statements like "I feel like everything has been a bit of a struggle" and "I would feel a bit odd or out of place."

- **Mentorship and Support:** A critical component of success in a collegiate aviation program that was mentioned by every participant was mentorship and support. Supportive faculty, staff, family, and experienced aviation professionals were cited as a crucial element leading to successful completion. Statements like "My mom helped me a lot" and "A teacher in high school" demonstrate the impact that positive support has on success in higher education. Guidance and encouragement from mentors help participants feel that they belong in the aviation industry.

- **Awareness and Early Exposure:** Introducing aviation as an option earlier through school programs and community events was mentioned to encourage more minorities and females to consider aviation career opportunities. Participants recommended "more social media aimed at high school kids" and "having pilots come to schools to talk" to raise awareness and spark interest at a younger age.

Recommendations and Conclusions

The presentation concluded with the following recommendations to increase diversity in the aviation industry:

- **Financial Support:** Financial aid options, scholarships, and work-study programs targeted at women and minority students should be increased by educational institutions and industry organizations to decrease the financial challenges and make careers in aviation more accessible.

- **Inclusive Support Systems:** Collegiate aviation programs should strive to create an inclusive culture that is welcoming to women and minorities. Examples include providing anti-bias training for faculty and instructors and resources for women and minority students to help them feel part of the aviation community.

- **Mentorship Programs:** The data clearly supported the importance of mentors from similar backgrounds in the aviation industry to provide guidance and encouragement to women and minorities pursuing an aviation degree. Participants frequently stated that groups like the Women in Aviation International and the Organization of Black Aerospace Professionals were instrumental in fostering connections in the aviation industry.

- **Early Exposure Initiatives:** Universities and aviation organizations should partner with secondary schools to introduce students to aviation as a potential career path. Effective ways to provide early exposure include discovery flights, aviation camps, and outreach events.

- **Encouraging Participation in Student Organizations:** Students who participate in student-led aviation organizations build networks and support systems within collegiate aviation programs and beyond. Student organizations provide opportunities for students to connect with one another and share experiences that will help them prepare for careers in the aviation industry.

Conclusion

The preliminary results of this study highlight the challenges and potential solutions for increasing diversity in the aviation industry. Inclusivity and accessibility in the aviation industry can be improved by addressing financial, emotional, and cultural barriers and promoting mentorship and early exposure to opportunities in the industry for women and members of minority groups. Addressing these challenges will foster an inclusive environment that supports the next generation of diverse aviation professionals.

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Collegiate Aviation Review International

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The Role of Mental Health Training and Education in Achieving Resilience for Collegiate Aviation Pilots

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The tragic events surrounding Germanwings Flight 9525 and similar safety events have highlighted the urgent need to address mental health (MH) issues in aviation, particularly among Part 141 collegiate pilots. This ongoing quasi-experimental study evaluates the effectiveness of a Mental Wellness workshop intervention aimed at enhancing collegiate aviation pilots' knowledge and skills in recognizing and managing MH challenges. Conducted over five days and integrated into the flight safety course curriculum, the workshop focuses on resilience, stress management, emotional regulation, and lifestyle changes. Using a one-group pretest-posttest design, participants will complete the Predictive 6-Factor Resilience Scale (PR6-50) before and after the workshop, alongside demographic questions, to capture descriptive data. The study will employ SPSS® to conduct a paired t-test to determine significant differences in resilience scores. Qualitative data will be analyzed to explore participants' experiences concerning existing models of mental health awareness and stigma reduction in aviation. Expected findings include significant improvements in resilience scores, increased awareness of MH issues, and reduced stigma surrounding help-seeking. Participants are anticipated to report enhanced skills in stress management and emotional regulation, fostering healthier lifestyle choices and greater willingness to seek support for MH concerns. The study's conclusions will emphasize the importance of MH training in aviation and advocate for supportive systems that encourage collegiate pilots to prioritize their mental well-being, advancing the safety objectives established by the Federal Aviation Administration and bolstering the overall safety performance of the U.S. National Airspace System.

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Introduction

On March 24, 2015, Germanwings Flight 9525 crashed in the French Alps, killing all 150 people on board. After the captain left the cockpit, the first officer, who had struggled with mental health (MH) issues since 2009, deliberately initiated a descent. Despite efforts to regain access to the cockpit, the aircraft impacted the terrain at high speed. Investigations revealed the first officer had been suffering from severe depression, which he had not fully disclosed to his employer (Federal Aviation Administration [FAA], 2024a). This tragedy, along with similar accidents such as JetBlue Flight 191 in 2012, where a captain exhibited bizarre behavior and was subdued by passengers, and Malaysia Flight 370 in 2014, which remains shrouded in mystery but is suspected of possible deliberate actions by the captain, has sparked increased focus on pilot MH. These events underscore the urgent need for better support systems and regulatory measures to address MH issues in aviation (DeHoff & Cusick, 2018).

MH problems have also impacted students in Part 141 collegiate aviation flight programs. For example, on October 18, 2021, a collegiate aviation flight student tragically took his life by crashing his aircraft during a solo flight. In a letter left behind, the student expressed his depression and fear of losing flight privileges if he sought help, highlighting the urgent need for better support systems and regulatory measures to address MH issues in aviation (Pitts & Faulconer, 2023). College can be a highly stressful period for students, marked by academic pressures and personal challenges such as family separation and various academic and job responsibilities. This environment often triggers the onset or worsening of MH and substance use issues, with an estimated 26% of Americans aged 18 and older experiencing a diagnosable MH disorder each year. On campuses, MH concerns are widespread, with about one-third of undergraduates reporting significant symptoms; depression is the most common issue, affecting 38% to 55% of students. Additionally, many students experience comorbid conditions—76% of those with major depression also have another MH issue, such as generalized anxiety disorder or non-suicidal self-injury. Other MH challenges include eating disorders and panic attacks, often exacerbated by factors like overinvolved parenting, dependence on technology, and increased academic demands (Oswalt et al., 2020; Peddrelli et al., 2015).

When conducting a literature review for a study on mental health training for Part 141 collegiate aviation pilot students, it is important to acknowledge that mental health challenges affect not only general college student populations but also extend specifically to professional pilots, which includes Part 141 college aviation flight students (Romero et al., 2020). For example, studies involving Part 141 collegiate aviation pilots have found a prevalence of poor sleep quality, high levels of psychological distress, and a significant impact on their well-being. These students often face challenges such as adjusting to being away from home, managing excessive workloads, and dealing with uncomfortable classroom environments, which can contribute to psychological distress (Mendonca et al., 2023). The demands of flight training and academic pressures frequently lead to significant levels of stress and poor sleep quality, negatively affecting their academic performance, and physical and mental health. These college demands may also contribute to obesity, increased substance use, physical and mental fatigue, poor judgment, and reduced situational awareness.

Findings by Mendonca et al. (2019) indicated that fatigue significantly impacted flight training, with pilots overlooking mistakes due to fatigue, leading to decrements in alertness and cognitive function. Keller et al. (2020) found that collegiate aviation pilots frequently struggle with both the quantity and quality of their sleep. Contributing factors include inadequate preparation for sleep, such as optimizing the sleep environment, limiting the use of electronic devices before bed, and failing to plan for 7-9 hours of rest. Additionally, the authors noted that collegiate flight students often face difficulties in maintaining healthy lifestyles. Romero et al. (2020) found that while students recognized their fatigue and its negative impact on training, they struggled to make necessary adjustments. Another study by Mendonca (2021) revealed that 60% of participants experienced mental and physical symptoms of fatigue during flight activities, with 43% lacking training in fatigue identification and management. Factors such as insufficient rest and poor work-life balance further exacerbate these issues, as noted by Levin et al. (2019), where many students failed to engage in adequate exercise, nutrition, and stress management.

Part 141 collegiate aviation pilots face unique stressors and pressures that contribute to MH issues within this demographic, as highlighted in a study by Pitts and Faulconer (2023). Their research reveals that a significant portion of collegiate pilots' experience MH concerns. Their research found that 56.6% of surveyed collegiate pilots met the criteria for depression, and 13.8% reported self-injurious or suicidal ideation within the past two weeks. This study emphasizes that the barriers to seeking MH care—commonly observed in airline and military pilots—are also prevalent among collegiate pilots. Many collegiate pilots expressed apprehensions about seeking help due to fears that disclosing MH issues could jeopardize their medical certification, which is critical for their future careers. The rigorous demands of flight training programs, including academic performance and flight proficiency, create a high-pressure environment that can exacerbate MH concerns. Unlike typical college students, aspiring pilots must navigate the complexities of aviation regulations and the potential consequences of disclosing MH issues. Studies indicate that collegiate pilots often experience significant anxiety related to performance and fear of failure, adding to the MH challenges they face. Addressing MH in this specific population is crucial for ensuring their well-being and future success in aviation.

There are two perspectives on safety in aviation: the traditional view, which focuses on avoiding costs associated with accidents, and a more modern approach that emphasizes the link between safety and efficiency. While the cost of a single major accident can be devastating to an organization, research shows that investing in safety enhances productivity and reduces insurance costs (Ayres Jr. et al., 2009). A Safety Management System (SMS) allows aviation organizations and stakeholders to proactively address safety issues, enabling effective management of accidents and near misses to improve overall safety and efficiency. Central to the effectiveness of an SMS is training and education, which serve as vital pillars in fostering a positive safety culture (DeFusco et al., 2015). Safety training equips personnel with the necessary skills and knowledge to perform their duties safely and competently. It acts as a catalyst for developing a robust safety culture by ensuring that safety information is effectively communicated throughout the organization. By focusing on training, organizations can change shared values among employees and management, reinforcing the importance of safety and cultivating an environment where hazards and risks are well understood and addressed. Ultimately, improving safety culture requires a commitment to continuous training and education, which enhances both safety outcomes and organizational efficiency (Ayres Jr. et al., 2009).

In this study, the College of Aviation's researchers and a clinical team from the University Counseling Center will collaborate. This partnership allows both areas to share their expertise to best serve the students and the aviation industry. Addressing the MH and wellness needs of students cannot be done in isolation, and counseling center staff increase their impact and reach when collaborating with other departments on campus. Building campus partnerships leads to increased participation from students, faculty, and staff and more tailored and relevant programs (Golightly et al., 2017). As such, educational programs such as those offered by MH experts are vital for reducing stigma and empowering individuals to learn more about mental health literacy/care and increase awareness around normal emotions and when to seek help and support. Prevention and education are key interventions including when to seek professional help without feeling stigma and to adopt therapeutic lifestyle changes that promote mental and physical well-being, which is essential for preventing MH issues.

Addressing MH in aviation requires a multifaceted approach. National policies should establish a non-punitive pathway for disclosing MH conditions. Moreover, the Federal Aviation Administration's (FAA) information management system and Aviation Medical Certification Subsystem must be modernized to facilitate easier reporting (FAA, 2024a). A critical aspect of this strategy is education and training (Aller et al., 2021; Conley et al., 2015). Educational campaigns should enhance MH literacy and promote a safety culture, encouraging aviation professionals to seek care without stigma. MH literacy can be as basic as understanding that feeling sad, anxious, or angry at times is a normal part of the human experience. What is important is educating students about understanding the difference between what is within normal range without self-pathologizing and when to seek mental health support from a professional, essentially understanding the difference between mental health and mental illness. The purpose of this ongoing study is to assess the effectiveness of a Wellness and Resiliency workshop intervention designed to enhance the knowledge and skills of Part 141 collegiate aviation pilots. This four-part workshop, titled *Wellness and Performance: How Resilience Enables Optimum Performance* aims to raise awareness and understanding of MH issues from a well-being and resiliency perspective, which teaches coping strategies and stress management skills. It also works to reframe mental health care as a normal part of self-care and an integral part of aviation safety culture. When presented in the classroom as a normal part of addressing safety through increased awareness of self and self-care needs, students may begin to see their mental health care in a less stigmatizing way. By focusing on prevention through the adoption of healthy lifestyles, as well as learning the various interventions, collegiate aviation pilots can be empowered to proactively seek help and address MH concerns early on, ultimately preventing more serious health issues. This quasi-experimental study advances the FAA's (2024b) broader objectives of improving safety performance within the U.S. National Airspace System.

Methods

A one-group pretest-posttest quasi-experimental design will be utilized (Leedy & Ormrod, 2020). The dependent variables will be the pre-and post-test scores measured using the Predictive 6-Factor Resilience Scale (PR6-50) and demographic questions (gender, enrollment level, age). The Predictive 6-Factor Resilience Scale (PR6-50) is a psychological assessment tool that measures resilience across six key factors: emotional regulation, optimism, social support, problem-solving skills, self-efficacy, and adaptability. It consists of a series of statements rated on a Likert scale, providing insights into an individual's resilience levels before and after interventions (Rossow & Rossow, 2016). The population of interest includes collegiate aviation pilots enrolled in a flight safety course during the fall 2024 and spring 2025 semesters at a university located in Central Florida. All participation will be in accordance with the Institution Review Board (IRB) guidelines.

The Mental Wellness workshop will be led by a clinical team of licensed MH experts from the University's Counseling Center and will span five days, with sessions integrated into the flight safety course curriculum. The original curriculum for the workshops was developed by Dr. Mazza, the author of Dialectic Behavioral Skills Training for Emotional Problem Solving for Adolescents (DBT-STEPS-A) in collaboration with Dr. Chungani from the University of Pittsburg. There, the curriculum was presented as a full 3-hour course that was given over a 16-week period with 14 original lessons. With permission, the clinical team condensed the course into four modules for this study. Topics covered will include: 1. Wellness and Resilience (Lacomba-Trejo et al., 2022), 2. Mindfulness for Stress Reduction, (Brown & Ryan, 2003) 3. Dialectical Behavioral Therapy (DBT) Skills (Mazza et al., 2016), and 4. Developing Therapeutic Lifestyle Changes (TLCs) (Walsh, 2011). These evidence-based strategies aim to improve MH and overall well-being through the introduction of new cognitive and behavioral skill development, as well as emphasizing the mental health benefits of regular physical activity, balanced nutrition, good sleep hygiene, stress management techniques, and other healthy lifestyle habits.

Data collection will occur in two phases: a pre-test administered during an initial information session one week before the workshop, followed by a post-test at the end of the semester. The posttest will include the PR6-50 (Rossow & Rossow, 2016) and a self-reflection component, where participants will reflect on their experiences with the Mental Wellness workshop, including how it influenced their understanding and behaviors related to MH, any challenges faced, future applications of learned concepts, and feedback on the workshop.

Participants' descriptive data will be examined to help researchers gain a better understanding of the overall trends and patterns (Salkind, 2012). SPSS® will be used to conduct a paired t-test, comparing pre-and post-test scores to determine if the Mental Wellness workshop intervention results in significant improvements for Part 141 collegiate aviation pilots. A deductive approach will guide the qualitative data analysis, aiming to explore how the findings align with established mental health awareness, coping strategies, and stigma reduction models in aviation (Patton, 2015). The primary goal will be to assess how effectively the workshop enhances participants' mental health knowledge, skills, and willingness to seek help.

Expected Findings and Conclusions

MH in aviation is a subject area that demands more attention and understanding by the FAA and the entire aviation community. One approach to support improving MH is through training and education (Aller et al., 2021; FAA, 2024a) so that collegiate pilots who enter the professional arena are best equipped to manage their own mental well-being. Effective mental health educational approaches can lead to better mental health literacy among pilots, fostering a culture that prioritizes mental well-being within the aviation industry. Through this workshop, the research team expects to see an improvement in resiliency and mental health literacy among collegiate pilots. This research aims to evaluate the resiliency of collegiate pilots following their exposure to the Mental Wellness workshop. The research team will assess participants' resiliency levels using the PR6-50 pretest and compare these results to the posttest to determine any improvements. The team anticipates an increased demonstration of resilience as a result of the training and education provided.

By equipping collegiate aviation pilots with the tools to manage the emotional and other challenges of their careers early on, mental well-being can be promoted, and stigma surrounding MH issues can be reduced. The findings of this study can provide the empirical foundation for developing improved national policies and procedures from aviation organizations like the FAA, as well as for enhancing university policies and strategies focused on MH initiatives for future aviation professionals. Most importantly, as these pilots enter the aviation industry, fostering mental well-being from the start of their Part 141 collegiate flight training and education will support their personal and professional growth while contributing to a safer and more supportive aviation industry.

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Advance Qualification Program Integration in Aviation Higher Education

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The Federal Aviation Administration's 2004 introduction of the Advanced Qualification Program (AQP) was introduced to provide an alternative approach to pilot training and evaluation. This study evaluates the impact of AQP-centered aviation education on student performance, specifically in advanced jet transport systems course. Building on Karp's integrated aviation learning model, which seamlessly combines various instructional methods, the research utilizes one-way ANOVA to compare student academic performance in AQP-centered, traditional classroom, and blended learning environments. The findings of this study revealed that students with the AQP-centered approach in this advanced jet transport system course benefited from higher academic performance than those with a traditional or blended delivery.

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Introduction

The Federal Aviation Administration (FAA) serves a crucial role in regulating aviation operations and maintaining aviation safety in the United States. Safety remains the top priority for the FAA in all aspects of aviation operations. In 2004, the FAA introduced the Advanced Qualification Program (AQP), an innovative initiative offering an optional systematic training program for pilot training. The AQP training methodology was incorporated into Title 14 of the Code of Federal Aviation Regulations (CFRs) N.58 (FAA, 2004). Although AQP training is generally used by airlines or operators to train their pilots, little to no research has evaluated the impact of AQP in aviation-focused higher education institutions.

The significance of aviation education at aviation-centered higher education institutions cannot be overstated. Aviation-focused higher education prepares future aviation professionals with essential skills to thrive in the industry and, most importantly, enhance safety. As the aviation industry has evolved, advancements in flight simulations and a greater emphasis on diversity, equity, and inclusion (DEI) have significantly enhanced training programs. AQP offers an innovative alternative to traditional aviation training methods in this context. This study aimed to assess the impact of AQP training methodology in an aviation higher education institution on student performance in the context of an advanced jet transportation systems course. The course has four measurable learning objectives: (1) applying air carrier systems knowledge to operational procedures, (2) describing the complex systems of jet transport aircraft, (3) analyzing developments in aircraft systems design, and (4) evaluating the evolution of jet transport aircraft system designs.

Advancements in Aviation Education

In recent years, additional advanced simulation technologies and DEI have been integrated into aviation education. Aviation simulation technology, including virtual and augmented reality, has improved the immersive experience by enhancing situational awareness and decision-making (Thomas et al., 2021; Thomas et al., 2022). The integration of DEI principles in the aviation workforce underscores the importance of diverse perspectives in the aviation industry. The infusion of diverse perspectives has enriched the industry and has improved safety outcomes (Albelo et al., 2023), maintaining a strong aviation safety culture.

AQP Overview

The AQP systematic methodology fundamentally aligns training and evaluation activities to develop skills in specific operational aviation roles (Federal Aviation Administration, 2004; Federal Aviation Administration, 2022; Longridge, 1997). It identifies essential skills, knowledge, and abilities relevant to various demands of operational roles, including normal, abnormal, and emergency scenarios. This structured approach is based on a thorough job task analysis detailing the necessary competencies for pilots in diverse flight phases (Esser, 2006). Unlike traditional training frameworks found in Title 14 of the CFR for Part 121 (Domestic, Flag, and Supplemental Operations) and Part 135 (Commuter and On-Demand Operations), this program offers a systematic approach to pilot training driven by data analysis and scenario-based training and evaluation (FAA, 2022).

Theoretical Framework

This study employs Karp's (2000) integrated aviation learning model as a theoretical foundation. The model incorporates a learning framework designed for the aviation context to improve effectiveness, understanding, and safety in aviation training programs. It incorporates a range of instructional methods, such as theoretical study, practical exercises, simulation training, and real-world applications, enabling learners to comprehend aviation principles thoroughly. Additionally, integrating initiatives like AQP into Karp's framework enables aspiring aviation professionals to apply their knowledge effectively, enhance problem-solving skills, and respond accurately to emerging situations.

Methods

The present study used a quantitative approach to assess the integration of AQP training methodologies and the impact on student academic performance in the advanced jet transportation systems higher education course. The study used archival data from four academic semesters at Embry-Riddle Aeronautical University, focusing on AS 411, a course designed to introduce students to complex jet transport systems. A purposeful sampling technique was used to acquire data from three professors who have taught the course in either an AQP-centered structure, traditional, or blended format. This purposeful sampling ensured that the data accurately reflected the effectiveness of each teaching approach.

The primary data included students' final grades in the AS 411 course, which evaluates their understanding of complex jet transport systems and operational techniques. A total of 398 grades were collected for analysis. After a comprehensive descriptive statistics analysis was used to detect outliers, eight outliers were removed. The independent variables were identified as the education experience (AQP-centered, traditional, and blended education). The dependent variable, on the other hand, was recognized as the student's academic performance. A one-way ANOVA was used to analyze the mean scores among the three groups, examining the relationship between the type of educational experience and student performance. Normality was assessed using the Shapiro-Wilk test, and homogeneity of variances was tested with Levene's test. Post hoc comparisons were conducted using Tukey's HSD to explore specific differences between groups.

Results

The ANOVA analysis revealed statistically significant differences in academic performance among the three groups ($F(2, 387) = 12.356$, $p < 0.001$). Traditional and blended groups showed no significant deviations from normality, while the AQP group did exhibit a considerable deviation.

- Traditional: $W(131) = 0.982$, $p = 0.077$
- Blended: $W(124) = 0.984$, $p = 0.146$
- AQP: $W(135) = 0.971$, $p = 0.005$.

The AQP group demonstrated a mean score of 85.35 (SD = 2.59), significantly outperforming both the traditional group (M = 83.63, SD = 7.94, $p = 0.037$) and the blended group (M = 81.85, SD = 5.20, $p < 0.001$). Assumption of homogeneity, Levene's test, revealed no significant differences among group variances $F(2,387) = 58.445$, $p < 0.001$.

Conclusions

The study's findings demonstrated the effectiveness of AQP in enhancing academic performance in an aviation higher education course. The AQP utilizes a systematic approach that aligns training and evaluation with specific operational roles and requirements. It offers an alternative to traditional aviation training by integrating informed decision-making skills into the training process while promoting academic success and enhancing aviation safety. The findings of this study suggest that aviation training programs consider the incorporation of AQP in their curricula as an alternative to traditional training. As the aviation industry evolves, academic institutions must evaluate alternatives to enhance students' learning experiences and academic performance.

Future studies should explore the effectiveness of the AQP approach in other aviation higher education institutions and courses. To validate the findings of this study, other institutions should evaluate the AQP approach to student academic performance. An essential aspect of this integration involves examining students' perspectives regarding AQP. Understanding how students perceive knowledge retention and their overall experience with AQP could significantly enhance their learning outcomes. Furthermore, additional research could focus on incorporating artificial intelligence into AQP training to improve personalization and effectiveness in skill development.

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Collegiate Aviation Review International

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Understanding Mental Health Awareness and Resources in a Collegiate Aviation Program

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The research purpose is to explore mental health awareness among student pilots and offer recommendations on how aviation flight departments can better support students facing mental health challenges in a Collegiate Aviation program. The research begins by categorizing types of mental health disorders and mental health conditions outlined in FAA Part 67 that can disqualify students from pursuing an aviation career. An essential area of the study is the examination of resources available to aviation flight departments and student pilots for aviation-related assistance on general mental health support. The study will be used to explore mental health awareness and the familiarity of mental health resources among students in UVU's aviation flight department. The study will further give insight into a student's tendency towards self-diagnosis, the reluctance to seek advice and information on mental health, and their comfort levels in approaching peers struggling with mental health challenges. The study results will be used to identify priorities and develop an action plan of best practices and resources available for providing support systems for aviation flight training departments. The recommendations and best practices formulated by UVU's flight department can be considered and integrated into other flight training programs.

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Introduction

Whether acknowledged or not, mental health issues have long been a part of aviation. It's a common refrain that flying an aircraft of any kind can be stressful and that stress can have an impact on a person's ability to operate an aircraft effectively. However, stress is a fact of mental health issues that can impact professionals within the aviation and aerospace industries. In recent modern times, several accidents have identified mental health issues as part of the root cause, notably the Germanwings accident (Bureau d'Enquêtes et d'Analyses, 2016). As a result of this and other accidents, mental health issues have come into sharper focus within the realm of aviation and aerospace, and in particular, within the pilot community. This trend of increased awareness impacts all areas, from new students learning to be pilots all the way to experienced pilots at the end of their careers.

However, lacking within this focus was a basic understanding of what resources are currently known to students within a flight training environment. Thus, a study was undertaken to identify the knowledge base that students currently have within a collegiate flight program. Students in the population sample had no formal mental health training program within their curriculum, nor did they have any formal course to teach and identify what mental health issues truly are.

Literature Review

To begin, a discussion on current mental health standards, information, and resources is needed. Current regulations within the Federal Aviation Administration (FAA) list several standards for mental issues within the larger medical standards and certification requirements. (Federal Aviation Administration, 2024a). Title 14, Part 67 of the Code of Federal Regulations lists several disqualifying mental health conditions for each level of medical certificate, as evaluated by an Aviation Medical Examiner (AME) within § 67.107, § 67.107, and § 67.107, respectively. These include a personality disorder, psychosis, bipolar disorder, substance dependence, or any other mental condition that could make "the person unable to safely perform the duties or exercise the privileges of the airman certificate applied for or held" or "reasonably be expected, for the maximum duration of the airman medical certificate applied for or held, to make the person unable to perform those duties or exercise those privileges" (Federal Aviation Administration, 2024a).

To better define these conditions, in 1972, the FAA aligned its terminology for mental health issues with the Diagnostic and Statistical Manual of Mental Disorders (Federal Aviation Administration, 1972). Within the Diagnostic and Statistical Manual of Mental Disorders (DSM), as printed by the American Psychiatric Association, mental health issues like those mentioned within the Code of Federal Regulations are defined with high levels of detail. For example, psychosis is a disqualifying condition within part 67. However, as defined by the regulations, psychosis is a condition in which the individual has either "manifested delusions, hallucinations, grossly bizarre or disorganized behavior, or other commonly accepted symptoms of this condition" or "may reasonably be expected to manifest delusions, hallucinations, grossly bizarre or disorganized behavior, or other commonly accepted symptoms of this condition" (Federal Aviation Administration, 2024). However, within the 5th edition of the DSM (DSM-

IV), psychosis can be defined as a schizotypal (Personality) disorder, a brief psychotic disorder, a schizophreniform disorder, schizophrenia, a schizoaffective disorder, substance/medication-induced psychotic disorder, psychotic disorder due to another condition, catatonia, other specified schizophrenia spectrum and other psychotic disorder, or any unspecified schizophrenia spectrum and other psychotic disorder (American Psychiatric Association, 2015). As such, there is more that goes into the diagnosis of mental health conditions than just what is described within the regulations. In addition, there are temporary mental health conditions that could impact a pilot's ability to effectively fly and manage a cockpit environment, such as brief depressive episodes or momentary inability to deal with the stressors of flight.

In response to the increased focus on Mental Health issues, the FAA established a rulemaking committee to study and clarify mental health standards for pilots. This committee, the Mental Health and Aviation Medical Clearances Aviation Rulemaking Committee, made 24 recommendations, including changing the way the FAA handles medical applications with regard to psychotherapy, creating non-punitive processes for the reporting of previous mental health conditions, establishing peer support programs for mental health issues, enhance mental health decision processes, and clarify medication allowances for mental health issues (Federal Aviation Administration, 2024b).

In addition to the FAA efforts, there are other groups that provide mental health resources and assistance to not only pilots but other aviation professionals. These include the Aviation Medicine Advisory Service (AMAS), Flight Safety Foundation, Aircraft Owners and Pilots Association (AOPA), Mental Health America (MHA), and the Pilot Peer Support Network, which is part of the Air Line Pilots Association International. These outreach efforts range from formal counseling with a licensed medical practitioner (Aviation Medicine Advisory Service, 2024), informal information assistance through a repository of education materials (Aircraft Owners and Pilots Association, 2024), to support through unlicensed peer support groups (Air Line Pilots Association International, 2024). There are also other mental health resources available through non-aviation-specific organizations, such as those already available within a college or university, like the one where this study took place.

Research Methodology

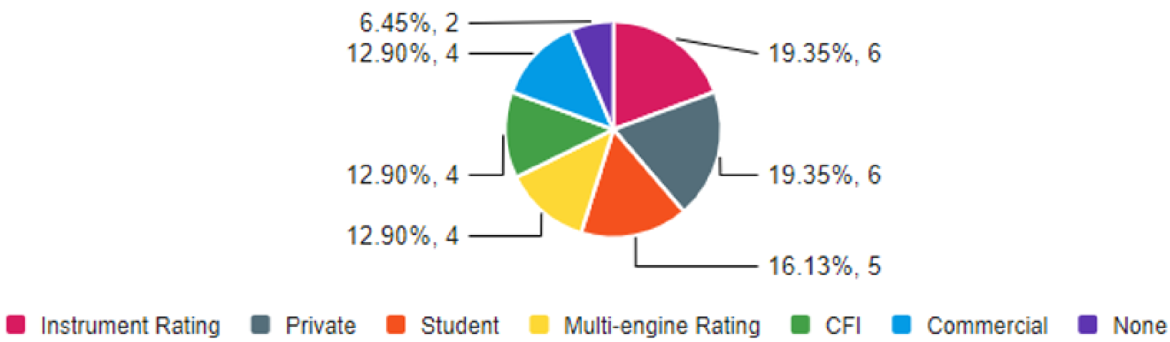
Utah Valley University (UVU) conducted a survey to understand the mental health awareness of pilot students and their familiarity with aviation mental health resources available to students conducting flight training in UVU’s School of Aviation Science Flight Department. This research study focused on student awareness within the following areas: FAA CFR Part 67 mental health standards and criteria for pilots seeking a medical certification, mental health concerns not identified under Part 67, and the mental health awareness involving current student pilots within the UVU flight department. In addition to the survey, information was gathered from a literature review.

The mental health awareness survey received approval through UVU’s Institutional Review Board (IRB), approval number 1653. The qualitative survey was administered online with Qualtrics to collect the data. The internal study limited participation to current professional pilot flight students in UVU’s flight department. Participants were required to be eighteen years of age or older to participate in the study. No personal information was collected, and confidentiality was maintained because of the survey's anonymity.

Survey Population

The survey was sent out to a selected sample population of approximately 160 active professional pilot flight students at UVU, and it resulted in 31 respondents. Of the respondent population, 40% held a private pilot certification with an instrument rating. Pilots holding a student pilot certificate made up the next highest rating at 17%. The remaining respondents were equally divided between commercial, flight instructor, and multi-engine pilots, apart from two respondents who did not identify as holding either a pilot certificate or rating. (See Figure 1)

Figure 1
Survey Population



Survey Analysis

The goal of the survey analysis was to gather data on the awareness of mental health concerns and resources available to student pilots in UVU's aviation flight department. Mental health concerns focused on the tendency of student pilots to self-diagnose and whether students were hesitant to seek advice and information on mental health issues. Data was also collected to determine if student pilots in the flight program were aware of peers who may be struggling with mental health issues and how comfortable they are with approaching their peers to address those mental health concerns.

The survey analysis presented in this report adopts a question-and-response format, accompanied by a brief report on the researchers' observations on the familiarity of mental health resources available for student pilots and the significance of how students address their mental health concerns and that of their peers. Questions from the survey deemed significant to the study are included below.

Question 4 – Do you agree or disagree with the following statement: I am aware of various aviation mental health resources for pilots.

The response to the question indicated that 62% of the respondents were somewhat to not unaware of mental health resources available to pilots. Of those respondents, 27% strongly disagreed with the question, whereas 35% somewhat disagreed. Only 20% of the population indicated that they were aware of aviation mental health resources available to pilots.

The survey included a follow-up question allowing a written response to Question 4. The question asked respondents to explain what specific aviation resources regarding mental health they were familiar with. The following resources were identified by the respondents: Aviation Medical Examiners (AME), social support through academic clubs, general therapy, and UVU's emergency numbers and suicide prevention cards. UVU pilot students must get an FAA medical from an AME before starting flight training. The response indicated that respondents were overall unfamiliar with aviation resources available to pilots other than what was required in UVU's flight training curriculum.

Question 6 – Do you agree or disagree with the following statement: I tend to self-diagnose my own mental health issues.

The response to the question indicated that 70% of respondents tend to self-diagnose their mental health issues. A significant majority of the respondents were self-diagnosing mental health concerns, and the analysis from Question 4 above suggests that pilots in flight training departments were unfamiliar with, and possibly lacked access to, mental health resources.

Question 7 – Do you agree or disagree with the following statement: Students in flight training departments are often reluctant to seek advice and information on mental health.

The response to the question was high, with 98% of respondents somewhat or strongly agreeing that they are hesitant to seek information and advice when it comes to mental health. The overwhelming majority suggest that barriers exist to accessing resources and support and suggest the need for increased support through education and access to the availability of mental health information and resources.

Question 8 – Do you agree or disagree with the following statement: I am aware of peers in the UVU flight department who may be struggling with mental health issues."

Question 9 – Do you agree or disagree with the following statement: I am comfortable approaching peers in the UVU flight training department who may be struggling with mental health issues to discuss these concerns.

Responses from Question 8 indicated that half of the respondents were aware of peers at UVU who may be struggling with mental health; however, the results from Question 9 resulted in only 42% of respondents that would approach peers to discuss mental health concerns, while 34% would not approach peers. Questions 7 through 9 highlighted the need for not only increased education and awareness of resources but also providing an environment where students feel supported and comfortable with addressing concerns.

Question 10 – What steps do you feel can be taken to improve the awareness of mental health resources available to flight students in the UVUY Flight Department? Are there any areas of concern that you feel should be addressed?

Respondents' written suggestions for increasing awareness of resources included having information provided through open discussions and seminars. Respondents also suggested having information provided by other means, such as flyers, pamphlets, and email announcements. Respondents indicated that steps could be taken to improve awareness through new student orientation training and recurrent training as students progress through flight training. Respondents also suggested providing flight instructors with resources and training to support and educate students on available resources. Comments identified a need to prioritize a flight training culture at UVU centered on support, encouragement, and learning.

Conclusions

The primary result of this research into student pilot mental health awareness is that most students are not familiar with aviation mental health resources available. Nor do they know how to get help or even if help is available. As a result, they tend to self-diagnose and avoid seeking assistance and/or treatment. An additional complicating factor in aviation is that students fear their careers may be negatively affected if they admit to mental health issues. While many are aware of a peer struggling with mental health and are willing to approach them to discuss their concerns, they have little training in how to be effective. Some may fear doing more harm than good if they attempt to help.

At Utah Valley University, the flight department has had experience with students who have had mental health issues resulting in everything from panic attacks to suicide. If students had been more aware of the resources available to them and of the assistance they could have received without jeopardizing their careers, some of these outcomes may have been different. While efforts have been started to address the gaps in mental health awareness and training even prior to this research, it is upon everybody to continue developing more and better ways of combating the effects of mental health issues within our student population.

The first step was to introduce all students and employees to the concept of lifestyle medicine. Proper habits of nutrition, exercise, and rest can go a long way in overcoming the stress experienced by student pilots. A video training program in lifestyle medicine was developed and is now included in all flight courses. UVU Aviation recently started taking advantage of the mobile food pantry that's part of the UVU "CARE" Hub. The Coordinated Access to Resources and Education (CARE) Hub is dedicated to helping students connect to resources that will help them address insecurities around food, housing, health, and safety (UVU "CARE" Hub, n.d.). For example, the mobile food pantry anonymously delivers food to students once a week upon request. While student mental health is not currently under The CARE Hub's purview, it could become a mental health resource with some coordination. Survey participants also identified the value of social support through academic clubs. Interacting with their peers outside of the classroom provides a way to connect with people who may have different interests and who might offer unique perspectives. Aviation students share a powerful bond that is reinforced through their common experience. Collegiate aviation programs should recognize the importance of these connections and create a variety of social opportunities through aviation-related clubs and organizations. Students should also avoid limiting their social circle to aviators only. A wide selection of gathering opportunities for university students is available, and they should be encouraged to participate in the mental health benefits offered by socialization.

One of the biggest challenges to improving the mental health of our students will be connecting them with current aviation-specific resources. FAA rules are changing, and much of the information available is not current. Mental health professionals with knowledge of aviation issues are difficult to find. UVU needs to develop these resources with guidance from other institutions that are leading the way in various aspects of mental health treatment. All students and employees should have access to a written guide that outlines the steps to take in dealing with a mental health crisis. A network of trained peers and mentors who can take referrals regarding suspected mental health issues could serve as a further link to professional help. The most important thing is awareness. Students must be aware that help is available, and all they have to do is let someone know that they are struggling. It's our job to create this awareness and to make sure there is always someone in the department who is trained to help.

It is important not to overlook another form of prevention. In addition to lifestyle medicine, or as part of it, efforts should also include resilience training for students. Resilience is the ability to recover from a setback and is accomplished through a combination of personal confidence and professional competence (Mayo Clinic, 2024). Resilience training employs the use of countermeasures or coping strategies to overcome stress.

This research helped identify additional questions that should be considered. Among those are what qualifications are necessary and/or what training is required to be effective at intervening in a mental health crisis? In other words, do we have the resources to provide the resources? And at what point should we consider having a mental health professional in-house? Mental health is a delicate but vitally important subject in aviation, and it deserves our attention.

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Collegiate Aviation Review International

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12-27-2024

Assessing the Impact of Implemented Safety Culture Recommendations in a Collegiate-Level Flight Training Program

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The purpose of this research is to report on the effectiveness of implementing the recommendations that were the outcome of the previously completed research involving the identification of best practices to improve overall safety performance and safety culture within Utah Valley University's flight training operations. Prior to the safety culture research that was conducted in 2022, UVU observed an underreporting of safety issues within flight and maintenance operations. There was concern that an insufficient understanding existed related to the impact that safety culture has on safety performance. A survey was conducted across all flight and aircraft maintenance functions and the collected data was analyzed to determine trends and opportunities for implementing related to the safety culture that existed at the time. Through 2023, recommendations were prioritized and implemented through all flight and maintenance departments. In 2024, another survey was conducted to once again collect data to determine if the implemented recommendations achieved the desired positive change in safety culture, safety performance, and risk mitigation. The research report identifies and describes the effectiveness of the implemented action plan to improve safety performance through an effective and integrated safety culture. Lessons learned and best practices will be shared to allow other schools to develop and engage an effective safety culture of their own within their flight training programs.

Recommended Citation:
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Safety Culture in Collegiate Aviation – 2024 Update

Why Research Safety Culture?

In 2022 UVU conducted research on safety culture within a collegiate aviation program. The research was conducted in response to several safety concerns in UVU flight department, specifically within the maintenance and flight operations area. Observations made by UVU's safety coordinator determined that safety issues were being underreported in UVU's safety reporting platform, Aviation Information Management Systems (AIMS). The AIMS safety reports were not representative of what was being observed in the flight department and at times reflected repeat occurrences of simple mistakes. Another concern was that not all safety related aircraft discrepancies were being captured by the safety reports resulting in a missed opportunity to discuss safety concerns across departments. Furthermore, the safety reporting system was inappropriately being used to report tension between departments. Grievances by individuals that were not getting along and communicating within the organizations were being reported through the safety reporting systems. It was determined though these reports that interdepartmental relationships and communication between flight operations and maintenance were not healthy. These observations led UVU to conclude that the lack of safety culture and a poor safety reporting culture can impact overall performance (Silcox, Ley, & Sutliff, 2022).

Research Goal

The goal of our research and the safety culture survey in 2022 was to identify how safety culture can impact safety performance in flight operations and identify actions to mitigate safety concerns and improve overall performance in the flight department. In addition to the distribution of a safety culture survey, research was conducted on safety culture initiatives in high-risk organizations outside aviation, a search of the ASRS data base on safety culture related accidents and looked at the implementation of aviation industry wide safety initiatives. At the conclusion of the 2022 research study and survey we identified the following priorities to improve the safety culture and performance in UVU's aviation program: "1) Interdepartmental Relationships, 2) Communication between Departments, 3) Quality of Flight Instruction, 4) Employee and Safety Training, and 5) Professionalism among Employees" (Silcox, Ley, & Sutliff, 2022). Recommendations were identified for each priority and were implemented throughout academic years 2022-2024.

Research Methodology

The UVU School of Aviation Sciences conducted a survey the Summer 2022 to determine the impact organizational culture and departmental relationships have on operational safety within the UVU School of Aviation Sciences Flight Department. The same survey was conducted a second time during the early Summer of 2024. The results of each were compared to determine if the recommendations implemented between 2022 to 2024 were effective or impactful to the goals of the Safety Culture program. The research surveys 2022 and 2024 included populations from the same functional roles that were involved in flight training operations within the School of Aviation Sciences at Utah Valley University. These roles included Flight Instruction, Staff within Records, Scheduling, and Dispatch Services, Flight

Students, Aircraft Maintenance, and Flight Line Services. The research survey received UVU Institutional Review Board (IRB) approval (No.1105) and was conducted through an online hybrid quantitative and qualitative survey using Qualtrics as a data collection tool.

Comparing 2024 Survey Responses to 2022 Survey – Has the Needle Moved?

For consistency to the 2022 survey analysis, this section will follow the same simple inclusion of the survey question, data, and brief analysis commentary on the observations made by the researchers and only to those survey questions determined to be significant to the study and actionable by the UVU Flight Department. As a result, some survey questions utilized in the 2022 survey report are not included in the 2024 report.

Survey Population: The 2024 survey resulted in 63 respondents, which is 49% of the 2022 population of 129 respondents. Decline in participation is likely due to the removal of participation incentives during the 2024 survey. The percentage of population within roles participating in the survey is closely matched between 2022 and 2024 with more respondents from Flight Instruction in 2024, 39%, compared to 2022, 25.6%. and a reduction in Flight Student respondents in 2024, 39%, compared to 2022 at 51.1%. The 2024 distribution of the remaining respondents' roles are consistent with the relative size of the population of roles within the flight department.

<u>Question</u> **-** *Relationships and trust amongst functional groups within the flight department, either positive or negative, can impact safety to flight operations. To what level do you agree or disagree with this statement?*

> 2024 survey results indicated 91% of respondents feel relationships and trust can impact safety. This is down 3% from the 2022 survey that was quantified at 94%. The researchers' impression is that the decrease is not an actionable opportunity. Overall, the flight department continues to feel that relationships and trust are important and can impact flight safety. There is a suggestion from the research team that the decrease could indicate that relationships and trust is not as much of a focal point in 2024 as it was in 2022. Could this mean that implemented programs are resulting in less tension within the functional groups? An interesting observation of data within this question indicated that the response 'Neither agree nor disagree' went from 2% in 2022 to 7% in 2024 which cannot be explained adequately by the research team. Too many assumptions would be required without direct commentary being provided by the respondents.
>
> According to Silcox, Ley, and Sutliff (2022), "…the elements that make up an organizational culture, relationships, and trust, are viewed as impactful to safe flight operations. This is a critical finding. The reverse of this, a discordant organizational culture with fractured or no relationships nor trust within or between groups can negatively impact safety within the department." The researchers continued to find this true 2 years later. Anecdotal observations within the day-to-day flight operations confirm this as well. It is essential that safety culture continue to be imbedded within flight operations to ensure positive relationships within the different flight department roles results in positive safety outcomes.

Question – *For the focus area listed, rate the effectiveness of each within the UVU flight department.*

As in the 2022 survey, the 2024 survey respondents were given 16 functional categories in which they were to rate the level of perceived effectiveness. An average score for each category was calculated and then plotted using a graph (Ref. Figure 1 and Figure 2). Note, Figure 1 does not include the average scores in the graphed data as the Qualtrics software version changed between 2022 to 2024 resulting in different graphic choices and characteristics.

Table 1
Focus Areas, Most Effective and Opportunities for Improvement

2022 Survey		**2024 Survey**	
Most Effective	**Opportunities-Improvement**	**Most Effective**	**Opportunities-Improvement**
*Operational condition of aircraft	*Interdepartmental relationships	*Operational condition of aircraft	*Communication b/w departments
*Maintenance of aircraft	*Communication b/w departments	*Maintenance of aircraft	*Interdepartmental relationships
*Line operational safety	*Employee training	Addressing safety concerns	*Employee training
		*Line operational safety	Dispatch & scheduling of aircraft
		Safety culture	

* Topics repeated between 2022 and 2024 survey results

Reference Table 1. The 2024 survey resulted in a repeat of the top 3 most effective functional categories, Operational Condition of the Aircraft, Maintenance of the Aircraft, and Line Operational Safety. In the 2024 survey, notice ‘Safety Culture’ and ‘Addressing Safety Concerns’ have both landed in the top 3 of most effective functional categories each achieving the same score of 2.7, reference Figure 1. The top 3 opportunities for improvement in both the 2022 and 2024 survey were related to characteristics assigned to organizational behavior. For the context of this paper, the researchers attribute this behavior to safety culture as was previously identified in the 2022 paper (Silcox, Ley, & Sutliff, 2022).

Figure 1
Rating of Effectiveness (2022)

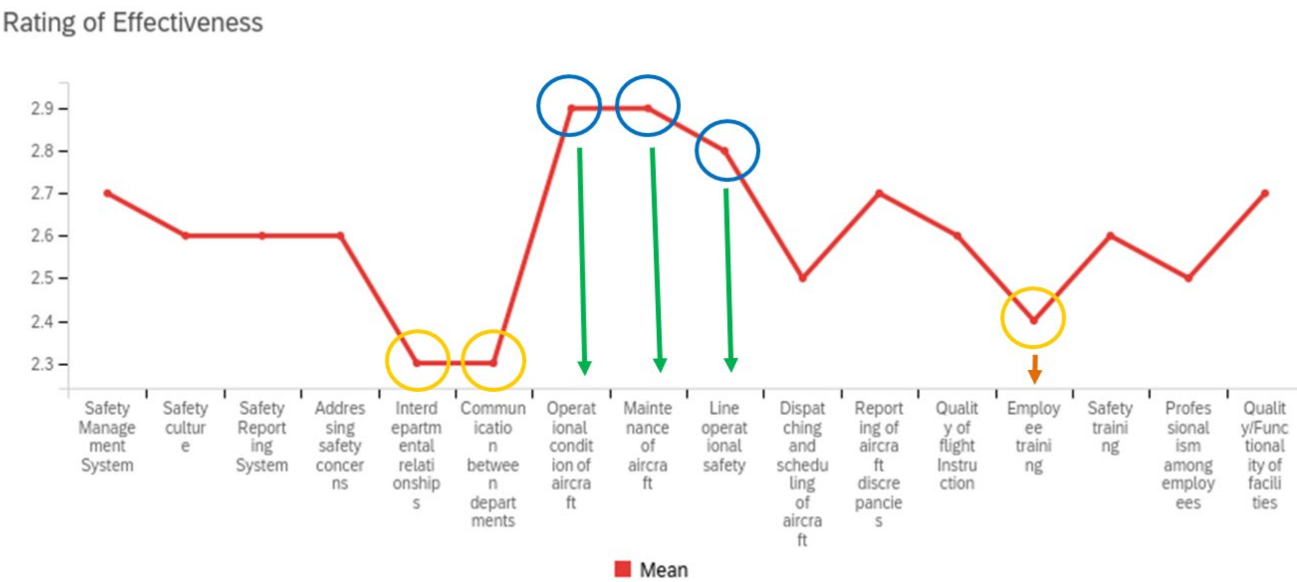
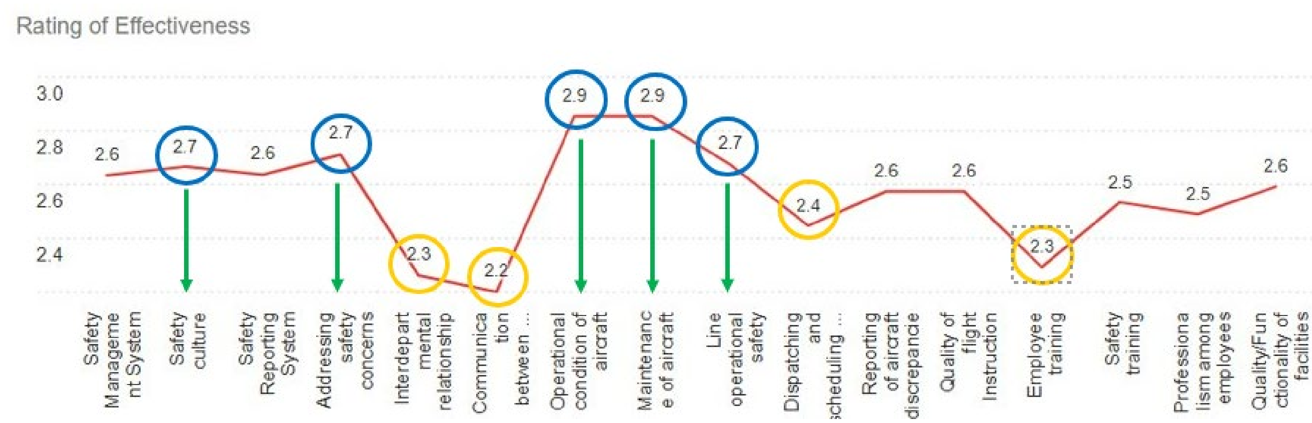


Figure 2
Rating of Effectiveness (2024)



<u>Question</u> – *For the focus areas listed, what are the top 3 focus areas that you feel has the greatest impact on achieving an effective safety program at UVU Flight?*

Reference Table 2. A clear pattern exists in respondents' priorities in identifying what the top three focus areas are that have the greatest impact on achieving an effective safety program. Safety culture and quality of flight instruction recur between the 2022 and 2024 surveys and also in the same order of priority. Safety culture leads in priority with quality of flight instruction following. The data infers that the flight department must remain vigilant to these perceptions and ensure the safety program aligns with the expectations of all roles within the department and that policy and process must ensure the safety goals are achieved.

In the 2024 survey, communication between departments was added to the top 3 focus areas while maintenance of aircraft dropped out of the list. In fact, maintenance of aircraft dropped significantly down in the list of respondents expressed priorities. The researchers' opinions of this drop in priority are not concerning and may indicate the level of confidence the flight department has in the quality and flight readiness of the aircraft. Communication between departments is not a new subject of concern within the flight department and the survey results from this question bring greater attention and priority to finding solutions to address this topic.

Table 2
Top 3 focus areas having greatest impact on effective safety program

2022 Survey	2024 Survey
*Safety Culture	*Safety Culture
*Quality of Flight Instruction	*Quality of Flight Instruction
Maintenance of Aircraft	Communication Between Departments

* Topics repeated between 2022 and 2024 survey results

<u>Question</u> **-** *How would you grade the current safety program within UVU Flight Operations?*
In 2022, 89% of respondents scored the safety program at B or better. The 2024 response indicated a 3% improvement from 2022 measuring at 92% of respondents rating the current safety program at a grade of B or better. Overall, the researchers consider this to be a general high level of confidence in the flight department's safety program between both surveys. Also, the implemented initiatives from 2022 to 2024 had a positive impact.

<u>Optional (Open) Questions</u> – Two optional questions were asked within the 2022 and 2024 surveys that required the respondent to provide a free form written comment/response. The two questions included:

1) Do you feel the safety procedures and policies are effectively communicated, accessible, and utilized within the UVU flight department for your role?
2) What steps can be taken to improve the safety culture or safety effectiveness within the UVU Flight Department? Are there any areas of concern that you would like to have addressed?

The researchers carefully reviewed and grouped each written comment into at least one or multiple categories. All researchers were in consensus as to the category or common subject assignment of each comment. The same 16 common subjects in 2022 were used in 2024 to ensure an effective comparison between the two data sets. There were a minor number of comments that did not adequately align within the identified 16 categories; however, they were identified but excluded from the data set. The excluded comments were considered 'unactionable' for the purpose of the survey. In some cases, 'positive comments' were given in which the researchers felt it was important not to lose these important data points and were added to a separate, new category in the 2024 analysis. In the 2022 survey, there were a total of 73 usable written comments and 36 generated by respondents in 2024. A frequency count of each category was generated in a table in which the top 80% of the total comments were used for analysis in this report.

Below are the frequency results of the top 80% of the most commented subjects (Table 3).

Table 3
Subject topics most frequently commented

2022 Survey		2024 Survey	
Category/Topic	**Frequency**	**Category/Topic**	**Frequency**
Safety Culture	21	Interdepartmental Relationships	10*
Safety Training	20*	Positive Comments	10
Professionalism	19*	Employee Training	9
Interdepartmental Relationships	15*	Professionalism	9*
Communication b/w Depts	15*	Safety Training	7*
Quality of Flight Instruction	14	Communication b/w Depts	7*
		Quality of Flight Instruction	6

* Topics repeated between 2022 and 2024 survey results

Reference Table 3. The 2024 survey resulted in six categories of comments having an equal number of responses and were included in the analysis and weighted equally within the topic pairs. The following topics were repeated between the 2022 and 2024 surveys, Safety Training, Professionalism, Interdepartmental Relationships, and Communication Between Departments. In 2024, the category ‘Safety Culture’ dropped below the 80% threshold while ‘Employee Training’ was elevated to above the 80% threshold and was added to the list of most frequently mentioned topics within the open comments provided in the two questions. The researchers believe ‘Safety Culture’ dropping out of the top 80% of most frequently mentioned topics within the open questions could be an indicator that this is not a hot button topic of concern within the flight department. The category ‘Interdepartmental Relationships’ elevated to one of the most frequently commented topics within the 2024 survey and is an area of concern to the researchers indicating that this is an important topic to address and aligns with its importance indicated in previous questions.

There was a quantifiable number of positive comments within the 2024 study that were assigned a new category ‘Positive’ that reached well above the 80% threshold. This is considered to be a very important indicator, unsolicited, that the implemented improvements from the 2022 study recommendations have taken root and have added value to improving overall safety culture within the flight department.

What Worked, and What can be Improved

The 2024 survey revealed that many of the safety initiatives implemented following the 2022 survey resulted in a more robust safety culture. Through increased student and employee training both in person and online, the perception of the effectiveness of UVU’s safety program rose by three percent. Our CFI safety stand downs now occur twice annually and include training events on aircraft inspections, pre and post flight procedures, and aircraft systems operation led by our maintenance technicians. Annual online training on our Safety Management System (SMS) and Emergency Response Plan (ERP) was embedded into the university’s Learning

Management Systems (LMS) for both students and employees. Other reasons for the improved perceptions are increased access to the safety reporting system for sharing concerns and/or suggestions and an active and well received open-door policy with our dedicated aviation safety officer. Specific survey results indicating the effectiveness of the above initiatives include "operational condition" and "maintenance of aircraft" no longer being focus areas within our safety program. While "safety culture" continues to be an area with greatest impact on safety, it is no longer a focus area according to written comments received.

Recommended Next Steps

Opportunities for improvement remain. Concerns regarding "interdepartmental relationships" and "communication between departments" carried over from the 2022 survey as did "employee training." A new area for improvement for 2024 was "dispatching and scheduling of aircraft." To address these concerns, we plan more active interaction between maintenance, flight operations and dispatch personnel and a quick reference guide on policies, procedures, and expectations along with universal training on each within all departments. We are planning team building exercises independent of work-related duties to increase goodwill between departments. Meetings that include all functional areas to address concerns, safety culture, etc. will be conducted each semester.

Further improvement is needed in "quality of instruction" and "professionalism." Both will be addressed by more active supervision of CFIs by assistant chief instructors. Since looking professional is a step toward acting professionally, a new uniform policy is now in effect and the assistant chiefs are leading by example. Professionalism training has been added to all monthly CFI meetings. From a student perspective, each student has been assigned an assistant chief as their flight advisor. Professionalism also applies to students and training in this area will be included as a component of classroom instruction, added to course objectives and integrated into assignments. We are considering a uniform policy for students.

Key Observations

A key takeaway from the 2024 survey is that students and employees welcome more safety training. We can provide written or electronic manuals and training programs. We can schedule more mandatory meetings in which safety is discussed. And we will do both, but maybe what's also needed is a safety training culture shift. Every interaction, whether formal or informal, with a student or other employee is an opportunity for transfer of knowledge. What if you ended every conversation with "can you tell me something about safety of flight that I don't already know," or "may I ask you about a safety concept that I don't fully understand?" You would not only look forward to learning each time, but you would always have to be ready with something important to share when one of those questions is asked of you.

Conclusion – Safety Improvement Will Never Stop

The purpose of this research is to identify cultural influences within the organization that impact safety and to find ways to create and maintain a positive safety culture. We have had some success with both as outlined in this publication.

In the latest survey, unsolicited positive comments regarding UVU's safety culture increased. While this is encouraging, it doesn't mean the job is done. It is merely an indication that what we are doing is making a difference. It's upon us to continue finding innovative ways to enhance safety in all areas of the organization.

We will continue with the actions that have been identified as effective and may conduct further surveys to quantify results and point out areas that need more attention. Additional research could be undertaken to identify the role of strategic hiring and timely termination in an organization's safety culture.

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Collegiate Aviation Review International

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Determining the Best Way to Integrate New Flight Students Who Already Possess a Private Pilot Certificate

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There are a number of ways collegiate aviation programs handle the unique needs of students who have already completed flight training outside of the university environment. This article summarizes the findings of two surveys: one survey that sought to find out how other UAA-member schools evaluate and integrate transfer flight students into their curriculum; and one survey that sought to find out how well one formal integration course is working. The goal of this research is to provide collegiate flight educators with the information they need to consider how well their evaluation and transfer processes are working in their own programs.

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This exploratory research was presented at the 2024 UAA Education Conference during the September 26, 2024, Best Practices session. The purposes of the presentation were to share the results of two surveys that were conducted to identify challenges and best practices related to the acceptance of private pilot students into university flight programs, and to explain how one transition course model is intended to work.

The Best Practices presentation, followed by participant feedback and questions, validated the need for this research. The survey results shared during the session are the basis of two journal articles: one focusing on the perspectives of flight training providers, an article recently accepted for publication in the Collegiate Aviation Review International, and one focusing on the perspectives of transfer flight students, an article currently in the draft stage.

Introduction

As university flight programs admit students into their flight programs, they are often faced with the challenge of deciding how to evaluate the quality of previous flight instruction received outside of the university, particularly if they are entering the university with a private pilot certificate. They must also decide if supplemental ground or flight instruction is needed in order to successfully integrate transfer students into the university's flight curriculum.

The conference presentation discussed how common it is for universities to accept transfer flight students, reported various ways university programs are integrating transfer flight students into their programs, reported survey findings asking about differences between the two cohort groups (transfer and ab-initio), shared how some universities are integrating transfer students into their flight programs, and discussed how Southern Illinois University Carbondale (SIUC) uses a leveling-type of flight course in an attempt to successfully integrate transfer flight students into their program. The presentation also shared students' opinions about the course, and session attendees were invited to discuss the approaches they used in their own programs.

Research Methodology

To learn how common it is for universities to admit transfer flight students and how they evaluate and integrate transfer students into their programs, a Survey Monkey survey was sent by email to all University Aviation Association member schools. The targeted respondents were Chief Flight Instructors. To learn how to transfer students at SIUC feel about the leveling course developed to better integrate them into the flight curriculum; a Survey Monkey survey was sent to all students who were currently enrolled or had been enrolled in the course (AF 199) within the past three years. The most pertinent survey responses, representing the perspective of flight training providers and transfer flight students, were shared during the conference presentation.

Highlights of Survey Results & Discussion

Acceptance of Transfer Flight Students

To learn how common it was for universities to admit private pilots into flight programs, one survey question asked, "Does your program allow students to begin post-private pilot flight training and potentially complete a flight degree if they have completed the Private Pilot Certificate elsewhere?" All respondents answered in the affirmative. This response, of course, doesn't mean that all collegiate aviation programs admit transfer flight students, but it suggests that many, if not most, do.

Percentage of Transfer Flight Students

Another survey question asked, "What is the estimated percentage of students currently in your flight program who received their Private Pilot Certificate outside of your program?" About 21% of the respondents indicated that a low number, "fewer than 10%," of the total number of flight students earned a Private Pilot Certificate before coming to the college or university. On the highest end, just over 7% answered, "about 40-50%." No response indicated that more than 50% of students transferred in with the certificate already completed.

Significance of Research

These two survey responses validate the importance of this research. A high number of collegiate aviation programs are admitting students who hold a Private Pilot Certificate, and up to 40 or 50% of students may be entering a college or university with this certification and are expected to adapt to a different flight training experience immediately upon starting college.

Why are students pursuing the Private Pilot Certificate before coming to college?

Transfer students who were surveyed said their number one reason for getting their private pilot certificate before coming to college was interest (75%). They had the motivation and the means to complete flight training, and they were excited to get started as soon as possible. The number two reason for pursuing a private pilot certificate before coming to college, cited by 62% of the students surveyed, was cost savings. These students felt that they could complete private pilot training outside of the university environment in more cost-effective ways if they started flying early.

Anecdotally, most participants in the Best Practices session said they are seeing far more students transferring into their programs with previous flight experience than they have in previous years. If these responses are indicative of the wider collegiate aviation environment, this challenge for university programs may be growing.

Evaluation and Integration Methods

In terms of evaluating students as they enter the program, the training provider survey results showed that over 50% of aviation programs conduct either a written or oral test that is modeled after the Federal Aviation Association (FAA) written or practical exam. Almost half do not.

Presumably, an integration experience for all transfer flight students should include aircraft familiarization and airport/airspace familiarization topics because many different types of training aircraft exist, and students will have flown at a wide variety of airports and in different airport environments prior to transferring into a collegiate program. The provider survey results, however, showed that only 43% include aircraft and airspace familiarization topics in their integration practices.

SIUC makes sure to include these topics in the AF 199 course because flight instruction is conducted at a towered airport, and about half of the transfer flight students are unfamiliar with flying in a towered environment. Also, about 40% of transfer flight students at SIUC need aircraft differences training due to having earned their Private Pilot Certificate in an airplane different from the airplanes used in the SIUC flight program.

Differences Between Transfer and Non-Transfer Students

When university representatives were asked to consider differences between their transfer flight students and those who did all of their training at the university, the survey asked, "When comparing overall quality of ab-initio and transfer students, at the time of graduation, which statement best describes your opinion of the two groups?" Response options were, "There is little to no difference between the two groups" (43%); "The transfer students are more likely to become flight instructors for us and do well in the industry;" (0%); "The ab-initio students are more likely to become flight instructors for us and do well in the industry," (14%); "I'm not sure which group would be considered generally more successful in terms of these measures," (36%); and "prefer not to answer," (7%).

Measuring student success is both important and challenging. An assumption with this question was that flight program faculty and staff generally hire their best students to be flight instructors for the program, and they can usually predict which of their graduates will be successful in the industry. These assumptions may be inaccurate and too speculative. As other researchers explore this topic, they would do well to consider more objective and possibly different measures of student success.

Most noteworthy with this survey response is the admission by flight training providers that many think there is either no difference between the two cohort groups or they simply do not know.

One Course Model

One model used at the researchers' institution is an eight-week credit-bearing course that includes eight hours of dual, local flight instruction, 1.5 hours of dual cross-country instruction, less than an hour (.8) of IFR, and 17 hours of oral ground instruction. Ground knowledge topics include university-specific procedures, a review of the Private Pilot Airman [sic] Certification Standards (ACS), aircraft limitations, pre-flight procedures and required inspections, communications, aerodynamics, systems, emergencies, aeromedical, weather theory and products, aircraft performance and weight & balance, cross-country planning, and a private-pilot style mock oral examination.

Upon course completion, the student is required to successfully complete a practical exam that follows the Private Pilot ACS. Students who receive a recommendation from their instructor have the option of testing out of this course early. Students who do not pass the practical exam must take AF 201B, which is the second half of SIUC's private pilot course.

Effectiveness of the SIUC Leveling Course

When asked, "What feedback can you share about AF 199? What was helpful, and what would you change?" The most common answer (44% of respondents) indicated that the course met objectives, 25% stated the course should be shorter, and 23% wanted more flexibility. The survey also showed that some flight instructors delivering the course are not always clearly communicating the intention of the course to the students, nor are they sharing the information that testing out of the course is an option for students who feel confident about already meeting the course objectives.

In terms of the ground and flight instruction provided in the course, the survey illustrated some flight instructor shortcomings that may not have been discovered as readily had the survey not been conducted. About 25% of the students reported issues that could be attributed to flight instructors either not understanding how flexible and individualized the course can be delivered, or not clearly communicating that information to students.

Conclusion & Future Research

Additional research should better define student success measures, suggest ways that other programs could build a flexible, individualized model to meet evaluation and integration goals, and urge collegiate flight programs to better track the outcomes of ab-initio and transfer students within their own programs.

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UNIVERSITY AVIATION ASSOCIATION

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Exploring Collegiate Flight Training Students' Perceptions of Safety Culture

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As flight training organizations expand and adapt to meet the growing demands of the industry, organizational leadership and safety departments are continuing to intensively focus on aviation safety and quality assurance through the core values of safety promotion, culture, and education. A flight school's safety culture, shaped by students' risk perceptions, can predict safety behaviors. Understanding students' trust and confidence in this safety culture could potentially aid in early risk mitigation strategies. The purpose of this study was to investigate flight students' perceived safety culture at a Title 14 Code of Federal Regulations (CFR) Part 141 flight training school in the Southeast region of the United States. The survey was adapted from the Safety Culture Indicator Scale Measurement System. Quantitative and qualitative data were obtained from 398 students. Confirmatory factor analysis and structural equation modeling were used to test structural relationships among organizational commitment, operations interactions, formal safety indicators, and safety behaviors. Results indicated a good model fit for analyzing the nine hypotheses. Two of the nine hypotheses were supported. Safety Values and Safety Personnel significantly influenced perceived personal risk. The textual data analysis revealed strong student opinions towards a medical grounding and no-show procedure initiated by the Flight Department. Additionally, themes identified students' desire to receive more communication of safety information, and the language barriers present in a multi-cultural operation.

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Introduction

An Alaska Department of Public Safety (DPS) helicopter encountered a snowstorm and poor visibility while attempting to rescue a stranded snowmobiler in Alaska, ultimately resulting in a crash (National Transportation Safety Board [NTSB], 2014). The NTSB identified an unhealthy safety culture within the DPS as one of the contributing factors to the mishap. According to the Agency, the Alaska DPS had a "punitive safety culture that impeded the free flow of safety-related information and impaired the organization's ability to address underlying safety deficiencies relevant to this accident" (p. viii). The term safety culture first appeared during the investigation of the Chernobyl disaster in 1986. Organizational pressures, program shortcomings, and a flawed safety culture were also causal factors of the Space Shuttle Columbia disaster in 2003 (National Aeronautics and Space Administration [NASA], 2003). Safety culture is a multi-dimensional construct and includes an informed culture, a reporting vulture, a just culture, a flexible culture, and a learning culture (Reason, 1998).

> Safety culture refers to the enduring value, priority, and commitment placed on safety by every individual and every group at every level of the organization. Safety culture reflects the individual, group, and organizational attitudes, norms, and behaviors related to the safe provision of air navigation services (Civil Air Navigation Services Organization, 2008, p. 1).

Until the early 1970s, accident investigators and researchers focused on weather conditions, technological failures, and especially human errors as root causes of accidents. However, aviation professionals began to recognize that errors and violations are often triggered by organizational factors such as organizational climate, safety culture, safety oversight, safety values and beliefs, and safety programs. Aircraft accidents and incidents are typically the result of multiple contributing factors, with frontline personnel's unsafe acts (e.g., pilots) often influenced by organizational factors and latent conditions (Shappel et al., 2007).

Effective safety management requires much more than just a safety office and safety standards and procedures. According to Ayres Jr. et al. (2009), Safety Management Systems (or any safety program) are most effective in organizations with a strong safety culture. A strong safety culture is difficult to quantify. Nonetheless, in an organization with a healthy safety culture, personnel are proactive and understand that they are responsible and accountable for the safety of their organization. Moreover, employees truly understand the risks associated with their jobs and take action to mitigate those risks. Additionally, they strongly believe that safety should not have to come at the cost of productivity. Most importantly, safety is an integral part of the education and training personnel receive so that they have the knowledge and skills to work safely and effectively (Ayres Jr. et al., 2009).

There is an inherent risk associated with flight training in a collegiate aviation environment (Byrnes et al., 2022). Organizational factors such as the organization's safety climate and safety culture play significant roles in the safety efforts in such a system. Previous studies have suggested that organizations with a healthy safety culture are less prone to experiencing safety related events. Thus, it is important to better understand the safety culture of students in a Part 141 college flight program. Findings can provide Part 141 flight training schools with data and information to develop or enhance their safety management systems.

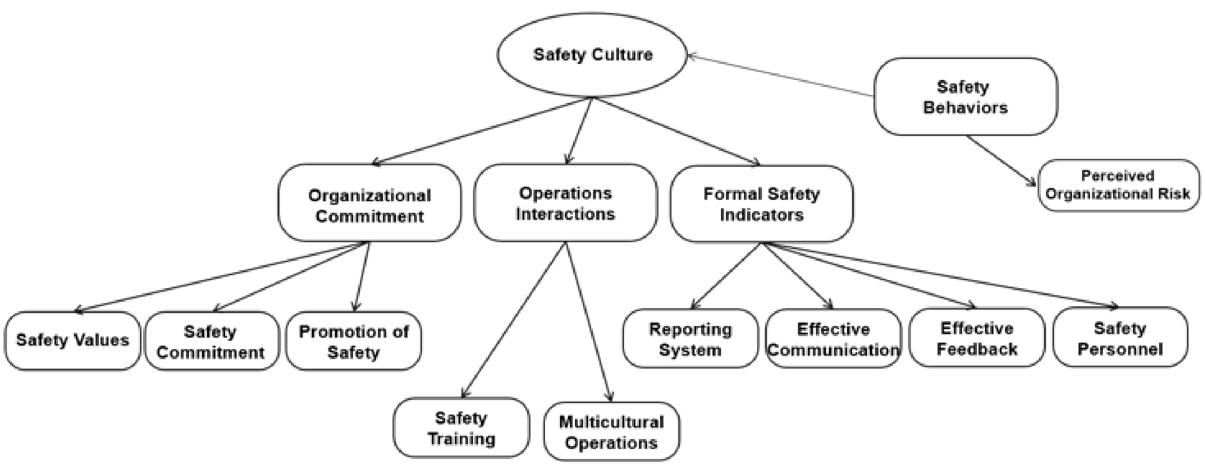
Methodology

Survey Framework

The purpose of the study was to investigate flight students' safety culture at a Title 14 Code of Federal Regulations (CFR) Part 141 flight training school in the Southeast region of the United States. A survey was conducted to determine the relevant factors influencing flight students' perception of the organization's safety culture. The quantitative results of the survey were then analyzed using Structural Equation Model (SEM) techniques. SEM in the form of a relational path model was used to test hypotheses postulated about predictive relationships between the factors and the dimension of safety culture. It was also used to determine the strength of relationships between these factors and the dimension of safety culture. Additionally, researchers generated a Word Cloud from the limited qualitative data, as explained in the results section of this manuscript.

The questions selected for use in the survey were drawn from the Safety Culture Indicator Scale Measurement System (SCISMS), originally based on the Commercial Aviation Safety Survey (CASS). Factors affecting students' perceived safety culture were divided into second-order factors, including organizational commitment, operations interactions, and formal safety indicators. Second-order observed variables were then developed.

Figure 1
Modified safety culture framework.



The survey included two open-ended questions, allowing respondents to provide suggestions and comments (see below). The open-ended questions were optional and not mandatory to successfully complete the survey.

1. Please describe any additional comments you have regarding safety in the Flight Department.
2. Please describe any recommendations for improving safety in the Flight Department.

Survey Distribution

After Institutional Review Board (IRB) approval was obtained, purposeful sampling was used to target the population of interest. The survey was administered through Microsoft Forms in the English language to allow for simplicity of delivery and anonymity of participants. Participants were assured of the confidentiality of their responses. The survey was open for two weeks.

Hypotheses

The following hypotheses were investigated in the study:

H_1: Safety values significantly influence perceived organizational risk
H_2: Promotion of safety significantly influences perceived organizational risk
H_3: Safety commitment significantly influences perceived organizational risk
H_4: Reporting system significantly influences perceived organizational risk
H_5: Effective communication significantly influences perceived organizational risk
H_6: Effective feedback significantly influences perceived organizational risk
H_7: Safety personnel significantly influences perceived organizational risk
H_8: Safety training significantly influences perceived organizational risk
H_9: Multicultural operations significantly influence perceived organizational risk

Population

The population of interest consisted of 1,501 active flight students at a large, accredited Title 14 CFR Part 141 flight training and four-year degree-awarding university in the Southeast regions of the United States (FAA, 2017). The sample (n = 398) was drawn from active flight students accounting for approximately 27% of the population.

Results

Demographics

Demographic information such as gender, age, enrollment status, and international status were collected during the survey. Table 1 shows the demographics of the sample (n=398). Almost 24% of the respondents were international students. Fifty–eight of these students were juniors or seniors. Interestingly, most respondents (80.9%) had not filed a safety report before.

Among all the respondents, 82.2% were men, 17.1% were women, and 0.8% preferred not to say. The gender ratio disbursement of the sample was representative of the population demographics, which has a male-female ratio of 83.3% to 16.7%. Most respondents were domestic students (76.6%). This was also representative of the population with a 77.7% domestic student population.

Table 1
Demographic Variables

Characteristics	Subgroup Categories	Frequency	Percentage
International	International	93	23.4%
	Domestic	305	76.6%
		398	100%
Private Pilot License	Internally earned	169	42.5%
	Earned elsewhere	144	36.2%
	No License received	85	21.4%
		398	100%
Flight Certifications	Student Pilot	91	22.9%
	Private	94	23.6%
	Instrument	104	26.1%
	Commercial-Single	56	14.1%
	Commercial-Multi	16	4.0%
	CFI	16	4.0%
	CFI-I	20	5.0%
	Multi Instructor	1	0.3%
		398	100%
Enrollment	Freshman	93	23.4%
	Sophomore	68	17.1%
	Junior	113	28.4%
	Senior	117	29.4%
	Graduate	7	1.8%
		398	100%
Age	Below 20	128	32.2%
	20-25	249	62.6%
	26-30	16	4.0%
	31-35	2	0.5%
	36-40	2	0.5%
	41-45	0	0%
	46-50	1	0.3%
	Above 50	0	0%
		398	100%
Gender	Male	327	82.2%
	Female	68	17.1%
	Prefer not to say	3	0.8%
		398	100%

Table 1 (*continued)*

Characteristics	Reports Submitted	Frequency	Percentage
Safety Report	0	322	80.9%
	1	52	13.1%
	2	13	3.3%
	3	6	1.5%
	4	4	1.0%
	5	1	0.3%
		398	100%

Analysis of the Responses to the Safety Culture Questionnaire

The current study examined the impact of nine factors – safety values (SV), promotion of safety (PS), safety commitment (SC), reporting system (RS), effective communication (EC), effective feedback (EF), safety personnel (SP), safety training (ST), and multicultural operations (MP) – on perceived organizational risk (SR). In the survey questionnaire, each factor was measured by three- to five-item questions. The respondents were asked to evaluate these items based on a 5-point Likert scale, from 1 (strongly disagree) to 5 (strongly agree). Table 2 shows the values of the mean and standard deviation of the scale items. Figure 2 shows the final specified CFA model, and Figure 3 shows the final specified SEM model.

The sample mean (M) is the average of the observations, and SD indicates the dispersion of individual observations about M. Both the sample mean and standard deviation play important roles, particularly in the context of model fit evaluation and parameter estimation. When the observations are more dispersed, then there will be more variability. In this case, a relatively low SD signifies less variability of data.

Table 2
Mean and Standard Deviation Scores of Constructs

Construct		*M*	*SD*
Safety Values	SV1	4.37	0.816
	SV2	3.54	1.066
	SV3	4.26	0.779
	SV4	4.19	0.865
	SV5	3.90	1.138
Promotion of Safety	PS1	4.09	0.785
	PS2	4.08	0.805
	PS3	4.42	0.723
	PS4	4.40	0.780
	PS5	4.48	0.683
Safety Commitment	SC1	4.21	0.745
	SC2	4.27	0.746
	SC3	3.46	1.176
	SC4	4.15	0.806
Reporting System	RS1	3.71	0.845
	RS2	3.82	0.959
	RS3	4.07	0.766
	RS4	4.07	0.819
Effective Communication	EC1	3.80	0.957
	EC2	3.90	0.884
	EC3	3.97	0.841
	EC4	3.88	0.927
Effective Feedback	EF1	3.79	0.794
	EF2	3.84	0.805
	EF3	3.82	0.817
	EF4	3.39	1.114
Safety Personnel	SP1	4.04	0.810
	SP2	4.07	0.731
	SP3	4.16	0.755
	SP4	4.16	0.724
Safety Training	ST1	4.20	0.801
	ST2	4.10	0.924
	ST3	4.25	0.757
	ST4	4.36	0.698
Multicultural Operations	MO1	3.49	1.153
	MO2	4.00	0.946
	MO3	3.73	1.152
Safety Behaviors	SR1	3.27	1.163
	SR2	2.90	1.197
	SR3	3.51	1.133

Figure 2
The final specified CFA model.

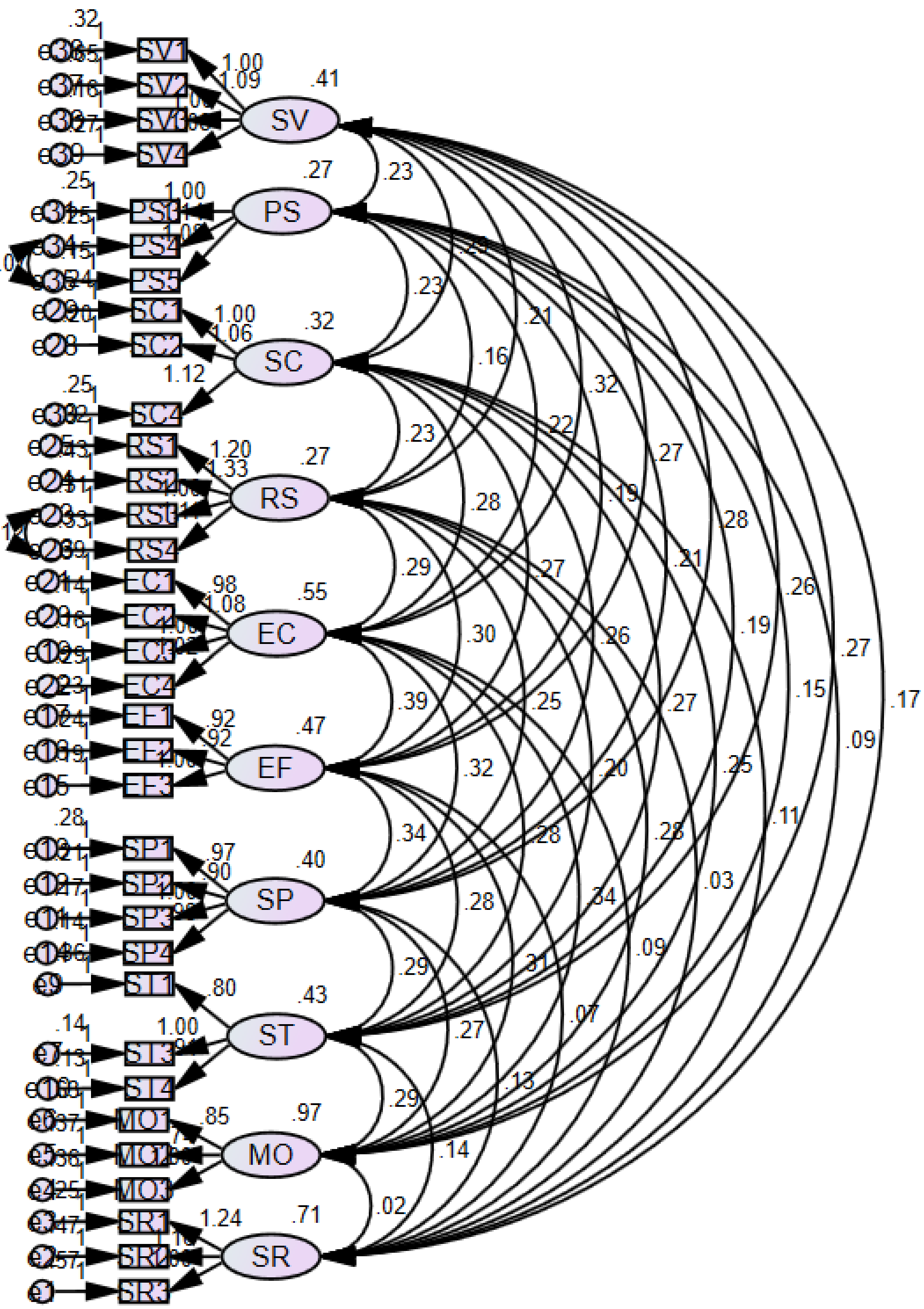
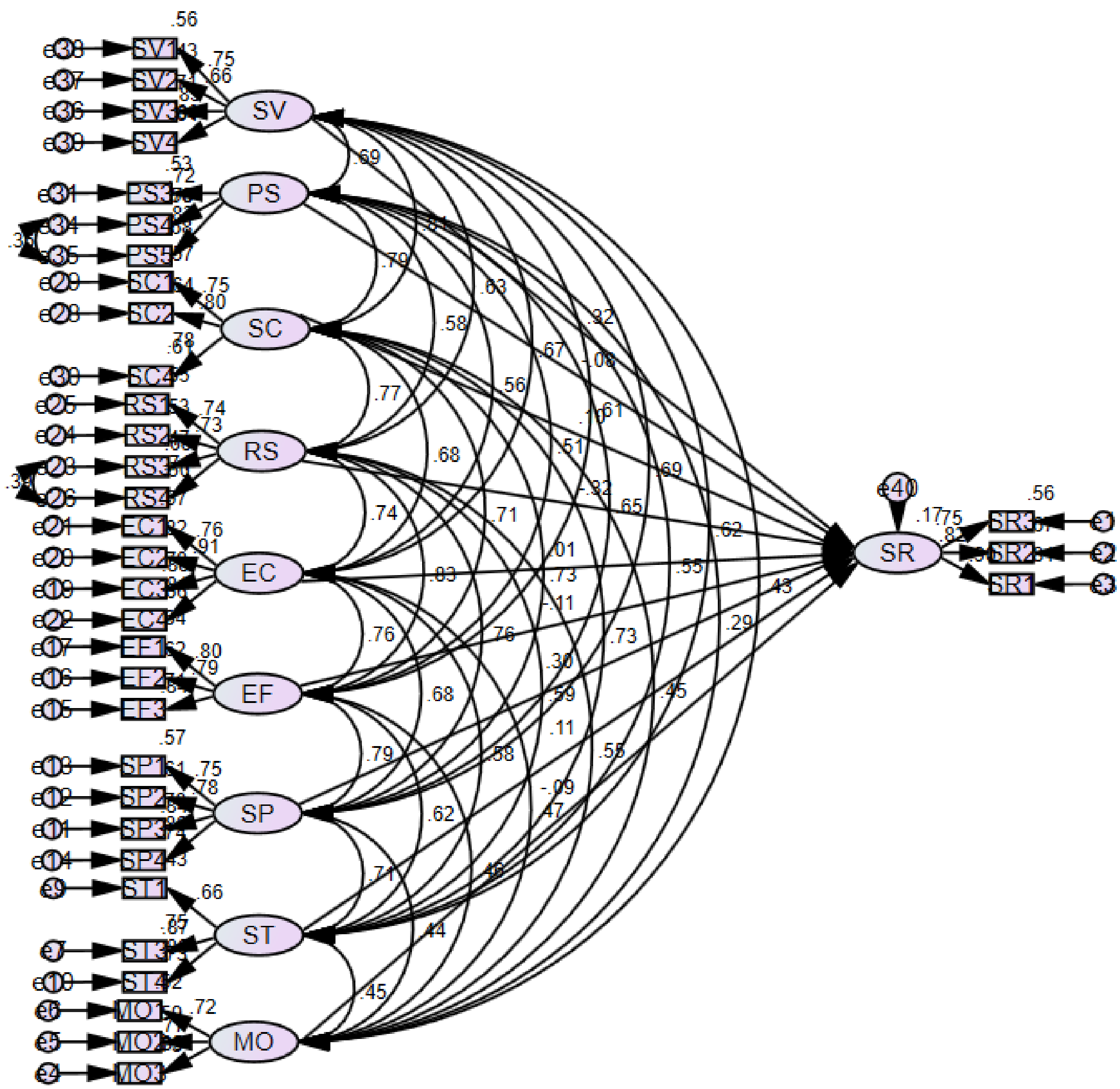


Figure 3
The final specified SEM model.



Convergent validity and discriminant validity were examined for the final specified CFA model. PS1, PS2, SC3, EF4, and ST2 items were removed from the initial specified CFA model for reliability and validity. Four indicators of convergent validity were evaluated, including factor loadings, Construct Reliability (CR), Average Variance Extracted (AVE), and Maximum Shared Variance (MSV). The acceptance value for factor loading was ≥ .65, CR was ≥ .70, Cronbach's alpha was ≥ .70, and AVE was ≥ .50 (Hair et al., 2010; Vogt et al., 2012). All the standardized factor loadings passed the .65 threshold, and the CR and Cronbach's alpha were greater than .70, indicating satisfactory consistency among items. AVE values for all factors were greater than .05, indicating satisfactory convergent validity. Table 3 shows the results of the convergent validity assessment for the final CFA model.

Table 3
Convergent validity assessment of the final CFA model.

Construct	Item	Factor Loading	Squared multiple correlations	CR	Cronbach's alpha	AVE
SV	SV1	.75	.56	.78	.83	.59
	SV2	.66	.44			
	SV3	.85	.72			
	SV4	.80	.64			
PS	PS3	.73	.53	.82	.84	.60
	PS4	.76	.58			
	PS5	.83	.69			
SC	SC1	.75	.56	.82	.82	.60
	SC2	.80	.64			
	SC4	.78	.61			
RS	RS1	.74	.55	.81	.82	.51
	RS2	.73	.53			
	RS3	.68	.46			
	RS4	.71	.50			
EC	EC1	.76	.58	.91	.90	.71
	EC2	.91	.83			
	EC3	.88	.77			
	EC4	.81	.66			
EF	EF1	.80	.64	.85	.85	.66
	EF2	.79	.62			
	EF3	.84	.71			
SP	SP1	.75	.56	.88	.88	.65
	SP2	.78	.61			
	SP3	.84	.71			
	SP4	.86	.74			
ST	ST1	.66	.44	.84	.83	.64
	ST3	.87	.76			
	ST4	.86	.74			
MO	MO1	.72	.52	.82	.82	.61
	MO2	.77	.59			
	MO3	.85	.72			
SR	SR1	.90	.81	.87	.86	.68
	SR2	.82	.67			
	SR3	.75	.56			

Note. CR = Construct Reliability, AVE = Average Variance Extracted

Discriminant validity was tested by using the Fornell-Larcker method, which compared the AVE values to the correlation estimates between the constructs, as shown in Table 4. If the square root of AVE is greater than the correlation estimates, the discriminant validity is supported (Zait & Bertea, 2011). Table 4 shows the discriminant validity values. Discriminant validity showed large values for four correlations. However, the correlation between SC and SV, as well as SC and PS, can be explained by the framework in Figure 1. All three variables are the second factors of organizational commitment. Additionally, the correlation between RS and EF, as well as RS and SP, can also be explained by the framework. RS, EF, and SP are the second-factor variables of formal safety indicators.

Table 4
Discriminant Validity Values

	SV	PS	SC	RS	EC	EF	SP	ST	MO	SR
SV	**.768**									
PS	.688	**.775**								
SC	**.808**	**.788**	**.775**							
RS	.634	.583	.769	**.714**						
EC	.674	.564	.684	.739	**.843**					
EF	.607	.515	.712	**.828**	.765	**.812**				
SP	.687	.650	.732	**.761**	.680	.786	**.806**			
ST	.617	.549	.733	.585	.581	.615	.713	**.800**		
MO	.435	.290	.447	.547	.473	.465	.440	.454	**.781**	
SR	.313	.207	.233	.068	.150	.115	.253	.257	.027	**.825**

Structural Model Assessment

The final CFA model in Figure 1 was transformed into a SEM model, as shown in Figure 2. The endogenous variable was perceived personal risk. The data was then assessed for normality and outliers. All kurtosis values were less than 5.00, and squared Mahalanobis values were less than 65. Two error covariances were created between error terms from the largest MI values.

Overall Model Fit

The same acceptance value was used to analyze the model fit. Two pairs of covariances were added between the largest values of error terms. The revised SEM model indicated an acceptable model fit, as shown in Table 5. The Goodness of Fit (GFI) is the proportion of variance accounted for by the estimated population covariance (Hair et al., 2010). The GFI value was slightly off the acceptance value but tolerable (Hu & Bentler, 1999). Hu and Bentler (1999) supported the idea that although a GFI value larger than .90 is recommended, a value larger than .80 may be used with caution.

Table 5
Model Fit Indices for the Final CFA Model

Model Fit Index	Acceptance Value	Final Model
X^2	-	853.324
df	-	481
Probability	>.05	***
GFI	>.90	.888
NFI	>.90	.906
CFI	>.95	.956
CMIN/df	≤ 3.00	1.774
RMSEA	<.06	.044

Note. *** significant at $p < .001$. GFI = Goodness of Fit Index, NFI = Normed-Fit Index, CFI = Comparative Fit Index, RMSEA = Root Mean Square Error of Approximation.

Following the model estimation, hypotheses were tested. Figure 4 illustrates the standardized regression weights for the SEM model. Table 6 shows the standardized path coefficients and *t*-values for the SEM model. Hypotheses with *p*-values less than .05 were supported. H_1 and H_7 had path estimates that were statistically significant in the expected direction, indicating that safety value and safety personnel were significantly correlated with perceived personal risk.

Figure 4

Standardized regression weights for the SEM model.

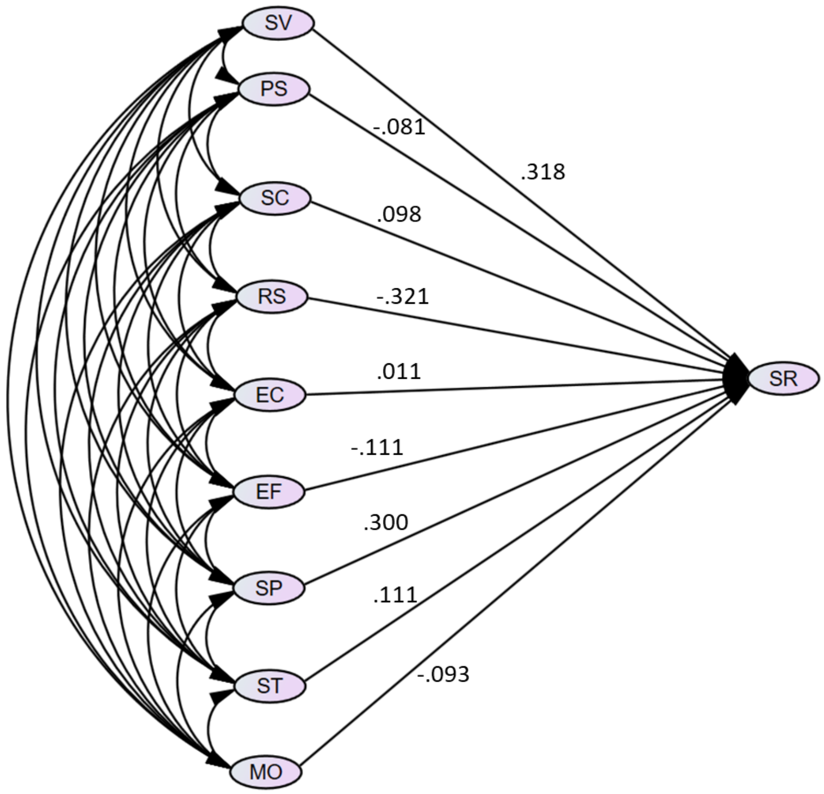


Table 6

Hypothesis Testing Results

Hypotheses	Relationships	SRW	*t*-values	*p*-values	Result
H_1	SV → SR	0.318	2.402	.016	Supported
H_2	PS → SR	-0.081	-0.595	.552	NS
H_3	SC → SR	0.098	0.409	.683	NS
H_4	RS → SR	-0.321	-1.706	.088	NS (Close)
H_5	EC → SR	0.011	0.102	.919	NS
H_6	EF →SR	-0.111	-0.682	.495	NS
H_7	SP → SR	0.300	2.011	.044	Supported
H_8	ST → SR	0.111	0.945	.345	NS
H_9	MO → SR	-0.093	-1.216	.224	NS

Note. SRW = Standardized Regression Weights, NS = Not Supported, SR was reverse-coded, so the direction of the SRW and *t*-values should be opposite.

Analysis of the Qualitative Data

As previously noted, the survey included two open-ended questions, allowing respondents to provide invaluable qualitative information. While not all respondents provided an open-ended response, 162 comments were received for textual analysis. The original goal of the researchers was to conduct a sentiment analysis based on the comments and the results of the survey. However, with the limited number of open-ended responses, the study was limited to only a descriptive and qualitative analysis of the textual data. The textual data was then analyzed using various libraries and functions of the Python programming language. Firstly, all punctuation from the data was removed to improve processing. Additionally, all the words were reduced to lower case to maintain consistency and further tokenized into individual features. Stopwords were removed from the textual data to eliminate superfluous words that had a minimal contribution to the textual analysis. Finally, the textual data was lemmatized to improve the comprehensibility of the data. Lemmatization is a process where words are reduced to a root word, such as the word *better* would be reduced to the word *good*. Lemmatization was preferred over stemming due to improved accuracy and domain understanding of the subject.

Once the textual data was processed, a Word Cloud was developed. Based on the initial Word Cloud, the researchers added more stopwords to reduce superfluous words from the generated Word Cloud. Words such as “against”, “other”, “or”, “reason”, listed”, “student”, “safety”, “flight”, “department”, and “feel” were added to the stop words list. Figure 5 was the generated Word Cloud from the textual data. Table 7 displays the frequency and relative frequency of words with a relative frequency of more than 0.5.

Figure 5
Word cloud from textual data.

Table 7
Frequency of Words in the Textual Data

Word	Frequency	Relative Frequency
Fatigue	33	1.0
Ground	30	0.909
Sick	19	0.576
No-Show	18	0.545
Training	18	0.545

Note. The word "Ground" refers to the grounding policy for students. Only words with a relative frequency of more than 0.50 and not included in the stop words are included in this table.

Qualitative Analysis for Perceived Risks

A qualitative analysis was conducted to capture relevant and recurring themes in the data. Phenomenological reduction, bracketing, and composite textual and structural description procedures were applied for qualitative analysis. The researchers read the comments and manually coded sentiments to identify themes. Three significant themes regarding perceived safety risks were captured from the data.

Medical Grounding and No Show Policy

The Medical Grounding and No Show Policy was the most recurring theme in the textual data. Respondents had a negative sentiment regarding a recently implemented policy. The "No Show Policy" changes were reviewed using the SMS risk assessment process, and no increase in risk severity and probability was found. Nonetheless, we recommend further studies on the impact of this "No Show Policy" on flight students' perceptions of safety culture.

Information Sharing and Communication

Information sharing and communication was theme evaluated in 13 comments. The findings supported that some students feel that communication regarding safety incidents and accidents could be improved. Effective safety communication is vital for a sound safety culture. "The free exchange of safety information, across all areas and through all levels, both vertically and horizontally, is actively promoted by management and facilitated by mechanisms and processes" (Ayres Jr. et al., 2009, p. 156).

Multi-cultural Operations

Multi-cultural operations was a theme evaluated in four comments. The findings supported that some students feel that a language barrier due to a multi-cultural environment could affect their perceptions of safety as suggested by the International Civil Aviation Organization (ICAO, 2002). Part 141 flight training organizations are increasingly and steadily becoming multicultural. Individuals from different nations may be paired in the cockpit, and language barriers may disrupt effective communication.

Thematic Analysis

The qualitative data analytics procedures described in this paper were intended to gather better insight into the sentiments of the respondents regarding the organization's safety culture. The qualitative analysis utilized a phenomenological framework that allowed the respondents to share their lived experiences in the specified area of study. A significant theme identified from the responses focused on policy making in the organization, specifically related to a “no show” policy. These results supported previous research in the literature review and the SEM model that highlighted the role of policy-making in an organization having a significant impact on safety awareness and culture. Additionally, the theme of information sharing in improving safety culture supported the need for management to share data, trends, and policy changes with employees to improve trust and accountability. The results of the qualitative data were coherent with the SEM analysis and previous literature on the subject; however, it adds to the literature on incorporating a robust safety culture in a flight training environment through an increased focus on policy-making and better-informed communication from management.

Discussions and Conclusions

The overall purpose of this study was to investigate flight students’ perceived safety culture at a Title 14 Code of Federal Regulations (CFR) Part 141 flight training school in the Southeast region of the United States. The results suggested a direct and strong predictive relationship between safety culture in collegiate flight training and the perceptions of respondents of the safety value and safety personnel multidimensional constructs of safety culture. Based on the operational definition of the constructs, Safety Personnel and Safety Values were directly related to the policy, objectives, and actions of the management of the Flight Department. While 81% (n=322) of students had never submitted a safety report, and only 3% (n=11) had submitted three or more safety reports, this could be attributed to the fact that 97% of flights are conducted with a flight instructor on board.

The textual data was used to analyze the impact of Safety Values and Safety Personnel on students' perceptions. Findings indicated that students have positive sentiments regarding the organizational safety values of the Flight Department. While the qualitative analysis highlighted some negative sentiments regarding specific policies, especially the No-Show policy, the overall safety culture and awareness for students are positively influenced by the safety values instilled by management and safety personnel. Respondents' feedback can be utilized to modify policies and to improve the safety culture and communication.

Researchers acknowledged that there are limitations to this study. For example, the narrow band of age and flight experience, as well as the sample size, will not make the results generic to other aviation professionals outside that domain. Psychosocial and other human factors such as stress, family issues, workload, and organizational pressures may have biased the opinions of respondents. Only 24% of the respondents were international students. Additionally, only 10% of them were CFIs.

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Eagles Flight: A Curriculum Blend of Aviation, Engineering, and Industry Standards

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The work presented herein represents an ongoing study examining integrating industry standards into aviation and engineering curricula. Our goal is to provide insights into enhancing student preparedness for professional careers in aviation and engineering by analyzing the challenges and best practices in curriculum development. This National Institute of Standards and Technology (NIST)-funded project aims to bridge the gap between academia and industry. The research investigates the implementation of standards such as AS9100, ISO 31000, ISO 9001, ISO 14001, and ASHRAE 62.1 into three undergraduate and graduate engineering and aviation/aerospace courses. In this scholarly context, we investigate the preliminary developments and articulate the existing data-gathering techniques utilized in the pioneering aviation course initiated on August 24th, 2024, consisting of two sections with an aggregate of 50 students. Future work shall integrate initial findings obtained from a collection of surveys designed to assess the effectiveness of the standards-integrated curriculum related to the introductory module.

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Introduction

The rapidly evolving landscapes of aviation and engineering demand a workforce equipped with theoretical knowledge and practical skills aligned with industry standards. Our work investigates the crucial role of integrating industry standards into higher education curricula, focusing on a three-year project funded by the National Institute of Standards and Technology (NIST). We herein present preliminary data for work in progress, with data collection currently underway for the piloted classes implementing the standards-integrated curriculum. Our preliminary findings and methodologies will be refined and expanded as more data becomes available throughout the project.

Integrating industry standards into higher education curricula represents a critical strategy for enhancing the preparedness of students pursuing careers in aviation and engineering. This approach ensures that graduates comprehensively understand their respective fields' practical constraints and regulatory requirements. Integrating certification schemes into instructional design helps align educational programs with industry standards, improving employability (Aziz & Surono, 2024). Such knowledge significantly augments the value of graduates to potential employers by improving their workplace readiness and minimizing the necessity for extensive on-the-job training (Miller & Schademan, 2020; Patel et al., 2020). Developing a novel educational framework for the Maintenance, Repair, and Overhaul (MRO) sector underscores the importance of collaborative efforts between academic institutions and industry enterprises. This framework is designed to produce highly qualified graduates who meet the industry's evolving demands (Ichou & Veress, 2024). Furthermore, project-based learning models, which facilitate deep integration between industry and academia, have demonstrated remarkable efficacy in enhancing students' practical skills and innovation capabilities (Wang & Liu, 2024). This pedagogical approach effectively bridges the gap between academic theory and industry practice, equipping students with the necessary skills to operate within and extend existing regulatory frameworks. Implementing such models has shown promising results, with a recent study by the National Association of Colleges and Employers (NACE) reporting that 91% of employers prefer job candidates with work experience, and 65% favor candidates with relevant industry experience (NACE, 2024).

This ongoing project has the following aims: (1) Examine the role of standards in aviation and engineering education, (2) Analyze the implementation of specific standards (AS9100, ISO 31000; ISO 9001; ISO 14001, and ASHRAE 62.1) in curricula, (3) Present the challenges and best practices in integrating standards into higher education programs, (4) Evaluate the impact of standards-based education on student preparedness for professional careers, and (5) Assess student perceptions and learning outcomes through a series of surveys throughout each of the investigated courses.

The Role of Standards in Industry

Standards play a crucial role in ensuring safety, efficiency, and reliability across various sectors, yet they often remain unnoticed by the public and undervalued by decision-makers. These standards are essential for addressing global issues such as quality assurance, food safety, and environmental concerns, and they significantly influence innovation and competitiveness

(ANSI, 2024). Standards are benchmarks for quality and achievement across various fields, including aviation, engineering, science, technology, healthcare, and business. The National Institute of Standards and Technology (NIST) defines a standard as "a document that provides requirements, specifications, guidelines, or characteristics that can be used consistently to ensure that materials, products, processes, and services are fit for their purpose" (Breitenberg, 2009). Standards are crucial in aviation and engineering, ensuring safety, reliability, and operational efficiency while promoting product consistency. The importance of these standards extends beyond technical aspects, encompassing health, safety, and environmental (HSE) considerations in industrial operations. Employers highly value new graduates' knowledge of technical and HSE standards, recognizing their essential role in maintaining high-quality designs and processes (Crow, 2023). This comprehensive approach to standardization not only safeguards workers and protects the environment but also enhances overall operational resilience (Anaba et al., 2024).

The Gap Between Academia and Industry

Despite the well-recognized importance of industry standards, a significant gap often exists between academic curricula and industry requirements, as highlighted in numerous studies over the past decade. For instance, Lang et al. (1998) surveyed aerospace and defense companies and found that engineering curriculum reform needed to meet industry demands. This disconnect has important implications, including graduate employability, as those unfamiliar with industry standards may struggle in the job market (McPherson et al., 2019). Additionally, graduates without a strong foundation in standards often require extensive on-the-job training, affecting their initial productivity and placing added pressure on employers. Moreover, a lack of knowledge in this area can hinder their ability to innovate within regulatory frameworks, further emphasizing the need for alignment between education and industry expectations.

Description of the NIST-funded Project

Our research team has embarked on a three-year project funded by NIST to address this gap. This initiative endeavors to establish a replicable framework for integrating industry benchmarks within the curricula of engineering and aeronautics, with the primary aim of optimizing instructional modules. Our work aims to serve as a model for other STEM academic institutions and enhance educational outcomes at both undergraduate and graduate levels. Simultaneously, the long-term objectives of this project focus on fostering sustained collaboration and exchanging knowledge with colleges, universities, and industry stakeholders to refine the model curriculum and its educational effectiveness continuously.

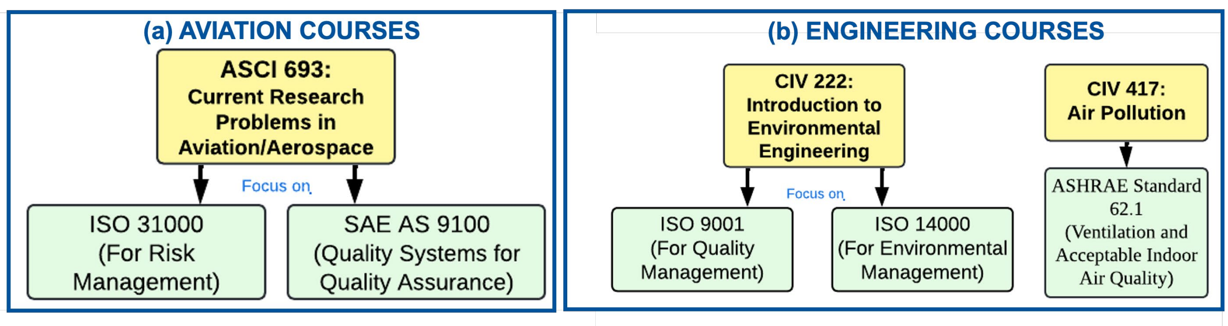
The project focuses on five critical standards due to their widespread adoption in the aviation and engineering industries and their potential to provide students with a comprehensive understanding of quality, risk, and environmental management principles. These standards are:

1. **AS9100:2016** Aviation quality management systems
2. **ISO 31000** Risk management
3. **ISO 9001:2015** Quality management systems
4. **ISO 14001:2015** Environmental Management systems
5. **ASHRAE 62.1** Ventilation and Acceptable Indoor Air Quality

Methodology

Our project employs a mixed methods approach to investigate the implementation of industry standards in aviation and engineering curricula. The research is being conducted as part of a three-year NIST-funded project to bridge the gap between academia and industry. Data is collected through student performance assessments pre- and post-implementation of standards-based curricula, semi-structured interviews with key stakeholders, and student surveys throughout each course. Three short surveys were administered within three modules of each investigated course. Each survey contains several multiple-choice choices with Likert scale questions and two open-ended questions. These surveys aim to capture students' perceptions, understanding, and application of industry standards at different course stages. In addition, the end-of-course evaluation includes additional questions related explicitly to integrating industry standards into the curriculum. The questions are designed to assess overall student satisfaction, perceived relevance to future careers, and areas for improvement. The Likert scale questions are designed to measure various aspects, including (1) Perceived relevance of standards to future careers, (2) Confidence in applying standards to real-world scenarios, (3) Understanding of specific standards (e.g., AS9100, ISO 31000; ISO 9001; ISO 14001, and ASHRAE 62.1), and (4) Satisfaction with the teaching methods used to convey standards-related content. The courses taking part in this project are presented in Figure 1.

Figure 1
A sketch showing the (a) aviation and (b) engineering courses participating in this project.



The open-ended questions enable students to provide detailed feedback, offer suggestions for improvement, and share examples of how they have applied the learning standards in course projects or internships. This survey approach allows for quantitative analysis of student perceptions and qualitative insights into the effectiveness of the standards-integrated curriculum. The data gathered from these surveys are instrumental in refining the curriculum and teaching methods as the project advances. While this research is ongoing, much of our current efforts are dedicated to data collection and preliminary analyses. We expect that the end-of-course evaluations will offer a comprehensive assessment of the program’s effectiveness, particularly in determining the impact of the standards-integrated curriculum.

Some critical areas we plan to analyze include the correlation between exposure to standards and student performance in practical assessments, changes in student attitudes toward industry standards, and differences in learning outcomes between traditional and standards-integrated curricula. Additionally, critical areas of focus will be identifying the most effective teaching methodologies for conveying standards-related content and understanding the long-term impact on career readiness and early career performance of graduates.

Preliminary Results

This section presents the preliminary results of a comprehensive survey conducted during the Fall 2024 semester for the ASCI 693 course. This advanced course, offered in two sections, enrolled 50 students. To gauge the effectiveness of our teaching methods and course content, we administered a focused survey to Classes 1 and 2. The survey was designed to capture student perceptions across four key course dimensions, providing valuable insights into the learning experience. By analyzing responses from both sections, we aim to identify variations in course delivery and student satisfaction and highlight areas of consistency in the educational experience. The results reveal interesting patterns and similarities between the two classes.

Table 1 summarizes the descriptive statistics of the first module's classes (Class 1 and Class 2), each with four questions from Q1 to Q4, with nine data points in each class. The mean values for both classes are 5.3 for all the questions, meaning that the answers are relatively similar between the two classes. Compared to Class 1, the standard deviation (stdev) has demonstrated that, on average, Class 2 is relatively more variably spread. Additionally, the values are more spread out for Q1 and Q2. The range between the minimum and maximum values shows the variability in the student's responses. Class 1 had a smaller range compared to Class 2. Further, the percentiles (25%, median=50%, and 75%) depict the data distribution relatively in the same pattern for both classes among the questions. The variation of responses is more significant in Class 2. However, their means are yet close to each other. These results are presented in Figure 2, where each boxplot shows a distribution rating, where the boxes represent the 25th to 75th percentiles, the orange line indicates the median of the datasets, and the whiskers show their range. Along the x-axis, the labels represent the ratings for each class on the respective questions; along the y-axis, the scale is used for ratings. The rating refers to the numerical scores assigned to questions answered by students. Figure 2 provides a visual assessment of the differences in ratings between the two classes for each question.

The remarkable response similarity between the two classes suggests a well-standardized course experience. This initial survey reveals a highly consistent and generally positive experience across both class sections, with some nuanced variations in specific areas. The uniformity in responses suggests effective teaching practices and course design that resonated similarly with students in both sections.

Table 1
A Comparative Analysis of Class Ratings Across Four Questions

	Q1		Q2		Q3		Q4	
	Class 1	**Class 2**	**Class 1**	**Class 2**	**Class 1**	**Class 2**	**Class 1**	**Class 2**
Count	9	9	9	9	9	9	9	9
Mean	5.33	5.33	5.22	5.22	5.33	5.33	5.33	5.33
Stdev	0.71	1.22	1.09	1.09	0.71	0.71	0.71	0.71
Minimum	4	3	4	4	4	4	4	4
25th percentile	5	5	4	4	5	5	5	5
Median	5	6	5	5	5	5	5	5
75th percentile	6	6	6	6	6	6	6	6
Maximum	6	7	7	7	6	6	6	6

Figure 1
Comparison of student ratings between Class 1 and Class 2 for all questions.

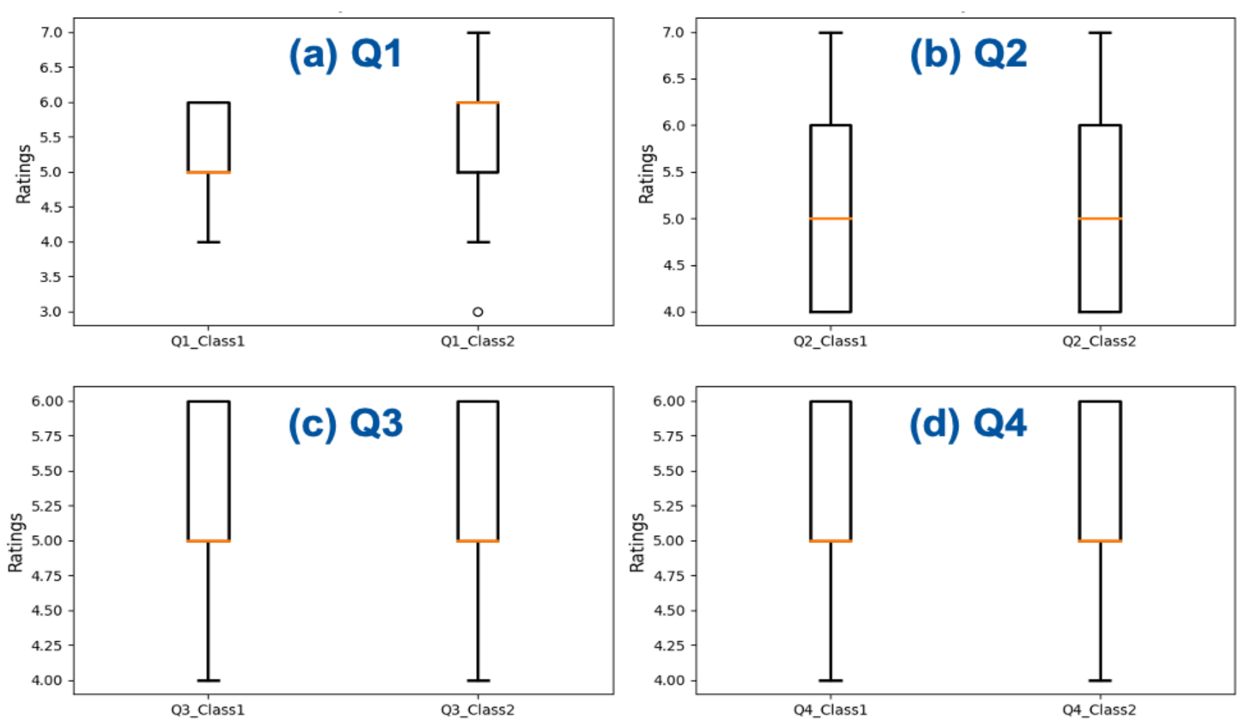
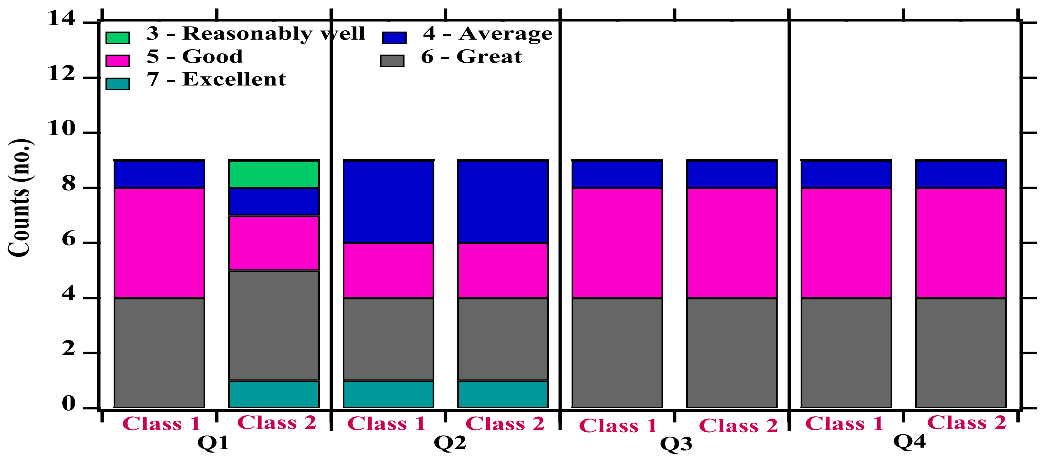


Figure 3 compares student responses from the two classes across the four survey questions. Student ratings ranged from "reasonably well" (3) to "excellent" (7), with no responses falling below three or exceeding 7. While the responses for questions 2 through 4 were similar between both classes, notable differences appeared in question 1. Class 2 exhibited a broader range of responses, from 3 to 7, whereas Class 1 responses were more concentrated, ranging only from 4 to 6.

Figure 3
A comparison of student response distributions across four survey questions.



The results of this survey reveal intriguing patterns and notable similarities between the two class sections, offering a nuanced understanding of the course's impact and effectiveness. These findings provide a snapshot of current student experiences and serve as a foundation for potential course refinements and enhancements in future semesters.

Challenges and Emerging Best Practices

As standards are integrated into curricula, challenges and best practices emerge. One of the critical challenges is balancing the depth of standards coverage with existing course material without overwhelming students. Another issue is ensuring that standards are consistently interpreted and applied across different courses and instructors, which can lead to varying levels of understanding. Additionally, maintaining student engagement, especially with material seen as dry or overly technical, requires thoughtful instructional methods and creative presentation styles. On the other hand, several best practices are also coming to light. These include utilizing real-world case studies and industry examples to highlight the practical application of standards, incorporating hands-on projects that require students to apply standards in simulated industry scenarios, and fostering collaboration between academic departments and industry partners to ensure the curriculum stays relevant. These observations will be further refined as ongoing surveys and assessments provide more data.

Conclusions and Future Directions

As this research is ongoing, we focus on data collection and preliminary analysis. We anticipate that the three short surveys embedded within the course modules will provide valuable insights into students' evolving perceptions and understanding of industry standards. As we investigate these surveys more thoroughly, the complexities of integrating these standards into higher education curricula are becoming increasingly apparent. However, early results are encouraging, suggesting this approach could significantly enhance student preparedness for professional careers in aviation and engineering. Despite the positive findings, challenges such as content overload and assessment complexities indicate the need for continuous refinement. A global perspective on standards education emphasizes its universal importance and shows diverse approaches that can inform our methodologies. As industries evolve, so must our strategies for preparing students for future challenges, with areas like AI, sustainability, and international harmonization shaping the future of standards education.

In conclusion, while this study remains a work in progress, initial findings highlight the value of integrating standards into higher education. Ongoing data collection and analysis will further shape our understanding and potentially reshape how academia and industry collaborate. Several areas for future research have emerged, including longitudinal studies to track graduate outcomes, expanding this approach to other disciplines, developing standardized curriculum modules for broader use, and fostering industry partnerships to ensure that students gain real-world experience with standards implementation.

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Exploring Mental Health Disorders Among Air Traffic Controllers

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Air traffic control facilities nationwide are at approximately 81% staffing, which the Federal Aviation Administration (FAA) considers a critical shortage (Duncan, 2023; Shepardson, 2023). Despite staffing shortages, air traffic control remains a safety-critical environment where controllers must continue to perform while shouldering intensive cognitive demands and high levels of responsibility (Imroz et al., 2022; Maxwell, 1986; Raduntz et al., 2021). With studies showing that high-stress levels, shift work, long hours, and inadequate recovery time can result in mental health disorders, the mental health status of air traffic controllers should be evaluated to ensure the continued safety of the National Airspace System (Ericsson et al., 2021; Lee & Park, 2022; Skypalova et al., 2022). A lack of research exists related to controller mental health disorders; the current quantitative study aims to fill the gap in recent research and provide possible recommendations for improving controller mental health and reducing controller attrition rates.

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Introduction

Over the past couple of years, a significant amount of media coverage focused on the pilot shortage and the mental health of pilots. However, until recently, there has been minimal discussion of the severe shortage of air traffic controllers and, more importantly, the potential impact of this shortage on their mental health (Duncan, 2023; Russell, 2023; Steel & Ember, 2023). During the last decade, the number of fully certified air traffic controllers has decreased by 1,200, and 6% of current controllers are now eligible for retirement (FAA Reauthorization: Navigating the Comprehensive Passenger Experience, 2023). The United States air traffic control system is operating at 81% staffing (Duncan, 2023). Although this may not sound severe, the Federal Aviation Administration (FAA) considers a critical shortage when staffing falls below the 85% threshold (Shepardson, 2023). Although research shows that working long hours can lead to potential mental health disorders (Lee & Park, 2022), there is a lack of recent research related to controller mental health disorders (Imroz et al., 2022). The current study aims to fill the gap in recent research and provide possible recommendations for improving controller mental health and reducing controller attrition rates.

Literature Review Summary

According to the U.S. Bureau of Labor Statistics (2024), air traffic control is potentially stressful and exhausting. Air traffic controllers deal with complex work environments and must remain focused while responding to ever-changing conditions, often with little notice (Imroz et al., 2022; Maxwell, 1986; Raduntz et al., 2021). Additionally, the shortage of air traffic controllers (Duncan, 2023; Russell, 2023; Steel & Ember, 2023) has led to working long hours, shift work, and inadequate recovery time, all of which can lead to potential mental health disorders such as anxiety and depression (Ericsson et al., 2021; Lee & Park, 2022; Skypalova et al., 2022). Furthermore, poor social interactions and high workloads can negatively impact mental and physical health (Repetti, 1993).

Unfortunately, air traffic controllers avoid discussing mental health, treating mental health as a sensitive topic due to the potential for controllers to lose their medical clearance to work. As a result, air traffic controllers avoid seeking help, regardless of how difficult the struggle is, and resort to self-medicating (Counseling, Depression and Psychological Support, 2024; Hembree, 2023). For example, controllers working rotating shifts may take sleeping pills to help them sleep and then consume substantial amounts of caffeine to stay awake the next day (Hembree, 2023).

In response to the increasing need among the general population, the medical community has created instruments designed to ascertain levels of depression and anxiety quickly. The current study used two such instruments, the Patient Health Questionnaire-9 (PHQ-9) and the Generalized Anxiety Disorder-7 (GAD-7) (Kalkbrenner et al., 2023). The PHQ-9 consists of nine test items, each scored 0-3, indicating the severity of depression. The PHQ-9 has a high alpha ($\alpha = .82$) and takes less than five minutes to complete (Kalkbrenner et al., 2023; Kroenke et al., 2001). The GAD-7 is a newer instrument consisting of seven test items scored from 0-3, indicating the severity of anxiety. The GAD-7 has a high alpha ($\alpha = .89$) and takes less than five minutes to complete (Kertz et al., 2013; Spitzer et al., 2006; Sapra et al., 2020).

Methodology

This quantitative study evaluated the mental health status of air traffic controllers. The researchers used purposive and snowball sampling to acquire participants by accessing private social media groups and utilizing personal contacts. Due to the sensitive nature of the assessed topic, data was collected via an anonymous survey. A recruitment script approved by the Institutional Review Board (IRB) of Southern Illinois University (SIU) was posted along with a link to the survey in the private social media groups. In addition, the research team sent the survey link and recruitment script to individual controllers known by the team members with a request for the controllers to take the survey and share it with other controllers they knew.
The survey included the PHQ-9 and GAD-7 instruments and demographic questions. The PHQ-9 and GAD-7 questionnaires were used to evaluate controllers' levels of depression and anxiety, respectively. Both assessments have strong reliability and validity, take five minutes to complete, and can be completed by controllers anonymously (Kalkbrenner et al., 2023). Quantitative analytics are being conducted through IBM's SPSS statistics application.

Results

A total of 168 respondents started the survey, but only 92 (55%) completed the survey. Of the 92 respondents, 47 (51%) were from the United States, and 45 (49%) were international. Although the survey results are still being analyzed, some preliminary results were available for the conference presentation. According to Spitzer et al. (2006), approximately 5% of the general global population presents with generalized anxiety disorder (GAD). On the GAD-7, individuals who demonstrate moderate to severe anxiety would typically be referred for further assessment and treatment (Sapra et al., 2020). That being said, nine (19%) of the U.S. participants and six (13%) of the international participants presented with moderate to severe anxiety (ref. Table 1), significantly higher than the general population.

Table 1
Results of GAD-7

Anxiety Scale	*United States*		*International*	
	n	%	*n*	%
Minimal Anxiety	25	53.19%	24	53.33%
Mild Anxiety	13	27.66%	15	33.33%
Moderate Anxiety	3	6.38%	3	6.67%
Severe Anxiety	6	12.77%	3	6.67%
Total	47		45	

In addition, depression affects approximately 7% of the U.S. adult population and 5% of the global adult population (Chand & Arif, 2024; World Health Organization, 2023). Individuals scoring within the moderately severe to severe range on the PHQ-9 generally present with major depressive disorders (Kroenke et al., 2001). A total of six (12.77%) U.S. participants and five (11.11%) international participants presented with moderate-severe to severe depression (ref. Table 2), both higher than the global average.

Table 2
Results of PHQ-9

Depression Severity	*United States*		*International*	
	n	*%*	*n*	*%*
Non-minimal	23	48.94%	23	51.11%
Mild	10	21.28%	11	24.44%
Moderate	8	17.02%	6	13.33%
Moderately Severe	3	6.38%	1	2.22%
Severe	3	6.38%	4	8.89%
Total	47		45	

Discussion

Air traffic control is a challenging career with the potential for complex environments, high workloads, long hours, and limited recovery time (Ericsson et al., 2021; Hembree, 2023; Imroz et al., 2022; Maxwell, 1986; Raduntz et al., 2021). Based on existing literature, individuals exposed to high stress, shift work, long working hours, and poor social environments can experience anxiety and depression; thus, the focus of this study is on evaluating the mental health of air traffic controllers. (Lee & Park, 2022; Maxwell, 1986; Repetti, 1993; Skypalova et al., 2022).

The results of the GAD-7 indicate that nearly 20% of U.S. controller participants and 13% of international controller participants are working with moderate to severe anxiety. Individuals scoring that high on the GAD-7 in a medical office would be recommended for further evaluation and possible prescriptive treatment (Sapra et al., 2020). The results indicate that two in five U.S. controller participants should be further examined for mental health intervention to help with their anxiety.

According to Kroenke et al. (2001), individuals with PHQ-9 scores that are at moderately severe to severe levels tend to present with major depression. Based on the results of this study, over 10% of the participants scored moderately severe to severe on the PHQ-9, indicating a likelihood that one in ten controller participants is working while suffering from major depressive disorders.

Limitations and Next Steps

The current study is limited by its small sample size. Air traffic controllers tend to avoid anything related to mental health, making it challenging to obtain data (Counseling, Depression and Psychological Support, 2024). Additionally, the current data is still being analyzed; therefore, the data analysis is incomplete. The current survey results will be further analyzed using IBM's SPSS to identify potential relationships between demographic data and the GAD-7 and PHQ-9 results. The goal is to fill the research gap and provide potential recommendations for improving controllers' mental health and reducing attrition rates.

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Integrating Enhanced Flat Panel Trainer (EFPT) and Virtual Reality (VR) Technologies into an Aircraft Systems Course

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The Advanced Commercial Aircraft Systems course at Metropolitan State University of Denver delves into the design and operation of regional jet aircraft systems, specifically focusing on the Bombardier CRJ 700. The virtual training environment developed early on to simulate pilot-system interactions or procedural flows originally incorporated two separate elements: 1) a desktop workstation flight deck simulation software and 2) a separate static layout of the flight deck. Technological advancements have since enabled the integration of these components into a single interactive touch-screen procedural trainer platform, which provides systems simulation within the spatial context of the flight deck layout. This enhanced flat panel trainer (EFPT) technology has been successfully employed in the Aeronautics and Aerospace Systems Jet Laboratory at Metropolitan State University of Denver and has been utilized for this class since 2015. As of fall 2024, the facility has expanded to include a 3D computer-generated Virtual Reality (VR) representation of the flight deck for procedural flow training, providing a more immersive experience for the learner. This presentation will review the implementation of VR technology, including preliminary student feedback received thus far.

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Introduction

The senior-level course "Advanced Commercial Aircraft Systems" in the professional pilot degree curriculum at Metropolitan State University of Denver's Aviation and Aerospace Science Department focuses on the study of Transport Category aircraft systems. Using the Bombardier CRJ 700, a 70-seat regional jet aircraft, as the case study, students explore the various aircraft systems and examine standard operational procedures, as well as abnormal and emergency protocols in the event of system failures. Therefore, a key component of the course is the study of pilot-system interactions within the flight deck environment, also known as procedural flows. These procedural flows are memory-based task patterns that crew members can perform independently to optimize workload balance on the flight deck (Federal Aviation Administration, 1995). A procedural flow completes a series of actions that configure the aircraft while operating on the ground or during different phases of flight. Once a procedural flow is completed, the crew verifies the configuration by reviewing a corresponding checklist, ensuring no critical items essential for the safe operation of the aircraft are omitted (Federal Aviation Administration, 1995). When utilized in response to critical system failures, flows are referred to as immediate action memory items. These emergency procedural interactions are generally much shorter in sequence than flows conducted during normal operations, explicitly addressing items that must be performed in immediate response to an emergency event. Studying these procedural interactions reinforces the student's understanding of aircraft systems in the context of standard operating methods utilized in Transport Category aircraft.

This presentation outlines the evolution of the training environment employed in this course to simulate the aircraft systems and flight deck layout of the CRJ 700 regional jet aircraft. Challenges encountered by some students in learning the procedural flow interactions are discussed including an overview of the implementation of Virtual Reality (VR) technology as a potential solution to these challenges, including preliminary student feedback and the observed effectiveness.

Training Environment

The training environment for the Advanced Commercial Aircraft Systems course has evolved over the past 12 years, driven primarily by both technology and increased budget allocations. In the earlier course design, desktop workstation software from Aerosim (now L3Harris) was utilized to simulate aircraft systems during the in-class lecture. A separate photo-realistic scale model of the flight deck layout was then employed to practice procedural flows. The computerized aircraft systems simulation, combined with the separate static depiction of the cockpit, formed a non-immersive virtual training environment (Duburguet & King, 2015). Using this approach, students were restricted to exploring system responses and procedural interactions using two separate mediums asynchronously.

The acquisition of an Enhanced Flat Panel Trainer (EFPT), designed by L3Harris, improved the training environment for this course by providing an accurate aircraft system simulation with touchscreen interfaces aligned in the correct spatial layout of the CRJ 700 cockpit. This higher fidelity design provided a more immersive experience for students, allowing them to interact with the aircraft systems while utilizing procedural flows simultaneously.

Training sessions in the EFPT now permitted a realistic application of systems knowledge while employing meaningful crew interactions.

To optimize the new EFPT training environment, the course was redesigned to incorporate a blended learning modality. Aircraft system lectures were moved to an asynchronous online format, while students scheduled weekly EFPT sessions in the Aeronautics and Aerospace Systems Jet Laboratory with the instructor. During each session, two students worked under the instructor's supervision, one in the role of Captain and the other as First Officer. The students progressed through the simulated scenario, applying the proper procedural flows and checklists to modify aircraft configuration. Abnormal or emergency conditions were also properly addressed when encountered in the lesson. After completing all tasks in the session and reviewing the corresponding checklists, the two students swapped roles and repeated the scenario.

Procedural Training Limitations

In addition to studying the aircraft systems online, students prepared for the EFPT sessions by reviewing written descriptions, graphical representations, and demonstration videos detailing the pertinent procedural flows. Students also practiced these flows on a photorealistic static scale model of the cockpit environment. Physically practicing flows establishes a procedural memory of the pilot-system interactions, often referred to as a "muscle memory" because it appears the muscles have recalled the procedure (Budson & Kensinger, 2023).

Despite these resources, some students still struggled to accurately apply the procedural flows from memory during a session in the EFPT's interactive cockpit environment. This may indicate that students are not effectively engaging in non-immersive practice to establish a useful retention of the flow procedures. When a student is not adequately prepared for an EFPT session, the efficiency and effectiveness of the lesson are compromised due to the lag time of recalling the procedure from either a written description or diagram. These situations have arisen often enough to underscore the need for a more engaging approach for students to practice procedural interactions in preparation for scenarios in the EFPT.

Virtual Reality (VR) and Procedural Training

Modern virtual reality (VR) systems consist of both the software to render a simulated three-dimensional (3D) space and the hardware to immerse users in that environment (Steffen et al., 2019). Terminology associated with VR includes augmented reality (AR), mixed reality (MR), and extended reality (XR). As the name suggests, AR augments the physical environment and is not a full replacement for it since AR superimposes virtual objects within the context of the user's real-world surroundings (Steffen et al., 2019). In contrast, mixed reality (MR) is a hybrid of VR and AR by allowing a user to interact with both digital and real-world objects in real time, optimizing benefits of each technology to enhance the user experience (Milgram, 1994). Extended reality (XR) has become the comprehensive umbrella term that encompasses VR, AR, and MR, along with any other technology that blends physical and virtual realities.

VR technology enables users to interact within the 3D artificial setting in a cost-effective and controlled manner without requiring direct interaction with the real-world scenario. Numerous case studies have demonstrated VR's applicability as an effective procedural training tool across a wide variety of industry domains (Renganayagalu et al., 2021). Adoption of VR training is driven, in part, by how effective VR can be in fostering the retention of procedural tasks that require spatial and visual information (De Lorenzis et al., 2023; Jensen & Konradsen, 2018; Majchrzak et al., 2022). In addition, when used for immersive learning in education, the novelty of VR's realistic simulations and interactive scenarios spark student motivation and engagement (Allcoat & von Mühlenen, 2018; Sanfilippo et al., 2022). By allowing students to directly interact with a simulated cockpit during procedural flow practice, VR provides a unique active learning experience compared with passive methods of learning through written descriptions and video demonstrations (Allcoat & von Mühlenen, 2018). This more immersive approach can better engage students and make their preparation time for the EFPT session more effective.

Although at the time of this writing, no specific VR training devices have been approved by the Federal Aviation Administration (FAA), in 2021, the European Union Aviation Safety Agency (EASA) granted the first regulatory approval for a VR-based flight training device (Auer et al., 2023; Shevchenko, 2021). This milestone suggests a clear potential for integrating VR training into traditional flight training curricula. VR software that facilitates procedural flow practice on Transport Category aircraft are becoming more available in the market. For example, VRPilot (https://vrpilot.aero/) offers VR training solutions for aircraft such as the Airbus 320 and Boeing 737. In collaboration with the Metropolitan State University of Denver's Aviation and Aerospace Science Department and funded by an aviation educational grant from the Colorado Department of Transportation (CDOT), VRPilot customized a VR procedural flow trainer for the Bombardier CRJ 700 tailored to the procedural flows developed for the Advance Commercial Aircraft Systems course.

VRPilot Implementation

The VRPilot software immerses the student in a three-dimensional simulation of the CRJ 700 regional jet cockpit for the purposes of flow training. Utilizing a PICO 4 head-mounted display (HMD) and two handheld controllers, students can interact with the artificial cockpit environment from either the captain seat or the first officer seat position. Students train with either a virtual automated crew member or with another student in a shared VR session. Shared VR sessions require only an internet connection, which permits students to interact within the same virtual cockpit without having to be physically in the same location. Furthermore, a shared VR session can also be hosted from such devices as an iPad or computer where the instructor can observe the students procedural flow training.

The VRPilot software supports self-guided procedural flow training, allowing students to select and practice various flows and immediate action memory items. In training mode, the VRPilot software guides students through a selected procedural flow by providing visual cues to interact with the applicable control interface in the correct sequence. Interaction with the specified control is achieved when the student physically reaches out and touches the control location in the virtual cockpit using the handheld controller's index finger trigger. When applicable, the software also directs where students must look to acknowledge any system feedback and ensures compliance through gaze-based eye tracking. The VRPilot software also offers a testing mode where students do not receive any guidance from the system. Employing this feature allows students to work through the selected procedural flow from memory while the software assesses their accuracy.

When providing a VR experience for students, it is crucial that the facility can support a dedicated space, or VR arena, that facilitates unobstructed use of the VR hardware (Majchrzak et al., 2022). An open room with seats spaced widely around the perimeter is more suitable than a traditional classroom with rows of chairs and desks. The open room allows students to sit along the outer perimeter and face inward toward the center of the room. During the VR simulation, students remain seated and can freely reach outward, upward, and side-to-side without colliding with desks, chairs, or other students. In addition to establishing a VR arena, it is also helpful to locate the VR hardware in an easily accessible location. To this end, the Looking Glass XR PowerCart is an ideal storage solution. The PowerCart is a wheel-mounted storage unit that can charge up to 24 VR HMDs simultaneously and can easily be repositioned as needed.

Informal Student Feedback and Observations

After purchasing the VR hardware, establishing the software licenses, and identifying the VR arena, implementing the VR technology for this course proved surprisingly straightforward. Students, already familiar with other flight simulation technologies, required minimal guidance on setup and immediately recognized the value of this immersive resource. Students also intuitively understood how the use the VR handheld controllers to interact with the simulated flight deck environment. After a brief demonstration on how to configure the VR hardware and interact with the VRPilot software, students were quickly able to engage in the self-paced training activities. An initial demonstration at the beginning of the course ensures students will not waste time struggling with the administrative aspects of establishing a VR environment (Majchrzak et al., 2022).

Student responses to working with the VR technology for procedural flow practice were resoundingly positive. They reported a high level of satisfaction with being immersed in the three-dimensional rendering of the CRJ 700 flight deck and enjoyed the self-paced guided training. Several students reported that during their non-immersive flow practice, they would only look at the controls and not reach out to touch them. These students appreciated that the software required them to physically reach out to the controls during the flow, thereby reinforcing "muscle memory." Furthermore, many students felt strongly that flow documentation should be reviewed prior to training in the VR system. These students observed that their training time improved when they could anticipate the next item in sequence rather than rely solely on the VRPilot software to guide them.

One of the benefits of VR technology is that it can provide a multi-sensory learning approach involving visual, auditory, and tactile feedback (Sanfilippo et al., 2022). Students liked the visual interaction and audio responses of the VRPilot system. Some students felt that the normal view mode in the VR environment was visually "blurry", but this issue could be quickly mitigated with the magnification function in the VR handheld controllers. Students did not comment on the lack of tactile response with this simulation. Although haptic stimulation makes the experience more realistic, it is less important than visual and auditory feedback (Auer et al., 2023). Since students apply the procedural flows in the EFPT, a device that uses touch-screen technology to simulate most of the aircraft system interface, tactile response in the VR environment was not a necessary feature.

Swivel chairs and chairs on wheels are not ideal for this application. During the VR sessions, students in these types of seats slowly crept forward toward the center of the VR arena. In addition, students practicing flows from the captain position tended to slowly pivot to the right, given that most actions in the flow involve reaching in that direction. The use of stationary chairs, however, completely mitigated this issue.

Previous studies have noted the use of the HMD when interacting in a fully immersive environment can induce motion sickness, referred to as cybersickness (Auer et al., 2023; Majchzak, et al., 2022; Oberhauser et al., 2018; Sanfilippo et al., 2022; Thomas et al., 2021; Weech et al., 2019). While students did not report any nausea in this application, a few did comment on experiencing oculomotor eye strain. To address this concern, time-limited exposure to the VR environment was recommended. In addition, the non-immersive photorealistic scale cockpit model remains available to students who find discomfort in using VR technology to practice procedural flows.

Conclusions

The VRPilot software effectively enables students to independently practice procedural flow interaction within a virtual cockpit and receive real-time feedback on the accuracy of their procedural execution. This activity is self-paced and, once students are familiar with the hardware setup, requires little to no guidance from an instructor to achieve. Implementing VR involved no change to the existing course design but did require infrastructure considerations regarding classroom space and storage of the HMDs and handheld controllers.

The student feedback received so far suggests a strong preference for using VR technology instead of the non-immersive approach when practicing procedural flows. While preliminary observations are promising, a quantitative analysis of measurable student performance with procedural flows must be conducted to make any conclusive statements. A quantitative analysis could not only evaluate student performance of procedural flow execution from a timing and accuracy perspective, but also from a human cognition perspective to gain a comprehensive understanding of the workload associated with task performance. This type of analysis will yield greater insight into the implementation of VR systems in flight training.

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Pathways to Retention for Women in Aviation Education

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Although there have been strides in aviation, women continue to be underrepresented, especially in pilot roles. To address this gap, Embry-Riddle Aeronautical University launched the Women's Ambassador Mentoring Program (WAMP) to improve female students' recruitment and retention in aeronautical science programs. However, there are ongoing concerns that limited support structures may hinder progress. Our line of research uses a transformative mixed-method approach, integrating quantitative data and qualitative feedback from students involved in the program. It evaluates trends in female aviation student enrollment alongside the growth of certified female pilots, focusing on the university's female enrollment and retention rates over time. The findings underscore the critical role of a supportive environment, highlighting how connection and positive mentorship can help current and future women pilots thrive in the aviation field.

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Introduction

The historical underrepresentation of women in aviation underscores the need for strategies that actively promote retention and diversity. While there has been notable progress in increasing gender diversity through initiatives such as scholarships and mentorship programs, retention remains a significant challenge due to persistent stereotypes, biases, and insufficient support structures (Albelo & O'Toole, 2021; Kim & Albelo, 2020). Our research investigates retention obstacles for women in collegiate aviation education and training, focusing on how targeted interventions can promote a more inclusive aviation workforce.

Gender-Specific Challenges

The retention of women in aviation education and flight training is impacted by numerous gender-specific challenges, which include entrenched stereotypes, a shortage of support structures, limited visibility of role models, and the complexities associated with balancing work and life responsibilities. Together, these factors create an environment where women face disproportionate obstacles compared to their male counterparts, contributing to higher rates of attrition among female students pursuing careers in aviation. One of the foundational gender-specific challenges that women encounter in aviation is the prevalence of ingrained stereotypes and biases, which continue to shape the industry's culture and expectations. Historically, aviation has been regarded as a male-dominated field, with the perception of technical and piloting roles as predominantly masculine. These stereotypes often reinforce the notion that aviation is "unsuitable" for women, subtly or overtly questioning their capabilities in these roles. This results in an environment where female students may feel unwelcome or judged more critically than their male peers. A study by Kim and Albelo (2020) highlighted that such biases can profoundly affect female students, diminishing their confidence and sense of belonging within their programs. These biases, often held by both faculty and male peers, can manifest in discouraging comments, reduced expectations, or unequal access to learning opportunities, ultimately impacting female students' motivation and perseverance.

In addition to stereotypes, the lack of support systems tailored to address the unique needs of women in aviation poses a significant retention barrier. In many aviation programs, there is a scarcity of mentorship opportunities specifically designed for women, which leaves female students without essential guidance and support as they navigate their education and training. Female students in aviation often express that they lack access to mentors who can empathize with their experiences and provide relevant advice. Research by Kim and Albelo (2021) indicates that the absence of these critical support structures leads many women to feel isolated and unprepared for the challenges they encounter, which could be alleviated by mentorship from women who have succeeded in similar paths. The establishment of mentoring networks has shown the potential to mitigate feelings of isolation and discouragement, creating a sense of community that can significantly impact female retention in aviation education (Albelo et al., 2023; Kim & Albelo, 2021; Lutte & Morrison, 2022).

Another critical challenge is the limited visibility of successful female role models in aviation, which exacerbates the feeling of isolation and affects women's self-efficacy in the field. Women in aviation programs often struggle to envision themselves in leadership or advanced technical roles due to the scarcity of women in these positions. As Albelo et al. (2023) found, the lack of relatable role models hinders female students' ability to see a clear and achievable career path in aviation. While organizations like the Ninety-Nines and Women in Aviation International have made strides in promoting female accomplishments, visibility remains limited within educational institutions and flight schools. Greater representation of women in faculty and leadership roles within aviation programs could counteract this effect, providing female students with tangible examples of success and encouraging them to persist in their training.

Balancing work-life responsibilities presents an additional gender-specific challenge, as many women face societal expectations regarding family obligations that may conflict with the demanding nature of aviation training. Unlike many other professions, aviation training often requires long hours and a significant commitment of time and energy, which can be difficult to reconcile with family or personal obligations. According to research by Stevenson et al. (2021), work-life balance is a significant factor in female students' decision-making, with many women perceiving aviation careers as incompatible with their long-term personal or family goals. Women in aviation education often feel compelled to choose between their aspirations in aviation and potential family responsibilities, a choice not as commonly faced by their male peers. Addressing this barrier requires institutional flexibility, such as accommodating schedules or promoting career options that allow for a balanced work-life structure, to ensure that women feel empowered to pursue their aviation goals without compromising their personal lives.

Finally, unconscious bias presents a persistent challenge for women in aviation education and flight training, where assessments of women's performance are sometimes unfairly influenced by gendered perceptions. This can take the form of biased grading, unequal feedback, or the tendency to overlook women for advanced training opportunities, which further discourages their participation. As highlighted by Dennehy and Dasgupta (2017), unconscious bias is often subtle but can lead to a perception among female students that their skills are undervalued, affecting their motivation to persist. This bias is particularly problematic in aviation, where performance evaluations are crucial to progression and career opportunities. By implementing diversity and sensitivity training, educational institutions can reduce unconscious bias, ensuring that assessments are objective and based solely on performance.

In sum, the gender-specific challenges faced by women in aviation education and flight training contribute significantly to attrition rates. Addressing these issues necessitates a multifaceted approach, including challenging stereotypes, providing support systems, increasing the visibility of role models, accommodating work-life balance, and mitigating unconscious bias. Implementing these changes can foster an inclusive and supportive environment where women feel empowered to pursue and succeed in aviation, ultimately strengthening the diversity and capability of the future aviation workforce.

Organizational Culture and Support Structures

The culture and support structures within educational institutions and aviation organizations play a crucial role in shaping female students' experiences and retention rates in aviation education. An inclusive and supportive organizational culture is essential for creating an environment where all students, regardless of gender, feel welcomed, valued, and empowered to succeed. Yet, many aviation programs and organizations continue to operate within a framework that unintentionally marginalizes women, impacting their sense of belonging and long-term commitment to the field. Organizational culture in aviation education is often rooted in traditional, male-dominated norms that have historically defined the industry. This cultural legacy can create an unwelcoming or even hostile environment for female students, who may feel as though they must constantly prove their competence to be taken seriously. As highlighted by Kim and Albelo (2020), the dominant culture within aviation education can often lead to an implicit "prove-it-again" bias, where women are frequently asked to demonstrate their skills or knowledge more than their male counterparts. This culture of skepticism toward female competence can be exhausting, causing women to feel alienated and frustrated, ultimately contributing to higher attrition rates. Institutions committed to diversifying their student body must acknowledge these implicit biases and take concrete steps toward fostering an inclusive environment where all students are supported equitably.

Mentorship and networking opportunities are also essential to support structures that play a significant role in retaining female students in aviation education. Access to mentors who can offer guidance, encouragement, and industry insights is invaluable, especially for women who may lack role models in their immediate academic environment. Albelo et al. (2021) have shown that women with access to mentors, particularly female mentors, demonstrate higher retention and completion rates in aviation programs. This is partly because mentorship provides emotional support and practical advice that help female students navigate their unique challenges. However, aviation programs often lack formal mentorship structures, leaving many female students to rely solely on informal connections or external organizations for support. Establishing formal mentorship programs within aviation institutions can bridge this gap, providing female students with access to consistent support and encouragement throughout their educational journey.

In addition to mentorship, creating supportive networks that foster a sense of community among female students and faculty can enhance retention rates significantly. Many women in aviation education report feeling isolated or disconnected due to the small number of female peers and faculty members within their programs (Albelo et al., 2024). This isolation can be mitigated by institutional initiatives that encourage peer networking, collaboration, and community building. Examples include women-focused student organizations, professional development workshops, and events that promote networking among female students and industry professionals. These support networks allow female students to connect with others facing similar challenges, creating a collective sense of belonging and resilience. When students feel that they are part of a community that understands and supports them, they are more likely to persist in their studies and enter the aviation workforce.

Access to resources and equitable opportunities is another critical aspect of organizational support that affects female retention in aviation. Resource disparities—whether in access to flight training, funding, or career counseling—can disadvantage female students, impeding their progress and diminishing their motivation to continue. Research has shown that male students often receive more informal support from faculty or peers, while female students may struggle to access the same resources or guidance. Providing equitable resources, including financial support and access to necessary training tools, is essential to leveling the playing field and ensuring that female students can succeed on equal footing. Institutions should assess their resource distribution policies and practices to identify and eliminate disparities that hinder female students' progress. Therefore, organizational culture and support structures are fundamental to creating an environment where women can thrive in aviation education. Inclusive culture, formal mentorship programs, supportive networking, and equitable access to resources all play crucial roles in retaining female students in aviation. By addressing these areas, aviation institutions can foster a positive and supportive atmosphere that encourages women to persist in their studies, ultimately contributing to a more diverse and skilled aviation workforce.

Educational Environment

The educational environment in aviation education plays a fundamental role in shaping the experiences and outcomes of female students. One of the key issues affecting female students is the implicit and sometimes explicit gender bias present in classroom dynamics and educational practices. Female students feel marginalized during theoretical and practical (flight) lessons. They may experience differential treatment from instructors, such as assumptions about their capabilities based on gender rather than merit (Kim & Albelo, 2020). These experiences can undermine self-confidence and hinder participation, making it challenging for women to engage fully in their studies. Addressing these biases requires a proactive approach, including sensitivity training for faculty and promoting gender-neutral interactions to ensure that all students, regardless of gender, feel equally valued and supported.

The availability and design of learning resources, including textbooks, instructional materials, and equipment, also play a critical role in shaping the educational environment for women in aviation. Many of these materials and resources have traditionally been tailored to male-dominated industries, which can inadvertently alienate female students. For example, training materials and aircraft simulators are often designed around male physical attributes, creating ergonomic challenges for women and reinforcing the perception that they are "outsiders" in the field.

The physical and social environment within aviation learning spaces further impacts retention. Learning spaces where women feel uncomfortable, isolated, or underrepresented can amplify their challenges, reinforcing a sense of exclusion. Creating inclusive learning environments fosters supportive classroom cultures and offers opportunities for female students to engage in peer networking and collaborative projects. For instance, aviation programs could develop women-focused study groups, project teams, or lab partnerships to build community among female students and allow them to support each other in overcoming shared obstacles. Lastly, fostering inclusivity within the educational environment is essential for building a strong, diverse aviation workforce. Institutions that prioritize inclusivity through open discussions on gender equity, inclusive policies, and diversity-oriented curricula help create a supportive environment that enables all students to thrive. By actively cultivating a learning environment that values diversity, aviation programs can empower female students to overcome traditional barriers, persist in their education, and contribute meaningfully to the aviation industry.

Case Study: The Women's Ambassador Mentoring Program (WAMP)

The Embry-Riddle Aeronautical University Women's Ambassador Mentoring Program (WAMP) was launched to address the gender disparity in aviation and provide essential support structures to improve retention for female students pursuing careers in aeronautical sciences. The program was designed as a targeted intervention, aiming to mitigate the isolation, bias, and structural barriers that women often encounter in a male-dominated field. By focusing on mentorship, peer support, and empowerment, WAMP offers a case study of how structured programs can foster inclusivity and significantly influence retention rates among female aviation students.

One of the key components of WAMP is its mentorship network, which pairs incoming female students with mentors who are further along in their academic journey or are experienced professionals in the aviation industry. This mentor-mentee relationship is designed to provide female students with guidance, support, and a role model they can relate to, helping them navigate academic challenges and adjust to the demands of flight training. Mentors help their mentees with everything from understanding course material to coping with the pressures of flight training, creating a continuous support system that often extends beyond academics. This close-knit mentorship community addresses the lack of representation that can make female students feel disconnected, reinforcing a sense of belonging and community that is essential for their retention and long-term success.

Another core element of WAMP is its emphasis on professional development, offering workshops, guest speakers, and networking opportunities specifically for women in aviation. These events expose participants to industry leaders and potential career pathways, enabling female students to envision themselves in various aviation roles and set clear career goals. Additionally, by bringing in guest speakers who share insights on overcoming gender-specific challenges in the industry, WAMP normalizes conversations around inclusivity and resilience, reinforcing female students' confidence and commitment to their chosen field.

The program also fosters a culture of collaboration and peer support, encouraging participants to work together on projects, share experiences, and celebrate each other's successes. This environment creates bonds between female students, which can be crucial in sustaining morale and motivation during challenging periods. WAMP's focus on peer relationships means that female students are building their network within the university and are more likely to find allies and collaborators in the industry post-graduation. This sense of community serves as a buffer against the biases and isolation that female students may face, allowing them to maintain focus on their education and career goals despite external pressures.

Since its inception, WAMP has demonstrated a measurable impact on female retention rates within the university's aviation programs. Institutional data shows an increase in the enrollment and retention of female students, with higher graduation rates among those participating in WAMP compared to those who do not (Albelo et al., 2024). These outcomes underscore the importance of specialized programs in bridging the gender gap in aviation, highlighting WAMP as a replicable model that other institutions can adapt to promote diversity and inclusivity within their aviation education programs. By addressing the specific needs of women in aviation, WAMP offers a sustainable solution to fostering gender equity in this field, illustrating how targeted support structures can empower female students to succeed and thrive in aviation.

Conclusion and Implications

This research highlights the urgent need for targeted interventions to address gender disparities in aviation education and training, specifically through initiatives like the Women's Ambassador Mentoring Program (WAMP). The challenges faced by women in aviation are multifaceted, encompassing gender-specific stereotypes, organizational culture constraints, and a lack of tailored educational support structures. These barriers not only hinder the recruitment of women into aviation but also contribute to high attrition rates among female students. Additionally, WAMP's policy of simply inviting all freshwomen into the program without the barrier to "join" appeared to have a positive impact on participation. WAMP's case study demonstrates how structured mentorship, peer support, and empowerment-focused initiatives can counteract these challenges, creating an inclusive environment that significantly enhances retention rates for women in aviation programs.

The findings of this research have far-reaching implications for both educational institutions and the aviation industry. Institutions that incorporate mentorship and support networks tailored to women's unique challenges are more likely to retain female students, thereby increasing the pipeline of qualified women entering the aviation workforce. Furthermore, programs like WAMP offer a replicable model that other aviation and STEM fields can adopt to foster diversity and inclusivity within male-dominated sectors. Such programs benefit individual students and contribute to an industry-wide shift toward a more equitable and supportive culture for all aspiring aviation professionals.

At an industry level, improving the retention and success of women in aviation education has long-term implications for workforce diversity, innovation, and productivity. Companies that prioritize gender diversity benefit from a wider range of perspectives, skills, and ideas, which ultimately drive operational and competitive advantage. Addressing gender equity in aviation education also enhances the industry's reputation, attracting more women to consider careers in this field and gradually closing the gender gap. As this study demonstrates, implementing targeted programs to support women in aviation is not only an educational imperative but also a strategic industry investment that promises to strengthen the aviation sector's growth and resilience in an increasingly diverse global market.

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Mental Health Resiliency Training: A Workshop Intervention in Collegiate Aviation Coursework

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The tragic events surrounding Germanwings Flight 9525 and similar safety events have highlighted the urgent need to address mental health (MH) issues in aviation, particularly among Part 141 collegiate pilots. This ongoing quasi-experimental study evaluates the effectiveness of a Mental Wellness workshop intervention aimed at enhancing collegiate aviation pilots' knowledge and skills in recognizing and managing MH challenges. Conducted over five days and integrated into the flight safety course curriculum, the workshop focuses on resilience, stress management, emotional regulation, and lifestyle changes. Using a one-group pretest-posttest design, participants will complete the Predictive 6-Factor Resilience Scale (PR6-50) before and after the workshop, alongside demographic questions, to capture descriptive data. The study will employ SPSS® to conduct a paired t-test to determine significant differences in resilience scores. Qualitative data will be analyzed to explore participants' experiences concerning existing models of mental health awareness and stigma reduction in aviation. Expected findings include significant improvements in resilience scores, increased awareness of MH issues, and reduced stigma surrounding help-seeking. Participants are anticipated to report enhanced skills in stress management and emotional regulation, fostering healthier lifestyle choices and greater willingness to seek support for MH concerns. The study's conclusions will emphasize the importance of MH training in aviation and advocate for supportive systems that encourage collegiate pilots to prioritize their mental well-being, advancing the safety objectives established by the Federal Aviation Administration and bolstering the overall safety performance of the U.S. National Airspace System.

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Introduction

On March 24, 2015, Germanwings Flight 9525 crashed in the French Alps, killing all 150 people on board. After the captain left the cockpit, the first officer, who had struggled with mental health (MH) issues since 2009, deliberately initiated a descent. Despite efforts to regain access to the cockpit, the aircraft impacted the terrain at high speed. Investigations revealed the first officer had been suffering from severe depression, which he had not fully disclosed to his employer (Federal Aviation Administration [FAA], 2024a). This tragedy, along with similar accidents such as JetBlue Flight 191 in 2012, where a captain exhibited bizarre behavior and was subdued by passengers, and Malaysia Flight 370 in 2014, which remains shrouded in mystery but is suspected of possible deliberate actions by the captain, has sparked increased focus on pilot MH. These events underscore the urgent need for better support systems and regulatory measures to address MH issues in aviation (DeHoff & Cusick, 2018).

MH problems have also impacted students in Part 141 collegiate aviation flight programs. For example, on October 18, 2021, a collegiate aviation flight student tragically took his life by crashing his aircraft during a solo flight. In a letter left behind, the student expressed his depression and fear of losing flight privileges if he sought help, highlighting the urgent need for better support systems and regulatory measures to address MH issues in aviation (Pitts & Faulconer, 2023). College can be a highly stressful period for students, marked by academic pressures and personal challenges such as family separation and various academic and job responsibilities. This environment often triggers the onset or worsening of MH and substance use issues, with an estimated 26% of Americans aged 18 and older experiencing a diagnosable MH disorder each year. On campuses, MH concerns are widespread, with about one-third of undergraduates reporting significant symptoms; depression is the most common issue, affecting 38% to 55% of students. Additionally, many students experience comorbid conditions—76% of those with major depression also have another MH issue, such as generalized anxiety disorder or non-suicidal self-injury. Other MH challenges include eating disorders and panic attacks, often exacerbated by factors like overinvolved parenting, dependence on technology, and increased academic demands (Oswalt et al., 2020; Peddrelli et al., 2015).

When conducting a literature review for a study on mental health training for Part 141 collegiate aviation pilot students, it is important to acknowledge that mental health challenges affect not only general college student populations but also extend specifically to professional pilots, which includes Part 141 college aviation flight students (Romero et al., 2020). For example, studies involving Part 141 collegiate aviation pilots have found a prevalence of poor sleep quality, high levels of psychological distress, and a significant impact on their well-being. These students often face challenges such as adjusting to being away from home, managing excessive workloads, and dealing with uncomfortable classroom environments, which can contribute to psychological distress (Mendonca et al., 2023). The demands of flight training and academic pressures frequently lead to significant levels of stress and poor sleep quality, negatively affecting their academic performance, and physical and mental health. These college demands may also contribute to obesity, increased substance use, physical and mental fatigue, poor judgment, and reduced situational awareness.

Findings by Mendonca et al. (2019) indicated that fatigue significantly impacted flight training, with pilots overlooking mistakes due to fatigue, leading to decrements in alertness and cognitive function. Keller et al. (2020) found that collegiate aviation pilots frequently struggle with both the quantity and quality of their sleep. Contributing factors include inadequate preparation for sleep, such as optimizing the sleep environment, limiting the use of electronic devices before bed, and failing to plan for 7-9 hours of rest. Additionally, the authors noted that collegiate flight students often face difficulties in maintaining healthy lifestyles. Romero et al. (2020) found that while students recognized their fatigue and its negative impact on training, they struggled to make necessary adjustments. Another study by Mendonca (2021) revealed that 60% of participants experienced mental and physical symptoms of fatigue during flight activities, with 43% lacking training in fatigue identification and management. Factors such as insufficient rest and poor work-life balance further exacerbate these issues, as noted by Levin et al. (2019), where many students failed to engage in adequate exercise, nutrition, and stress management.

Part 141 collegiate aviation pilots face unique stressors and pressures that contribute to MH issues within this demographic, as highlighted in a study by Pitts and Faulconer (2023). Their research reveals that a significant portion of collegiate pilots' experience MH concerns. Their research found that 56.6% of surveyed collegiate pilots met the criteria for depression, and 13.8% reported self-injurious or suicidal ideation within the past two weeks. This study emphasizes that the barriers to seeking MH care—commonly observed in airline and military pilots—are also prevalent among collegiate pilots. Many collegiate pilots expressed apprehensions about seeking help due to fears that disclosing MH issues could jeopardize their medical certification, which is critical for their future careers. The rigorous demands of flight training programs, including academic performance and flight proficiency, create a high-pressure environment that can exacerbate MH concerns. Unlike typical college students, aspiring pilots must navigate the complexities of aviation regulations and the potential consequences of disclosing MH issues. Studies indicate that collegiate pilots often experience significant anxiety related to performance and fear of failure, adding to the MH challenges they face. Addressing MH in this specific population is crucial for ensuring their well-being and future success in aviation.

There are two perspectives on safety in aviation: the traditional view, which focuses on avoiding costs associated with accidents, and a more modern approach that emphasizes the link between safety and efficiency. While the cost of a single major accident can be devastating to an organization, research shows that investing in safety enhances productivity and reduces insurance costs (Ayres Jr. et al., 2009). A Safety Management System (SMS) allows aviation organizations and stakeholders to proactively address safety issues, enabling effective management of accidents and near misses to improve overall safety and efficiency. Central to the effectiveness of an SMS is training and education, which serve as vital pillars in fostering a positive safety culture (DeFusco et al., 2015). Safety training equips personnel with the necessary skills and knowledge to perform their duties safely and competently. It acts as a catalyst for developing a robust safety culture by ensuring that safety information is effectively communicated throughout the organization. By focusing on training, organizations can change shared values among employees and management, reinforcing the importance of safety and cultivating an environment where hazards and risks are well understood and addressed.

Ultimately, improving safety culture requires a commitment to continuous training and education, which enhances both safety outcomes and organizational efficiency (Ayres Jr. et al., 2009).

In this study, the College of Aviation's researchers and a clinical team from the University Counseling Center will collaborate. This partnership allows both areas to share their expertise to best serve the students. Addressing the MH and wellness needs of students cannot be done in isolation, and counseling center staff increase their impact and reach when collaborating with other departments on campus. Building campus partnerships leads to increased participation from students, faculty, and staff and more tailored and relevant programs (Golightly et al., 2017). As such, educational programs such as those offered by MH experts are vital for reducing stigma and empowering individuals to learn more about mental health literacy/care and increase awareness around normal emotions and when to seek help and support. Prevention and education are key interventions, including when to seek professional help without feeling stigma and to adopt therapeutic lifestyle changes that promote mental and physical well-being, which is essential for preventing MH issues.

Addressing MH in aviation requires a multifaceted approach. National policies should establish a non-punitive pathway for disclosing MH conditions. Moreover, the Federal Aviation Administration's (FAA) information management system and Aviation Medical Certification Subsystem must be modernized to facilitate easier reporting (FAA, 2024a). A critical aspect of this strategy is education and training (Aller et al., 2021; Conley et al., 2015). Educational campaigns should enhance MH literacy and promote a safety culture, encouraging aviation professionals to seek care without stigma. MH literacy can be as basic as understanding that feeling sad, anxious, or angry at times is a normal part of the human experience. What is important is educating students about understanding the difference between what is within normal range without self-pathologizing and when to seek mental health support from a professional, essentially understanding the difference between mental health and mental illness.

The purpose of this ongoing study is to assess the effectiveness of a Wellness and Resiliency workshop intervention designed to enhance the knowledge and skills of Part 141 collegiate aviation pilots. This four-part workshop, titled *Wellness and Performance: How Resilience Enables Optimum Performance,* aims to raise awareness and understanding of MH issues from a well-being and resiliency perspective, which teaches coping strategies and stress management skills. It also works to reframe mental health care as a normal part of self-care and an integral part of aviation safety culture. When presented in the classroom as a normal part of addressing safety through increased awareness of self and self-care needs, students may begin to see their mental health care in a less stigmatizing way. By focusing on prevention through the adoption of healthy lifestyles, as well as learning the various interventions, we can empower collegiate aviation pilots to proactively seek help and address MH concerns early on, ultimately preventing more serious health issues. This quasi-experimental study advances the FAA's (2024b) broader objectives of improving safety performance within the U.S. National Airspace System.

Methods

A one-group pretest-posttest quasi-experimental design will be utilized (Leedy & Ormrod, 2020). The dependent variables will be the pre-and post-test scores measured using the Predictive 6-Factor Resilience Scale (PR6-50) and demographic questions (gender, enrollment level, age). The Predictive 6-Factor Resilience Scale (PR6-50) is a psychological assessment tool that measures resilience across six key factors: emotional regulation, optimism, social support, problem-solving skills, self-efficacy, and adaptability. It consists of a series of statements rated on a Likert scale, providing insights into an individual's resilience levels before and after interventions (Rossow & Rossow, 2016). The population of interest includes collegiate aviation pilots enrolled in a flight safety course during the fall 2024 and spring 2025 semesters at a university located in Central Florida. All participation will be in accordance with the Institution Review Board (IRB) guidelines.

The Mental Wellness workshop will be led by a clinical team of licensed MH experts from the University's Counseling Center and will span five days, with sessions integrated into the flight safety course curriculum. The original curriculum for the workshops was developed by Dr. Mazza, the author of Dialectic Behavioral Skills Training for Emotional Problem Solving for Adolescents (DBT-STEPS-A), in collaboration with Dr. Chungani from the University of Pittsburg. There, the curriculum was presented as a full 3-hour course that was given over a 16-week period with 14 original lessons. With permission, the clinical team condensed the course into four modules for this study. Topics covered will include: 1. Wellness and Resilience (Lacomba-Trejo et al., 2022), 2. Mindfulness for Stress Reduction, (Brown & Ryan, 2003) 3. Dialectical Behavioral Therapy (DBT) Skills (Mazza et al., 2016), and 4. Developing Therapeutic Lifestyle Changes (TLCs) (Walsh, 2011). These evidence-based strategies aim to improve MH and overall well-being through the introduction of new cognitive and behavioral skill development, as well as emphasizing the mental health benefits of regular physical activity, balanced nutrition, good sleep hygiene, stress management techniques, and other healthy lifestyle habits.

Data collection will occur in two phases: a pre-test administered during an initial information session one week before the workshop, followed by a post-test at the end of the semester. The posttest will include the PR6-50 (Rossow & Rossow, 2016) and a self-reflection component, where participants will reflect on their experiences with the Mental Wellness workshop, including how it influenced their understanding and behaviors related to MH, any challenges faced, future applications of learned concepts, and feedback on the workshop.

Participants' descriptive data will be examined to help researchers gain a better understanding of the overall trends and patterns (Salkind, 2012). SPSS® will be used to conduct a paired t-test, comparing pre- and post-test scores to determine if the Mental Wellness workshop intervention results in significant improvements for Part 141 collegiate aviation pilots. A deductive approach will guide the qualitative data analysis, aiming to explore how the findings align with established mental health awareness, coping strategies, and stigma reduction models in aviation (Patton, 2015). The primary goal will be to assess how effectively the workshop enhances participants' mental health knowledge, skills, and willingness to seek help.

Expected Findings and Conclusions

Mental health is a subject area that demands more attention and understanding by the FAA and the entire aviation community. One approach to support improving mental health is through training and education so that collegiate pilots who enter the professional arena are best equipped to manage their own mental well-being. This leads to better mental health literacy amongst pilots and will become more ingrained into the aviation culture. Through this workshop, this research team expects to see an improvement in the resiliency and mental health literacy of collegiate pilots. This research will seek to evaluate the resiliency of collegiate pilots as a result of exposure to the Mental Wellness workshop. The research team will determine the level of resiliency the participants demonstrate based on the PR6-50 pretest and compare this result to the posttest to see if improvement in resiliency occurs. The team expects to see an increased demonstration of resilience as a result of training and education.

The results can be shared with the FAA, university leadership, and other collegiate aviation programs in order to establish procedures and resources to best prepare collegiate pilots for the demands of their chosen academic and career paths. Leveraging tools that help collegiate pilots develop the skillset needed to handle the emotional demands of this career early on can decrease the need for mental health support. Better understanding from both future carer pilots and the FAA may also improve the policies and general attitudes toward mental health support.

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Collegiate Aviation Review International

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Taking Off with Crowdsourcing: HeroX's Pioneering Role in Redefining the Future of Aviation

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The article explores HeroX's pioneering role in aviation innovation, emphasizing how crowdsourcing can be used to solve complex issues in the aviation industry and how it has the potential to shape the future of aviation. By highlighting a number of HeroX-led initiatives, the article sheds light on the platform's distinct approach to fostering global collaboration, enhancing technological advancements, and facilitating educational opportunities in the aviation industry.

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Introduction

Crowdsourcing is an online model used by businesses for problem-solving that is accessible to a global audience (Brabham, 2010; Howe, 2006). This approach has gained popularity with advancements in information and communication technologies. Crowdsourcing, introduced by Howe (2006), is defined as the act of a company or institution outsourcing a function traditionally performed by employees to an undefined, often large, network of individuals via an open call (Brabham, 2008). This model may take the form of peer production, where tasks are performed collaboratively or as individual contributions to specific projects (Boukouyen, 2020; 2024). Key characteristics of crowdsourcing include the use of open calls and engagement with extensive networks of potential contributors.

Crowdsourcing initiatives are facilitated through virtual platforms, called crowdsourcing platforms, which host contests focused on ideation, graphic design, problem-solving, and product innovation. The winners of these contests are awarded either monetarily or non-monetarily to maintain their motivation. The success of a crowdsourcing campaign depends on the crowd's willingness to participate (Boukouyen, 2020).

There are three types of crowdsourcing platforms based on the interactional model (i.e., community space). Cooperative platforms foster collaboration and idea-sharing for specific projects. Competitive platforms that seek effective solutions to complex problems. Finally, coopetitive platforms merge cooperative and competitive functionalities (Bullinger et al., 2010).

The aviation industry, characterized by its demand for unique, high-quality products that meet industry standards, has increasingly adopted crowdsourcing as a tool for innovation. Organizations in this sector have utilized crowdsourcing to solicit ideas from the public and launched contests on various platforms, harnessing the diverse knowledge, skills, and talents of the crowd to address complex industry issues. HeroX stands out as a key platform for enabling this innovative approach. It connects various types of organizations, including aviation companies, government agencies, and enthusiasts, with a global community of problem solvers. By hosting challenges tailored to specific issues within aviation, HeroX facilitates the development of innovative solutions (HeroX, n.d.-b).

This paper explores the contributions of HeroX to the aviation industry through the lens of crowdsourcing. Drawing on the HeroX case study, this paper explains how crowdsourcing is used to spark breakthroughs, drive industry advancements, and shape the future of aviation.

The role of HeroX in aviation

HeroX is a leading international crowdsourcing platform recognized for its capacity to facilitate diverse collaborations among organizations and participants. Its heterogeneity lies in its ability to connect a wide range of stakeholders, attracting a community of over 200,000 participants. HeroX is based on a coopetitive model because it provides a community space where participants engage in both competition and cooperation. Through this model, participants submit ideas for specific challenges while simultaneously collaborating in groups or individually, providing feedback, and assisting one another in refining their solutions.

Beyond hosting challenges, HeroX contributes to the aviation industry through a variety of initiatives (see Tables 1 and 2). These initiatives illustrate the significant role of crowdsourcing in driving innovation within the aviation sector. By leveraging the power of the crowd, HeroX enables aviation stakeholders to address complex issues and develop ingenious solutions. The success of these initiatives underscores the value of crowdsourcing platforms like HeroX in fostering a culture of collaboration, innovation, and creativity in aviation.

Challenges

Notable HeroX challenges in the aviation industry have brought together diverse participants and stakeholders. These challenges, summarized in Table 1, demonstrate the platform's role in advancing innovation and resolving critical issues through collaborative problem-solving.

Table 1
HeroX Challenges (HeroX, 2022; 2024a; 2024b)

Name	**GoAERO Prize**	**The 2024 FAA Data Challenge**	**Metaverse and the Future of Flight**
Nature	A single contest with multiple stages and challenges	A single contest focusing on data analytics and AI in aviation	A specific contest focused on aviation and the metaverse
Focus area	Fostering developments in aircraft capabilities, focusing on versatility, affordability, and technological innovation	Enhancing the National Airspace System using AI and machine learning, focusing on safety and operational efficiency	Exploring how the metaverse could improve the passenger experience
Launching organization	Multiple aviation stakeholders (e.g., Boeing, NASA, Council of European Aerospace Societies (CEAS))	FAA	Airbus
Number of participants	62 Teams and 346 Innovators	66 Innovators	56 Teams and 462 Innovators
Categories of participants	Innovators who can develop aircraft systems capable of performing specific tasks	University students are the primary target for this challenge	All categories from any country, except those under 18 years old, and participants must comply with the country's restrictions

			regarding crowdsourcing
Winners	Up to 10 Stage 1 winners, up to 8 Stage 2 winners, and additional winners based on performance in the Fly-Off missions	Multiple winners in different phases	5
Rewards	$10,000 for up to 10 Stage 1 winners, $40,000 for up to 8 Stage 2 winners, and a total of $1,500,000 in prizes for the Fly-Off, including specific prizes like the Pratt & Whitney Disruptor Prize and Autonomy Prize	A total prize pool of $100,000	$30 000 was shared between the winners
Timeline	Key dates include an April 8, 2024, comment period closure, an October 9, 2024, Stage 1 submission deadline, a June 18, 2025, Stage 2 submission deadline, and the Fly-Off event scheduled for February 5, 2027	From March 2024 to March 2025	From April 26, 2022, to September 13, 2022

Conferences

Although not classified as a contest but rather a conference, this initiative highlights the engagement of major aviation organizations with crowdsourcing practices (see Table 2).

Table 2
Other HeroX Initiatives (HeroX, n.d.-a)

Airbus HeroX Supplier Conference	**Objective**	Focusing on discussing the impact of crowdsourcing on aviation and aerospace innovation
	Organizer	Hosted by Airbus in partnership with HeroX
	Focus area	It discusses the importance of crowdsourcing in innovation strategies and managing intellectual property while engaging with the crowd, demonstrating a 90% success rate in innovation projects through crowdsourcing.
	Benefit(s)	Facilitating dialogue among industry leaders, innovators, and the public, fostering a shared understanding of crowdsourcing's potential
	Impact	By highlighting successful case studies and facilitating discussions on best practices, the conference underscored the importance of collaborative innovation and community engagement in addressing industry-wide issues.

HeroX's distinction from other challenges

HeroX sets itself apart within the aviation industry by providing unique features and methods that show the broad applicability of crowdsourcing in addressing challenging issues. These distinguishing features include:

- **Broad scope of challenges:** HeroX hosts a wide range of challenges from various industries, including aviation. This breadth attracts a large community of innovators from different backgrounds and areas of expertise, which is beneficial for cross-disciplinary innovation in aviation.
- **Open and inclusive participation:** HeroX emphasizes inclusivity by welcoming participants regardless of their educational or professional background. This democratization of innovation enables global contributions and yields a greater range of solutions.
- **User-friendly platform and support:** HeroX offers an extremely user-friendly interface that simplifies the entire challenge experience. Participants are provided with resources and tools to understand the challenge requirements, collaborate with others, and improve their entries. Moreover, HeroX's support team helps both partners and participants, ensuring a unique and enjoyable experience.

- **Flexible challenge design or adaptability:** HeroX provides flexibility in how challenges are structured and executed, allowing organizations to customize rules, prizes, evaluation criteria, and timelines to align with specific objectives. This flexibility ensures that challenges are effectively tailored to attract participants and encourage high-quality submissions.
- **Focus on community building and engagement:** HeroX focuses on creating a community of innovators who are passionate about solving the world's most pressing issues. Through forums, social media, and other interactive tools, participants are encouraged to build connections and foster a sense of belonging. This community aspect promotes lasting relationships between innovators and challenge sponsors, resulting in a thriving ecosystem of continuous innovation.
- **Partnership and collaboration opportunities:** HeroX facilitates partnerships and collaborations that extend beyond individual challenges. Participants gain visibility among industry leaders, which may lead to partnerships, investments, and further development opportunities outside of the scope of the initial challenge.

HeroX's key contributions to aviation

HeroX has made significant contributions to the aviation industry, demonstrating the power of crowdsourcing in addressing its unique challenges. These key contributions include:

- **Collaboration and partnership:** Enabling collaborations among various stakeholders to tackle critical industry issues and efficiently solve complex problems.
- **Open innovation:** Inviting a global community of innovators to share their ideas and solutions. By incorporating diverse perspectives and expertise, this approach has led to breakthroughs in technology, safety, sustainability, and operational efficiency.
- **Technology acceleration:** HeroX challenges encourage the development and implementation of emerging technologies, such as the metaverse, hastening their adoption in the aviation industry. Moreover, HeroX accelerates the delivery of cutting-edge solutions to the market.
- **Educational impact:** Many HeroX challenges are designed to engage students and researchers by presenting them with real-world aviation problems to solve. For example, the 2024 FAA Data Challenge provides an opportunity for participants to address industry-relevant issues, preparing the next generation of aviation engineers, scientists, and innovators.
- **Sustainability and safety initiatives:** HeroX supports the aviation industry's goals of reducing environmental impact and enhancing passenger and crew safety. By focusing on sustainability and safety, these challenges contribute to the development of innovative solutions that align with the industry's long-term objectives.
- **Community and awareness building:** By hosting aviation-focused challenges, HeroX raises awareness of the industry's needs and opportunities for innovation. By fostering a collaborative community of aviation stakeholders, HeroX promotes a culture of continuous improvement and drives innovation across the sector.

HeroX's crowdsourcing process

HeroX promotes innovation in aviation through a structured crowdsourcing process that engages a global community of innovators to solve complex challenges. This process illustrates how HeroX uses crowdsourcing to advance innovation within the aviation sector. By connecting industry leaders with a diverse community of problem-solvers, HeroX facilitates the emergence of creative solutions to tackle pressing aviation issues (see Figure 1).

Figure 1

HeroX Crowdsourcing Process in Aviation

1 Challenge identification

Collaboration with industry partners: HeroX partners with aviation stakeholders to identify pressing issues.
Needs assessment: A thorough assessment of the challenge's specific needs and goals is carried out to ensure that the problem is well-defined and that the outcomes are meaningful.

2 Challenge design

Defining objectives and criteria: Participants are guided by clear objectives, submission criteria, and evaluation methods to ensure that the solutions developed achieve the desired results.
Rules and guidelines: Specific rules and guidelines are established to manage expectations, ensure fairness, and define the scope of the challenge.

3 Launch and promotion

Announcement: The challenge is announced on the HeroX platform and promoted via multiple channels to reach a large number of potential solvers, including innovators, students, startups, and researchers.
Community engagement: HeroX generates interest and encourages participation in its community by hosting webinars, forums, and social media.

4 Solution submission

Participant support: Throughout the challenge, participants have access to resources and assistance as they refine their ideas and develop their submissions.
Collaborative environment: HeroX encourages participants to discuss ideas, form teams, and provide feedback.

5 Evaluation and selection

Expert review: Submissions are evaluated by a panel of experts from the aviation industry, academia, and other relevant fields using predefined criteria.
Selection: Winners are chosen based on their solutions' innovation, feasibility, impact, and alignment with the challenge objectives.

6 Implementation and follow-up

Awards and recognition: Winners receive prizes, including cash, mentorship, and collaboration opportunities with industry partners.
Post-challenge support: HeroX and its partners assist winners in implementing their solutions.

7 Impact assessment

Review and analysis: Challenge results are reviewed to determine their impact on aviation and to gather insights for future challenges.
Sharing success stories: Success stories and case studies highlight participants' achievements and the tangible benefits of their solutions.

Conclusion

This paper has explored the power of crowdsourcing in fostering innovation within the aviation industry, using HeroX as a case study of one of the leading crowdsourcing platforms. Through initiatives such as the GoAERO Prize, the 2024 FAA Data Challenge, and the Metaverse and the Future of Flight, as well as conferences like the Airbus HeroX Supplier Conference, HeroX demonstrates how crowdsourcing bridges the gap between groundbreaking ideas and real-world applications.

The platform's crowdsourcing process not only democratizes innovation by engaging a global community of innovators but also highlights the power of collaborative problem-solving in addressing some of the aviation industry's most complex challenges. Therefore, the benefits of these crowdsourcing initiatives include increased idea generation, lower research and development costs, and the capacity to solve intricate problems through collective efforts.

By opening challenges to participants worldwide and from diverse backgrounds, HeroX ensures that the aviation industry can access a broad spectrum of creative perspectives and expertise.

Therefore, crowdsourcing emerges as a highly effective strategy for harnessing collective intelligence and cultivating an environment of continuous innovation. Its adoption can enable the aviation industry to accelerate progress toward a future defined by technological advancements, operational excellence, and an unwavering commitment to improving the passenger experience.

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