Collegiate Aviation Review International

Volume 37 | Issue 1
Spring 2019

The Peer Reviewed Journal of the University Aviation Association

ISSN: 1523-5955

COLLEGIATE AVIATION REVIEW INTERNATIONAL

A PEER REVIEWED JOURNAL OF THE

UNIVERSITY AVIATION ASSOCIATION

COLLEGIATE AVIATION REVIEW INTERNATIONAL
2019 VOLUME 37 ISSUE 1
Ryan J. Wallace, Editor

ISSN: 1523-5955

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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:

- To encourage and promote the attainment of the highest standards in aviation education at the college level
- 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

REVIEWER ACKNOWLEDGEMENT

Thank you to all of the individuals who served as reviewers for the scholarly works contained in this issue!

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Examining the Perception and Effectiveness of a System Awareness Briefing During Cruise Flight

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Automation has increased the safety of air transportation by assisting pilots during periods of high workload and during critical phases of flight. However, an unintended consequence of automation proliferation has been the reduction in attention resulting from its use. Prior research has shown that during periods of high automation and low workload, pilots' minds begin to wander and occupy themselves with thoughts other than the current task at hand. This research involved conducting a study to address the following research question: does a system awareness briefing actually improve pilot awareness of automation and aircraft parameters during cruise flight? The results indicated pilots who used the system awareness briefing were more accurate in reporting current heading, fuel flow, and electrical volts, compared to pilots who did not use the briefing. They also reported that they felt more situational awareness compared to the control group.

Recommended Citation:
Winter, S.R., Milner, M.N., Anania, E.C., Rice, S., Walters, N.W., Garcia, D., & Baugh, B.S. (2019). Examining the Perception and Effectiveness of a System Awareness Briefing During Cruise Flight. *Collegiate Aviation Review International*, *37*(1), 1-18. http://dx.doi.org/10.22488/okstate.19.100201

The purpose of this study was to determine if a system awareness briefing during the cruise phases of flight may increase pilot diagnostic ability during a hypothetical emergency or issue of automation surprise. The goal was to gain a better understanding of how a pilot's attention may fade during low workload periods of the flight. The system awareness brief may work to re-engage the pilot into the system and decrease response time during the automation surprise event. This briefing was designed to be completed at 5-minute intervals during the cruise phase of flight, a traditionally low workload period for pilots. Similar to an approach briefing, the system awareness briefing reviewed the current flight state. Objects included in the system awareness brief were: current route, upcoming waypoint, and waypoint after that, current automated flight mode status, navigation source, communication frequencies, systems status, fuel load, and flight time remaining. The conceptualization of the awareness briefing was taken from the success of an instrument approach briefing, which is commonly used in both single-pilot and multi-crew operations.

Effects of the Man/Machine Interaction between Automation and Manual Flying Skills

The concept of automation has been described as the opportunity for the pilot to think ahead of the task at hand and not have to focus on manual flying skills (Casner & Schooler, 2014). Multiple studies show that the more reliable the system is, the more the participants were likely to be complacent and subject to latent errors than those who were told their device was less reliable (Bailey & Scerbo, 2007). Operators often rely so much on their systems that it leads them to make shortcuts in the decision-making process. For example, pilots have admitted to not making full use of all the information and cues that are being offered to them in the cockpit when deciding because they are relying on the automation (Mosier, Skitka, Heers, Burdick, 1998)).

Automation is intended to give the pilots extra time to think ahead and analyze the situation; however, many studies have shown that accidents have occurred as a result of poor use of that extra time (Chow, Yortsos, & Meshkati, 2014). There is a widespread belief that pilots lose their manual flying skills because of increased cockpit automation. Some studies showed that while manual flying skills tended to remain the same, there was a decline in cognitive flying skills (Casner, 2014). Research based on the pilots' ability to fly the aircraft manually showed that those manual skills are less likely to be forgotten than cognitive skills over a certain period with no flying experience (Casner, Geven, Recker & Schooler, 2014). A connection was made between the number of hours flown by the pilot and their capacity to control the flight within its tolerances. Additionally, another connection was established between the number of raw data approaches flown by the pilot and the smoothness of their maneuvers (Young, Fanjoy, & Suckow, 2006). The researchers recorded several factors such as instrument crosscheck proficiency, smoothness of control or completion of instrument procedures. A study highlighted that after a period of manual handling, a certain task eventually gets automated, thus not requiring the same amount of monitoring as before (Farrell & Lewandosky, 2000).

Automated systems offer many benefits and were first designed to enhance the safety of the fight by allowing pilots to monitor the computer's calculations and intervene when needed. However, the continuous improvement of autonomous systems has led to the emergence of new types of errors such as difficulties to take over the controls in case of emergency, degradation of manual and cognitive skills when not rehearsed, difficulties to diagnose a situation, errors of the crew in setting up the equipment or errors introduced by the computer not being diagnosed by the crew (Wiener & Curry, 2007).

Pilots' Behavior and Complacency

Several studies have analyzed complacency due to automation and trust in automated systems. The first important factor that affects monitoring performance has been reported to be the attentional capacity of the operator. By varying over a period of time, the lack of attention leads to increased reliance on the automated system, hence allowing errors to occur (Bailey & Scerbo, 2007). Tasks requiring the highest attentional capacity from the operator are the first ones to suffer from a decreased monitoring performance. Bailey and Scerbo (2007) have investigated the concept of trust between humans and machines with extreme levels of trust but also with the impact of early and late failures of the system.

Situational awareness is described as the perception of surrounding elements concerning time and space. It also implies constant monitoring, which enhances the frequency of workload-related tasks during the flight (Billings & Cheaney, 1981). Damos, John, and Lyall (2005) recorded data concerning what pilots were looking at, what they were touching, or whether or not they were talking at different moments of the flight. The results showed that with increasing level of automation, the frequency of simple actions, such as holding the yoke, was decreasing. Their research supports a Casner, Geven, Recker, and Schooler's study (2014) concerning the pilots' ability to manually fly the aircraft and the forgetting of cognitive skills over a sustained period. It is not uncommon to have instances in which highly experienced pilots chose to manually fly the aircraft shortly before landing (Ebbatson, Harris, Huddlestone & Sears, 2010).

Human-Machine Trust

Thanks to technological advancements, a new type of inactivity are rising: passiveness in the cockpit. Pilots tend to process information by acknowledging correlated cues and tend to omit less obvious or less flexible information (Mosier, Skitka, Heers, Burdick, 1998). Studies have shown that complacency induced by automation reduces the pilot's ability to detect system malfunctions from 70% when flying the aircraft manually to 55% with the help of automation (Farrell & Lewandowsky, 2000). Additionally, the study researched the effect of trust in the automated system on pilots' performance, and the results showed that performance was degraded if the reliability of the system was kept constant instead of varying.

Other research has reported that the level of automation has an impact on the number of time pilots spent looking outside the cockpit (Damos, John, & Lyall, 1999). The higher the reliability of the system, the higher the complacency seems to be, and mental workload decreased throughout the simulation session, as well (Singh, Tiwari, & Singh, 2009). An interesting concept of 'automation surprise' was introduced by a study in which pilots qualified to fly aircraft equipped with automated systems described the surprises they experienced that were related to automation (Sarter, 1994). The research concluded that there is no solution to pilots being 'surprised' by a sudden malfunction or warning in the cockpit without being aware of the overall situation and the interconnectedness between human, machine, and the environment. Fortunately, automation surprise can be reduced with constant monitoring and surveillance of the flight deck associated with the correct use of cockpit communications and cockpit behavior. One study addressed the problematic relationship between crew performance, loss of manual flying skills and reflexes, and seniority (Feaver, 1987). However, complacency and automation biases occur as often in inexperienced pilots as in expert pilots (Parasuraman & Manzey, 2010).

Mind Wandering and Task Efficiency

Although automation allows for more accuracy and faster decisions, it leads to increased passiveness in the cockpit (Casner, Geven, Recker, & Schooler, 2014). Since pilots do not have to fly the aircraft by hand during the entire flight, several researchers have tried to determine how pilots utilize this free time (Casner & Schooler, 2014). They classified the pilots' thoughts into three categories: *task-at-hand* thoughts, which correspond to actions currently being achieved; *task-related* thoughts correspond to planning ahead to something related to the flight; and *task-unrelated* thoughts; which represent something completely unrelated to the flight. As automation increased, pilots were more likely to think about future tasks rather than the current task-at-hand. However, as everything was happening as expected and the flight was running its course, pilots' minds were wandering to task-unrelated thoughts.

The more advanced the automated technology, the more it simplifies the pilot's job of decision-making (Chow, Yortsos, & Meshkati, 2014). However, cultural factors usually intervene and make every situation different regarding how the pilots react. Previous pilot training combined with previous work experiences will cause each pilot to react differently when facing a similar issue. The accuracy of a pilot's reaction and its success in a timely manner is highly related to the state of mind of the pilot performing that action. If a pilot allows their mind to wander, the pilot will inevitably become complacent in their situational awareness. The pilot will be disconnected from the situation, and fail to act correctly following an alarm, or simply fail to act promptly (Wiener & Curry, 2007). The mind starts to wander when the focus is shifted from the dominant task, which leads to a decrease in performance and loss of situational awareness (Smallwood & Schooler, 2006). The authors describe the process of mind wandering as unconscious and initiated by a stimulus that puts the person into a state of reduced consciousness. At that moment, information from the external environment has more difficulty getting to the person who gradually drifts away from the real world. Therefore, it takes more time and effort to snap out of that mind-wandering state in case of a sudden malfunction (Feaver, 1987). During mind-wandering, thoughts can range anywhere from a functional to conceptual nature (Cowley, 2012). The degree of un-relatedness of the thought in comparison with the task being performed can be translated into the hypothesis that the pilot's state of mind wandering has consequences on their flying performance.

The constant improvement of technology in the cockpit has led to the creation of automation systems more powerful than ever in both general aviation and commercial aircraft; however, automation can be seen as a blessing and a curse. It allows pilots more free time to focus on important aspects of the flight without having to hand fly for a sustained period, but it can also lead pilots to lose situational awareness due to lack of focus. Studies have shown that the more advanced the automated system, the more the pilots were likely to rely on it and be complacent, which results in degraded performance. The performance of the pilot and safety of the flight are closely related and depend on factors such as communications in the cockpit. General observations, inquiries or agreements are examples of communications between pilots, which are extremely effective in keeping them aware of their surroundings at any point of the flight. In the absence of communications, when complacency is easy, mind-wandering can come into play, endangering the safety of the flight.

Current Study

A review of the literature reveals that as automation increases, such as in technologically advanced general aviation aircraft and commercial airliners, an unintended consequence has been a decrease in pilots' manual flying skills, cognitive awareness, and an increase in mind-wandering during flight, especially during highly-automated phases. These concerns have been addressed in light of many recent commercial airline accidents and incidents. However, to date, there does not appear to be any system awareness briefing that is required by the FAA or the major airlines.

The purpose of this study is to address the following research question:

> Does a system awareness briefing actually improve pilot awareness of automation and aircraft parameters during simulated cruise flight when using a sample of university aviation pilots?

In this study, we attempted to capture information on the following data points after the simulator flight ended: current heading, current altitude, distance in nautical miles to the next waypoint, fuel flow in gallons per hour, time remaining until destination in hours and minutes, indicated airspeed, engine revolutions per minute, groundspeed, main electrical bus voltage, and gallons of fuel remaining.

Methods

Design

The study used a between-participants experimental design. Participants were randomly assigned to either the control or experimental condition.

Participants

Sixty-nine (11 females) participants completed the study. The mean age was 22.26 (*SD* = 3.14) years old. Participants indicated that they had an average of 302.83 (*SD* = 289.98) total flight hours. All participants were student pilots at a large southeastern university with a flight school. To participate in the study, participants must have been at least a private pilot with prior experience using the Garmin G1000 avionics suite and autopilot experience. These requirements were self-reported by participants.

Procedure and Materials

Participant were recruited through advertisements posted across the subject university's campus, email notifications, and in-class announcements. The study was completed in the Aviation Human Factors lab. When participants arrived, they were presented with and signed a consent form. In both the control and experimental condition, participants were directed to sit at a desktop computer workstation and told to complete the self-guided on-screen tutorial. In the control condition, the presentation was related to an aviation x-price competition hosted by Boeing to create a personal flying device, such as a jetpack. In the experimental condition, participants were presented with a tutorial on how to use the system awareness briefing. Both presentations were matched to include the same length, amount of content, and same verbal and non-verbal cues.

Upon completion of the computer-based session, all participants were presented with a flight briefing packet. This packet contained information on the flight route, a flight plan form, and weather information for the intended flight from the Winter Haven's Gilbert Airport in Winter Haven, Florida (KGIF) to the Early County Airport in Blakely, Georgia (KBIJ). Participants in the experimental condition were presented with a system awareness briefing handout to use during the flight (Appendix A). The Elite Flight Training Device (FTD) was configured as a Cessna 172, and it was prepositioned on runway 29 at KGIF with all the avionics programmed. The weather for the scenario was visual meteorological conditions (VMC). The lab assistant provided each participant with a handout offering instructions on the flight (Appendix B).

When the participants were ready, the lab assistant told them they could take off. Participants were instructed to climb to 4,500 feet mean sea level (MSL) and proceed on course. Upon reaching cruising altitude, participants were instructed to engage the autopilot. In both conditions, pilots were instructed to act as they would in a real aircraft. Participants in the experimental condition were additionally asked to complete the system awareness briefing every 5 minutes, while participants in the control condition were asked to complete the flight as they would in a real aircraft. At minute 43 of the simulator session, the lab assistant paused the simulation and blacked out the flight displays. Participants were removed from the simulator and instructed to complete the study post-test assessment, which asked participants to report the values of selected instruments (Appendix C). The lab assistants reported the difference between the participant's reported value for each instrument and the actual value that was recorded on the aircraft at the time the simulation was paused. The participant completed a post-test assessment, the Post-Trial Participant Subjective Situation Awareness Questionnaire (PSAQ) instrument (Strater, Endsley, Pleban, & Matthews, 2001), which is a self-reported measure of workload, performance, and awareness, was compensated $50, debriefed, and dismissed.

Results

Prior to conducting an independent samples *t*-test on the data, an initial data analysis examined for outliers. Cases that were determined to be extreme cases were removed before the analysis. The variable of *heading* had 2 cases removed, *altitude* had 2 cases removed, *distance from destination* had 8 cases removed, *fuel flow* had one case removed, *engine RPM* had 5 cases removed, *groundspeed* had 2 cases removed, *electrical volts* had 2 cases removed, and the *PSAQ Awareness* had 8 cases removed. No other extreme outliers were detected.

Significant Findings

Current heading. An independent samples *t*-test revealed the experimental group (*M* = 0.33, *SD* = 0.61) was significantly more accurate in reporting their current heading than in the control group (*M* = 7.25, *SD* = 11.94), *t*(33.193) = 3.374, *p* = .002, *d* = .82, indicating a moderate to large effect size between the two conditions.

Fuel flow. An independent samples *t*-test revealed the experimental group (*M* = 0.63, *SD* = 0.88) was significantly more accurate in reporting current fuel flow than in the control group (*M* = 2.17, *SD* = 2.43), *t*(42.79) = 3.442, *p* = .001, *d* = .84, indicating a moderate to large effect size between the two conditions.

Electrical volts. An independent samples *t*-test revealed the experimental group (*M* = 3.14, *SD* = 3.80) was significantly more accurate in reporting electrical volts than in the control group (*M* = 7.10, *SD* = 7.55), *t*(38.99) = 2.289, *p* = .028, *d* = .66, indicating a moderate effect size between the two conditions.

PSAQ Awareness. an independent samples *t*-test revealed the experimental group (*M* = 4.08, *SD* = 0.49) did report significantly better awareness than in the control group (*M* = 3.59, *SD* = 0.86), *t*(54.29) = -2.778, *p* = .007, *d* = .70, indicating a moderate effect size between the two conditions.

Non-Significant Findings

Current altitude. There was no variation in answers between participants, and therefore, no statistical analysis was possible.

Distance from destination (NM). An independent samples *t*-test revealed the experimental group (*M* = 6.10, *SD* = 5.04) was not significantly more accurate in reporting their distance than in the control group (*M* = 8.86, *SD* = 8.85), *t*(46.86) = 1.305, *p* = .198.

Remaining rime to destination (min). An independent samples *t*-test revealed the experimental group (*M* = 6.59, *SD* = 6.51) was not significantly more accurate in reporting their time remaining than in the control group (*M* = 8.62, *SD* = 8.76), *t*(64) = 1.060, *p* = .293.

Indicated airspeed. An independent samples *t*-test revealed the experimental group (*M* = 1.91, *SD* = 2.01) was not significantly more accurate in reporting their indicated airspeed than in the control group (*M* = 1.78, *SD* = 2.32), *t*(64) = -0.237, *p* = .814.

Engine RPM. An independent samples *t*-test revealed the experimental group (*M* = 3.06, *SD* = 4.60) was not significantly more accurate in reporting their engine RPM than in the control group (*M* = 4.03, *SD* = 4.90), *t*(60) = 0.802, *p* = .426.

Groundspeed. An independent samples *t*-test revealed the experimental group (*M* = 2.90, *SD* = 3.23) was not significantly more accurate in reporting their groundspeed than in the control group (*M* = 3.40, *SD* = 3.84), *t*(62) = 0.561, *p* = .577.

Total fuel remaining (gal). An independent samples *t*-test revealed the experimental group (*M* = 10.04, *SD* = 12.82) was not significantly more accurate in reporting their gallons remaining than in the control group (*M* = 12.03, *SD* = 15.50), *t*(58) = 0.533, *p* = .596.

Workload on PSAQ. An independent samples *t*-test revealed the experimental group (*M* = 1.88, *SD* = 0.89) did not report significantly more workload than in the control group (*M* = 1.82, *SD* = 0.76), *t*(65) = -0.273, *p* = .785.

Performance on the PSAQ. An independent samples *t*-test revealed the experimental group (*M* = 3.94, *SD* = 0.86) did not report significantly better performance than in the control group (*M* = 4.00, *SD* = 0.78), *t*(65) = .302, *p* = .764.

General Discussion

Four of the measures that were captured turned out to be significant, and all four were in the direction that favored the system awareness briefing. That is, when pilots used the awareness briefing, they were more accurate in reporting current heading, fuel flow, and electrical volts. They also reported that they felt more situational awareness compared to the control group. Pilots also did not report any significant difference in workload between the two conditions. Therefore, we can conclude that not only did pilots feel that the system awareness briefing was doing what it was designed to do, but that it also improved actual performance in several areas of important information. Of particular interest was the improvement to heading awareness. It is critical for pilots to be aware of their heading, as this determines where they are going. For pilots to lose track of heading during autopilot flight can lead to dangerous events where they encroach in airspace where they do not belong. The additional variables of fuel flow and electrical volts may not typically be items included in the main scan of pilots, and it is possible that the awareness briefing helped pilots pay more attention to these important values. Due to the mixed findings, it is recommended that additional research is completed to explore the use of a system awareness briefing further to examine its effects on pilot performance. Additionally, the authors disclose that certain parameters which were found to not be significant, such as indicated *airspeed*, *distance*, and *fuel remaining*, are also very important variables to the safe outcome of flight. This further suggests the need for additional research to provide more context into what variables may be influenced by a system awareness briefing and also, if there is any significant effect of pilot decision-making resulting from a systematic and reoccurring briefing.

The use of automation provides a valuable resource to pilots which often results in them being able to think ahead of the aircraft (Casner & Schooler, 2014), but this is also not without some detriments as not all pilots may use this time effectively. Some may suffer from complacency (Bailey & Scerbo, 2007) or suffer from reductions in their ability to detect issues (Farrell & Lewandosky, 2000) or omit less obvious issues (Mosier, Skitka, Heers, Burdick, 1998). The system awareness briefing was designed to try and compensate for some of these unintended issues of increased automation usage. Participants who used the system awareness briefing were more accurate in their reporting of current heading, fuel flow, electrical volts, and perceived awareness. Additionally, participants who used the system awareness briefing did not report an increased perception of workload compared to the control group. It is possible that the system awareness briefing helped pilots' minds wander less (Casner & Schooler, 2014) and stay focused on the flight activities. A leading concern of mind wandering is the pilot's inability to properly diagnose a failure, especially during periods of high automation (Wiener & Curry, 2007). It is possible that the system awareness briefing could help prevent mind wandering, and thus increase pilot's ability to diagnose a failure during periods of high automation accurately. Participants who used the system awareness briefing did report a significantly higher level of awareness compared to those participants in the control group.

However, while the system awareness briefing was effective for some variables, there were also some other variables for which there were no differences in reporting between the two conditions. Variables such as altitude, time remaining to the destination, airspeed, engine RPM, ground speed, total fuel remaining, and perceived performance all had null effects. While it is possible that there is an underlying pattern which may help identify why some variables were significant and others were not, the current study is limited in its interpretative abilities of these differences. Although, it is important to consider that the current study used a very limited (less than 5-10 minutes) self-guided training tutorial of the system awareness briefing. In future studies, a more formal and thorough training program of the awareness briefing may increase its effectiveness.

Practical Applications

General aviation (GA) pilots represent many of the pilots flying in the National Airspace System. Unfortunately, GA pilots also represent a large proportion of aviation accidents and incidents. A critical factor is the role of increasing levels of automation on aviation safety. While, automation has been lacking in general aviation aircraft for a long period of time, since the early 2000s, there has been a proliferation of technologically advanced aircraft developed for general aviation that has tools such as glass cockpits and autopilots. Although automation offers many benefits, potential consequences include automation complacency, automation surprises, and pilot skill degradation. The system awareness briefing investigated in this research aimed to address these issues by helping pilots become re-engaged with the current status of the flight at regular intervals during periods of low workload and high automation. The study attempted to experimentally examine the application of the system awareness briefing in a laboratory setting.

The findings from this study were mixed but warrant further investigation. It is possible that the insights gained from this line of research may be far-reaching, potentially enhancing aviation safety, reducing the effect of automation surprises, and ultimately saving lives. Beyond general aviation, the system awareness briefing could be adapted for other complex domains that rely on automation and possess variable levels of operator workload. For example, the system awareness briefing could be applied to unmanned system operators to maintain situation awareness during long missions. Similarly, the system awareness briefing could benefit other industries which have extended periods of low workload and high automation.

Recommendations for Future Research

Follow-on research should include conducting further studies to evaluate the utility of the system awareness briefing in different abnormal situations. Examples of further scenarios to be investigated include exposing pilot participants to slowly deteriorating weather or an auxiliary system failure (e.g., fuel gauge malfunction). New measures of task performance and situation awareness should also be developed and evaluated, such as the measures used to examine pilot mind wandering (Casner & Schooler, 2014). Additionally, future research could examine if the system awareness briefing has a “macro-scale” effect on pilot’s decision-making or views toward safety. The majority of the variables measured in this study relate to system status indications, and therefore, pilot’s responses to various stimuli such as diversions, flight path adjustments, and emergencies may be influenced and could be manipulated when using the system awareness briefing.

Future research can also explore how the system awareness briefing could be adapted for other complex domains, such as unmanned aircraft system (UAS) long endurance missions. An expanded version of the system awareness briefing also may be evaluated as a useful tool to support UAS crew shift change activities during these operations.

Limitations

The study was limited through the use of a convenience sample of participants from the subject university. These students complete the majority of their flight training in a university’s professional pilot program, and their knowledge, skills, abilities, and training may restrict the generalizability of the findings. However, this was the first study in which the system awareness briefing was used so we wanted to start with a local sample of pilots to examine for any effects before working on replication studies to expand the generalizability of the findings. Care should be given in the generalizability of these findings for this reason, and it is recognized that samples consisting of pilots with differing demographic factors from the sample used in this study may be affected differently. Therefore, replication of the current study is encouraged.

This study was supported through an internal university grant program designed to offer seed funding for the beginning stages of new research ideas. It is for these reasons that we selected to use university pilots, despite the resulting restrictions to the generalizability of the findings. The research was also conducted using a fixed-base flight simulator, and the use of the simulator could change the responses of participants compared to how they would perform in an actual aircraft. Additionally, the system awareness briefing was completed at 5-minute intervals. It is recognized that to be applied in a commercial aviation setting; this time interval would have to be expanded in-between administrations of the briefing. The current study was limited in administration time of the total experimental procedure, and thus, the interval between briefings was 5 minutes. In future studies, the length of time between briefings in another variable that could be investigated to help determine the ideal period in between briefings.

Conclusions

The purpose of this research was to investigate the application of a system awareness briefing. The system awareness briefing was designed to help keep pilots engaged mentally during periods of low workload and high automation. In laboratory trials, participants were asked to report their answers on a post-test of current flight status after performing in either the control or experimental conditions. The findings from the study presented mixed results as to the effectiveness of the system awareness briefing. Participants using the system awareness briefing were significantly more accurate when reporting current heading, fuel flow, electrical voltage, and their perceived awareness when compared to the control group. Participants in the system awareness briefing group also did not express a significant increase in their workload compared to the control group. However, there were no significant differences between the two groups in the reporting of current altitude, time to destination, indicated airspeed, engine RPM, ground speed, total fuel remaining, and perceived performance. Further research is recommended to examine how the system awareness briefing may influence pilot performance.

Acknowledgements

The authors wish to thank Dr. Haydee M. Cuevas and Ms. Stephanie G. Fussell for their constructive comments and guiding recommendations for this study.

Funding

Funding for this study was provided through Embry-Riddle Aeronautical University's Faculty Innovative Research in Science and Technology (FIRST) Grant program. The FIRST grant program consists of internal research awards provided by the university to establish seed funding for innovative faculty research projects.

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Appendix A

Awareness Briefing

The Awareness Briefing is designed to increase your situational awareness of the flight environment during low workload, high automation phases of flight, such as cruise and en-route. It can be used for both single pilot resource management (SRM) and Crew Resource Management (CRM).

Similar to an instrument approach briefing, the Awareness Briefing is intended to have you verify key and pertinent sources of information related to aircraft status, heading, and automation settings and modes. A checklist of items to include in your Awareness Briefing and an example Awareness Briefing is provided below:

Awareness Briefing Checklist:

- Identify Current Heading
- Identify Current Altitude
- State of Automation
    - Verify and describe automation mode settings
- Current source of navigation information
- Current routing from present position to destination
- Name of upcoming waypoint
    - Estimated Time Enroute to Waypoint
    - Distance to Waypoint
- Name and location of the following waypoint and any changes to flight route
- Verify engine instruments and systems displays
- Confirm fuel flow rate and fuel remaining
- Any questions

Example Awareness Briefing:

"We are currently flying heading 180 at FL350. The autopilot is currently engaged and flying the aircraft. The current modes of operation are NAV mode and altitude hold. We are tracking the GPS course based off of our flight management system. We are currently 35NM north of the Orlando VOR (ORL) and tracking directly to that waypoint. We are scheduled to pass over the VOR in 7 minutes. After passing the VOR, we will turn left to a heading of approximately 140 and join V159 southeast toward our destination of Miami while maintaining FL350. The next waypoint after Orlando is PRESEK intersection. Our engine instrument and system indicators are all functional and in the green. Fuel flow and amount of fuel remaining are accurate per our flight plan. Do you have any questions?"

Appendix B

Participant Instructions

Thank you for your participation in our study. In this experiment, you will be asked to fly the simulator on a specified flight route in VFR conditions.

Important: Please read all instructions before beginning the study!

- After you enter the simulator, program to the Early County Airport in Blakely, Georgia (KBGE) via the following routing: KGIF to KBIJ.
- During this experiment, fly the aircraft as you normally would, but do not worry about ATC communications nor airspace restrictions.
- When you are ready to depart, notify the lab assistant.
- Take off and join your course.
- Climb and maintain 4,500 feet MSL.
- Please direct any questions to the lab assistant.

Appendix C

Participant Post-Experiment Survey/Interview Questions

Instructions: Please answer the following questions. Your responses will be kept confidentially, and you may opt out at any time.

What is your age?___________________

Are you an ERAU pilot or a local pilot? _________________

What is your degree program (if applicable)?_______________

What is your total number of flight hours?_____________________

How many hours do you typically fly per year?_________________

What are the most common aircraft that you fly (manufacturer and model)?_________________

Which pilot certificates do you hold (check all that apply):

_____: Student Pilot

_____: Private Pilot

_____: Instrument Rating

_____: Commercial Pilot

_____: Airline Transport Pilot

_____: Multi-Engine rating

_____: Certified Flight Instructor

_____: Certified Instrument Instructor

_____: Multi-Engine Instructor

What is your gender (please circle)? Male Female Prefer Not To Say

Interview Questions:

Overall, describe how you felt your level of awareness was during the flight?

Would you say this level of awareness more, less or the same as what you would consider a traditional flight?

What are some techniques you commonly use to maintain awareness during flight?

Do you have any final thoughts or comments on your simulator flight?

Flight Status Questions:

1) Identify the current heading of the aircraft:__________
2) What was the current altitude in MSL?__________
3) What distance, in nautical miles, were you from the next waypoint?__________
4) What was the fuel flow in GPH?__________
5) What was the time remaining until your destination in hours:minutes?_________
6) What was the airspeed in KIAS?__________
7) What was the engine RPM?__________
8) What was your ground speed?__________
9) How many volts were being drawn on the main electrical bus?__________
10) How many gallons of fuel were remaining?__________

Collegiate Aviation Review International

Volume 37 | Issue 1 Peer-Reviewed Article #2

1-1-2019

The Impact of Flipped Learning on Student Academic Performance and Perceptions

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The purpose of this study was to explore if flipped learning has an impact on aviation students perceptions and academic performance in a human factors course. A total of 81 students from a large Midwestern university participated. The Course Evaluation Survey (CES) was used to measure student perceptions, while course exams were used to measure academic performance. To analyze the data, the researchers use paired sample *t*-tests, independent sample *t*-tests, and a MANCOVA. Findings show students in the flipped classroom did not perform better than the lecture classroom. In addition, students in the lecture group had significantly higher overall course satisfaction. These findings suggest students are familiar with lecture and changing the pedagogical approach is more nuanced, requiring students more time to adjust.

Recommended Citation:
Dusenbury, M.J. & Olson, M.R. (2019). The Impact of Flipped Learning on Student Academic Performance and Perceptions. *Collegiate Aviation Review International*, 37(1), 19-44. http://dx.doi.org/10.22488/okstate.19.100202

Located in a small rural community in Colorado is Woodland Park High School. Related to its remote location, student athletes are required to travel to other schools to compete in athletics; the consequence of this requirement is that students miss considerable class time for lengthy travel times. In response, Jonathan Bergmann and Aaron Sams, chemistry teachers at Woodland Park, decided to flip their classrooms. Bergmann and Sams (2014) define flipped learning as "…direct instruction delivered to the individual outside of class, and more strategic use of in-class time for group work and individualized attention" (p. xi). Their impression was that flipped learning was more engaging and that deeper learning occurred, asserting that flipped learning is a viable learning approach.

Woodland Park High School was not the only success story related to flipping the classroom. Clintondale High School, located in Detroit, Michigan, had high failure rates, many discipline issues, and a number of parental complaints. In 2010, the school's principal, Greg Green, decided that drastic change was needed. In 2011, Green flipped all freshman classes, and based on the success, flipped the classes in the entire high school in 2012. The results at Clintondale High School were as follows: failure rates dropped by 30%, discipline cases dropped 74%, and parental complaints virtually disappeared. Data clearly showed students at Clintondale High School responded to the pedagogical change of flipping the classroom (Green, 2012). Because of Woodland Park and Clintondale High School successes, flipped learning has gained national attention and is a growing part of the dialogue among educators at all levels. A survey of faculty by the Center for Digital Education and Sonic Foundry revealed that 29 percent are using the flipped classroom model, and 27 percent plan to use it within the next 12 months (Bart, 2013). Flipping the classroom is changing the national conversation regarding education. The shift from a teacher-centered to a student-centered classroom is underway.

Background

It is important to understand what a flipped classroom is before discussing the broader aspects and implications. The flipped classroom is:

> …a model of learning that rearranges how time is spent both in and out of class to shift ownership of learning from the educators to the students. In the flipped classroom model, valuable class time is devoted to higher cognitive, more active, project-based learning where students work together (*NMC Horizon Report*, 2015, p. 38).

Students arrive for class having watched the recorded lecture and completed the assigned material. During class time, students use their newly acquired knowledge actively, which gives them the opportunity to reinforce and apply the information. The key piece is not the particular activity selected in class; rather, it is that class time is student-centered and active. This broader understanding of learning leads to the two parts of flipped learning.

The Two Parts of Flipped Learning

Flipped learning combines the positive aspects of lecture with the benefits of active learning, which makes flipped learning effective and student-centered. The lecture addresses factual knowledge, while active learning promotes comprehension and application (Kavous Ardalan, 2008; McKeachie, 1990).

Lecture. Even as calls for more active learning have been recommended (Prince, 2004), studies such as Watts and Schaur's (2011) national survey of economists shows that direct instruction (lecture) remains the dominant method of instructional delivery. They examined four surveys from 1995 to 2005, and noted that direct instruction was the leading form of delivery (i.e., reported 83% of time spent lecturing). The lecture remains the favorite choice among faculty to deliver instruction in higher education.

The research shows lecture is a good way to transfer facts, yet inadequate when it comes to promoting discussion and deeper thought (Bligh, 1998). The purpose of lectures should be to acquire knowledge and facts, and then apply that knowledge by actively using it in the classroom or lab. It is not a question of whether lecturing is good or bad, but where and how it should be utilized (Burgan, 2006). Flipped learning connects the lecture to active learning, which promotes learning.

Active Learning. Chickering and Gamson (1987) brought active learning to the forefront when they listed active learning as one of the seven principles of good teaching in undergraduate education. A more recent call for active learning was made by The President's Council of Advisors on Science and Technology (PCAST) to engage students and increase retention rates (Olson & Riordan, 2012). The traditional paradigm in higher education has students sitting in large classrooms, listening to, and hopefully assimilating the knowledge and information the lecturer is presenting. Active learning shifts this paradigm by putting the student at the center of learning, not the instructor. This shift to student-centered learning in higher education makes learning more experiential, which facilitates higher level critical thinking. Active learning places learning in the hands of the students, and the educators become the guides.

Flipped learning connects the acquisition of knowledge and facts through lecture, to active learning in the classroom. Flipped learning is changing the way education is approached, and providing a new way to utilize the time-tested and popular approach to teaching, the lecture.

The popularity of the flipped classroom and body of research findings--albeit small and largely anecdotal--gives hope that this pedagogical approach may be a solution. Yet, as Millman (2012) says, "…no empirical research exists to substantiate its use, anecdotal reports by many instructors maintain it can be used at any education level…" (p. 86). This statement suggests that research must empirically validate that flipping the classroom improves student learning, and cultivates the development of critical thinking skills and dispositions. This gap in the literature was the impetus for this study.

The researchers attempted to answer two research questions:

1) Do students in a flipped learning course perform better academically than students in a lecture course?
2) Do students' perceptions of flipped learning change during the semester?

Flipped Learning

Flipped learning combines two learning approaches: lecture and active learning. The lecture gives faculty a method to demonstrate expertise to students, passing on valuable knowledge from their experiences. The problem is that the delivery of the lecture makes learning active for the lecturer, not the students. Students need to actively use this newly acquired information, exploring and hypothesizing, to facilitate comprehension and retention (Huba & Freed, 2000). Exploring and hypothesizing can lead to higher levels of learning, which is the goal of flipped learning. The flipped learning approach uses recorded lectures before class for factual information, and active learning during class to promote higher level learning. The use of these two approaches, in this sequence, has made flipped learning an exciting new teaching approach. Before exploring specific flipped learning research, it is helpful to understand the history of lecture and the resistance to move to more active learning teaching strategies.

Lecture

The lecture has been around since medieval times and has remained popular throughout the 20th century. The lecture has remained the dominant form of instruction, largely related to economics, and familiarity to educators, as described in the following two sections.

Economics. The popularity of lecture on college campuses is driven largely by economics. From a monetary, time, and effort standpoint, lecture provides substantial value. Undergraduate enrollment in higher education increased from 10.8 million in 1970 to 17.7 million in 2012 ("Fast Facts," n.d.). Along with increasing enrollments in higher education, state and local appropriations declined from a peak of 60.3 percent in 1975, to 30.4 percent in 2010 (Mortenson, 2012). The demand for resources, coupled with decreased funding, has made lecture the popular choice, based purely on economics. The issue of increasing enrollment and declining appropriations is not likely to improve. Sentiments nationally are that higher education should be affordable and accessible to every U.S. citizen. Some may question the effectiveness of lecture; however, economically, lecture makes sense, and economics is currently driving the conversation in higher education.

Familiarity. There is no nationally aggregated data to confirm lecture is still the most popular form of instruction; however, surveys in economics and math provide a lens that shows the majority of faculty in those respective disciplines favor lecture (Bressoud, 2011; Watts & Schaur, 2011). The lecture showcases faculties' expertise, providing students a way to explore topics on a level that they are not capable of on their own. Stunkel (1999) captures the power and beauty of the lecture: "at its best, a lecture is a critical, structured, skillful, thoughtful discourse on questions and findings, delivered by a person who knows what he or she is talking about" (p. 424). The lecture provides a way for faculty to demonstrate their expertise, on topics that may be difficult for students, by modeling their thought process.

The use of lecture because of familiarity is not only borne out of preference; it is also out of necessity. Faculty are working long hours not only teaching, but doing research and service as well. The workload requirements of the professoriate make it difficult to spend extensive time researching and instituting new teaching approaches in the classroom; therefore, faculty continue teaching using a method such as lecture, that is familiar to them; an approach they were likely on the receiving end of as a student, and now are delivering themselves (Ziker et al., 2014).

Active Learning

Although lecture remains popular, another teaching approach known as active learning is showing promise, yet the idea of active learning is not a new concept in higher education, as calls for it can be traced to the 1987 report by the American Association of Higher Education titled *Seven Principles for Good Practice*. The third of seven principles indicates learning should be active, and that the purpose of active learning is to promote interaction between students and faculty. This increased interaction is an essential component of active learning and critical to the overall intellectual and personal development of the students (Chickering & Gamson, 1987).

Prince (2004) provides a broad definition of active learning, "…any instructional method that engages the student in the learning process" (p. 223). In essence, this definition of teaching involves students in the learning process. This broad definition encompasses collaborative learning, cooperative learning, and problem-based learning. Unlike lecture, active learning connects teaching and learning, meaning students are processing the information as they learn the material, not listening passively.

Actively engaging students in the process of learning seems simple; yet, it is fraught with barriers, particularly in how faculty view their role. Education is rich in traditions, and as surveys indicate, lecture is a part of that tradition. Central to this tradition is the faculty perception that their role is at the front of the classroom, delivering "the lecture" to the students (Bonwell & Eison, 1991). The broader movement of active learning minimizes their expertise, effectively moving faculty to the side of the classroom. Change causes discomfort and creates anxiety. The long held tradition of faculty lecturing at the front of the classroom is being challenged, and this change can be a difficult adjustment, yet the evidence suggests higher education needs to change.

A review of the literature indicates the primary proponent of active learning is the Science, Technology, Engineering, and Math (STEM) fields. A meta-analysis conducted by Freeman et al. (2014) shows students in STEM courses who use active learning outperform traditional lecture courses in exam scores, and students were less likely to fail. The average effect size on exam scores was 0.47, falling just below what is considered large. Their findings validate an earlier meta-analysis that compared active learning to lecture and found similar effect sizes (Ruiz-Primo, Briggs, Iverson, Talbot, & Shepard, 2011). A key finding in their study was failure rates, and how they quantified those rates monetarily. Out of the 29,300 students in their analysis, 33.8% of lecture students failed courses, and 21.8% of active learning students failed courses. These course failures translated to a $3.5 million tuition savings to the students in active learning classes. These findings also demonstrate that students engaged in active learning achieve higher academically, are less likely to fail, and as a consequence, the cost is lower. Given these findings, active learning is an educational approach that faculty, administrators, and stakeholders can align with and support.

Lecture and active learning are well researched approaches supported by empirical evidence (Bligh, 1998; Freeman et al., 2014). Educators need to understand the value of each method as well as its weaknesses; combining lecture and active learning results in flipped learning.

Flipped Learning Research

Jonathan Bergmann and Aaron Sams are considered the pioneers of flipped learning by many (Ash, 2012; K. Fulton, 2012; K. P. Fulton, 2012; Schaffhauser, 2009), yet a search of the literature reveals that the basic principles of flipped learning have been around since the mid-1990s (Meibom, Sadler, Moses, & Litzkow, 1994). Studies in the 1990s evaluated active and passive forms of instruction using web-based lecture software and student perceptions of inverted learning, known as flipped learning today. Jonathan Bergmann and Aaron Sams popularized flipped learning with their successes at Woodland Park High School chronicled in their book: *Flipped Learning: Gateway to Student Engagement.* Educators have been using the idea of flipped classrooms for some time, moving direct instruction outside of class, allowing time in class to be active and student-centered.

While Woodland Park and other schools (e.g., Clintondale High School) experienced success with flipped learning, the body of academic peer-reviewed research is small. Bishop and Verleger (2013) conducted the first and only study to date that provides a synthesis of flipped learning studies. They made three observations from their review: studies focused on student perceptions, generally did not contain control groups, and did not adequately explain the conceptual and theoretical framework used in flipped learning. Therefore, a need existed to provide a theoretical framework for flipped learning and to determine empirically if students achieve higher academically. A thorough review of flipped learning was conducted to determine what has been studied, the methodology used in the studies, and the findings. The investigation uncovered two categories: student perceptions and academic achievement.

Student Perceptions. Students perceptions of the curriculum and teaching approaches may have a significant impact on their academic performance and intellectual development, and positive perceptions of flipped learning are essential to ensure successful student learning outcomes along with its continued growth (Ferreira & Santoso, 2008). Overall, the majority of studies found students preferred the flipped learning format, compared to lecture. Students' positive comments were: (1) they liked working with peers, (2) felt they learned more and were better prepared for practice, and (3) felt more self-directed when the class was over. Students disliked that: (1) the flipped class required more work than traditional lecture, (2) that class was a little crazy at times, and (3) some felt they were not being taught the material (Day & Foley, 2006; Franciszkowicz, 2009; Garver & Roberts, 2013; Gaughan, 2014; McLaughlin et al., 2014; Jennifer Moffett & Mill, 2014; Toto & Nguyen, 2009).

A small number of studies measured students' perceptions longitudinally; they found that students resisted the flipped format early in the semester, yet their views changed positively as the semester progressed. Overall, the students liked the recorded lectures, yet their perceptions of how they should be utilized changed as the semester progressed. Initially, students tried to use the videos to study; however, as the semester progressed, they found that the videos were better for introducing new material and did not work well for studying (Day & Foley, 2006; Mason, Shuman, & Cook, 2013).

Student preferences, not just learning outcomes, plays a role in how teaching approaches are viewed by students. Overall, students have a positive perception of flipped learning, yet some findings show faculty need to improve the course experience by better explaining what flipped learning is, and showing the students how to utilize the recorded lectures. Student perceptions of the teaching approach and course structure are an important consideration, when determining how to teach specific content. A negative view of the approach and structure of the course can impact student learning and development.

Student Achievement. The literature review on flipped learning revealed a limited number of studies that used some form of a control group. In some studies, researchers used control groups from different semesters and failed to control for aptitude (Grade Point Average). The quality and a small number of studies make it difficult to claim empirically that flipped learning leads to higher student achievement. Overall, findings showed that students had higher academic achievement in flipped learning classrooms (Day & Foley, 2006; Meibom et al., 1994; Jennifer Moffett & Mill, 2014).

Day and Foley (2006) found students in the flipped section had significantly higher grades than the lecture section. Students in the flipped section had statistically significant higher means scores on homework assignments, class projects, exams, and the final course grade. The results of this well-designed study show flipped learning can increase students' achievement, yet one study makes it difficult to claim flipped learning is a success.

A significant portion of the flipped learning literature consists of anecdotal claims and stories of how educators implemented the flipped learning approach into their classes. To move forward, educators need to build a body of scientific research that demonstrates students perform better academically in flipped classrooms, compared to traditional approaches.

Flipped learning is an exciting new teaching approach; however, there is a lack of empirical evidence affirming educators' anecdotal claims of increased student achievement and higher level learning. As flipped learning research moves forward, it will be vital to use control groups and provide more detailed methodology that goes beyond anecdotal claims of success, and move toward empirical evidence. This study aims to add to this body of research, and to build on past findings.

Methodology

This study utilized a convenience sample of students enrolled in a sophomore level human factors aviation course. The research design for this project was guided by the Day and Foley (2006) study and the Tiwari, Sai, So, and Yuen (2006) study. Day and Foley (2006) were the first to employ a longitudinal design in flipped learning research (Bishop & Verleger, 2013).

To provide a baseline for the study, a lecture section control group was utilized for the study. A basic pretest/posttest over the course of a 16-week college semester was used to determine if changes in student disposition were significant after exposure to the flipped learning treatment.

A total of 109 students participated across 16 weeks: 56 students in the flipped section and 53 in the lecture section. The students in the flipped learning section met once each week on Friday from 9-10:50 AM. The lecture section met two times per week on Mondays and Wednesdays from 1-1:50 PM.

To measure students' perceptions the Course Evaluation Survey (CES) was utilized. Some revision to the wording on CES were made to address cultural differences. It should be noted that the CES has been modified and used in various studies and settings, and is also referred to as the Course Evaluation Questionnaire (CEQ).

Course Evaluation Survey. The CES was created by Paul Ramsden to explore student perceptions of the quality of courses they had completed (Ramsden, 1991; Ramsden & Entwistle, 1981). Five constructs are "intermixed" within 24, five-point, Likert-type questions ranging from "strongly disagree" to "strongly agree." The five constructs examined by the CES are: teaching, goals and standards, assessment, workload, and skills. The final question on the CES, which is not part of a construct, asks a student to rate overall course satisfaction. The CES has been extensively used in higher education, in that over 50,000 university graduates have been administered the instrument (Ainley & Long, 1994).

Validity and Reliability of Instruments. An investigation of the literature showed the CES were valid and reliable instruments. A study conducted by Broomfield and Bligh (1998) validated the use of the CES by "…demonstrating satisfactory construct validity and reliability for the inventory" (p. 367). A recent study on flipped learning by Moffett and Mill (2014) used the CES (called the CEQ in their study) to measure student perception and reported a Cronbach Alpha of .83, indicating the instrument is consistent and reliable. A basic reliability analysis was conducted on the CES for this study and can be seen in Table 1.

Table 1

CES Reliability Analysis

Scale	*N*	Possible Range	Actual Range	*M*(SD)	Cronbach's Alpha
Pre-Test					
Teaching	76	1-5	2-4.83	3.84(.50)	.79
Goals	79	1-5	2.25-4	3.61(.34)	.74
Assessment	76	1-5	1.33-4.67	2.88(.81)	.82
Workload	76	1-5	1-4	2.40(.60)	.70
Skills	76	1-5	2-5	3.52(.59)	.86
Post-Test					
Teaching	79	1-5	1.50-5	4.13(.60)	.85
Goals	79	1-5	2.25-4	3.61(.34)	.73
Assessment	79	1-5	1.33-5	2.73(.72)	.53
Workload	79	1-5	1-3.75	2.30(.57)	.68
Skills	79	1-5	2-5	3.68(.65)	.86

Results

Research Question 1: Do students in a flipped learning course perform better academically than students in a lecture course?

Block Exam Analysis

Before analysis of the block exams and final exam started, the students GPA was tested to determine if differences existed between the groups. In addition, a brief explanation of how the exam was designed is provided, followed by the statistical results for exam 1, exam 2, and the final exam. A critical alpha value of .05 ($\alpha = .05$) was used to determine statistical significance.

GPA. To determine if GPA differences exited between the lecture and flipped groups, an independent samples *t*-test was conducted prior to analyzing the test scores statistically. Table 2 shows the results were not significant, indicating that the groups have similar GPAs. Regardless, GPA will be used as a covariate on all analysis in this section.

Table 2

Results of GPA Analysis

		N	*M*	SD	*M*diff	*t*	*df*	*p*
GPA					.03	-.161	79	.872
	Lecture	38	3.32	.69				
	Flipped	43	3.35	.86				

Exam Design. The exams used in this course were designed to measure student performance in four areas: their overall score, their knowledge level, their comprehension level, and their application level. Overall score is a traditional way to measure academic performance; however, to examine performance at a more granular level, the tests are designed based on the first three levels of learning in Bloom's Taxonomy. Guidance on constructing test questions based on Bloom Taxonomy was provided by a paper published by Allen and Tanner (2002). Due to this course being a 200-level university course, levels above application (analysis, synthesis, and evaluation) were not measured.

Block 1 Exam. A multivariate analysis of covariance (MANCOVA), that controlled for GPA, was used to determine if mean differences existed between the lecture and flipped sections on the Block 1 Exam. No statistically significant differences were found in the students academic performance based on a participants' grouping (lecture or flipped), F (4, 75) = 2.48, p > .05, partial η^2 = .158. Results are presented in Table 3.

Table 3

Block 1 Exam Results

Block 1 Exam	*N*	*M*	SD	*M*diff
Overall Score				4.68
Lecture	38	86.21	7.17	
Flipped	43	81.53	9.41	
Knowledge Score				.61
Lecture	38	12.03	1.15	
Flipped	43	11.42	1.65	
Comprehension				.35
Lecture	38	10.84	1.42	
Flipped	43	10.49	1.87	
Application				.39
Lecture	38	11.47	1.18	
Flipped	43	10.58	1.84	

Block 2 Exam. A multivariate analysis of covariance (MANCOVA), which controlled for GPA, was used to determine if mean differences existed between the lecture and flipped sections on the Block 2 Exam. No statistically significant difference was found in academic performance on the Block 2 Exam based on a participants grouping (lecture or flipped), F (4, 75) = .632, p > .05, partial η^2 = .033. Results are presented in Table 4.

Table 4

Block 2 Exam Results

Block 2 Exam	*N*	*M*	SD	*M*diff
Overall Score				1.27
Lecture	38	82.03	8.096	
Flipped	43	80.76	11.163	
Knowledge Score				.20
Lecture	38	11.87	1.19	
Flipped	43	11.67	1.39	
Comprehension				.39
Lecture	38	10.92	1.76	
Flipped	43	10.53	2.06	
Application				-.15
Lecture	38	9.92	1.38	
Flipped	43	10.07	1.84	

*Critical α = .05

Final Exam. A multivariate analysis of covariance (MANCOVA), that controlled for GPA, was used to determine if mean differences existed between the lecture and flipped sections on the Final Exam. No statistically significant difference was found in academic performance on the Final Exam based on a participant's grouping (lecture or flipped), F (4, 75) = .632, $p > .05$, partial $\eta^2 = .033$. Results are presented in Table 5.

Table 5

Final Exam Results

Final Exam	*N*	*M*	SD	*M*diff
Overall Score				1.67
Lecture	38	90.00	6.51	
Flipped	43	88.33	8.31	
Knowledge Score				-.16
Lecture	38	19.00	1.34	
Flipped	43	19.16	1.48	
Comprehension				.92
Lecture	38	13.18	1.43	
Flipped	43	12.26	1.92	
Application				.15
Lecture	38	12.82	1.59	
Flipped	43	12.67	1.87	

Research Question 2: Do students perceptions of flipped learning change during the semester?

To determine if the students perceptions changed during the semester, two statistical tests were used, an independent samples *t*-test, and a paired-samples *t*-test, to analyze the results of the CES survey given in week 4 (pre-test), and again in week 15 (post-test). The paired samples *t*-test was used to investigate if a student's perceptions changed within their group (e.g, lecture pre-test to lecture post-test), and the independent samples t-test was used to determine if a significant difference existed between the lecture and flipped groups (lecture versus flipped).

The results of the CES are broken down by their summed scales which are named: teaching, goals, assessment, workload, and skills. In addition to the scales, one question was asked regarding how satisfied a participant was with the course. The alpha level for all statistical tests was set at .05, and effect size was calculated for the results which rejected the null hypothesis (significant). Prior to running the paired sample *t*-tests, the file was split based on the grouping variable, lecture and flipped.

Overall Course Satisfaction

A paired samples *t*-test was conducted to examine if within group differences of the lecture and flipped groups course satisfaction variable. Table 6 shows the mean score comparison from the pre-test to post-test for both groups. Satisfaction scores in the lecture section increased significantly $t(36) = -2.707$, $p = .010$, indicating students were more satisfied with the lecture course at the end of the course when compared to the beginning of the course. A small to medium effect was calculatated ($d = .443$). Scores in the flipped section were not significant, however, the mean increased slightly from the pre-test to post-test.

Table 6

Overall Course Satisfaction Variable

Variable: Course Satisfaction	*N*	*M*	SD	*M*diff	*t*	*df*	*p*	*d*
Lecture				0.35	-2.707	36	.010	-.443
Pre-Test	37	3.95	.62					
Post-Test	37	4.30	.62					
Flipped				.11	-.644	37	.524	
Pre-Test	38	3.92	.85					
Post-Test	38	4.03	.94					

CES Constructs Analysis. A paired samples *t*-test was conducted to determine if mean differences existed within the teaching variable. The results, summarized in Table 7, show that lecture and flipped sections teaching scale was significant. The means in both groups increased from the pre-test the post-test, indicating the students felt that the teaching had improved at the end of the semester. Evaluation of effect size on the teaching variable shows the flipped section had a small mean change ($d = .35$) while the lecture section had a medium change ($d = .67$).

Table 7

Teaching Variable

Variable: Teaching	*N*	*M*	SD	*M*diff	*t*	*df*	*p*	*d*
Lecture				.36	-4.019	36	.000	-.667
Pre-Test	37	3.79	.36					
Post-Test	37	4.14	.51					
Flipped				.23	-2.071	37	.045	-.347
Pre-Test	38	3.90	.61					
Post-Test	38	4.13	.69					

A paired samples *t*-test was run to examine the within group mean differences of the lecture and flipped groups for the goals and standards variable. The results, summarized in Table 8, show a significant difference in the lecture and flipped sections. The overall mean decreased from pre-test to post-test in both groups, which indicates that the students felt the goals and standards were less clear as the semester progressed. Effect size evaluation indicates the mean change for lecture was medium for both lecture and flipped sections.

Table 8.

Goals and Standards Variable

Variable: Goals and Standards	*N*	*M*	SD	*M*diff	*t*	*df*	*p*	*d*
Lecture				-.24*	3.121	36	.004	.585
Pre-Test	37	3.87	.50					
Post-Test	37	3.63	.21					
Flipped				-.45*	4.342	37	.000	.720
Pre-Test	38	4.07	.60					
Post-Test	38	3.61	.42					

*A negative number indicates a decrease from the pre-test to post-test score

A paired samples *t*-test was conducted to examine the within group differences of the lecture and flipped groups assessment scale. The results, summarized in Table 9, show no significant differences from pre-test to post-test for the lecture or flipped sections.

Table 9

Assessment Variable

Variable: Assessment	*N*	*M*	SD	*M*diff	*t*	*df*	*p*	*d*
Lecture				-.21*	1.419	36	.164	
Pre-Test	37	2.99	.82					
Post-Test	37	2.78	.83					
Flipped				-.13*	0.965	37	.341	
Pre-Test	38	2.77	.81					
Post-Test	38	2.64	.59					

*A negative number indicates a decrease from the pre-test to post-test score

A paired samples *t*-test was conducted to examine the within group mean differences of the workload variable. The results, summarized in Table 10, show no significant differences from pretest to posttest for the lecture or flipped sections.

Table 10

Workload Variable

Variable: Workload	*N*	*M*	SD	*M*diff	*t*	*df*	*p*	*d*
Lecture				-.16*	1.508	36	.140	
Pre-Test	37	2.51	.54					
Post-Test	37	2.35	.56					
Flipped				-.08*	0.673	37	.505	
Pre-Test	38	2.30	.64					
Post-Test	38	2.22	.60					

*A negative number indicates a decrease from the pre-test to post-test score

A paired samples *t*-test was run to examine the within group differences of the lecture and flipped groups skills variable. The results, summarized in Table 11, show a significant difference in the lecture group, with the overall mean increasing from pre-test to post-test, indicating that the students perceived their skills in problem solving, planning, and working within a group, improved as the semester progressed. Effect size calculations show a small mean change (d = .37).

Table 11.

Skills Variable

Variable: Skills	*N*	*M*	SD	*M*diff	*t*	*df*	*p*	*d*
Lecture				.20	-2.245	36	.031	-.368
Pre-Test	37	3.56	.48					
Post-Test	37	3.76	.53					
Flipped				.07	-.750	37	.458	
Pre-Test	38	3.50	.68					
Post-Test	38	3.57	.73					

Group Differences Results for the CES

CES Results. To begin the between groups analysis of lecture versus flipped sections, a delta (Δ) value was calculated for the pre-test to post-test score for the lecture and flipped groups, creating a new variable.

X_1=pretest scores
X_2=posttest scores
D (Δ) =X_2-X_1
(e.g. Lecture X_1 – Lecture X_2 = (Δ) D)

The difference score was then used to determine if between group differences existed between the lecture and flipped section for the CES overall score and five scales.

An independent samples *t*-test was conducted to determine if differences in mean scores on the CES existed between the lecture and flipped groups. Table 12 shows a comparison between the lecture and flipped group for the overall score and five scales. The results show there is not a significant difference between the lecture and flipped groups delta scores for overall course satisfaction, teaching, goals and standards, assessment, workload, and skills.

Table 12.

Group Differences for the Course Evaluation Survey

Variable	*N*	*M*	SD	*M*diff	*t*	*df*	*p*	*d*
Overall Course Satisfaction				.24	-1.175	73	.244	
Lecture	37	.35	.79					
Flipped	38	.11	1.01					
Teaching				.14	-.95	73	.346	
Lecture	37	.36	.54					
Flipped	38	.22	.67					
Goals and Standards				.22	-1.67	73	.100	
Lecture	37	-.24	.47					
Flipped	38	-.46	.65					
Assessment				.07	.389	73	.698	
Lecture	37	-.20	.87					
Flipped	38	-.13	.81					
Workload				.09	.591	73	.557	
Lecture	37	-.16	.65					
Flipped	38	-.07	.66					
Skills				.14	-1.156	73	.251	
Lecture	37	.20	.55					
Flipped	38	.06	.50					

Student Comments on Flipped Learning

Positive Comments. Students were asked a simple open-ended question on the week 15 CES: what are some good things about the course? Several comments centered on how much the flipped format promoted discussion, increased collaboration, the ability to ask frequent questions, and that they generally were more engaged:

> *I like the set up of the class. Help to keep student engage.*
>
> *I loved the flipped setting. It was always great to be able to collaborate in groups and share ideas. It was also nice to be able to clear up misunderstanding by talking about what each of us had learned. Additionally the "ask a question" lecture style was very helpful to me since it answered my questions and sometimes questions I didn't even know I had.*
>
> *Overall, I enjoyed the course. To be honest, staying motivated to actually watch the videos during breaks was difficult, but I think the lecture videos was a really good idea. This way, we could have discussions about the material in class and work on things we didn't understand. I really enjoyed the flipped course method!*

I thought the class periods were very informative, I liked that students got direct feedback to questions the didn't understand from the lectures. I also thought that working through the problems and situations as a group at a table was beneficial to my learning.
We got to work in groups which has helped me get a better understanding of the information when I don't understand the teacher.

The overall materiel was very interesting. I liked being able to review specific case studies to be able to match it to the information that we were learning. I also liked that everything was available online. If I missed class for some reason, I didn't feel like I missed a bunch because I could view the lesson online.

The emphasis on group work and discussion, the new classroom format. / The WSQ, although it seemed like busy work at times really does help understanding of the material.

It was very easy to ask questions. Any time i needed help I could just ask the teacher because of how the discussion orientated the class was.

I think that this course was a great change. i think that the lecturing is forcing students to memorize and forget when we should be applying these things. i think that this course was very good at showing the students the power that they have in a situation. assertive statements are a huge thing that i think to many do not have a good grasp of.

The flipped classroom environment made us more engaged and made us apply our short learned knowledge as opposed to sitting through a lecture.

I really liked the flipped classroom setting. I absolutely hate lectures and would rather be hands on learning. I think the video lectures outside of class were nice because I could watch them on my own time.

I really enjoyed the open atmosphere in the class and the fact that you could ask anything. I enjoyed doing the homework outside of class and then discussing it in class, I feel like that really had a positive impact on retention.

The teaching method in the way that the lectures would be entirely online and the whole class as one would come to discuss the lectures in class. The muddy points helped make misunderstandings clear and really helped in the note taking process.

I liked the group aspect of interacting with the content of the course and not just sitting in front of a lecture. The two hours of class definitely seemed to go by relatively quickly.

The conversational feel of the lectures both online and in class are great for developing ideas and comprehending things discussed. The active recall of information using the whiteboards as a group are effective in assisting the processing of information learned. / The WSQ sheets help to extract the key information and perspective from the video lectures.

Negative Comments. On the week fifteen CES survey students were asked a simple open ended question: what are some things you dislike about the course? While students in general had positive feedback (based on CES and qualitative responses), several identified and spoke to some areas of concern:

Several negative comments spoke to the frequency (interval) of the class and how it may have affected their retention:

> *I would prefer to have one lesson for each lecture rather than long lecture with two lessons.*
>
> *Only once a week will be too easy for students lose track and memory about what we learned last week. If can change this class to half semester and maybe 2 days a week it will be better for student.*
>
> *That it is once a week on Fridays, i feel that i missed some important things due to friday holidays.*
>
> *It is only once a week, by the time I get to the next class a week later, I have already forgotten some of the things from the previous week.*
>
> *The uncertainty of my grade. Only having it once per week makes it harder to retain the information.*

The students made several comments regarding the difficulties they faced with the size and layout of the room:

> *The room was OK. I really had to move around to face the teacher.*
>
> *The size of the room. I feel the same class structure on a smaller scale would work better for myself. / The videos are very in depth but I find them harder to pay attention to than a traditional lecture.*
>
> *I felt like the class was too separated. The room was really big, and the tables felt really spaced out. Also, When ever we had to talk to the class, we had to spend a lot of time trying to pass around the microphone, which took up class time. Last thing was that because we were all sitting in different directions (unlike a lecture hall where you maintain constant eye contact with the professor), I didn't feel as focused as I wouldve like to. I sometimes found myself going online when there was a lot of downtime (which also falls back on the trouble with the microphones), instead of focusing on the discussions. I think just over all, the class just needs to be streamlined so that there is less down time.*

A few participants commented that they did not like the flipped format, mainly because they preferred the lecture format, or felt it was difficult to prepare for exams:

> *Honestly, I wasn't a huge fan of the flipped classroom style. I think because I am so used to lecture style classes, I have learned to learn in a specific way from those courses, and this course changed that. I was able to do as well as I wanted to(hopefully) however, so I think the class style works.*
>
> *I did not like that there was not much help when it came to test preparedness. All we were given was packets that we were supposed to gain all of our knowledge from. There was nothing available to actually practice and apply the knowledge that we had. Having quizzes was helpful, but did not really help apply what we learned. It just tested our knowledge.*

Summary

Two research questions were addressed, which looked at student perceptions and academic performance. The results addressed the within group differences (e.g, lecture pre-test to lecture post-test), and the between group differences (e.g, lecture versus flipped). Provided is a detailed discussion of the results, implications for practice, and future research.

Research Question 1: Do students in a flipped learning course perform better academically than students in a lecture course?

This part of the study was designed to test if students performed better academically in the flipped group versus the lecture group. No statistical significance was found between groups on their overall scores, their knowledge level, their comprehension level, or their application level.

Findings. Although the results were not significant, there may be two explanations for why the flipped group failed to outperform the lecture group academically: intervals and the students lack experience with the flipped format. The concept of spaced learning intervals is important to understanding the results of this study, specifically on this question regarding academics. Time and frequency of the class meetings, which is dictated by a multitude of factors, can significantly impact learning. This class is a two credit course, which means the class usually meets two times per week for one hour; however, due to scheduling issues in the SCALE-UP (Student-Centered Active Learning Environment) classroom, the flipped section needed to be scheduled one time per week for two hours. On the surface, this scheduling difference seems like a minor detail. Nonetheless, the researcher believes that this variable had a significant impact on the academic results of this study.

Discussion. Why does the learning interval matter so much? The lessons in the flipped classroom, within each block of learning, are designed to build on each other, meaning the students need to master the current knowledge and retain it to be successful for the next lesson because they will be actively using the material in class. At one point in the semester, due to the holiday schedule, the class did not meet for three weeks; however, the time allotted in class also prevented a significant amount of review in-class. Qualitative comments from students in the flipped class regarding this issue follow:

> *only once a week will be too easy for students lose track and memory about what we learned last week. If can change this class to half semester and maybe 2 days a week it will be better for student.*

> *it is only once a week, by the time I get to the next class a week later, I have already forgotten some of the things from the previous week.*

> *The uncertainty of my grade. Only having it once per week makes it harder to retain the information.*

The flipped learning model requires the students to be more self-directed, meaning the burden to motivate themselves to study and review the course material falls primarily in their hands. Having to be more self-directed, coupled with a class that meets only once a week, required internal motivation skills some students may not have had, as this comment suggests:

> *It is harder to motivate myself outside of class, so while watching the video lectures i would often get side tracked and wouldnt fully understand what was being discused. I would also like to see the slide in the video lectures available for use so we are able to go back and look at deffinitions and theroies with out having to rewatch the videos.*

The qualitative comments showed that students struggled with the class only meeting once per week, and that they found staying motivated in the flipped format difficult. A large body of research, summarized in Thalheimer (2006) *Spacing Learning Events Over Time: What the Research Says,* covers spaced learning in detail; and while outside the scope of this study, this research should be applied to the flipped learning model.

Another issue was that 87% of students were experiencing the flipped learning teaching design for the first time, which may have caused frustration and anxiety. The literature speaks to some frustration students feel with the flipped classroom (Day & Foley, 2006), along with the qualitative comments of this study. Student comfort level in the classroom is essential to their success, and being in a large active learning space for the first time may have impacted their learning. The students made several negative comments regarding the class; following is an example:

> *I felt like the class was too separated. The room was really big, and the tables felt really spaced out. Also, When ever we had to talk to the class, we had to spend a lot of time trying to pass around the microphone, which took up class time. Last thing was that because we were all sitting in different directions (unlike a lecture hall where you maintain constant eye contact with the professor), I didn't feel as focused as I wouldve like to. I sometimes found myself going online when there was a lot of downtime (which also falls back on the trouble with the microphones), instead of focusing on the discussions. I think just over all, the class just needs to be streamlined so that there is less down time.*

Acclimating to a new space can take away from the educational experience. Conducting the research, this phenomenon was observed first hand in the classroom. The students had a hard time tracking me if I was speaking, and they genuinely disliked that the size of the classroom required the use of microphones to ensure others could hear them when they were speaking.

Research Question 2: Do students' perceptions of flipped learning change during the semester?

This part of the study was designed to test within-group differences, and between-group differences in students' perceptions as the semester progressed. The results of the CES showed that the students in the lecture section had higher overall course satisfaction and a significant increase in perceived skills over the semester, and both groups rated teaching and goals significantly higher on the post-test. No significance was found on the between groups analysis to substantiate the within groups findings.

Findings. Overall course satisfaction increased significantly from pre-test (M=3.95) to post-test (M=4.14) in the lecture group, indicating that students enjoyed the class more as the semester progressed. Also, scoring on the teaching scale significantly increased in the lecture group from pre-test (M=3.79) to post-test (M=4.14). The combination of these two significant results may indicate that the faculty member teaching the course had the largest impact on the students' overall course satisfaction in the lecture group; the literature validates this finding and claim, as a high score on the teaching scale has the highest correlation with overall course satisfaction (Ainley & Long, 1994). Faculty in a lecture setting are at the center of the classroom, making it logical that they will have a significant impact on course satisfaction. On the other hand, faculty in a flipped classroom are not the focal point, which may account for a slightly lower satisfaction score.

Discussion. While finding that the students had a higher overall satisfaction in the lecture group, and not in the flipped group, may be somewhat surprising; a possible explanation will be proposed. The lecture groups participants had a higher level of satisfaction overall and in the teaching variable also. In the flipped learning environment, the faculty member is, as Burgman (2006) states "a guide by the side rather than a sage on the stage" (n.p). When compared to lecture, this means that the faculty role is limited, being the source of less satisfaction. Another issue that may have affected the lower satisfaction scores in the flipped section is that only 5 of the 43 participants indicated they had previously taken a flipped course. A small number of studies that measured students' perceptions longitudinally (Day & Foley, 2006; Mason et al., 2013) found that there was some resistance to the flipped format, specifically at the start of the semester. Students who are thrust into a flipped style active learning classroom, where the instructor takes a smaller role, may feel some uneasiness, which may decrease over the semester, nonetheless, it may not be enough time for a complete adjustment. It is worth noting that the pre-test score for the lecture section and the flipped section were high M=3.95 and M=3.92 respectively, which indicates that the students generally "agreed" with the statement "Overall, I was satisfied with the quality of this course."

Conclusions. Faculty will continue to have a significant impact on the students' course satisfaction and academic performance regardless of the teaching approach. As higher education moves to more active learning techniques, faculty and administrators would be wise to remember that students who are new to the course delivery technique (as the majority were in this research) may experience more dissatisfaction with the course.

Future research would benefit by focusing more on the students' perceptions of flipped learning prior to starting the academic material. In addition, researchers should carefully consider intervals when planning their experiments. Active learning will continue to be a growing part of delivering higher education, faculty would be benefit from a larger body of scientific research on flipped learning.

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Collegiate Aviation Review International

Volume 37 | Issue 1 Peer-Reviewed Article #3

1-1-2019

Extraction of Zinc from Airport Stormwater Runoff using Oyster Shells

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Zinc (Zn) in stormwater runoff have been found to be highly toxic to aquatic ecosystems. A pilot program was evaluated for the removal of Zn levels from stormwater runoff at a west coast airport facility showing high levels of Zn runoff in the stormwater drainage. The objective of this research was to evaluate the effectiveness of the pilot program by reviewing three aspects of the stormwater runoff: 1) water sampling from influent and effluent roof runoff; 2) whether Zn particles were absorbed into the oyster shell fragments; and 3) whether Zn particles were attached to fragmented oyster shells and/or compost materials. The use of fragmented oyster shells mixed into compost and sand served as a medium for the remediation of Zn from stormwater runoff from unpainted galvanized hangar roofing. Influent and effluent water samples determined the effectiveness of an oyster medium in the removal of Zn levels. Data obtained from the influent water samples showed excessive amounts of Zn particles in stormwater, whereas the effluent levels showed a capture rate of > 99% of Zn from the stormwater system. No signs of Zn particles were found inside the fragmented oyster shells, nor were there an abundant amount of Zn particles found in the other medium.

Recommended Citation:
Long, T. & Zou, L. (2019). Extraction of Zinc from Airport Stormwater Runoff using Oyster Shells. *Collegiate Aviation Review International*, 37(1), 45-58. http://dx.doi.org/10.22488/okstate.19.100203

The objective of this study was to evaluate the effectiveness of a pilot program being done at the Snohomish County Airport (herein referred to as "the Airport" or "Airport") with their consultant, Landau Associates Inc., Edmonds, Washington, to lower Zn effluent to a level below the Washington State Department of Ecology benchmark of 117 µg/L. This study evaluates the effectiveness of the filtering system that Landau Associates Inc. designed to capture or extract Zn from stormwater before it can enter the watershed. To do this, there were three elements of the pilot program that were evaluated: 1) whether tests from influent and effluent showed a decrease in Zn levels to an acceptable level; 2) if the Zn penetrated the fragmented oyster shells; and 3) if Zn was captured within all the medium or the fragmented oyster shells alone.

The Airport is situated on 1,315 acres of land and is located 30 miles north of downtown Seattle, six miles southwest of Everett, Washington. The Airport is less than one mile from the Puget Sound. According to the airport master record, the Airport currently has approximately 524 based aircraft and 108,087 operations over a 12-month period ending January 1, 2018. This airport is classified as a reliever airport under the National Plan of Integrated Airport Systems (NPIAS). Runway 16R/34L is the primary runway with an orientation to the north/south. The runway is 9,010 feet long by 150 feet wide and has a Cat I ILS approach. The secondary runway is 16L/34R and is 3,004 feet long by 75 feet wide. The airport does have a third runway 11/29 with an orientation to the east/west. Runway is 4,504 feet long by 75 feet wide; however, the runway has been closed indefinitely. The airport is a certified FAR Part 139 airport and is home to The Boeing Company B747, 767, 777, and 787 aircraft manufacturing plants. Aviation Technical Services (ATS) is a Maintenance Repair Operation (MRO) located at the south end of the airport. The MRO performs maintenance and inspections on airlines. The Airport has a total of 326 general aviation hangars of all sizes located in the central and east sides of the airport, as well as six privately owned condominium T-hangars on the southeast side of the airport.

Literature Review

"A common use for zinc is to coat steel and iron as well as other metals to prevent rust and corrosion; this process is called galvanization" (Roney, Smith, Williams, Osier, & Paikoff, 2005, pp. 1-2). Airport facilities commonly have unpainted, galvanized corrugated metal hangar roofing, and over time, weathering and rain remove fine Zn particles from the galvanized metal, entering storm drains and flowing into streams and rivers. Good's (1993) study of roof runoff of metals and aquatic toxicity in stormwater found extremely high Zn concentrations in stormwater runoff from unpainted, galvanized roofing. The high levels of Zn discovered in the stormwater runoff were found to be very toxic to rainbow trout (Good, 1993). Irwin, VanMouwerik, Stevens, Seese, and Basham (1997) looked at Zn environmental hazards and found "in western watersheds that are affected by metals, particularly copper and zinc, that fish kills were associated with runoff and rainstorm events" (p. 7). The Seattle-Tacoma International Airport has tested a radial-flow filtration container to reduce stormwater Zn from airport buildings, resulting in a 60-90% reduction of dissolved Zn from leaf compost medium filters (Noling, 2004). Elevated Zn levels also have been discovered at other airports that have unpainted, galvanized hangar roofing such as the Snohomish County Airport in Everett, WA. (A. Rardin, personal communication, December 19, 2016).

Köhler, Cubillas, Rodríguez-Blanco, Bauer, and Prieto (2007) documented the effect of the size of fragments of calcium carbonate shells on their capacity to uptake, or absorb, dissolved metals. Their study found a progressive increase in the removal rate of cadmium, as well as Zn, as the shell size fraction decreased. From the Köhler et al. (2007) study, we expected to see high levels of Zn in the influent to the treatment tanks reduced by the incorporation of fragmented oyster shells in the treatment medium. The research team did not know if there would be any removal of Zn using the medium materials without the fragmented oyster shells.

Analyses of samples collected in accordance with the National Pollutant Discharge Elimination System (NPDES) permit for this site indicated elevated Zn levels greater than 14,000 µg/L in storm runoff from the east condominium hangars. The Washington State Department of Ecology - Industrial Stormwater General Permit (ISGP) Zn benchmark value is 117 µg/L (Bartlett, 2015).

Materials and Methods

Two of the six condominium hangars (C-17SE and C18-NE) at the Airport were used in the pilot program. Both hangars have unpainted, galvanized roofing panels. The partial treatment area for C17-SE is ~2,850 square feet (one-fourth the area of the total hangar roof surface), and for C18-NE ~1,476 square feet (one-fourth the area of the total hangar roof surface). Rainwater and weathering remove Zn particles from the roofing panels, which are then captured within the medium (Polka & Ninteman, 2015). Two types of tanks, cylindrical and rectangular, were used in the pilot program. For this research, only the medium from the cylindrical tanks were sampled. Figure 1 displays the location of the east condominium hangars in relationship to the surrounding area.

Existing rain gutters and modified downspouts were used on the hangars being evaluated in the pilot program. Large plastic tanks were then placed under the drain spouts and a French drain was inserted at the bottom of each tank. A treatment medium (consisting of 25% fragmented oyster shells, 15% compost, and 60% sand) fills the tank to within 17 inches from the top. This gap provided enough space in each tank to prevent water from overflowing as the water seeped through the underlying medium. Water samples were collected from the tanks three times in 2016 and twice in 2017 to determine the Zn levels in the influent and effluent from the tanks.

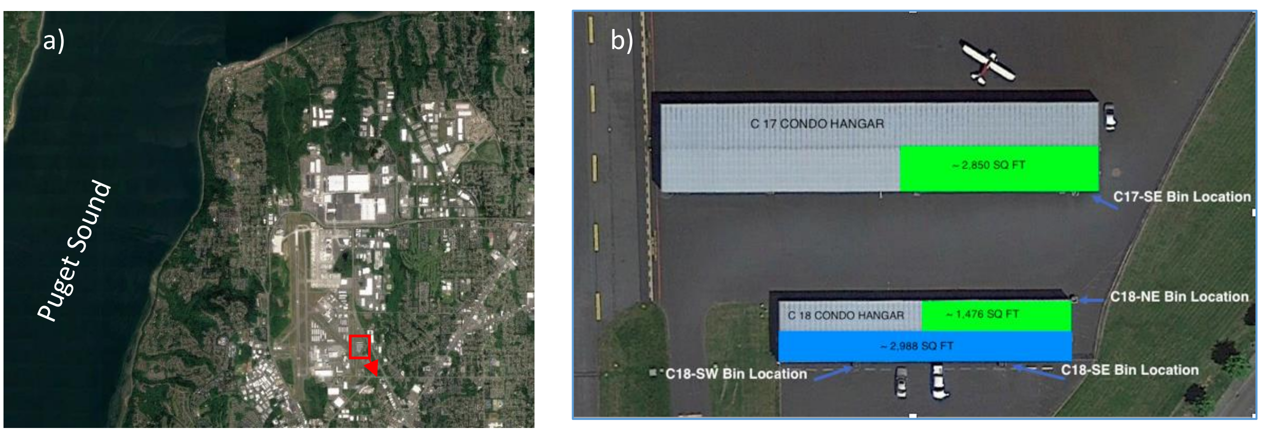


Figure 1. (a) Photo from Google Earth showing the location of Paine Field east condo hangars including watershed direction, (b) east condo hangars C-17 and C-18.

Treatment Tanks

Two cylindrical tanks are inside the Airport Operations Area; each have a capacity of 210 gallons. These tanks receive roof runoff from the southeast section of hangar C17 (known hereinafter as C17-SE) and the northeast section of hangar C18 (known hereinafter as C18-NE), respectively. Samples were collected from these tanks for evaluation in the University laboratory.

Two rectangular tanks outside the Airport Operations Area have a capacity of 276 gallons each. These tanks receive roof runoff from hangars C18-SE and C18-SW. Only water samples were collected from these tanks.

After the rainwater seeps through the medium in each tank, it then drains out of the French drain directly into storm drains. Stormwater from the east condominium hangars flows off airport property into the Swamp Creek drainage basin, which in turn feeds Lake Washington.

Figure 2(a) shows the cylindrical tank located at hangar C18-NE. Figure 2(b) is a typical view peering into the tank from the top, displaying the two areas (inside and outside sections) from which medium samples were collected, and later analyzed in the laboratory. A sample of fragmented oyster shells was provided to the researchers to be used to establish the starting level of Zn on the shells before they were used as part of the medium in the tanks.

Figure 2. (a) The cylindrical tank for C18-NE being tested. (b) Locations where samples were collected.

The Airport will replace the treatment medium when Zn levels in the effluent samples start to rise above the levels in previous quarterly samples. The medium used in this pilot study is expected to last up to three years (A. Rardin, personal communication, December 19, 2016).

Results and Discussion

Analysis of samples of stormwater runoff both before (the influent) and after (the effluent) water had filtered through the treatment medium indicated the effectiveness of the medium to remove total Zn from the water. The fate of the Zn removed from the inflowing stormwater was explored by analyzing samples of the treatment medium as well as subsamples of its various components - the oyster shells, the compost, and the sand.

Analysis of Water Samples

Water samples were collected from the cylindrical treatment tanks at hangars C-17 SE and C-18 NE by Landau Associates Inc. on January 12, May 19, and October 13, 2016, and on April 7, and October 23, 2017. The samples were placed in an ice chest, packed in ice, and delivered to an ALS Environmental Group Laboratory at a temperature of ~3.9°C. ALS Environmental used EPA Method 200.8 to test for Zn levels. This method provides for the determination of trace elements in waters and wastes by inductively coupled plasma-mass spectrometry testing method (Long, Martin, & Martin, 1990).

The Certificate of Analysis from ALS Environmental shows the results of the analyses of the influent (untreated runoff) and effluent (water that has passed through the treatment medium) samples for Zn in the stormwater for the period of January 2016 through October 2017 (Bagan, 2016), and (Tables 1 and 2).

The large increase in total Zn levels in samples collected on April 7, 2017, at C18-SW and C17-SE could not be explained. Record rainfall occurred between October and April, but there were no large increases in Zn levels in samples from either of the other two remaining tanks to indicate that the increased rainfall was the cause. Inspections of the roof drainage systems to the ground tanks and of the roofing itself indicated nothing out of the ordinary that would explain the higher Zn levels, although roof degradation in those areas may have been a contributing factor (A. Rardin, personal communication, May 9, 2017).

The NPDES permit for Snohomish County Airport specifies only total levels of Zn; therefore, only the total Zn was evaluated in this study. Results of the water analyses show a >99% reduction in total Zn to a level well below the Washington State EPA (WSEPA) benchmark value for Zn of 117 ug/L (micrograms per liter).

Table 1

Results of Analyses for Zn in Samples of Stormwater Runoff at Hangar C-17 SE

Date	C17-SE (Total Influent Zn) *(µg/L)*	Washington State EPA Benchmark for Zn *(µg/L)*	C17-SE (Total Effluent Zn) *(µg/L)*	Percentage Zn Removed
01/12/16	8,000	117	17.0	99.7875%
05/19/16	7,000	117	7.3	99.8957%
10/13/16	7,100	117	2.8	99.9605%
04/07/17	18,000	117	18.0	99.9000%
10/18/17	9,600	117	7.2	99.9250%

Influent samples are of untreated water as it runs off the hangar roof. Effluent samples are of the water after it has seeped through the treatment medium, but prior to entering the stormwater drainage system.

Table 2

Results of Analyses for Zn in Samples of Stormwater Runoff at Hangar C18-NE

Date	C18-NE (Total Influent Zn) *(µg/L)*	Washington State EPA Benchmark for Zn *(µg/L)*	C18-NE (Total Effluent Zn) *(µg/L)*	Percentage Zn Removed
01/12/16	10,000	117	19.0	99.8100%
05/19/16	6,200	117	8.3	99.8661%
10/13/16	6,200	117	6.2	99.9000%
04/07/17	11000	117	25.0	99.7727%
10/18/17	12,000	117	12.0	99.9000%

Analyses of effluent samples collected from two rectangular tanks at hangars outside the airport operations area, C-18 SW and C-18 SE, also showed a >99% efficiency in removal of Zn from the hangar roof runoff (Tables 3 and 4).

Table 3

Results of Analyses for Zn in Samples of Stormwater Runoff at Hangar C18-SW

Date	C18-SW (Total Influent Zn) *(µg/L)*	Washington State EPA Benchmark for Zn *(µg/L)*	C18-SW (Total Effluent Zn) *(µg/L)*	Percentage Zn Removed
01/12/16	14,000	117	13.0	99.9071%
05/19/16	7,300	117	3.5	99.9520%
10/13/16	8,200	117	1.25	99.9847%
04/07/17	52,000	117	5.3	99.9898%
10/18/17	14,000	117	9.0	99.9357%

Even though the analyses of influent samples collected at hangars C17-SE and C18SW on April 7, 2017, showed extremely high concentrations of Zn (Tables 1 and 3), the analyses of the effluent samples indicated the efficiency of the filtering medium (≥99%) in removing the Zn from stormwater runoff.

Table 4

Results of Analyses for Zn in Samples of Stormwater Runoff at Hangar C18-SE

Date	C18-SE (Total Influent Zn) *(µg/L)*	Washington State EPA Benchmark for Zn *(µg/L)*	C18-SE (Total Effluent Zn) *(µg/L)*	Percentage Zn Removed
01/12/16	2,700	117	8.8	99.6740%
05/19/16	7,300	117	1.25	99.9828%
10/13/16	8,700	117	1.25	99.9856%
04/07/17	6,000	117	3.6	99.9400%
10/18/17	12,000	117	11.0	99.9083%

Analyses of Treatment Medium Samples

To determine the fate of the Zn removed from the stormwater runoff, samples of the treatment medium were collected for analysis. The samples were collected (by the senior author) from the treatment tanks at hangars C17-SE and C18-NE with a plastic spoon (to avoid metal contaminating the samples) and placed in plastic laboratory-provided sample bags. The samples were frozen and remained frozen until analysis at the University laboratory. At the laboratory, subsamples of the various components of the treatment medium were then prepared for analysis using the Optima 8000 Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) and (or) Hitachi S-2600N Scanning Electron Microscopy with an Energy Dispersive X-Ray (SEM & EDX) technique.

ICP-OES is an analytical tool that can identify and quantify the elements present in a sample at concentrations down to parts-per-billion levels. A more qualitative method, SEM & EDX, allows the evaluation of the distribution and binding of metal ions on the surface of a sample. The scanning electron microscopy focuses a narrow beam of electrons on the sample to produce an image of the surface structure at the nanoscale. The EDX coupled with SEM characterizes the chemical composition within the SEM image and provides more quantitative elemental mapping of the sample surface.

Three test runs were made of 1-gram subsamples of each of the treatment medium samples collected from the two treatment tanks. Thus, six analyses were made on samples from each tank, three on the sample from the inside section of each tank, and three on the sample from the outside section of each tank (Figure 1(b)). The ICP-OES analyses were based on the Standard Reference Material 2781 for Domestic Sludge specified by the National Institute of Standards and Technology (NIST) (2015). The results of those analyses are shown in Tables 5 and 6.

A fresh specimen of the oyster shell fragments that were used in the treatment medium was obtained from the airport maintenance department. A sample of the fragments, which ranged in size from 1 mm to 20 mm, were then prepared for analyses in triplicate by ICP-OES methods. The results of those analyses – the concentrations of Zn in the shells alone (the control specimen) – represented the base level of Zn in the shells. These initial Zn levels in the shells could then be subtracted from those in the treatment medium samples to determine the “true” amount of Zn that was removed from the influent stormwater by filtration through the medium (Tables 5 and 6).

The results of the ICP-OES analyses of the samples of the medium from the two tanks indicate that the outside sections of the tanks “outperformed” the inside sections in terms of the extraction of Zn from the stormwater. Figure 2(b) shows the arrangement of the perforated pipes that allows the inflowing stormwater to be distributed across the top of the tank, which results in more water entering and filtering through the outside section of the tank. The sample from the inside section of the tank at hangar C18-NW contained an average (for three “runs”) concentration of Zn of 10,158 ug/g dw (micrograms per gram in dry weight); in the sample from the outside section of this tank, the analyses showed a concentration of Zn of 13,616 ug/g dw. Results were comparable for the samples from the tank at hangar C17-SE – concentrations of Zn were greater in samples from the outside section of the tank (Tables 5 and 6).

Table 5

Results of Analyses for Zn in Samples of Medium in Stormwater Treatment Tank at Hangar C17-SE

C17-SE	Run 1 µg/g dw	Run 2 µg/g dw	Run 3 µg/g dw	Average µg/g dw
Inside Sample	10,024	10,428	8,908	9,787
Controlled Specimen	(3.333)	(3.333)	(3.333)	3.333
Total Inside Sample	10,021	10,424	8,905	9,783.33
Outside Section	7,883	12,416	12,836	11,045
Controlled Specimen	(3.333)	(3.333)	(3.333)	3.333
Total Outside Sample	7,880	12,412	12,833	11,041.67

Note. The Controlled Specimen is the fresh oyster shells before being used in the treatment medium.

Table 6

Results of Analyses for Zn in Samples of Medium in Stormwater Treatment Tank at Hangar C18-NE

C18-NE	Run 1 µg/g dw	Run 2 µg/g dw	Run 3 µg/g dw	Average µg/g dw
Inside Section	11,524	10,037	8,914	10,158
Controlled Specimen	(3.333)	(3.333)	(3.333)	3.333
Total Inside Sample	11,521	10,033	8,911	10,155
Outside Section	16,297	10,245	14,301	13,614
Controlled Specimen	(3.333)	(3.333))	(3.333)	3.333
Total Outside Sample	16,294	10,241	14,298	13,611

Note. The Controlled Specimen is the fresh oyster shells before being used in the treatment medium.

Scanning Electron Microscope (SEM) deploys an electron beam on conductive or semi-conductive sample surface to obtain the surface imaging information at the nanoscale. Energy Dispersive

X-Ray (EDX or EDS) spectrometer coupled with SEM could characterize each element on the surface and provides more quantitative elemental mapping.

Fragmented oyster shells were collected from the medium and washed with tap water. One cleaned shell was cracked manually into two pieces for the measurements on the outer surface, the inner surface, and the cross-section. The samples were first coated with a thin gold (Au) layer to increase its conductivity in a Hummer VI Sputter Coating Machine (Hummer VI, Anatech Ltd., Hayward, CA). The scanning electron microscope (SEM) observations were carried out in a Hitachi S-2600 SEM. The "Quartz XOne" Energy-Dispersive X-ray (EDX) system (Quartz Imaging Corporation, Canada) equipped on the Hitachi SEM was used to collect the EDX spectra and analyze the element fittings.

The structure and the elemental components are found to be consistent at various sites on the outer surface. As shown in Figure 3(a), irregular-shaped clusters, in tens of microns, adhere to the top of a fine porous layer. The pore size is about 300nm and less. The EDX spectrum (Figure 3(b)) indicates three major components on the outer surface: zinc, calcium, and iodine. Among them, Zn is dominant, with a weight percentage of 80% ~ 90%.

Analyses of Oyster Shells within the Medium

Fragments of oyster shells were collected from the medium and thoroughly washed with tap water. The cleaned fragment was then cracked manually into two pieces to enable measurements and analyses of the outer surface, the inner surface, and the broken surface, or cross section of the shell. The samples were first coated with a thin layer of gold to increase their conductivity in a Hummer VI Sputter Coating Machine (Hummer VI, Anatech Ltd., Hayward CA). Scanning electron microscope images of the shell surfaces were made in a Hitachi S-2600 SEM. The "Quartz XOne" Energy-Dispersive X-ray (EDX) system (Quartz Imaging Corporation, Canada) on the scanning electron microscope was used to collect the EDX spectra and analyze the chemical character of the sample.

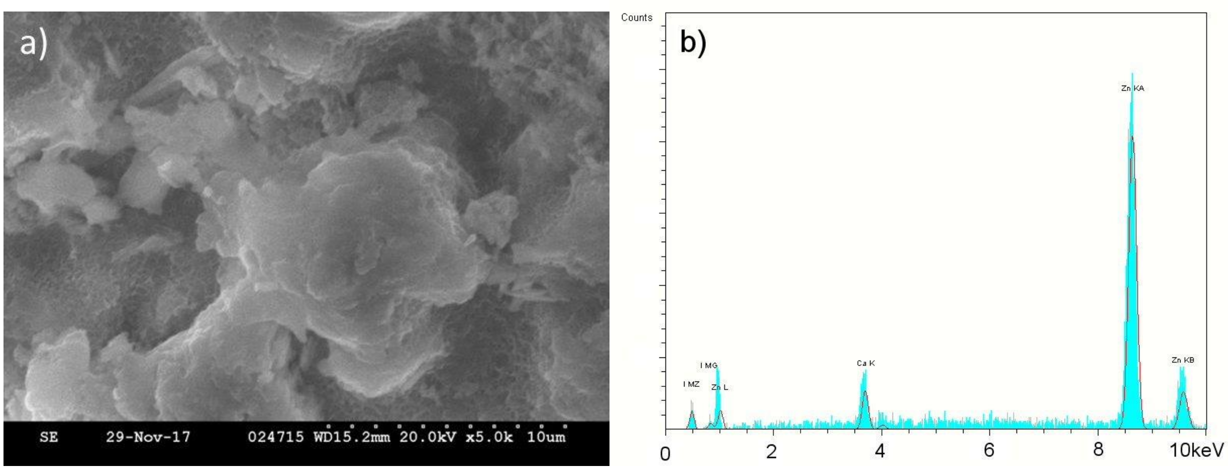


Figure 3. (a) The SEM image. (b) EDX spectrum on the outer surface of the oyster shell.

The inner surface of the shell shows a different morphology than the outer surface. Three typical morphological features were observed on the shell's inner surface, examples of which are designated by numbered arrows in Figure 4(a). EDX spectra indicate the presence of calcium and iodine in the features labeled 1 and 2; the spectrum for feature 1 and 2 is shown in Figure 4(b). Zinc was indicated only in the spectrum for feature 3 (Figure 4(c)). The proportion of each element on feature 3 was similar, within the error limits of the method, to that on the outer surface of the shell. Additionally, the feature labeled 3 shows a micro-structure (clusters and fine pores) similar to that on the outer surface. Therefore, we deduce that the elements contained in feature 3 could have come from the “crumbles” on the outer surface when the shell was cracked for sample preparation.

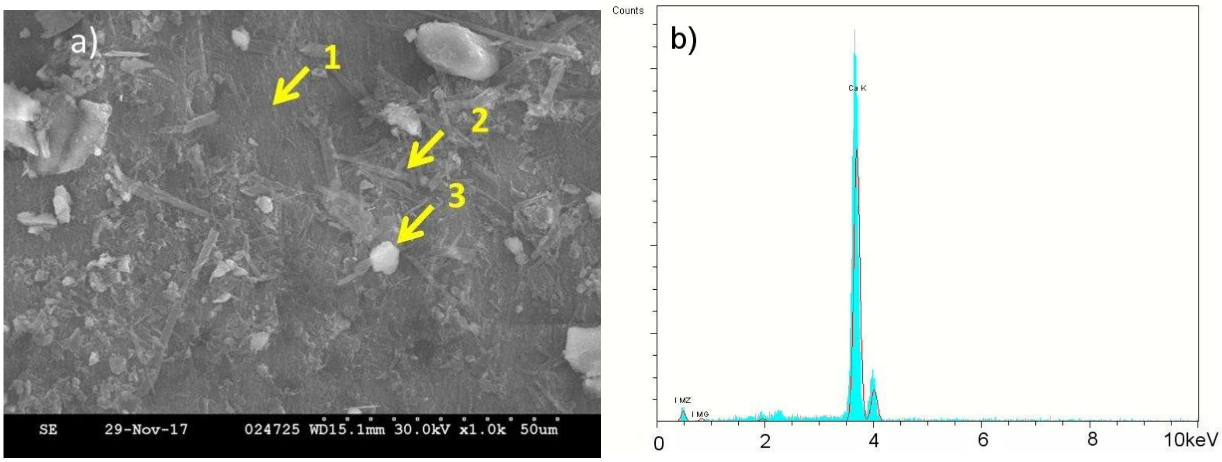
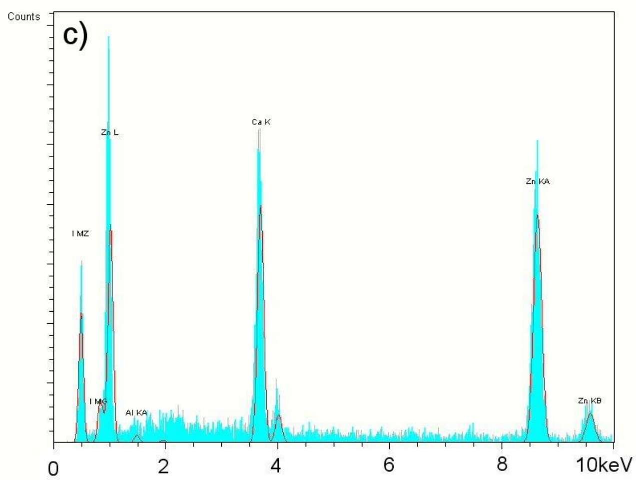


Figure 4. (a) The SEM image on the inner surface of the oyster shell. (b) EDX spectrum on Feature 1 and 2.



(c) EDX spectrum on Feature 3.

The SEM image of the shell cross section (Figure 5(a)) shows that most of the shell body is composed of stacked layers, except for a thin veneer at the outer surface. Three EDX scans were made of the shell cross section, from the inner surface to the outer surface (Figures 5(b), (c), and (d)). Zinc was present only in the veneer at the outer surface of the shell (Figure 5(d)). The exact thickness of this veneer could not be measured directly because of the limit of the EDX resolution. From the difference in the morphological structures on the SEM image, however, the thickness is estimated to be about 20 µm or less, which is <5% of the total shell thickness.

The absence of Zn inside the shell body (Figure 5(c)) supports our earlier conclusion that the Zn in the small clusters in the area labeled 3 on the inner surface of the shell (Figure 4(a)) is from the outer surface rather than being present within the internal structure of the shell itself. Additionally, the iron and chromium indicated by the EDX spectra near both the inner and outer surfaces of the shell (Figures 5(b) and (c)) is thought to represent contamination from the EDX sample holder, which is made of magnetic steel.

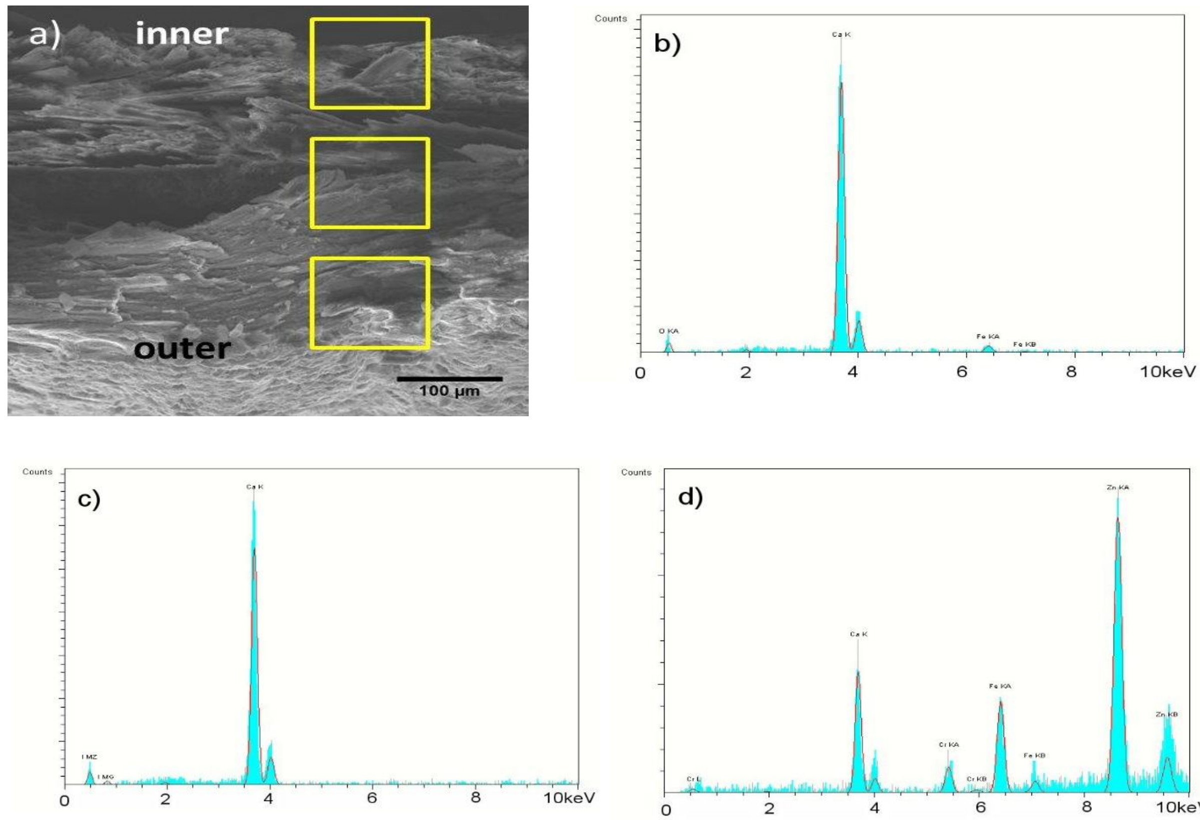


Figure 5. The SEM image of the shell cross section and the EDX spectra collected on three different regions. The three yellow squares in (a) the SEM image mark the scanning regions for the EDX spectra. (b), (c), and (d) from the inner surface (top) to the outer surface (bottom) correspondingly.

Analyses of Compost Mixture

A final set of analyses were made to determine if Zn was captured within the compost mixture or on the fragmented oyster shells alone. From the treatment samples of wet compost collected from the cylindrical tanks, 3-gram subsamples were prepared for analyses by SEM and EDX methods. The subsamples were air dried in a vacuum hood for one week. The dried powder was fixed on an SEM sample holder (stub) with conductive tape and a layer of gold was applied to the sample surface.

A typical view of the dried compost powder under SEM is shown in Figure 6. Six areas of interest were labeled, and the elements within these areas were analyzed with EDX. For the areas with a smooth surface, such as that labeled 1 in Figure 6 and shown in an enlarged view in Figure 7(a), the major component is silicon dioxide (SiO_2) (b).

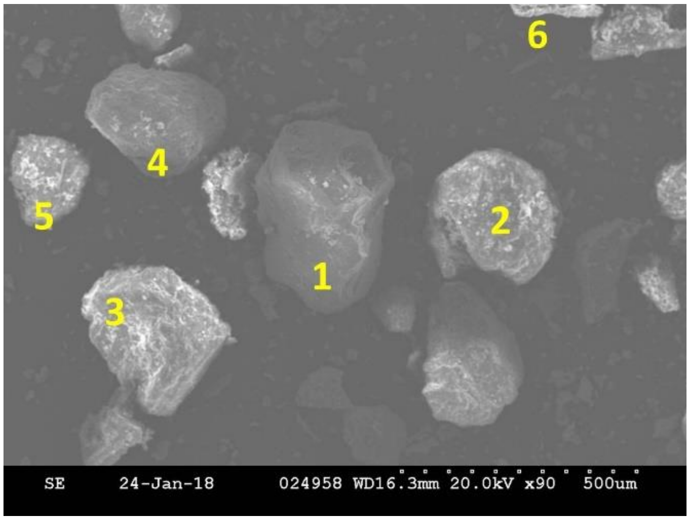


Figure 6. The SEM image of the dried compost at the magnification of ×90. Six areas of interest were marked with numbers for further EDX analysis.

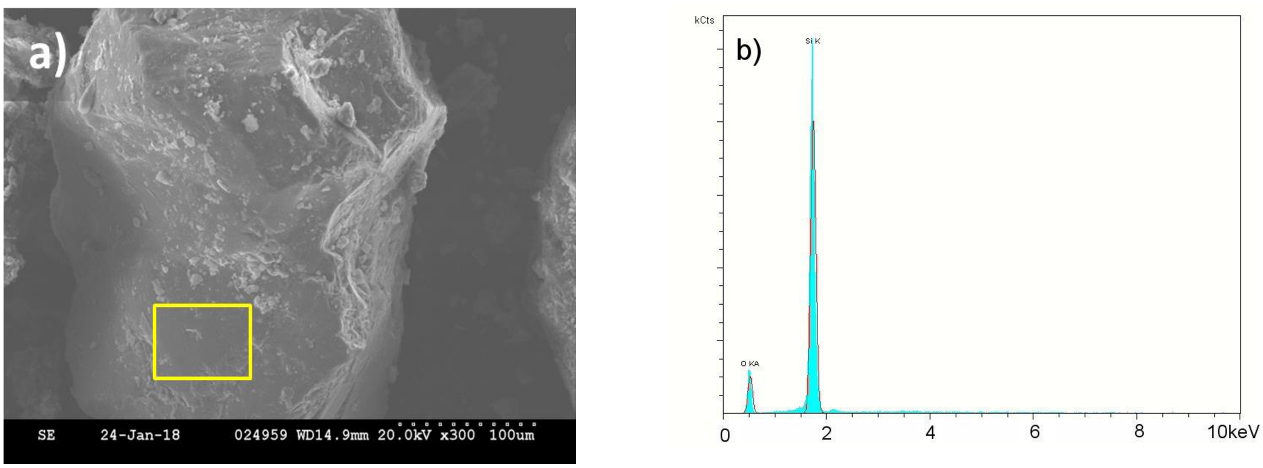


Figure 7. (a) The SEM image of Area No. 1. (b) The EDX spectrum of the smooth area marked with the yellow rectangle

Numerous fine crumbles on the surfaces of the bigger compost particles were identified on the SEM image in areas numbered 2 through 5 on Figure 6, and such a crumbled surface is shown in Figure 8(a). Examination of the EDX spectra of this area (b) indicates the presence of high concentrations of SiO_2 along with several other elements, such as calcium, magnesium, aluminum, iron, zinc, manganese, and barium. Among these constituents, Zn was present at a weight percentage of approximately 1.5 to 3.

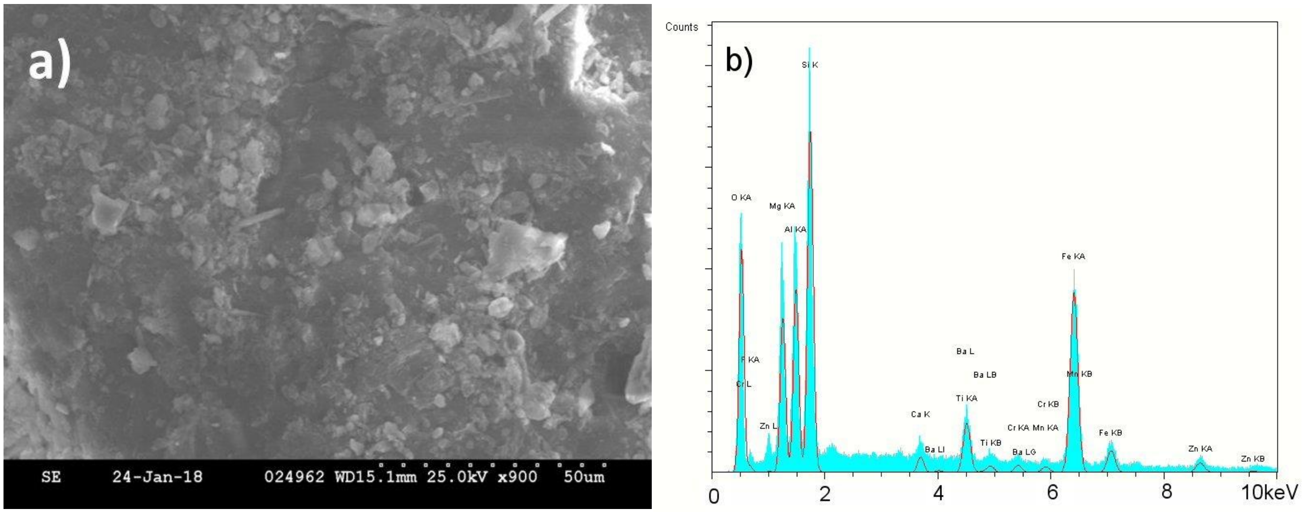


Figure 8. (a) The SEM image of the crumbles in Area No. 3. (b) The corresponding EDX spectrum.

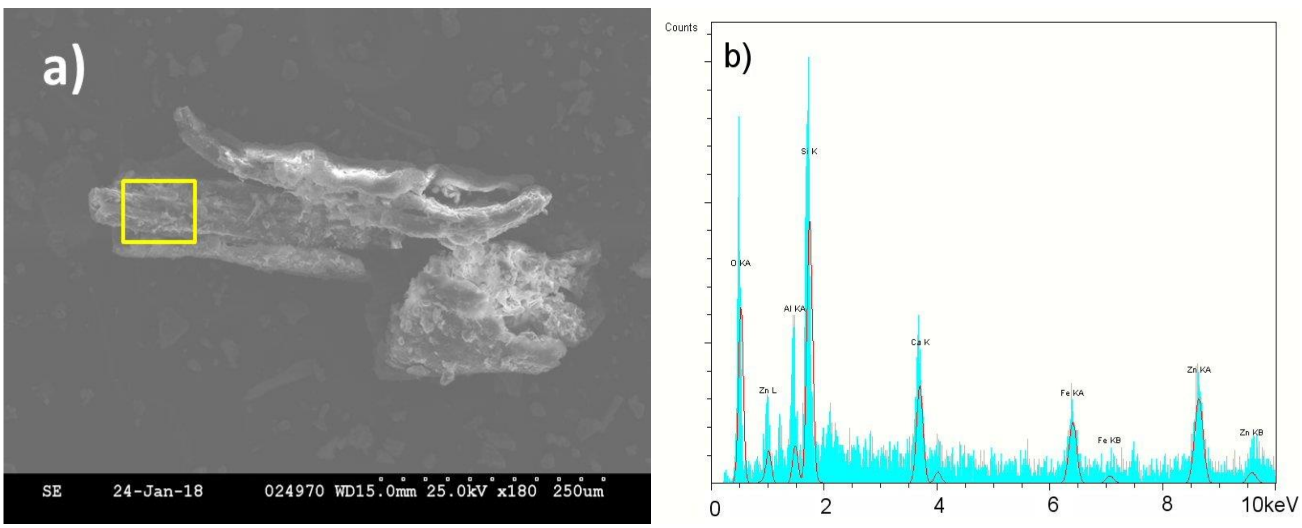


Figure 9. (a) The SEM image of the shell flakes mixed in the compost in Area No. 6. (b) The EDX spectrum corresponding to the area marked with the yellow rectangle.

Besides the smooth and crumbled surfaces of the particles in the powdered compost samples, oyster shell flakes were also observed, infrequently though not surprisingly. In the area outlined in the yellow rectangle in Figure 9(a), Zn was also identified along with the dominant SiO_2 and the other elements noted above (b). Even though the percentage of Zn in this specific area was as high as 20% by weight, the total proportion of Zn in the overall compost mixture is considered to be very low because similar structure was detected in far less than 1% of the area of the entire observed compost sample.

Conclusions

The presence of zinc (Zn) in runoff from unpainted, galvanized hangar roofing into airport stormwater drainage systems can be detrimental to wildlife and the environment. Airports across the northwest are noticing elevated levels of Zn in required quarterly water samples of their stormwater runoff. The Snohomish County Airport in the State of Washington, along with Landau Associates Inc. have installed a pilot treatment system that has been shown to remove excessive Zn from the runoff, which then can flow to adjacent creeks and lakes without adversely affecting the environment. The inclusion of oyster shell fragments in the treatment medium – a compost and sand mixture – has resulted in the extraction of virtually all (>99%) of the Zn in the runoff from the hangar roofing.

Analyses of samples of the runoff entering the treatment tanks (influent) and of the water flowing out of the tanks (effluent) documented the removal, or extraction, of Zn by the treatment medium. Determining the fate of the Zn removed from the runoff, however, required an analysis of the treatment medium itself.

Separate samples of the treatment medium, the oyster shell fragments, and the compost mixture with the shell fragments removed were analyzed by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) and (or) Scanning Electronic Microscopy with Energy Dispersive X-Ray (SEM & EDX) techniques. Those analyses indicated that Zn had been sorbed onto the outer surfaces of the oyster shell fragments, but only in a veneer that was less than 5% of the entire shell thickness, and was not present within the interior structure of the shell. Further analyses of samples of the compost mixture indicated their composition to be primarily SiO_2 (silica = sand), with very little or no Zn present. It is concluded that virtually all of the Zn was absorbed by the oyster shells incorporated in the treatment medium.

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Collegiate Aviation Review International

Volume 37 | Issue 1 Peer-Reviewed Article #4

1-1-2019

Choosing a Collegiate Training Aircraft with Confidence

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Qualitative preference is frequently used to make significant, programmatic choices between competing suppliers and products. Translating qualitative choice into defensible quantitative representation is possible with patience, method and, care. One example of this translation is the application of a popular Total Quality Management (TQM) tool, known as Quality Function Deployment (QFD), in the choice of a new/replacement, collegiate-training aircraft. Using QFD is especially important when a fleet replacement is being considered as the cost of a new, current aircraft can easily approach $500,000; thus a significant fiscal commitment is incurred in replacing a multi-aircraft fleet. A choice of this magnitude deserves multiple stakeholder inputs and requires respect from differing viewpoints. The successful outcome of any decision process ultimately hinges upon confidently exercising the best choice. The decision tool needs to be transparent, easy-to-understand and easy-to-apply. The corresponding choice of a preference scale can either mask or illuminate driving criteria in the decision process. This paper explores the application of QFD to the decision process across competing training aircraft choices and offers justification of the QFD non-linear “0, 1, 3, 9” preference scale. Application research into the mechanics of human preference showed that if 95% reliability in choice between alternatives is desired, then the perceived difference between the choices needs to be a factor of 3.0, as is the case in the employed QFD scale. Selection criteria used in the training aircraft decision, their dissimilar weighting, and the evaluation of competing aircraft in a recent collegiate-training aircraft selection are displayed as exemplars.

Recommended Citation:
Vance, S.M. (2019). Choosing a Collegiate Training Aircraft with Confidence. *Collegiate Aviation Review International,* 37(1), 59-72. http://dx.doi.org/10.22488/okstate.19.100204

Collegiate-training aircraft are consumable capital assets which require periodic replenishment. A complete fleet replacement is decision-intense and generates more attention and fiscal stress than a recurring investment which is less fiscally stressful but no less decision-intense.

The purpose of this paper is two-fold 1) to defend the illustrated scoring scale as necessary and proper for such an endeavor, and 2) to overview and recommend a repeatable methodology when choosing expensive, capital assets such as collegiate-training aircraft.

The two research questions probed in this paper both address this type of difficult, capital-intense decision:

- Research Question 1: How small a difference (in a criteria or attribute) can human preference reliably perceive?
- Research Question 2: Can a collegiate-training aircraft (specific make/model) be methodically chosen with confidence?

Decisions, even significant ones, are frequently are more of an art form than scientific. Often the decision logic is difficult to reconstruct, if it can even be reconstructed at all. It is a professionally respectful investment of the decision maker's time and finances if a repeatable process is used to organize the decision process. The U.S. aerospace industry Total Quality Management (TQM)/ISO 9000 revolution in in the late 1980s/early 1990s produced a bevy of tools. Stuart Pugh's Concept Selection process was a popular and simple tool to use to choose among competing alternatives (Burge, 2009). Numerous, Multi-Attribute Utility (MAU) tools also manifested themselves in this time frame, with two of the higher profile tools being The Analytic Hierarchy Process and Quality Function Deployment (QFD). All of these tools, which were once expensive software commercial purchases, are now freeware on web sites such as http://www.mindtools.com.

A typical flow in a decision process, as discussed in Hauser & Clausing (1988), Huber (1974), and Von Winterfeldt & Fischer (1975) follows these steps:

- A clear statement of the decision to be made
- Criteria with which to judge value – and the criteria's associated definitions
- User-defined preference weights on the criteria, especially if they are value judged as unequal
- Collecting the options from which to (ultimately) choose
- A method to evaluate the options v. criteria – and the associated scoring definitions
- Production of plausible results
- Ability to credibly explain the method used and the conclusion(s)/choice(s) drawn

QFD is a popular Japanese Total Quality Management (TQM) tool that migrated into the U.S. auto and aerospace industry in the late 1980s/early 1990s. Hauser & Clausing (1998) popularized the tool in a seminal Harvard Business Review article. To understand more about QFD's roots and the tool's mechanical, quantitative, decision-scale grounding, see Vance, Carstens, Gasper & Parker (2018).

Decisions should proceed from a requirements perspective. Asking "WHAT" is wanted/needed first is more important than examining "HOW" to satisfy the need; even though the latter is the more typical starting place. Focusing too early on solutions, especially in complex decisions, is almost always a false economy as the resulting choice(s) quickly become indefensible. "WHATs", can be categorized as the requirements or design criteria and must include their definitions and their priority. These properly precede "HOWs" which are represented by ideas, solutions, options, and concepts. While the "HOW" solution space also needs definitions, detailed solutions should not be assembled before an understanding of the decision requirements/criteria are documented.

"WHATs" are the harder of the two steps to take and, without process, will likely be avoided until they simply must be addressed for clarity. "HOWs" are the fun step and, without process, are all that likely may be attempted. Most decisions have multiple attributes for consideration, and most frequently these attributes are valued unequally by the evaluators chartered with the decision. In this type of decision, a MAU tool is needed and provides a proper balance between process and velocity. QFD employs a systematic identification of "WHATs", weights these requirements, and then mathematically evaluates each "HOW" against the "WHATs" to determine preference.

There are two critical, differentiating characteristics in the use of any decision tool 1) the ease of interpretation and credibility of the employed scoring scale, and 2) the level of documentation detail offered to support the decision, after the decision process is completed.

The first area of decision process differentiation is in the employed scoring scale. In the case of QFD, the 0-1-3-9 scale is purposefully non-linear and increments by a factor of three – why? This paper will overview the rationale for the scoring scale in an attempt to build confidence in its purposefulness, then apply the scoring scale to an exemplar application selecting a collegiate fleet training aircraft. Examples of QFD decision criteria (the "WHATs) in choosing a collegiate-training aircraft (the "HOWs") application include the macro balance between the aircraft's purchase price, characteristics and the aircraft's fit with the institution's current fleet, mission, vision and ethos.

The second area of decision process differentiation is in the care in which definitions are written. The value of definitions cannot be overstated. When employing QFD, a more complete application will offer definitions for the "WHATs", the "HOWs" and the scoring scale graduations applied to each "WHAT". While this may seem oppressive, the investment in time actually makes the scoring process easier and more efficient; and, more importantly, once the stakeholders have completed the decision process, the results are easier to reconstruct and defend. It is this ultimate defensibility that will distinguish a superior decision process application from a mediocre, or poor, application.

Literature Review

Multiple references concerning the history of QFD and using/optimizing QFD were easily located, starting with the QFD article by Hauser & Clausing (1988); however, no source was located that indicated any specific, QFD-scale basis or the rationale associated with the specific selection of QFD's nonlinear, 0-1-3-9 scale. An informative article tracing the history of QFD from 1978 to the present (Akao & Mazur, 2003) did not illuminate the scale basis. Burke, Kloeber, & Deckro (2002); Delano, Parnell, Smith, & Vance (2000); Fiorenzo & Alessandro, (1999); Franceschini & Rossetto (1995); and Franceschini & Rupil (1999) each produced excellent advice for employing and optimizing QFD, but none revealed nor discussed the basis for the preference scale.

When no basis was located, the literature review moved to the broader subject of human preference in which the concept of "Just Noticeable Difference" (JND) and Weber's Law was illuminated (Britt & Nelson, 1976). Weber's (and his mentor Fechner's) mathematical model, originally published by Weber in 1860, quantifies the perceived changes in the strength of a stimulus to any of the five senses (Britt & Nelson, 1976) as shown in equations (1) and (2).

(1) k = (perceived change [$p\Delta$]) = (change in stimulus [ΔS]) / (initial stimulus [S])

(2) $k = p\Delta = \Delta S/S = JND/S$

For example, if the weight of an article, which = 1, must be increased 33% before the difference is detectable, then the initial stimulus = 1 and the JND = 0.33. The k-value can be expressed as in equation (3):

(3) $k = .33/1 = .33$

Likewise, if the weight of the article must be increased 100% (doubled) before the difference is detectable, then the $k = 1$; correspondingly, if the weight must be increased 200% (tripled) to be detectable, then the $k = 2$.

Weber's Law is frequently quoted in consumer marketing with a reliability factor of 50% (Britt & Nelson, 1976), which seems inordinately low for consistent, dependable results in applications beyond marketing. Reliability of 50% would be unacceptable in aerospace engineering/program development applications where a 5% error (95% reliability) is typically considered the bare minimum of acceptance. How confident can a/should a decision maker be in their choice? To distinguish preference with confidence and a high reliability, does the QFD scoring scale need to be a factor of three (0-1-3-9)? Does the QFD scale of 0-1-3-9 achieve a

95% reliability in choice? Vance, Carstens, Gasper & Parker (2018) explored this exact question.

Preference Scale Investigation Methodology

Two, primary, data-collection methods were employed, each designed to contrast the other: an in-person, convenience sample taken on the Oklahoma State University (OSU) campus with physical weights taken in the spring of 2017, and an online survey of random respondents based on pair-wise, visual-size differences of circle areas taken in the fall of 2017. Both of these approaches were designed to elicit a preference response choice when presented with different stimuli. The on-line survey method drew from two sources: Amazon M-Turk and OSU students in the College of Education, Health & Aviation's online research solicitation system – called SONA (https://sona-systems.com).

The weight-based approach employed a structured, research script which contained 23, graduated-in-weight, pair-wise comparisons of ¼-20 plated nuts secured in small, uniform, cardboard boxes. Other ballast possibilities originally included the consideration of commercially identical shapes, such as marbles or batteries, and measured commodities such as clay, sand, or stones. Due primarily to cost considerations, ¼-20 plated nuts were chosen since over 650 were needed. Respondents were conveniently sampled on campus and randomly presented with five pairs of boxes and then queried, *"Can you detect a difference in weight? If so, please describe the difference? You can respond any way you wish such as 'Heavier', 'Lighter', or 'Equal'".* Figure 1 shows an exemplar box containing 10, ¼-20 plated nuts. Respondents were offered as much time as they desired to make the five comparisons; rarely did a single, pair assessment take more than three-five seconds.

Figure 1. One of the 23 boxes prepared for the research on top of a stock, new, unfolded box (note the small "A" inscription on the top edge). This alphabetical code, which only faced the researchers, indicated the box contained 10, ¼-20 nuts.

The on-line survey was designed to translate the same 23 weight pairs into an electronic-friendly form. Consistent with Krider, Raghubir, & Krishna (2001), area was selected as the visual metric to be scaled as it proportionally represented total weight more accurately than either a proportional increase in diameter or circumference. Figure 2 shows an exemplar screen from the Qualtrics® elicitation software. Respondents were offered each pair-wise view for three seconds before the software automatically advanced to the collection screen for the respective sample. Total survey time to assess the 23 circle pairs was typically less than three minutes.

Figure 2. An online screen shot presentation of the 40-to-44, ¼-20 nut pair translated (normalized) to area. Note there is a counter displayed in the upper left corner which has incremented to 2 seconds and the orange slider bar at the top of the screen is showing survey completion progress.

Findings & Discussion

The employed-survey tools, number of respondents, and number of collected pair-wise comparisons from the respondents were tallied as follows:

- OSU in-person survey on campus (*n* = 127 respondents [not paid], 633 comparisons)
- Amazon's M-Turk (*n* = 524 respondents [who were paid $0.35 each], 12,048 comparisons)
- OSU SONA (n = 210 respondents [not paid], 4,841 comparisons)
- Totals: *N* = 861: with 17,522 comparisons

Preference Scale Investigation Results

Figure 3 plots the mean difference in either the weight or area pair for a *k* = 1, 2 or 3 versus the percent correct that the respondents were able to obtain in each pair-wise comparison. The percent correct is a direct indicator of reliability of choice.

Each dot in Figure 3 represents one of the pair-wise comparisons in either the in-person, weight-based survey [blue], area in the M-Turk survey [orange], or area in the SONA survey [grey]. Recall the circle areas were normalized to follow the exact mathematical relationships scheduled for the ¼-20 nuts. The horizontal axis was plotted to show the results by weight (or area). For example, in the case of the 27-81 pair (k = 2.0), the mean of this pair is computed as (27 + 81)/2 = 108/2 = 54. Data for the 27-81 pair was plotted on the horizontal axis at 54, not 27 or 81.

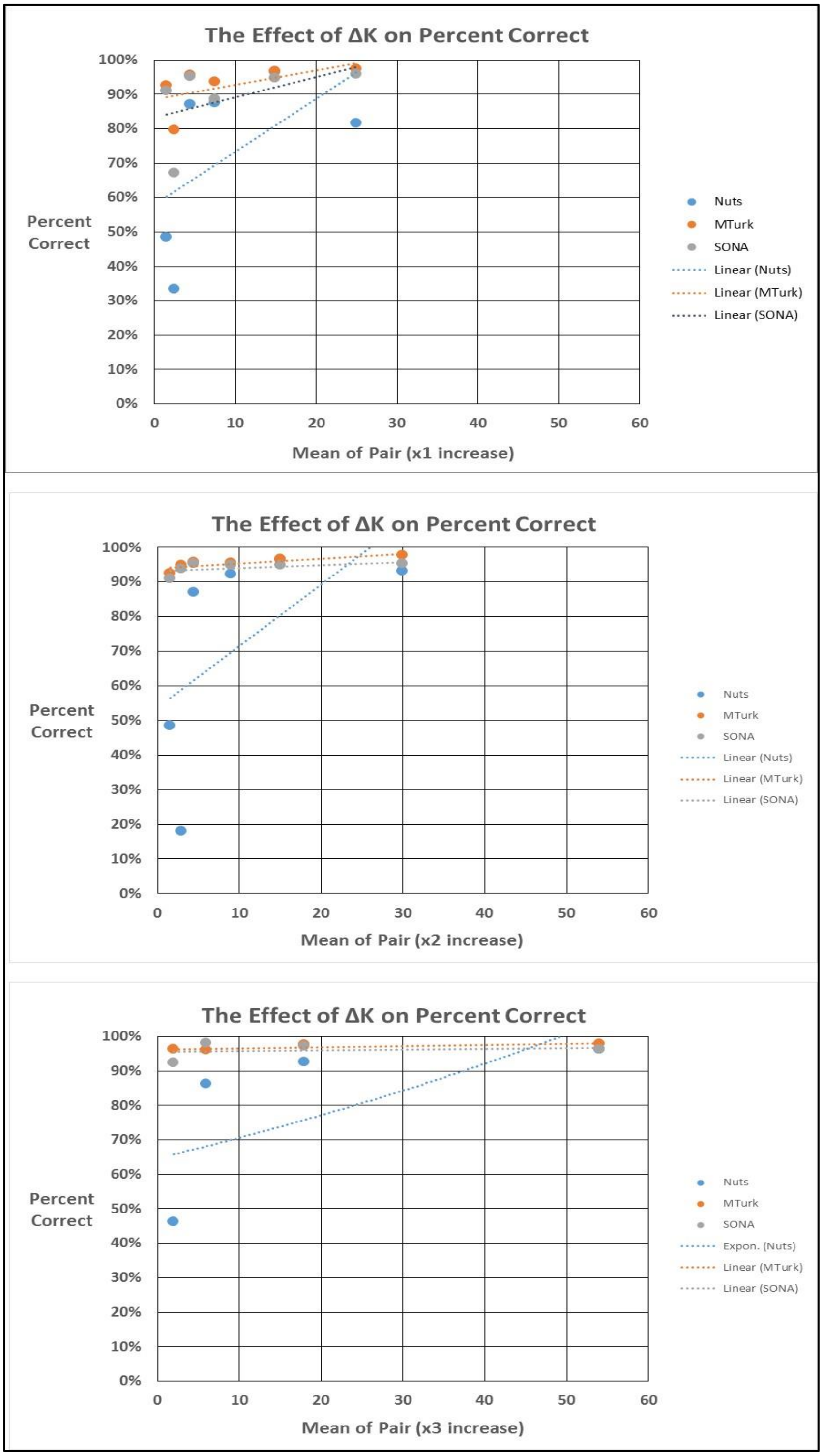

Figure 3. These three graphs show mean weight/area on the x-axis versus percent correct on the y-axis. From top-to-bottom, the graphs show a 1x, 2x, and 3x factor in the mean weight/area increases. All three data streams are shown in respective color codes.

Predictably, when the weight/area was increased at a larger rate (3x versus 2x, or 1x), the reliability (summarized by the least squares/best fit lines) increased quickly to more than 90% and, in many cases for the online survey data, more than 95% even at lower weight differences. These graphs document the area-based results produced superior reliability over the weight-based results. All of the OSU in-person survey results [blue] scoring less than 50% reliability were for small weight differences (1 or 2, ¼-20 Nuts).

Significantly, only when *k* = 2 (a tripling of the stimulus/factor of 3), and only for the M-Turk online, area-based elicitation method, does reliability consistently equal or exceed 95%. Note in the lower plot, the two on-line "Least Square/Best Fit" lines remain above the desired 95% threshold, but with the in-person, weight-based elicitation, three data points fall below this level, thus the associated least square/best fit lines does not consistently exceed 95%. Therefore, if the required level of reliability is 95%, then a 200% increase (a tripling) of the original stimulus is necessary; this result is more dependable if the physical weight or area difference is larger. These results validated the QFD factor of three (0-1-3-9) scoring scale is, in fact, necessary to achieve a 95% reliable choice.

Exemplar Application of Quality Function Deployment (QFD)

Hauser & Clausing (1988) describe the foundational elements of the QFD process as five sequential steps shown in Figure 4.

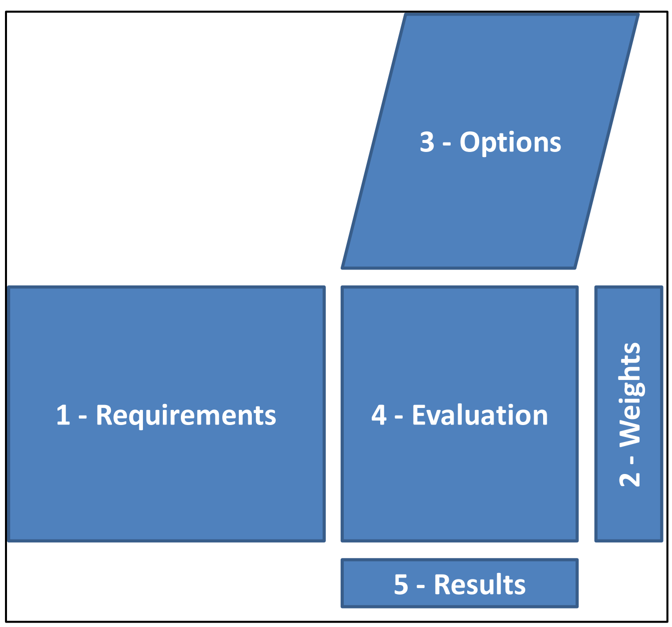

Figure 4. The five primary QFD steps, as described in Hauser & Clausing (1988), are designed to be competed in sequential order. The proportions of the boxes' areas are representative of level-of-effort and coincidentally connote a roughly equal number of Step-1 requirements with Step-3 solution options.

Step-1 is the collection of requirements against which the solution options will be judged. Not explicitly shown in the figure are the accompanying definitions of each requirement which are critical for both the evaluators and anyone interested in a deeper understanding of the resulting decision. The evaluators need definitions so the solution options can be judged from the same point of reference. After the decision is completed, the definitions help explain and document the decision for anyone wishing to reconstruct how the decision was made. A typical requirements list would include no fewer than four and no greater than nine requirements. When there are three or less requirements, there is a risk of them becoming too broad to accurately define; correspondingly, if there are more than nine the requirements can become too granular and/or over defined.

Step-2 is a weighting of the requirements. Typically, two perspectives are possible 1) all equal, or 2) unequal. In either case, using a 100-point pool is a common reference to most monetary systems and is easily understood. The question at this point is how would the 100 points be divided in whole point increments across the requirements to acknowledge which are more important than others? If all of the requirements are indistinguishable in value, then simply divide the 100 point pool by the number of requirements and set all to the same value. This approach is also an easy sensitivity analysis once the unequal weights are set. If equality is inappropriate, the evaluators must embark on a mutually-agreed upon distribution of the 100-point pool across the requirements to arrive at unequal weights.

Step-3 is the identification and definition of the solution options. Each should be defined to a similar level of detail so they can be fairly judged against the requirements.

Step-4 is the pair-wise comparison of each solution option to each requirement. Ideally, this comparison is done one requirement at a time, not one solution option at a time. Completing this matrix horizontally helps ensure each requirement is being evaluated consistently against each solution option. Completing the matrix vertically (evaluating one solution option against all the requirements then moving to the next solution option) risks a biased view of each requirement. QFD relies on a non-linear, decision scale to complete the translation of subjective/qualitative judgement into quantifiable/quantitative scores. The relationship scale is 0-None, 1-Weak, 3-Moderate, and 9-Strong. Ideally each of the 1-3-9 levels also has an associated definition for each requirement to ensure consistent scoring by the evaluators. A non-linear, ratio scale such as this is designed to purposefully over weight and accentuate solution options that strongly interact with, or strongly satisfy, a requirement. This helps focus attention of drivers and de-focus attention on the many potential details.

Step-5 is the sum-product-matrix math of the Step-2 requirement's weights with Step-4's 0-1-3-9 evaluations; therefore, when a 100-point pool is used to weigh the requirements, the maximum possible score obtainable by any solution option is 900. To more easily interpret output, the scores can be and typically are normalized back to a 0-100 scale simply be dividing each raw score by 9.

Figure 5 shows an exemplar taken from an actual application of QFD in a recent (2014-2015) collegiate-training aircraft purchase.

		A	B	C	D		
Non-Differentiating Criteria	HP	175	200	180	180		
	Avioncis package	GNS-1000	GNS-1000	GNS-1000	GNS-1000		
	Purchase Price	Nominal	Higher	Nominal	Nominal		
Differentiating Criteria						**Equal**	**Unequal**
Fleet Commonality	Make a logical transition aircraft moving from DA-20 to PA-28-201R	9	3	3	1	9	5
Business Basis	Investment value coupled with associated Level 5 simulator purchase	1	3	3	9	9	15
Ownership / Operating Costs	Direct and indirect operating costs	3	1	3	3	9	5
Enrollment Appeal	Ramp/curb/bling appeal - diversifies fleet, adding additional training basis	3	9	1	3	9	30
Pre-PVT Curriculum	Backwards compatible with Pre-PVT student abilities, supplements DA-20 fleet	9	1	3	3	9	5
Post PVT Curriculum - IMC Capable	Forward compatible with IMC need and adds value to overall professional training experience	9	9	9	9	9	10
Strategic Seed	Opens relationship with manufacturer with whom long-term fleet replacement would be considered	1	9	3	3	9	10
Ergonomics	Interior phyiscal layout, panel, controls, front / rear seats accommodate diverse student / insturctor profiles	3	9	1	1	9	5
Training Safety	Demonstrated compatibility with the demands of a training environment	3	3	3	9	9	5
Parental Safety Impression	A non-aviator's view of safety features and/or record	3	9	1	1	9	5
Flight Qualities	Overall quality of the flying experience; solidity, crispness of control, stability, airframe integration......	1	9	3	1	9	5
	Equal	405	585	297	387	**99**	**100**
	Unequal	360	670	280	440		

Value Scale	
blank	None
1	Marginal
3	Measurable
9	Cleary Superior

Figure 5. QFD fully applied to a collegiate-training aircraft selection. All five steps are shown completed. Note the output scores for options "A", "B", "C" and "D" in this example were not normalized to a 0-100 scale, rather they were left in their raw, 0-900 format.

In this application, the requirements space was first differentiated between three, non-differentiating and 11, differentiating criteria. *Non-differentiating requirements* were adjudged to be incapable of distinguishing one solution option over another and included engine horsepower, the avionics package (which was identical across the four, solution options), and purchase price (which was simply documented as either 'nominal' or 'higher'). The evaluator's recognized a difference in price, but did not consider it to be a driving consideration.

The 11 *differentiating criteria* reflect that the collegiate program was considering adding a third aircraft type to an already mixed fleet. Tactically, this new, third aircraft type was desired to be primarily an instrument flight trainer. Strategically, the addition was envisioned to be a seed-purchase which would open a relationship with the manufacturer to ultimately facilitate a complete fleet replacement with the same aircraft make/model type. Due to this decision complexity, there were more than the typical maximum nine requirements in this application – which potentially risked dilution and duplication of the requirements. Note the accompanying definitions which helped to defend the evaluator's desire for 11, distinct, requirements. Both an equal and unequal set of requirements weights were include on the right side of the evaluation matrix. In the equal weighting case, 100/11 = 9 whole points per requirement. The unequal array of weights was agreed to by the evaluators in a facilitated discussion and essentially contained three tiers of requirements by value. One requirement, 'Enrollment Appeal', at 30 of the 100-available points, dominated over the remaining 10 requirements. There were three requirements in the next tier, weighted at 10 or 15 points each, with the remaining seven requirements each valued at 5 points.

The evaluators also chose to modify the QFD “None/Weak/Moderate/Strong” scoring scale verbiage to “None/Marginal/Measurable/Clearly Superior” prior to completing the scoring of each solution option. No math is required to determine that one solution, option “B,” will almost surely lead the others in point value, simply because it has the largest number of “Clearly Superior” satisfied requirements.

The matrix, sum-product math was completed between the evaluations of each option’s ability to satisfy each requirement and each array of requirement weights and documented at the bottom of the matrix. For ease of discussion, the raw scores from Figure 2 were each divided by 9 and are shown below in Table 1.

Table 1.

QFD-output scores (Figure 2) re-normalized from the previous 0-900 scale to a 0-100 scale.

	A	B	C	D
Equal	45	65	33	43
Unequal	40	74	31	49

*Note: The resulting 0-900 point scale proportions were preserved with the ability to more efficiently interpret the data on a 0-100 point scale.

In this application, solution option “B”, scored better than the other three options and should have been considered the preferred option. Because all weights and the scoring scale are ratio scales, the outputs can be directly compared to each other in magnitude. Observe the equal Step-2 requirement’s weight scores show “B” as the preferred choice with twice the value of the “C” and half again as much as either “A” or “D”. However, when the unequal Step-2 requirement’s weight scores are used, option “B” retains the highest preference while option’s “A” and “C” preference erode and option “D” rises, but not enough to be competitive with option “B”. The option “D” score rose because it satisfied a valued requirement (‘Business Basis’) at the maximum level (9).

A significant, positive benefit of using QFD is the ability to successfully translate subjective and qualitative data into a quantitative and defensible choice and ultimately a defensible procurement position for presentation to executive leadership decision makers to purchase aircraft “B”. In this case, the weights on the requirements did not matter, either an equal or unequal view produced the same domination of option “B”. It is thus possible to methodologically choose a collegiate-training aircraft.

Conclusions & Recommendations

In response to Research Question 1) - using QFD with a 0-1-3-9 scoring scale offers a 95% confidence that if care has been taken with definitions and evaluation, the resulting preference choice is defensible. The trade for the evaluator's investment in time is reaped in dependable, after-the-fact, decision-logic reconstruction. Being able to defend with confidence capital-intense decisions, such as choosing a collegiate-training aircraft, has great value for stakeholders, students, executive leadership, and the institution.

In response to Research Question 2) – decisions without a method may seem easy but the employed decision logic is nearly impossible to reconstruct after the fact. Using a method (such as QFD), which is based on definitions and a ratio scoring scale, requires significant evaluator input and process buy-in but in exchange, offers, easy-to-follow, defensible preference of the resulting choice.

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Collegiate Aviation Review International

Volume 37 | Issue 1 Peer-Reviewed Article #5

1-3-2019

Gender Differences and their Relation to Hazardous Attitudes in Pilot Training

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It has been stated by the Federal Aviation Administration (FAA) that Aeronautical Decision Making (ADM) training for pilots has been effective in reducing in-flight errors by up to 50 percent. Hazardous attitudes and their associated antidotes are currently discussed as part of the FAA's ADM training for pilots. The purpose of this study is to add to the understanding of decision making differences and the effectiveness of instructing students on mitigating hazardous attitudes throughout their pilot training programs, in both male and female students using the New Hazardous Attitudes Survey. Results of this study discovered that only two of the six hazardous attitudes, Resignation and Self Confidence, were significantly lower in students who had advanced levels of flight training, as compared to those with only basic levels. Another significant result demonstrated that female's overall hazardous attitudes scores were higher in the more advanced levels of flight training while males scores were lower.

Recommended Citation:
Furedy, M.D. (2019). Gender Differences and their Relation to Hazardous Attitudes in Pilot Training. *Collegiate Aviation Review International*, 37(1), 73-89. http://dx.doi.org/10.22488/okstate.19.100205

A significant amount of aviation safety related research tends to focus in such research parameters as pilot age, training, and flight hours. In addition to these traditional "characteristics", could there be gender related factors that may be generalized to the pilot population as well? In March of 2015, well-known aviation educator, John King, wrote an article entitled "Sky Kings: Learning to fly like a girl." While there are negative connotations associated with the phrase "…like a girl", in this article King posits that female pilots may be less disposed to unsafe behaviors and personality traits than their male counterparts. This article referred to a Civil Aviation Authority report ("Safey Skies," 1995) that studied accidents over a ten-year period. The study found that male pilots were four times more likely to be involved in an accident than their female counterparts (King, 2015).

According to a report on general aviation accidents conducted by the Airport Owners and Pilots Association (AOPA), accidents caused by pilot error accounted for 75.3% of the total number of accidents and 75.0% of all accidents that involved a fatality (2015). As aviation's leading cause of accidents, there is an ever increasing number of studies that focus on finding effective mitigations for pilot error that, in turn, could potentially reduce the rate of occurrence. Research relating to safety and gender-based differences poses a challenge because of the relatively small percentage of female pilots. In 2012, women made up only 4.3% of certificated pilots (AOPA, 2015).

The suggestion from King (2015) that females might be safer pilots is supported by relevant research, such as Vail & Ekman (1986) and the study conducted in 1995. These findings are contradicted, in part, by other studies (Bazargan & Guzhva, 2011). Should measurable differences be identified by future studies? The question becomes "what gender-related characteristics allow female pilots to avoid involvement in accidents to the extent, or severity, that male pilots are"? Are there better ways to deliver flight education that leverages the differences between the behavioral tendencies of two genders?

Literature Review

Impact of Gender on General Aviation Accidents

The differences in the severity of accidents may be due to females listening to rules and regulations concerning how to stay alive. While direct comparisons between automobile drivers and pilots are not appropriate it is interesting to note the general compliance males and females have toward safety programs. Waldron, McClosky and Earle (2005) concluded that females had more of a tendency to comply with rules and procedures, and to favorably regard legal campaigns such as those addressing the use of seatbelts and the avoidance of driving while intoxicated.

According to a Swedler, Bowman, & Baker (2012) study conducted at the Johns Hopkins School of Public Health, it might have less to do with the number of accidents and more to do with the fact that males are more likely to be involved in fatal accidents:

> A total of 14,026 teen drivers were involved in 5,408 fatal crashes in 2007, 4,459 fatal crashes in 2008, and 4,159 fatal crashes in 2009. Of these 14,026 drivers, 6,261 were killed in the crash (45%). Males comprised 69% of teen drivers involved in fatal crashes, with slight variation for each age. (p. 98)

In comparison, studies have identified male pilots being involved in significantly more fatal accidents. Vail and Ekman (1986) found that males were twice as likely to be involved in a fatal accident. A study conducted by the Civil Aviation Authority ("Safer skies," 1995) stated the difference was four times more likely. Finally, a study by Bener et al. (2013) placed the odds of male pilots being involved in a fatal accident at three times that of their female counterparts.

A study by Bazargan and Guzhva (2011) concluded that instead of gender being the contributing difference in fewer fatal accidents, it is more likely that age is the deciding factor. Their reasoning is that pilots over the age of 60 grow increasingly more likely to be involved in an accident. The authors support this theory by referencing the reduced differences between genders in fatal accident rates shown between the first sample period (1983 – 1992) and the second sample period (1993 – 2002) suggesting that as the average age of female pilots increases so will the rate of fatal accidents (Bazargan & Guzhva, 2011).

Decision-Making Based on Risk Avoidance

The level of risk that men and women are willing to take on has been related in previous studies to how they display aggression (Fiengold, 1994; Maner et al., 2007). Thus, risk aversion differences between genders is another area to be explored when looking at factors that impact accident rates and accident severity. Could it be that differences in aggression and decision making styles develop out of differences in risk aversion?

As mentioned by Moffitt (2010), other studies have indicated that there is a tendency for women to avoid harmful or risky behavior. Waldron et al. (2005) showed that male pedestrians are 80% more likely to be involved in an accident then women pedestrians. Feingold (1994) found that females show a higher tendency towards anxiety than males, according to Maner et al. (2007), which relates to a low proclivity to take risks and may also be associated with an amplified pessimistic risk appraisal.

Emotions serve as relevant forms of information, signaling the presence of particular threats to be avoided or rewards to be acquired. Emotions, in turn, promote cognitive responses facilitating the avoidance of threat and the acquisition of rewards. "With respect to decision-making, some emotions (e.g., anger) promote decision-making biases that increase one's tolerance for risk, whereas other emotions (e.g., disgust) promote decision-making processes associated with risk-avoidance" (Maner et al., 2007, p. 666).

Maner et al. (2007) also indicates a link between anxiety and risk-avoidant decision-making, both of which were shown to be traits more prevalent in females. Harris, Jenkins, and Glaser (2006) found evidence to the contrary, suggesting the notion that women avoid risk due to pessimistic thoughts was incorrect. Harris et al. (2006) also described a more evolutionary explanation for why women preferred to take part in fewer risk related activities. According to Harris et al. (2006), this theory suggested that perhaps:

> Women have a tendency to see greater risks than men see, not because of different selection pressure relating to mate seeking, but rather because if one perceives more risks in the world, one will be more effective at keeping safe any offspring under one's care. (p. 60).

A link between a pilots' tolerance for risk and their behavior with regard to safety during a flight was shown by Wetmore and Lu (2006). Ji, You, Lan, & Yang, S. (2011) stated that this "shows pilots' hazardous attitude plays an important role in the relationship between risk tolerance and safety operation behavior, in which risk tolerance may directly influence hazardous attitude, and, in turn, may directly influences the safety operation" (p. 1413). The results of the 2011 research supported this, finding that pilots who had tendencies toward higher levels of risk tolerance also showed a tendency toward hazardous attitudes and ignored standard procedures.

Hazardous Attitudes

The FAA's definition of hazardous attitudes lists five attitudes that can negatively affect a pilot's judgement during the decision making process: *macho, resignation, anti-authority, impulsivity*, and *invulnerability*. Lee and Park (2016) add to that by saying that hazardous attitudes can be defined as "a personal motivation tendency that affects an individual's ability to make good decisions" (p. 70). Just as the FAA stated that good judgment can be taught, Lee and Park (2016) note that hazardous attitudes can also be corrected through training. This educational process includes learning how to recognize personal attitudes and the dangers associated with them, and what further can be done to change those attitudes.

Holt et al. (1991) used a comparison between automobile drivers and pilots in order to create a larger sample size due to the greater number of automobile accidents as compared to aviation accidents. This allowed them to measure attitudes and accident rates and extrapolate to the larger population of pilots. The measurements for the Holt et al. (1991) study used a new instrument with nearly the same attitudes with one exception. By considering answers from the automobile surveys, the researchers found that there was one additional attitude that related to the drivers' confidence in their ability, which they titled the *Self-Confidence* hazardous attitude. This study also identified an additional, unexpected factor that represented *self-confidence*. The result of this identified a new set of six hazardous attitudes that included *Macho, Resignation, Antiauthority, Worry/Anxiety, Impulsivity*, and *Self-Confidence*.

Another effect of studying hazardous attitudes from the Holt et al. (1991) study was to improve the type of instrument being used to measure hazardous attitudes, the New Hazardous Attitudes Survey (New-HAS). While the results of the Holt et al. (1991) study focused on drivers, the instrument switched from the FAA's ipsative type instrument, which was included within their Aeronautical Decision Making training manuals, to one using a Likert Scale. Ipsative type surveys limited the subject's responses to either one or the other type of attitude, known as the *Forced Choice* method. By choosing one attitude over another, the ipsative scales cause unintentional de-emphasis of the other possible measurements.

Wetmore, Lu and Caldwell (2007) theorized that the reason 86% of fatal general aviation accidents involve hazardous attitudes as a contributing factor, even after years of education and awareness efforts, could be the way Certified Flight Instructors (CFI's) are conducting training. "The answer to this question may be that certain tenets and beliefs of the educational philosophies, ideologies, and theories permeating our educational system can actually exacerbate rather than ameliorate hazardous attitudes" (Wetmore, Lu, & Caldwell, 2007, p. 30). Their conclusion was that each CFI must continuously evaluate their teaching style and ask themselves whether their students possess any hazardous attitudes, identify each hazardous attitude their students may have and then evaluate their teaching style to determine whether it is either mitigating the hazardous attitudes or making it worse.

Methodology

This study utilized a quantitative methodology that analyzed differences between male and female pilots concerning their tendencies toward one or more of the hazardous attitudes that could facilitate unsafe decision-making in the flight deck. In attempting to address this issue, it was necessary to first identify a population of pilots that included both males and females, and then survey them using the New Hazardous Attitudes Scale. The New-HAS is a self-assessment instrument used to assist pilots in assessing and understanding their own tendencies. This instrument was developed for previous studies and this variation presents 88 simple declarative statements with a five-point Likert-type response scale.

Analysis of the New-HAS was conducted by Hunter (2005) and produced six-factors that corresponded to the same factors detailed by Holt et al. (1991) which included *Macho*, *Resignation*, *Antiauthority*, *Anxiety/Worry*, *Impulsivity*, and *Self-Confidence*. The questions corresponding to these Hazardous Attitudes factors, developed by Hunter (2005), are detailed in Appendix A.

Research Hypotheses

In this study, the authors aimed to clarify the effect of gender and training on a student's tendencies toward hazardous attitudes. The corresponding research hypotheses are as follows:

Hypothesis 1. Overall, females score lower on hazardous attitudes inventories than do males.
Hypothesis 2. As flight training levels advance, hazardous attitudes will decrease for both genders.
Hypothesis 3. Overall, the Hazardous Attitudes *Macho* and *Resignation* will be more prevalent in inventory scores than the other attitudes.
Hypothesis 4. As training levels advance, females will score lower overall on hazardous attitudes than do males.

Data Analysis

Data analysis was performed using IBM's Statistical Package for the Social Sciences (SPSS) statistics program version 25. Prior to testing the hypotheses, an Overall Hazardous

Attitudes score was computed as the average of the six New-HAS scales. All seven scales were assessed for normality using *z*-scores formed by dividing skewness values by the standard error of skewness (*SK/SE*). Hypotheses 1 and 2 were analyzed using independent samples *t*-tests. Hypothesis 3 was tested by first computing an Overall Hazardous Attitudes score, excluding the *Macho* scale, and another Overall score excluding the *Resignation* scale. Then paired *t*-tests were used to compare the *Macho* scale to the average of the other five scales and the *Resignation* scale to the average of the remaining five scales. Hypothesis 4 was tested using two-by-two analyses of variance (gender by training level) on the six Hazardous Attitude scales as well as the Overall Hazardous Attitudes score. A multivariate analysis of variance (MANOVA) of the six Hazardous Attitude scales was also computed. An alpha of .05 was accepted as the level of significance.

Participants

The New-HAS was provided to 208 students in eight classes from two universities with Part 141 flight schools located within the Midwest region of the United States over a six month period between March and September 2017. In total, 23 of the surveys were returned at the end of the allotted time-frame unanswered, which resulted in an 88.9% response rate. The final sample of 185 students were over the age of 18, and included 26 females (14.1%), which is above the 2012 national average of 4.3% (AOPA, 2015). Due to the relatively small size of the sample--especially the female portion of the sample--the five levels of training that were included in the questionnaire were instead grouped together into two groups including basic level of flight training (student pilot & private pilot) and advanced flight training (instrument, commercial, and Certified Flight Instructors).

Limitations listed here represent potential weaknesses and include items that are mostly out of the control of the researcher. The identified limitations of this study include the limited number of collegiate flight schools that accepted the request to survey students. The participating schools were located in Missouri and Tennessee and the participants were enrolled in a private, instrument, or commercial ground course. This led to a reduced number of classrooms and number of participants representing each population.

G*Power indicates total sample size of 128 is needed to achieve power of 0.80 for a medium size effect for *t*-tests and *F*-tests. G*Power also indicated that MANOVA would have needed a sample size of 226 to achieve a power of 0.80. However, the MANOVA did not yield a significant difference.

Hypothesis Testing

Hypothesis 1: This hypothesis was tested by first computing an Overall Hazardous Attitudes score, as the average of the six Hazardous Attitude scales. Then, an independent samples *t*-test was conducted between males and females on the Overall score as well as for the individual Hazardous Attitude scales. The results are presented in Table 1.

Table 1

Males vs. Females on Hazardous Attitudes scales

	Females (n = 26)		Males (n = 159)				
	Mean	*SD*	*Mean*	*SD*	*t*	*df*	*p*
Macho	**2.46**	**0.56**	**2.75**	**0.55**	**-2.47**	**183**	**0.015**
Resignation	2.19	0.48	2.28	0.53	-0.79	183	0.433
Anti-Authority	2.02	0.45	2.14	0.44	-1.27	183	0.205
Anxiety/Worry	3.13	0.56	2.95	0.48	1.64	183	0.104
Impulsivity	2.39	0.46	2.51	0.43	-1.25	183	0.212
Self Confidence	3.74	0.44	3.78	0.47	-0.37	183	0.712
Overall Attitude	2.66	0.21	2.73	0.23	-1.62	183	0.107

Note. Scale showing a statistically significant difference is indicated in bold.

As shown, female scores were not significantly lower than male scores on the Overall Attitude score. This result does not support acceptance of Hypothesis 1. However, there was a significant difference in the scores for females (M=2.46, SD=0.56) and males (M=2.75, SD=0.55) on the *Macho* subscale: $t(183) = -2.47$, $p = .015$. The tendency for females to exhibit significantly lower scores of the *Macho* hazardous attitude confirms the findings previously identified by Holt et al. (1991) and Hunter (2005).

The sizes of groups compared in this study, such as those between female and male pilots are acknowledged as being unequal. According to Nolan and Heinzen (2017) if sample sizes are unequal, then the statistical test is generally valid as long as the largest variance is not more than twice the size of the smallest variance. Levenes's tests were conducted on all *t*-tests, *F*-tests, and MANOVA to assess the equality of variances between the groups. These tests indicated there was no violation of homogeneity of variances.

Hypothesis 2: This hypothesis was tested by conducting independent samples *t*-tests between those with basic flight training and those with advanced flight training on the six Hazardous Attitude scales as well as the Overall Hazardous Attitudes score. The results are presented in Table 2.

Table 2

Basic vs. advanced flight training on Hazardous Attitudes scales

	Flight Training						
	Basic (n = 139)		Advanced (n = 46)				
	Mean	*SD*	*Mean*	*SD*	*t*	*df*	*p*
Macho	2.69	0.57	2.75	0.50	-0.65	183	0.516
Resignation	**2.33**	**0.50**	**2.08**	**0.53**	**2.90**	**183**	**0.004**
Anti-Authority	2.14	0.45	2.08	0.44	0.80	183	0.426
Anxiety/Worry	2.97	0.48	2.99	0.55	-0.18	183	0.855
Impulsivity	2.50	0.41	2.47	0.50	0.37	183	0.712
Self Confidence	**3.82**	**0.45**	**3.64**	**0.47**	**2.28**	**183**	**0.024**
Overall Attitude	2.74	0.24	2.67	0.21	1.88	183	0.062

Note. Scales showing a statistically significant difference are indicated in bold type.

As shown, students with advanced training (*M*=2.67, *SD*=0.21) had slightly lower overall attitude scores, although the difference between their scores and those of the students with basic training (*M*=2.74, *SD*=0.24) did not achieve statistical significance: $t(183) = 1.88$, $p = .062$. However, two of the six Hazardous Attitudes scales were significantly lower in the students who had advanced training. There was a significant difference in the scores for the *Resignation* hazardous attitude for basic flight training (*M*=2.33, *SD*=0.50) and advanced flight training (*M*=2.08, *SD*=0.53); t (183) = 2.90, p =.004. There was also a significant difference in the scores for the *Self-confidence* hazardous attitude for basic flight training (*M*=3.82, *SD*=0.45) and advanced flight training (*M*=3.64, *SD*=0.47); t (183) = 2.28, p =.024.

Hypothesis 3: This hypothesis was tested by first computing an Overall Hazardous Attitudes score excluding the Macho scale, and another overall score excluding the *Resignation* scale. Then paired *t*-tests were used to compare the *Macho* scale to the average of the other scales and the *Resignation* scale to the average of the remaining scales. The results are presented in Table 3.

As shown, there was no difference in the degree to which the participants scored on the *Macho* scale as compared to all other scales combined. However, the *Resignation* scale was significantly lower than the mean of all other scales combined. These results support rejection of Hypothesis 3, since no significant difference was found for the *Macho* scale and *Resignation* was actually significantly lower, rather than higher than the average of the other scales combined.

Table 3

Macho and Resignation scales vs. other scales

	Scale		Overall Without Scale		Difference				
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*t*	*df*	*p*
Macho	2.70	0.56	2.73	0.24	-0.02	0.57	-0.54	184	0.589
Resignation	**2.27**	**0.52**	**2.82**	**0.22**	**-0.55**	**0.48**	**-15.38**	**184**	**< .001**

Note. Scale showing a significant difference is indicated in bold type.

Hypothesis 4: This hypothesis was tested using a two-by-two analyses of variance (gender by training level) on the six Hazardous Attitude scales as well as the Overall Hazardous Attitudes score. The results are presented in Table 4 and Table 5.

The MANOVA did not show overall significant differences by gender or training, but the interaction between gender and training was significant for the Overall Attitudes score. The interaction effect is illustrated in Figure 1.

Table 4

Gender by Training on Hazardous Attitudes scales

	Females/ Basic (n = 18)		Females/ Advanced (n = 8)		Males/ Basic (n = 121)		Males/ Advanced (n = 38)	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Macho	2.32	0.50	2.77	0.58	2.74	0.56	2.75	0.50
Resignation	2.24	0.48	2.09	0.50	2.34	0.51	2.08	0.54
Anti-Authority	1.94	0.50	2.20	0.25	2.17	0.43	2.06	0.46
Anxiety/Worry	3.11	0.46	3.17	0.78	2.95	0.49	2.95	0.49
Impulsivity	**2.28**	**0.41**	**2.64**	**0.49**	**2.53**	**0.41**	**2.44**	**0.51**
Self Confidence	3.82	0.43	3.57	0.44	3.82	0.46	3.65	0.48
Overall Attitude	**2.62**	**0.19**	**2.74**	**0.24**	**2.76**	**0.24**	**2.65**	**0.20**

The interaction effect indicates that hazardous attitudes were lower for females with basic training (M=2.62, SD=0.19) than for males with basic training (M=2.76, SD=0.24), but that females with advanced training (M=2.74, SD=0.24) had higher overall hazardous attitudes compared to the males with advanced training (M=2.65, SD=0.20); F = 4.76, p =.030. Table 11 also details a similar interaction effect for the Impulsivity scale, with females having more advanced training showing higher levels of impulsivity than males; F = 5.05, p =.026. The observed power and partial eta squared are shown in Table 11. These results support rejection of Hypothesis 4, since as levels of training advanced, females scored higher, rather than lower overall on hazardous attitudes than did males.

Table 5

Gender by Training on Hazardous Attitudes scales

ANOVAs	Gender				Training				Gender * Training			
	F	p	*Power*	η_p^2	F	p	*Power*	η_p^2	F	p	*Power*	η_p^2
Macho	2.49	0.116	0.35	0.01	3.21	0.075	0.43	0.02	3.15	0.078	0.42	0.02
Resignation	0.14	0.705	0.07	0.00	3.07	0.082	0.41	0.02	0.26	0.612	0.08	0.00
Anti-Authority	0.15	0.701	0.07	0.00	0.50	0.483	0.12	0.00	3.36	0.069	0.45	0.02
Anxiety/Worry	2.52	0.114	0.35	0.01	0.06	0.802	0.06	0.00	0.07	0.788	0.06	0.00
Impulsivity	**0.05**	**0.824**	**0.06**	**0.00**	**1.69**	**0.195**	**0.25**	**0.01**	**5.05**	**0.026**	**0.61**	**0.03**
Self Confidence	0.16	0.694	0.07	0.00	3.73	0.055	0.48	0.02	0.17	0.681	0.07	0.00
Overall Attitude	**0.28**	**0.601**	**0.08**	**0.00**	**0.02**	**0.883**	**0.05**	**0.00**	**4.76**	**0.030**	**0.58**	**0.03**
*MANOVA**	0.75	0.611			2.12	0.054			1.41	0.215		

Note. Scales showing significant differences are indicated in bold type.
* excludes the Overall scale

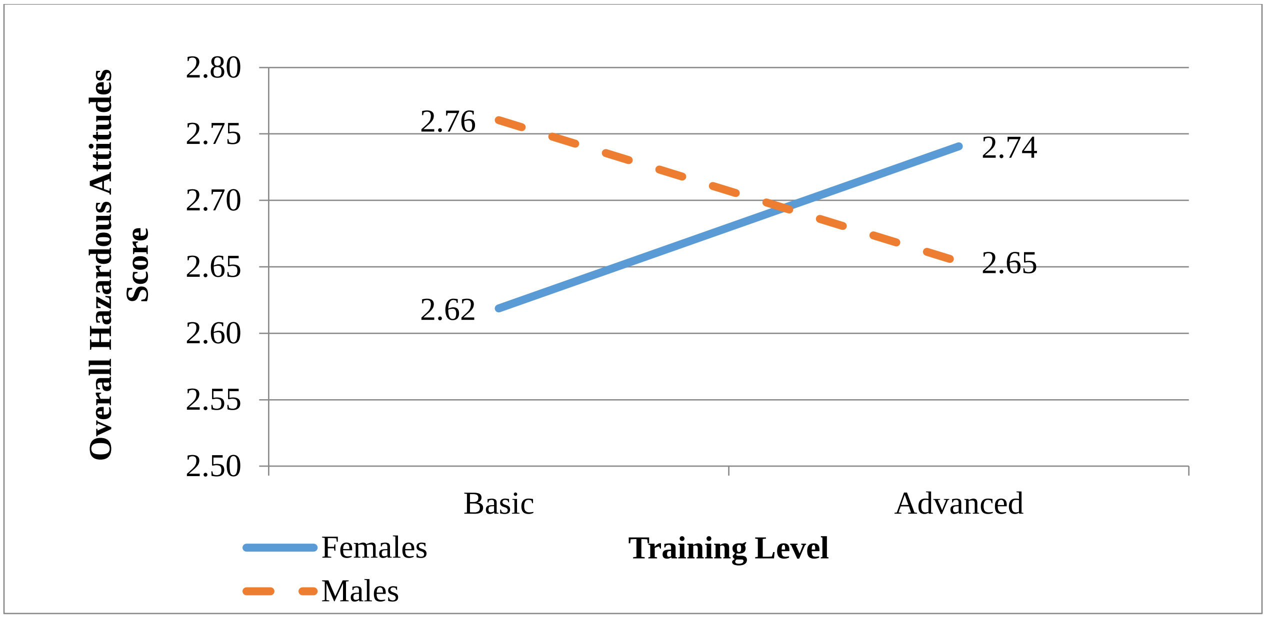

Figure 1. Gender by Training interaction effect on Overall Hazardous Attitudes

Findings and Conclusions

This study produced findings that suggest the possibility that previous research may not be generalizable or transferable between populations, regions, or timeframes. Population characteristics for this study limited the results to collegiate flight school students in their early 20's living in the Midwest region of the United States. Differences in these characteristics may have resulted in different results as suggested in previous literature. According to Reilly and Neumann (2013), societal factors can also modify the behavioral tendencies of young females to match those most acceptable to the norm.

Over the past decade, there have been campaigns throughout society to change the perceptions of what males and females should expect from gender. An example of one of these campaigns is the "Like a Girl" ad campaign conducted by Proctor & Gamble referenced by King (2015). These types of changes in what society perceives to be the norm could have an effect, over time, on the results of studies that address differences between genders.

Hypothesis 1 stated that overall, females will score lower on hazardous attitudes inventories than do males. According to the results from the New Hazardous Attitudes Scale, this hypothesis was not supported and the only significant finding confirmed previous studies results in which females demonstrated lower scores for the *Macho* hazardous attitude. While this finding confirms Holt et al. (1991) and Hunter (2005), it does not confirm that females demonstrated higher scores for the Resignation hazardous attitude.

Lester and Bombaci (1984) provide a possible explanation for the lack of *resignation* differences found in this study. They suggested that *resignation* should not normally be associated with pilots. A certificated pilot is required to spend a lot of time studying and training. This training, according to the authors, would eventually weed out any student who felt that their actions would not have an effect on the outcome, thus reducing the number who would demonstrate a high score in the *resignation* hazardous attitude.

Hypothesis 2 stated that as flight training levels advance, hazardous attitudes will decrease for both genders. The results support a partial acceptance of this hypothesis and potentially give support to the idea surrounding the effectiveness of collegiate flight programs in addressing hazardous attitudes to some degree. According to the results of this study, advanced flight students appear to exhibit slightly lower overall scores toward hazardous attitudes, especially *resignation* and *self-confidence* (when compared to basic flight students). The fact that the *resignation* and *self-confidence* hazardous attitudes exhibited lower scores in the advanced flight training suggests that advanced training provides some degree of mitigation to the decision-making abilities of students in stressful situations. As students progress through more advanced levels of flight education, the added skills and knowledge they acquire may be the reason they exhibit lower levels of *resignation* or *self-confidence*.

Hypothesis 3 stated that overall the hazardous attitudes *Macho* and *Resignation* will be more prevalent in inventory scores than the other attitudes. The results of this study indicated that the *Macho* hazardous attitude inventory presented lower scores for females and no significant difference for males. The *Macho* hazardous attitude exhibited no significant difference when compared with the average of the other scales. Conversely, the *Resignation* hazardous attitude did exhibit a significant difference when compared to the average of the other hazardous attitudes. Instead of being higher, the combined average was significantly lower. It was thought that since Holt et al. (1991) and Hunter (2005) did not separate results by training level or gender, that the results of this study would confirm their findings when each hazardous attitude was compared. Instead, only the finding on *macho* hazardous attitude was confirmed.

Hypothesis 4 stated that as training levels increase, females will score lower overall on hazardous attitudes than do males. It was believed that each of the hazardous attitudes would be partially mitigated through further flight training in both males and females. Previous literature suggested that females might be significantly safer overall than their male counterparts might, thus it was hypothesized that females might reduce their tendencies toward hazardous attitudes to a greater degree than males. Through the use of a MANOVA, the interaction between gender and training level identified a significant outcome in which females with advanced flight training had higher occurrences of hazardous attitudes, compared with males of the same level of flight training.

This study has implications in a variety of areas for collegiate flight schools at Midwestern universities. For collegiate flight school students, this study identifies areas where there may need to be more emphasis on determining learning preferences and what techniques may be more effective at reducing the presence of hazardous attitudes. For flight instructors, this study identifies potential successes and potential pedagogical pitfalls and how those may negatively impact both genders. A combination of factors might result in flight training better structured for males than for females. Females have attended and impacted the curriculum and training techniques of collegiate flight schools for a relatively short period of time as compared to males.

The results of this study indicate that the current instructional techniques or pedagogy are effective for males as they exhibited a decrease in their hazardous attitudes scores, while females exhibited a trend in the other direction. Identifying techniques for training populations of flight students who learn in different ways would potentially increase the effectiveness of learning beyond just the topic of hazardous attitudes, which could lead to safer and more knowledgeable pilots of both genders. The rise in overall hazardous attitudes scores for females should suggest to flight educational policy makers and associated stakeholders that they are not providing the female student pilots the same positive results, in regards to hazardous attitudes, as they are with their male student pilots. These results should provide a starting point for institutions determined to improve upon the instruction they provide to all students, which could result in the production of safer, better educated and more capable aviation professionals regardless of gender.

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Appendix A
Questions Corresponding to Hazardous Attitudes Factors (Hunter, 2005)

Table 1
Factor One questions from the New-HAS corresponding to the Macho Hazardous Attitude

Question	Factor Loading	Question Text
1	480	I'd like to be a bush pilot.
2	486	If there was a flying competition in my area, I'd participate in it.
3	755	I like to practice unusual attitudes in flying.
4	427	I like to see how close I can cut things.
5	409	I like landing on short fields just to show I can do it.
6	458	If gusty cross-winds were keeping other pilots on the ground, I'd consider flying anyhow to see if I could do it.
8	492	If I hear other pilots discussing a maneuver that can be done on my airplane, I'll try it out.
9	730	I like to practice spins.
10	430	I like to fly on the edge.
11	787	I like to practice unusual aircraft attitudes.
12	560	I like making turns steeper than 60 degrees, just to see if I can do it.
70	723	I like to practice stalls.
72	671	I like to practice steep turns.
73	485	If I find a sod (grass) field, I'll practice soft-field take off and landings.
74	514	When it's windy out, I like to work on my cross-wind landings.

Table 2.
Factor Two questions from the New-HAS corresponding to the Resignation Hazardous Attitude

Question	Factor Loading	Question Text
45	494	I might dip into my fuel reserve to avoid a fuel stop and save time.
46	436	Either an accident is going to happen to you or it isn't.
47	544	Sometimes I feel like the airplane has a mind of its own.
48	428	In a congested area, I figure that if I keep the correct altitude and heading I'll get through safely.
49	615	Sometimes I feel that I have very little control over what happens to the aircraft.
51	485	You don't go until your number is up.
52	401	I'll die when it's my time to go, but not before.
53	682	In a tight situation, I trust to fate.
54	625	When I'm in a tough spot, I figure if I make it, I make it, and if I don't, I don't.
55	522	If I think an accident is going to happen when flying, I tend to freeze at the controls.
56	531	If I had an accident, it would be the result of bad luck.
57	702	In flying, what will be, will be.
59	518	The strange noises in my airplane will just go away.

Table 3.
Factor Three questions from the New-HAS corresponding to the Antiauthority Hazardous Attitude

Question	Factor Loading	Question Text
61	752	The FAA is more of a hindrance than a help.
76	690	Air traffic control is often more of a hindrance than a help.
77	-530	In general, I get good service from Flight Service Stations.
79	-568	I will follow the FAA regulations even if they inconvenience me, because it's the right thing to do.
80	461	The FAA should do better things with their time than prosecuting pilots for minor airspace violations.
81	447	Random drug testing without any reason violates the rights of pilots.
83	-630	In general, I find ATC to be very helpful.
84	-629	FAA inspectors for GA are very competent.
86	630	Most of the Federal Aviation Regulations do not promote safety.
87	583	Ramp checks by FAA are a nuisance.
88	675	The FAA is more concerned with restricting access to aviation than in providing the services aviation needs.

Table 4.
Factor Four questions from the New-HAS corresponding to the Anxiety/Worry Hazardous Attitude

Question	Factor Loading	Question Text
13	464	I feel uncomfortable flying VFR in 3 miles visibility haze.
18	550	In an uncontrolled area with lots of traffic, I worry about the possibility of a mid-air collision.
19	-443	I feel comfortable flying at night.
20	636	I always worry about an accident when I'm flying.
21	636	I really worry about mid-air collisions.
22	630	While flying at night, I worry about not seeing navigation landmarks and getting lost.
23	617	I really worry about running out of fuel.
24	731	I really worry about having to make an emergency landing.
26	580	At night I worry about not being able to see an emergency landing field if the engine quits.
28	606	I feel very vulnerable to accidents.
30	623	If I fly over water, I worry about having to ditch if the engine quits.
31	409	If I'm on base leg and the wind shifts so I'd land with a tailwind, I'll go around to make a different approach.

Table 5.
Factor Five questions from the New-HAS corresponding to the Impulsivity Hazardous Attitude

Question	Factor Loading	Question Text
16	-542	If the weather is marginal, I don't mind waiting at the airport until it clears up.
33	695	I really hate being delayed when I fly on a trip.
34	417	I feel like yelling at people who don't clear the runway fast enough when I'm on final approach.
35	557	I'm basically an impatient pilot.
37	417	I get angry if I'm on approach on base leg and someone cuts in front of me doing a straight-in approach.
38	629	If I want to fly somewhere, I want to do it now.
43	441	If I could cut off a lot of time on a cross country flight by taking a short cut through an MOA, I'd do it.
82	574	If you want to protest a license suspension by the FAA, the odds are stacked against you.

Table 6.
Factor Six questions from the New-HAS corresponding to the Self-Confidence Hazardous Attitude

Question	Factor Loading	Question Text
51	409	You don't go until your number is up.
60	435	If I have done something illegal while flying, I will report it myself because I figure someone will report it anyway.
64	603	I am a pilot due entirely to my hard work and ability.
66	424	I can learn any flying skill if I put my mind to it.
68	407	In a tight situation, I believe in doing anything rather that doing nothing.
69	606	The thoroughness of my preflight mostly determines the likelihood of my having mechanical trouble with the aircraft.
78	529	A successful flight is solely due to good planning and good execution.

Collegiate Aviation Review International

Volume 37 | Issue 1 Peer-Reviewed Article #6

1-1-2019

Does a SWT Reverse Contagion Effect Exist from Humans to Automation?

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This study examines passengers' level of trust after a failure in a member of the flight crew. This study seeks to establish the possible presence of a reverse contagion effect wherein passenger trust in automated system components is affected by an error in a human system element. Trust was measured in five human entities and five automated aids with participants from both India and the United States. The human entities include the pilot, the co-pilot, the flight attendant, the maintenance manager, and the CEO of the airline. The automated aids were the oxygen masks, the auto-pilot system, the airplane's flaps, the landing gear, and the video screens on the backs of the seats. This study was conducted in three stages, including two three-way ANOVAs to determine to effect, and meditation analyses to determine if affect mediates the effect. Participants were posed with two hypothetical scenarios, a control condition and a failure condition. The participants rated their levels of trust in the five different human entities and the five different automated aids. Trust was measured on a 7-point Likert type scale from –3 to +3. Questions relating to the participants' feelings were also asked to measure affect. The results showed a decrease in trust in the automated aid after the human failure, as well as a country effect, and a mediating effect of affect.

Recommended Citation:
Mehta, R. Chauhan, B., Edwards, M., Rosser, T., Dunbar, V., & Rice, S. (2019). Does a SWT Reverse Contagion Effect Exist from Humans to Automation. *Collegiate Aviation Review International*, 37(1), 90-106. http://dx.doi.org/10.22488/okstate.19.100206

The prevalence and continued development of automation within the aviation and aerospace industries has warranted significant scholarly investigation into the manner in which human operators both perceive and interact with automated systems. To this end, System Wide Trust (SWT) Theory is a theoretical framework which describes the manner in which perceptions of precision and reliability in an independent system component are affected by inaccuracies in other independent components (Rice & Geels, 2010; Geels-Blair, Rice, & Schwark, 2013; Keller & Rice, 2010). Where previous studies focused primarily on the application of SWT Theory to pilot perceptions of independent automated aids, Mehta and Rice (2016) proposed and demonstrated the probable existence of a contagion effect whereby passenger perceptions of human elements within the system are negatively impacted by the failure of an automated aid. Furthermore, the effect may be asserted to apply to human entities who exercise no practical operational control over the aircraft (Mehta & Rice, 2016).

In an attempt to expand on the research of Mehta and Rice (2016), this study seeks to establish to determine if there is a reverse contagion effect wherein passenger trust in automated system components is affected by an error in a human system element. In order to determine the significance of culture in the application of SWT Theory in a reverse contagion scenario, this study will be inclusive of a cross-cultural analysis with participants from both the United States and India. Finally, the study will include a mediation analysis in order to determine whether the perceptions of passengers are based on affect rather than logic.

Trust and Automation

Anywhere in the world when an aircraft safely lands or takes-off, it is a result of decades of innovations, research, and development in technological aspect of various aircraft systems that have played an important role in shaping the aviation industry that we see today. Over the years, accidents per million take-offs have reached a new low (Chialastri, 2012). But, these innovations did not happen overnight. Time and again, the need for improvement came at a heavy price in the form. These accidents led to the discover of loopholes in the systems, technologies, and regulations, which then led to the development of safer and more reliable systems. These improvements lowered the accident rate and increased the reliability and trustworthiness of the industry.

The term automation can be defined in multiple ways. For the context of this research, automation can be defined as the use of a control system and the available information technologies to reduce the need for human work in the production of goods and services (Chialastri, 2012). Arnott (2007) defines trust as one’s ability to rely on a third party especially when personal risk is involved. Trust, in some sense, can also be defined as the level of expectation from a certain entity (Hoffman, Johnson, Bradshaw & Underbrink, 2013). For this paper, that entity would be automation. Whenever any expectation is not met, trust level goes down, and often times cannot be repaired or restored to the initial level (Slovic, 1993).

Hoffman, Johnson, Bradshaw & Underbrink (2013) defines the term interpersonal trust as a trustor's willingness to be vulnerable to a trustee's actions on the basis that the trustee will be able to perform in full expectancy of the trustor. In this study, the trustee would be the human entities and the automated aids. This willingness to depend on either a human or a machine depends on various factors which vary for humans and machines.

Trust in automation is a relatively broad concept and level of trust in any given form of automation greatly depends upon the setting that it is being used. Complex algorithms are being developed to use automation in various fields like aviation, manufacturing, and medicine. The ultimate goals of these complex algorithms are to make automation technology as least complicated as possible and assist the performance of the user which, when done by either human or automation is not possible (Fallon, Murphy, Zimmerman & Mueller, 2010). In order to maximize the human machine relationship, the strengths of the automation must be matched with the human's level of trust in the system.

Parasuraman and Riley (1997) stated that one of the key reason why humans are still not completely removed from the system is that humans are reliable, flexible, adaptable, and more creative than the present automation systems. These attributes allow human to react appropriately for unique situations that arise. Particularly, for aviation, there are far too many variables to consider when developing an automation system that can used onboard aircraft. Therefore, it is a reasonable argument that humans need to be present for a full assessment of the situation.

Cultural Considerations

The global nature of the aviation industry warrants the investigation of consumer perceptions across multiple cultures so as to determine how separate cultural groups of people react to similar scenarios. Hofstede (1984) defines culture as "the collective programming of the mind which distinguishes the members of one group or society from those of another" (p. 82). It stands to reason, therefore, that the evaluation of theoretical psychological constructs across multiple cultures is vital to the generalizability of the construct being investigated. The significance of these cultural differences from a commercial aviation perspective is highlighted in scholarly discussions and investigations of crew resource management (Helmreich & Merritt, 1998). Helmreich and Merritt (1998) emphasize the importance of these cultural considerations as the applications of practices based on investigated psychological constructs in one culture may not prove as successful in a difference cultural context. For the purpose of this study, survey responses from the United States and India will be used to identify how consumers from two distinct cultures experience the proposed reverse contagion effect differently, if at all.

In order to more empirically evaluate the differences between cultures, Hofstede (1984) proposed a series of cultural dimensions which attempt to categorize broad cultural phenomena, and explain such phenomena in a manner which allows for the estimation of behavioral responses from members of a given national culture. These dimensions included Individualism versus Collectivism, Large versus Small Power Distance, Strong versus Weak Uncertainty Avoidance, and Masculinity versus Femininity (Hofstede, 1984). The dimension of *Individualism* vs. *Collectivism* describes the degree to which members of a given culture identify as an individual or as a part of the wider collective (Hofstede, 1984). It describes the degree to which a member of a given society identifies as "'I' or 'we'," (Hofstede, 1984, p. 83). The dimension of *Power Distance* describes the degree to which individuals accept the existence of an unequal distribution of power within an institution. In *Large Power Distance* societies, persons have a tendency to favor and accept significant hierarchical structure. Conversely, members of *Small Power Distance* societies "strive for power equalization and demand justification for power inequalities," (Hofstede, 1984, p. 83). *Uncertainty Avoidance* refers to the degree to which members of a given society accept or reject "uncertainty and ambiguity," (Hofstede, 1984, p. 83). Finally, the dimension of *Masculinity* versus *Femininity* refers to the degree to which members of a culture value "achievement, heroism, assertiveness, and material success," or "relationships, modesty, caring for the weak, and quality of life" respectively (Hofstede, 1984, p. 84). Additionally, this dimension is used to describe the assignments and prevalence of gender roles (Hofstede, 1984).

The justification for the use of the United States and India in order to demonstrate anticipated differences in survey responses due to cross-cultural considerations comes from an empirical application of Hofstede's dimensions in the form of cultural indexes. Hofstede (1984) establishes that, with an Individualism versus Collectivism Index of 91, the United States significantly outscores India, at 48 (Hofstede, 1984). This suggests that, generally, the national culture of the United States may be purported to be significantly more individualistic than the Indian National Culture. Interestingly, Indians, having a median score of 48, can however sometimes display individualistic tendencies (Rice, et al., 2014). With respect to Power Distance, the national culture of India, with a Power Distance Index of 77, is significantly greater than that of the United States which has a Power Distance Index of 40. The remaining dimensions, namely Uncertainty Avoidance and Masculinity-Femininity, also suggest differences between the two national cultures with India scoring lower in both Uncertainty Avoidance and Masculinity (Hofstede, 1984).

Affect

Doss (2009) discusses affect, or emotion, as a significant element of the human condition. It is further established that, while there exists "the Habermasian vision of a rational public sphere," the significance of affect at both an individual and a societal level is such that modern society may be said to have been molded significantly by the expression of human emotion" (p. 10). It is, therefore, of significant importance to consider the effect of affect when investigating trust and risk perception.

Peters, Västfjäll, Gärling & Slovic (2006) states that affect can act as first-hand information during a decision-making process. During the time that requires a person to make a judgment on the given available choices, they tend to consult their emotions first before arriving at any decision. In a phenomenon termed "the affect heuristic," Slovic, Finucane, Peters and MacGregor (2007) establish that "affective responses occur rapidly and automatically" and suggest that the effect of this heuristic plays a significant role in day to day life (p. 1333).

While this is not inherently negative from a research perspective, there are instances in which the ability to manipulate affect may play some role in the resultant response of an individual to a given stimulus (Slovic et al., 2007). Consequently, Slovic et al. (2007) report that affect is liable to be manipulated via external influence such as music and emotive language, and via internal individual biases. The case for external manipulation is of significant importance to researchers of SWT theory because it implies that the context of a system component failure or the manner in which it is reported to passengers may manipulate their perception of the failure, as well as their subsequent perception of remaining system elements.

Several consumer research studies have showed that emotions play a key role when a person is put in a situation that involves decision-making, and can be a mediating effect in relation to consumer opinions and trust (Mehta, Rice, & Rao, 2016; Mehta, Rice, Winter, & Buza, 2017; Rice, Winter, Kraemer, Mehta, & Oyman, 2015; Winter, Rice, Friendenreich, Mehta, & Kaiser, 2017; Winter, Rice, & Mehta, 2014). As mentioned in the previous section, emotions can cloud a person's ability to make sensible decisions. Although the decisions that are made under the influence of emotions are not worse than those based on logic, but the output that comes out of them may not be as reliable. Heekeren, Schulreich, Mohr, & Morawetz (2017) states that emotions have long since played a major role in the decision-making process, and theoretic approach suggests that both cognition as well as affect play a key role when a person has to make a decision.

Current Study

Previous work that has been done in the field of SWT has focused on pilots' ability to trust automated aids (Rice & Geels, 2010; Geels-Blair, Rice, & Schwark, 2013; Keller & Rice, 2010). Passengers are an integral part of a flight. Their trust in the aircraft they are flying in, their feelings of safety when flying, or their trust in the pilots and the automation are some of the key factors that help in understanding their perceptions of any onboard failures. This paper focuses on passengers' level of trust during a human failure. A situation is presented to the participants from the United States and India where there is an unintentional mistake (failure) made by the pilot.

The study seeks to measure their changes in trust (if any), in five human entities and five automated aids. The human entities are the pilot, the co-pilot, the flight attendant, the maintenance manager, and the CEO of the airline. The automated aids involved are the oxygen masks, the auto-pilot system, the airplane's flaps, the landing gear, and the video screens on the backs of the seats. Sometimes emotions precede over rational decision making, which influences a person's choices, and therefore, meditation analyses are conducted to determine if affect mediates the effect. The hypotheses for the current study were as follows:

H1: In the failure condition, there will be a decrease in trust in the unrelated automated aids or human entities compared to the control condition.
H2: There will be a difference in trust and affect ratings for the unrelated automated aids or human entities as a function of country of origin.
H3: The relationship between the condition and trust will be mediated by affect.
H4: There will be an interaction between the independent variables.

Methods

This study was conducted in three stages in order to lend strength to the findings of the research. The explanation regarding each stage will be detailed in the design section.

Participants. A total of 400 hundred participants from the United States (*N* = 199) and India (*N* = 201) were recruited to participate in this research study. The mean age was 32.78 (*SD* = 9.46).

Materials and Stimuli. The instrument used for this research was developed using Google Forms®, and participants were recruited for the study using Amazon's ® Mechanical Turk ® (MTurk). Although participants completing human intelligence tasks online in exchange for compensation has its limitation, the large convenient sample that is obtained outweighs several of the limitations of this methodology. In fact, studies by Buhrmester, Kwang, and Gosling (2011) and Germine, et al. (2012) both suggest that data collected on MTurk is as reliable as data collected in a traditional laboratory. Participants were asked to verify that they were at least 18 years of age, before being given the instructions for the questionnaire. Participation was voluntary, and no identifying information was collected from the participants. Once they completed the questionnaire, they were given instructions on how to redeem the compensation.

Procedure. In the questionnaire, two independent samples of participants were posed with two hypothetical scenarios. The first sample was presented with the following scenario, and was considered the control condition.

"Imagine that you are flying on a 4-hour commercial airplane flight from one major city to another. Sometime during the flight, the pilot comes on the intercom and tells you the altitude of flight and how long it will be before you land."

The second sample was presented with the following scenario, and was considered the failure condition.

"Imagine that you are flying on a 4-hour commercial airplane flight from one major city to another. Sometime during the flight, the airplane starts descending significantly at a point you did not expect. Following this, the pilot comes on the intercom and says that he made an error, that they were not supposed to descend and will rectify the mistake. He says that there is no actual emergency and not to worry. The pilot then tells you the altitude of flight and how long it will be before you land."

The questionnaires asked the participants to rate their levels of trust in the five different human entities and the five different automated aids. Trust was measure on a 7-point Likert type scale from –3 to +3 (extremely distrust to extremely trust) with a neutral option of zero. Questions relating to the participants' feelings were also asked in an effort to measure affect. Before being dismissed, participants were lastly asked for demographic information.

Design

Stage 1. This stage uses an experimental design employing factorial ANOVAs on the affect and trust data sets. The two-way factorial ANOVA performed on the affect data sought to identify the differences in participant emotions regarding the scenarios between the two countries of origin. The IVs were country of origin, and Failure/Non-Failure of the human. The three-way factorial ANOVA (2x2x10) was performed on the trust ratings of the participants. The IVs in this analysis were country of origin, category of human entity/type of automated aid, and Failure/Non-Failure of the human. The trust ratings of the participants were used for the DV.

Stage 2. Stage 1 conducted an ANOVA with all five human entities and all five automated aids, including the pilot that had the failure. With the pilot performing erroneously (failure) it was expected to show decreased levels of participant trust. Therefore, a secondary analysis was conducted with the aim of separating out the negative influence of the decreased levels of pilot trust. In stage 2, the remaining four human entities were averaged into one rating, and the five automated aids were averaged into one rating. A new three-way factorial ANOVA (2x2x2) was conducted with this modified data set. The IVs were still country of origin, category of human entity/type of automated aid, and Failure/Non-Failure of the human, although the levels of the second IV were reduced to 2 instead of the initial 10. The DV was still the participants' trust ratings.

Stage 3. Lastly, four different mediation analyses were performed using the affect data to determine whether emotions (affect) mediated the effect. As in stage 2, the mediation analyses were conducted with the pilot that made the mistake (failure component) removed from the ratings. The four mediation analyses were American participants on human entities, American participants on automated aids, Indian participants on human entities, and Indian participants on automated aids.

All the stages of this study used interval scales of measurement for the DVs even though the data was ordinal, due to the values being assigned equal magnitude difference on the Likert type scale (Göb, McCollin, and Ramalhoto, 2007).

Results

Stage 1. To produce a single value describing the participant's overall trust in the situation, all the values of the trust questions were averaged into one. The same was done for the affect data. Eight Cronbach's Alpha tests were conducted for each as a measure of internal consistency. Cronbach's Alpha scores ranging from .87 to .94 were found for the affect data and trust data for both Indians and Americans in both the control and failure conditions. These instruments were used in a previous study that measured the SWT contagion effect (Mehta & Rice, 2016). The previous study being considered as a pilot study for the instrument along with these Cronbach's Alpha scores add support for the research instrument as being valid and reliable for use in this study's setting. A two-way ANOVA was conducted on the affect data, with Failure/Non-Failure of the automation, and Country of Origin of the participants as the factors. There was a main effect of Failure, $F(1, 396) = 203.323$, $p < .001$, *partial-eta squared* = 0.34. There was a main effect of Country, $F(1, 396) = 16.331$, $p < .001$, *partial-eta squared* =

0.04. These effects were qualified by a significant interaction between Failure and Country, $F(1, 396) = 28.849$, $p < .001$, *partial-eta squared* = .07. This suggests that the American participants were more extreme in their views towards failure condition as compared to their Indian counterparts. Figure 1 displays the affect data for both participant groups in both conditions.

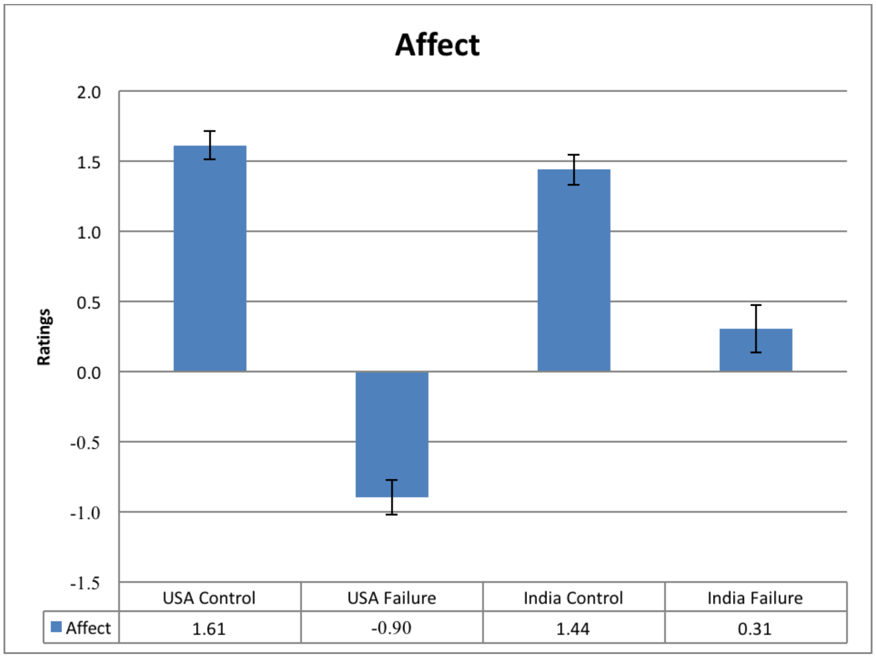

Figure 1. Affect Data for Indian and U.S. participants for Failure and Control Conditions.

A 2x2x10 ANOVA was conducted on the Trust data, with Type of automated device or category of human entity, Failure/Non-Failure of the automation, and Country of Origin of the participants as the factors. There was a main effect of Failure, $F(1, 396) = 107.981$, $p < .001$, *partial-eta squared* = .21. There were no other significant effects. There was a main effect of Type of automated device or category of human entity, $F(9, 396) = 23.413$, $p < .001$, *partial-eta squared* = .06; however, this effect was qualified by three significant interactions. The first was between items and country, $F(9, 396) = 5.508$, $p < .001$, *partial-eta squared* = .01. The second was between items and failure, $F(9, 396) = 25.125$, $p < .001$, *partial- eta squared* = .06. The final interaction was a three way interaction between items, country and failure, $F(9, 396) = 11.978$, $p < .001$, *partial-eta squared* = .03. Participants showed a significant decline in trust in both human entities and automated aids, suggesting the presence of SWT effect and a contagion effect. The trust data for the Indian and American participants are shown below in Figure 2 and Figure 3 respectively.

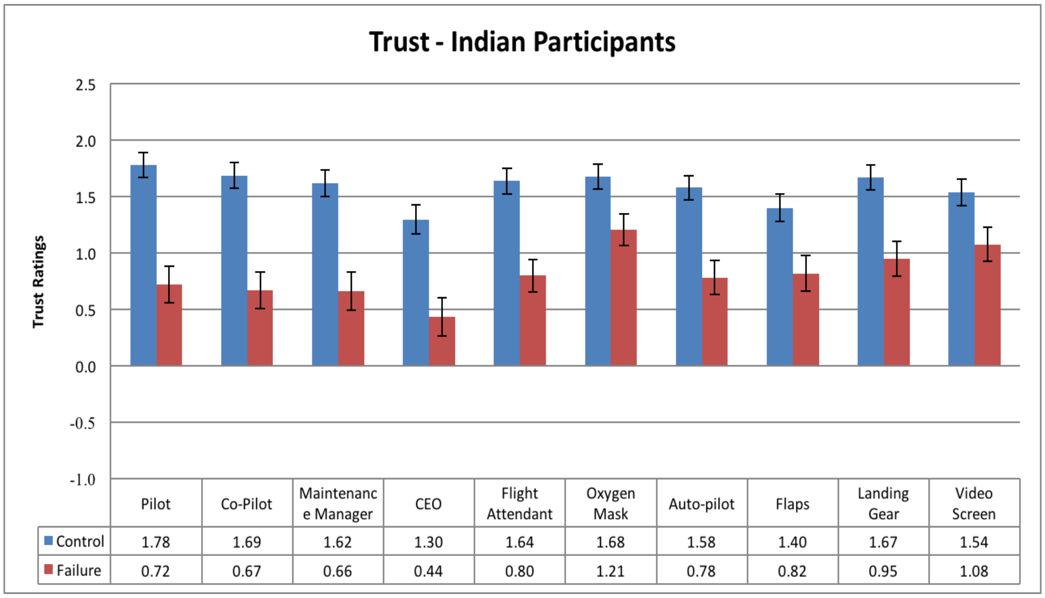

Figure 2. Trust Data for Indian participants for Failure and Control Conditions.

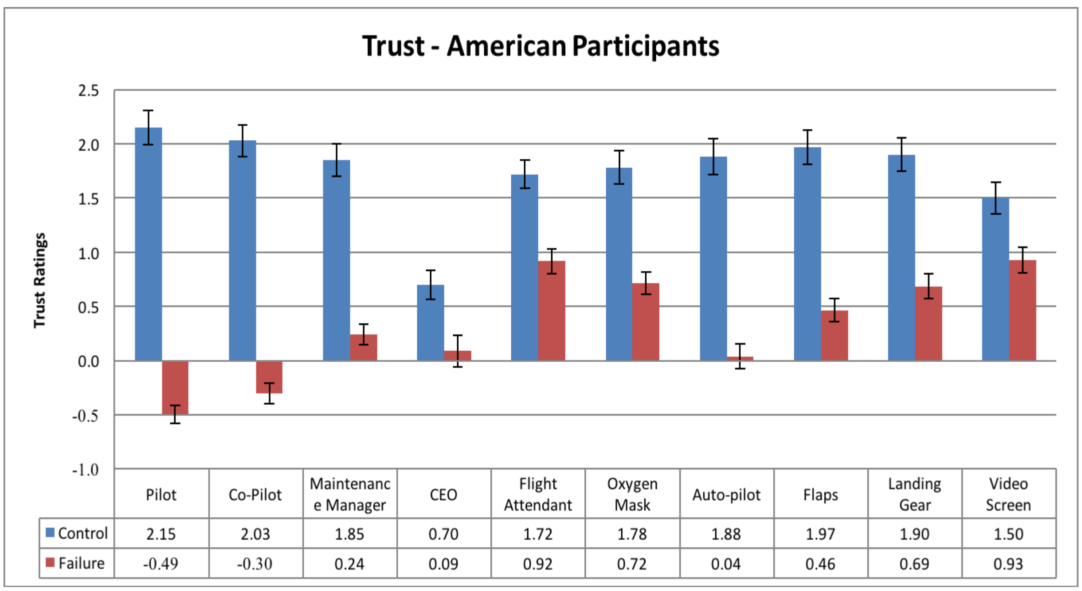

Figure 3. Trust Data for American participants for Failure and Control Conditions.

Stage 2. A 2x2x2 ANOVA was conducted on the Trust data, with Type of automated device or category of human entity, Failure/Non Failure of the automation, and Country of Origin of the participants as the factors. There was a main effect of Items, $F(1, 396) = 35.310$, $p < .001$, *partial-eta squared* = .08. This effect was qualified by an interaction between Items and Failure, $F(1, 396) = 7.46$, $p = .01$, *partial-eta squared* = .02. There was a main effect of Failure, $F(1, 396) = 92.939$, $p < .001$, partial-eta squared = .19 this effect was qualified by one significant interaction between Country and Failure, $F(1, 396) = 6.110$, $p = .01$, *partial-eta squared* = .02. There were no other significant effects.

This analysis suggested that the decrease in trust was still significant indicating the presence of the SWT effect and contagion effect with the effect of the human pilot removed from the analysis. Figure 4 shows the trust averages for both the Indian and American participants on the four Human entities and the five automated aids.

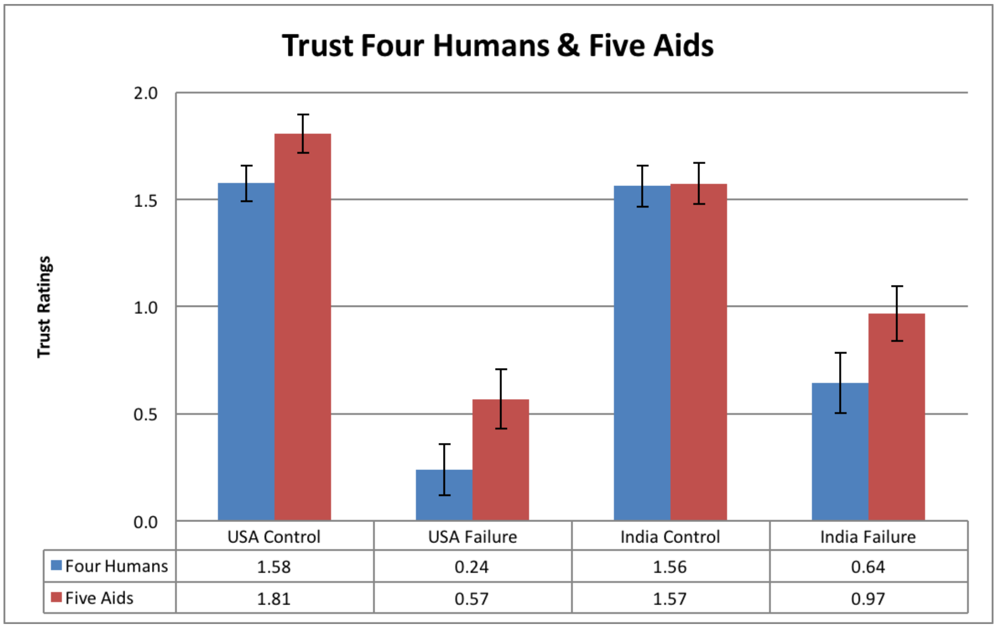

Figure 4. Trust data on the four human entities and the five automated aids.

Stage 3. The first mediation analysis was conducted using American participants to compare the failure condition to the non-failure condition with respect to their feelings towards the human entities. The paths for this mediation analyses can be found in Figure 5A. In order to conduct the mediation analysis, the correlation between Condition and Trust was first found to be significant, $r = -.552$, $p < .001$, showing that the initial variable correlated with the outcome variable. The standardized path coefficients were: condition to affect ($\beta = -.749$, $p < .001$); affect to trust ($\beta = .714$, $p < .001$); condition to trust controlling for affect ($\beta = -.017$; $p = .819$). These data show that Affect mediated the relationship between Condition and Trust.

The second mediation analysis was conducted using American participants to compare the failure condition to the non-failure condition with respect to their feelings towards the automated aids. The paths for this mediation analyses can be found in Figure 5B. In order to conduct the mediation analysis, the correlation between Condition and Trust was first found to be significant, $r = -.475$, $p < .001$, showing that the initial variable correlated with the outcome variable. The standardized path coefficients were: condition to affect ($\beta = -.749$, $p < .001$); affect to trust ($\beta = .598$, $p < .001$); condition to trust controlling for affect ($\beta = -.027$; $p = .753$). These data show that Affect mediated the relationship between Condition and Trust.

The third mediation analysis was conducted using Indian participants to compare the failure condition to the non-failure condition with respect to their feelings towards the human entities. The paths for this mediation analyses can be found in Figure 5C. In order to conduct the mediation analysis, the correlation between Condition and Trust was first found to be significant, $r = -.357$, $p < .001$, showing that the initial variable correlated with the outcome variable. The standardized path coefficients were: condition to affect ($\beta = -.373$, $p < .001$); affect to trust ($\beta =$

.619, $p < .001$); condition to trust controlling for affect ($\beta = -.126$; $p = .026$). These data show that Affect mediated the relationship between Condition and Trust.

The fourth mediation analysis was conducted using Indian participants to compare the failure condition to the non-failure condition with respect to their feelings towards the automated aids. The paths for this mediation analyses can be found in Figure 5D. In order to conduct the mediation analysis, the correlation between Condition and Trust was first found to be significant, $r = -.261$, $p < .001$, showing that the initial variable correlated with the outcome variable. The standardized path coefficients were: condition to affect ($\beta = -.373$, $p < .001$); affect to trust ($\beta = .549$, $p < .001$); condition to trust controlling for affect ($\beta = -.056$; $p = .373$). These data show that Affect mediated the relationship between Condition and Trust.

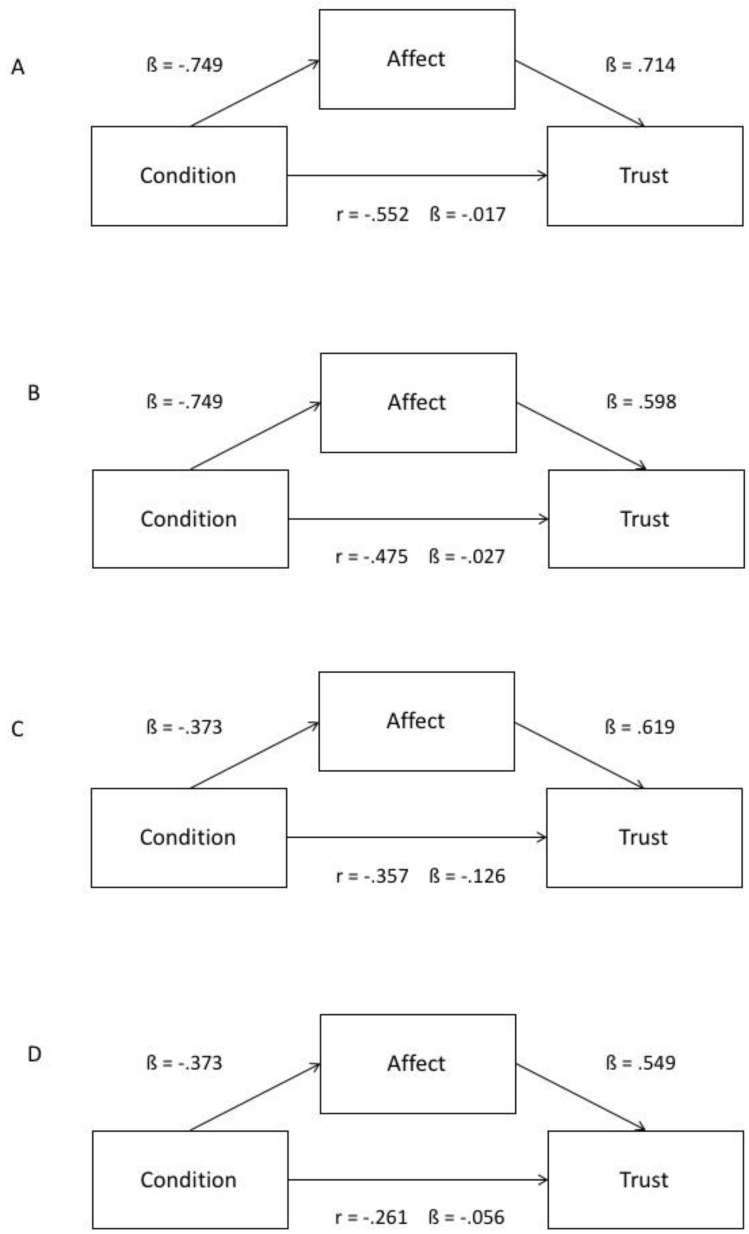

Figure 5. Paths for Mediation Analyses

General Discussion

The aim of this study was to determine if the SWT Contagion Effect, investigated by Mehta and Rice (2016), was applicable in a reverse contagion scenario wherein participant trust in system components was measured following a failure in a member of the flight crew as opposed to an automated system. Research findings support all the research hypotheses.

The first research hypothesis predicted that there would be a fall in trust in unrelated automated aids or unrelated human entities following the failure of a flight crew member as compared to the control condition. This proposition is supported by both stages of the data analysis. In Stage 1, findings depict significant decreases in passenger trust in all categories across both countries. Stage 2 data analysis depicted statistically significant decreases in passenger trust having removed the effect of the failed component from the analysis. This consistent decrease in passenger trust is evident of the existence of a reverse contagion effect. While the decrease in trust for other unrelated human entities is consistent with the findings of Mehta and Rice (2016), the decrease in trust in unrelated automated aids, while expected, is of particular interest. This decrease illustrates that SWT theory holds regardless of whether the failed entity is human or automated. Furthermore, it validates aforementioned research which establishes passenger trust in human operators, due to a perceived sense of human reliability, adaptability and flexibility.

The second research hypothesis predicted that trust and affect ratings for the unrelated automated aids or human entities would differ as a function of country of origin. To this end, the analyzed dataset depicts a lesser decrease in trust in the failed condition from Indian participants as compared to their American counterparts. These differences may be attributed to be the result of the significant cultural differences between the two countries as established by the analysis of Hofstede's (1984) cultural dimensions and their associated indexes. Of note are the ratings which depict India as being significantly more collectivistic and having a lower Uncertainty Avoidance. These prevailing qualities may be said to be conducive to the creation and prevalence of a generally more trusting society which manifests as smaller decrease in trust in a failed condition among Indians when compared to the decreases in trust by American respondents.

The third research hypothesis predicted that the condition and trust would be mediated by affect. To this end, the data analysis confirmed the hypothesis thereby establishing that the responses of survey participants were influenced by emotions rather than logic. This is consistent with the affect heuristic which establishes that, while emotion may not lead to the making of a bad decision, the decision-making process of an individual is based largely on the emotional response of that individual to, in this case, the failure condition. Consistent with the findings of Mehta and Rice (2016), the data also establishes that, while changes in passenger trust may differ between cultures, the responses of participants from both cultures were influenced by emotion.

The forth research hypothesis purported a non-directional prediction that there would be some interaction between the independent variables. Results also support this hypothesis as the fluctuations in passenger trust were qualified by interactions between the system component and the national culture, the system component and the failure condition, and the three-way interactions between system components, national culture and the failure condition. This too is consistent with the findings of Mehta and Rice (2016).

Limitations and Practical Implications

Any research work that is carried out has some restrictions. This study also has some limitations, and they have been well identified. The primary limitation is the data collection technique and methodology used. To achieve large samples sizes, the use of an online data collection source such as Amazon's ® Mechanical Turk ® (MTurk) is necessary, however in turn, this takes part of the control of the environment away from the researcher. While the data collection method allowed for a collection of large convenient samples, the generalization of the results is limited to just two countries. Therefore, the findings can only be applied to passengers in the United States and India and not all passengers around the globe.

Another limitation is the target participants. The study includes aviation consumers and non-aviation consumers—including those who may have never flown in an aircraft before. The rationale for this inclusion is that even though participants may not have flown on a commercial airline before, they may do so in the future and therefore can be considered potential future consumers. Additionally, the convenience sample including participants that have never flown on an airliner is beneficial to the sample size of the study, and is therefore an acceptable limitation. When conducting a study involving multiple stages of data analysis, a large sample size is required which comes with its own limitations, some of which are acceptable. Along with these limitations comes the limitation of the participants self-reporting levels of trust. Future research may seek to utilize a different means of studying participant trust that would be more free of bias, but for the purpose of this study to replicate the methodology of Mehta and Rice (2016), the same measurements of trust were incorporated.

Despite the limitations, the value of the study to the scientific community and the practical benefits to the aviation industry cannot be understated. Similar to the previous study in this context (Mehta & Rice, 2016), the practical implications of these findings is one of passenger understanding which could have significant financial consequences to the airline industry. Decreased trust in the airline system, the upper echelon of management (CEO) and in the industry as a whole could arise out of a failure of the human pilot.

It is important to understand these findings as failures in human pilots does not bring about an increase in trust in the automation. This is the most significant finding and practical contribution of this study. Had there not been the existing of this reverse contagion effect or rather a positive contagion effect (human failure leading to increased trust in automated components of the system), it could have indicated the turning of the tides to passengers' acceptance of more automated aircraft. The findings of this study show this not to be the case, and that knowledge is in fact value to aviation industry as it plans for the future with new more advanced automation in aircraft.

These findings could also be of use to industries outside of aviation, showing the human failure could have a negative contagion effect onto other independent components of the system.

Lastly, this study serves to revalidate the concept of the system wide trust theory as a whole by adding further evidence of its existence.

Future Work

The primary source of future research will be the replication of this study. It is hypothesized that the reduction of the contagion effect of human failure onto automated aids would indicate a change of perception to the increase in automation that controls airliners. If replication studies find a positive contagion of human failure resulting in an increase in passenger trust in automated aids, it could be a sign of acceptance towards completely automated aircrafts.

Previous studies have been mainly focused on the aviation industry, but as the wave of automation is slowly taking over other industries, this study could be carried out in those realms as well. Additionally, this study can be used as a foundation for understanding the mindset of participants in other fields that have started using automation as a method to improve their service or improve their products. Studies in similar fields can greatly help understand the effects and differences in trust and what failures affect consumers' trust. Future work should also be focused on removing the limitations that were present in this study. For example, including participants from more countries would serve to identify whether the reverse contagion effect is localized or a globally-observed phenomenon.

Conclusion

This study supports the theory that a System Wide Trust (SWT) reverse contagion effect does exist from human to automation in an aviation setting. Previous aviation studies have focused on the application of SWT Theory to pilot perceptions of independent automated aids. The purpose of this study was to determine if there was a reverse contagion effect wherein airline passenger trust in automated system components was affected by an error in a human system element. This was measured by examining passenger's level of trust after a flight crew member makes an unintentional mistake, or failure. Trust was measured in five human entities and five automated aids. In order to determine the significance of culture in the application of SWT in a reverse contagion scenario, this study was inclusive of a cross-cultural analysis with participants from both the United States and India. The research findings supported all the hypothesis, including a decrease in trust in unrelated automated aids, a difference in trust as a function of country, a mediation effect between the condition and trust, and an interaction between the independent variables. The most significant finding and practical contribution of the study is that the pilot failure (mistake) does not cause an increase in the passenger's trust in automation. This implies that passengers are not yet ready to accept more automated aircraft, such as unmanned aircraft.

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Collegiate Aviation Review International

Volume 37 | Issue 1 Peer-Reviewed Article #7

1-12-2019

Limitations of Helicopter Training within 14 CFR Part 147

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According to the 2018 Federal Aviation Administration (FAA) aircraft registration database, 10,600 of the 211,800 general aviation aircraft are helicopters. While making up only 5% of aircraft, helicopters are found in niche markets that are highly specialized such as aerial tourism, news reporting, rescue operations, and medical transport. In order to maintain airworthiness, these aircraft are inspected and maintained by Airframe and Powerplant (A&P) mechanics. Due to an increasing number of retirements, there is a need to train new mechanics. In order to earn an A&P certificate, a student must undergo 1,900 hour of training. The current curriculum used to train prospective mechanics is monitored and regulated by the Federal Aviation Administration under 14 CFR Part 147, Aviation Maintenance Technician Schools. However, within Part 147, helicopter training is only taught at a Level 1 which requires only lecture instruction with no hands-on requirements. Furthermore, of the 1,900 hours of training required, only one hour is required for helicopter specific training. This lack of training creates a possible gap in knowledge. When the maintenance on helicopters is performed to subpar levels there are catastrophic results. To demonstrate this, case studies of three specific accidents were used. All three accidents were caused by improper helicopter maintenance and resulted in fatalities. Major helicopter companies have attempted to mitigate this gap by creating additional training for A&P technicians after graduation from a Part 147 school. However, this additional training is costly and requires more time investment from students before they can enter the workforce.

Recommended Citation:
Torrez, C. & Kozak, B. (2019). Limitations of Helicopter Training within 14 CFR Part 147. *Collegiate Aviation Review International*, 37(1), 107-116. http://dx.doi.org/10.22488/okstate.19.100207

In total, there are 211,800 general aviation aircraft registered with the FAA. That number can be broken down into 166,200 fixed-wing aircraft, 35,000 experimental/light aircraft (both fixed-wing and helicopters), and 10,600 helicopters (FAA, 2018a). Helicopters occupy an important part of the airspace, assisting in tasks that are often unreachable by other modes of transportation. There are many uses for helicopters in the military, however, general aviation is defined as all civilian flying except scheduled passenger airline service, so only type-certificated civilian helicopters will be considered in the data (Aircraft Owners and Pilots Association [AOPA], n.d.). Ultra-light helicopters are not included in the helicopter data since they have different requirements for airworthiness certification standards, primarily due to their small weight (14 CFR 103).

As helicopters continue to grow in popularity and necessity, it is important that the aviation industry is prepared for the growth to ensure that aviation continues to be as safe as possible. When examining safety factors surrounding helicopters, it can be seen that there is currently a hole in technician training that can greatly impact the aviation industry. With the proper action, it can be resolved through the training of aspiring technicians. There are currently solutions to this issue that helicopter stakeholders are trying to address, however, a more permanent, standardized solution is required. Without such a solution, there is the potential of more tragic events.

In the civilian helicopter sector of the U.S., Robinson and Bell account for approximately 50% of the helicopters currently registered with the FAA. Airbus Helicopter, Enstrom, Sikorsky, and McDonnell Douglas account for another 30%. The remaining 20% are comprised of a number of smaller companies and are grouped together in the “other” category in Table 1.

Table 1.

Major Helicopter Manufacturers in the United States

Manufacturer	Number Registered With the FAA	Percentage of Helicopter Fleet
Robinson	2,749	25.93%
Bell	2,491	23.5%
Airbus Helicopter	1,440	13.58%
McDonnell Douglas	833	7.86%
Sikorsky	498	4.7%
Enstrom	348	3.3%
Other	2,241	21.14%
Total	**~10,600**	**100%**
Helicopter percentage in relation to general aviation		**5.0 % of GA Fleet**

Helicopters Companies

Robinson Helicopter, located in Torrance, California, was founded in 1979. They are currently the industry leader for helicopters. They manufacture the two most popular helicopters worldwide: the R44 and R66 models (Robinson, 2015). The R44 is a four seat, piston-powered helicopter used extensively by flight schools and private owners. In addition to being used by student pilots, the R44 is also used commonly for aerial photography, aerial tourism, and can be equipped with searchlights and an infrared cameras for law-enforcement use (Peltier, 2016). It is known for its versatility in fulfilling a large number of missions.

The R66 is the more powerful cousin to the R44. Turbine powered, the R66 has five seats and has of a greater carrying capacity of both fuel and cargo. According to Robinson Helicopter, part of what makes these helicopters so popular to so many customers is its affordability and easy maintenance, making it ideal both in day-to-day use and for training (Robinson, 2015). The popularity of Robinson is apparent, as they make up roughly 2,750 of the helicopters currently registered with the FAA (FAA, 2018b).

The next most popular helicopter brand, making up about 2,500 helicopters in the U.S, is Bell Helicopter, a subsidiary to Textron Aviation (FAA, 2018b). Founded in 1935, they were the first company to certify a commercial helicopter, and are known as trend setters in the future of helicopters (Bell, 2018). The two most popular models are the -206 and the -407, both of which are turbine powered. While Bell helicopters are more expensive than Robinson helicopters, they have larger cabins and customization features, making them highly appealing for uses such as corporate transport, firefighting and medical transport. The Association of Air Medical services (AAMS) currently recognizes the Bell -206 and -407 as the most popular helicopters for medical services (AAMS, 2015).

The remainder of the helicopters registered in the FAA are made by Sikorsky, McDonnell Douglas, Enstrom, Airbus Helicopter, and other smaller manufacturers. They range in uses from personal helicopters to utility surveying helicopters.

Airworthy Assurance

FAA airworthiness stipulates that the aircraft must maintain its approved type design, and be in a condition for safe operation (FAA 2015). For aircraft to be considered in a condition for safe operation, an annual inspection must be performed by an A&P with an inspection authorization. During the inspection, the A&P checks flight critical components, such as the condition of all flight instruments, the proper installation of all fittings on subsystems, the condition of structural components such as engine mounts, and the condition of wiring. The maintenance must be completed with a maintenance logbook entry stating the date of completion, description of the work performed, names of all people performing the work and the specific identifying serial numbers of the equipment being worked on (14 CFR 43).

Changing Industry Workforce

According to a recent article in *Transportation Today*, Airframe and Powerplant technicians currently working in industry are rapidly aging, motivating industry leaders to push for enough mechanics to replace them, as well as enough technicians to keep up with the overall growth within the sector (Carey, 2018). There is currently a job growth outlook of 7%, including all maintenance and repair operations (Bureau of Labor Statistics, 2016). According to a site that compares the average salaries for jobs around the U.S., a helicopter mechanic can expect to earn an average salary of $53,997 (Payscale, 2018), which can be compared to a fixed-winged aircraft mechanic's average salary of $61,260 (Bureau of Labor Statistics, 2016).

As stated by the Aircraft Owners and Pilots Association, a recent study done by the University of North Dakota and the Helicopter Association International (HAI) projected that between 2018 and 2036 the industry is expected to experience a deficit of 40,613 mechanics (Collins, 2018). As of 2017, there were currently 286,268 certified mechanics that are active within the U.S. (FAA, 2017). Within the next 18 years, the U.S. will experience a shortage comparable to roughly 14% of its current mechanics. With the salary higher for fixed-wing maintenance, and fixed-wing maintenance being more common, more technicians may seek work with fixed-wing aircraft instead of with helicopters.

Airframe and Powerplant Certification

In order to earn an Airframe and Powerplant certificate, one must adhere to the rules outlined in 14 CFR Part 65 – Certification for Airmen Other Than Flight Crewmembers. Subpart D specifically outlines the requirements for mechanics seeking both their Airframe and Powerplant rating. According to 14 CFR Part 65.77, applicants must provide significant evidence of completion from a certified aviation maintenance school, or a minimum of 30 months of experience in the field performing work requiring both the Airframe and Powerplant ratings.

Part 147 Schools

For a school to be considered a *certified aviation maintenance school*, certain curriculum topics must be taught. These requirements are outlined specifically in 14 CFR Part 147 – Aviation Maintenance Technician Schools. One of the requisites is that the school provides at least 1,900 hours of instruction, broken down into 400 hours of general, 750 of airframe, and 750 of powerplant instruction. According to 14 CFR Part 147, only a primary knowledge--*Level 1*-- is necessary on the topic of rigging helicopters in order to complete the airframe part of the A&P certificate. Within the entire Part 147, this is the only mention of rotary aircraft in the curriculum requirements. A Level 1 proficiency is defined in 14 CFR part 147 Appendix A as having an understanding of general concepts, without any practical applications. As a result there is a possibility that of a maintenance technician's entire 1,900 hour aircraft training, they could have only a one-hour lecture devoted to learning about rigging rotary wing aircraft.

In comparison, *Level 3* proficiency defined in 14 CFR part 147 Appendix A as having an understanding of general concepts, a high level of practical applications, with the development of skills that simulate a return to service. Examples of curriculum taught with a Level 3 proficiency for fixed wing maintenance include procedures for, the assembly of flight control surfaces, the rigging of secondary flight control surfaces, and measuring the weight and balance of the aircraft.

Figure 1. Schweizer 269A Trainer Used at a Part 147 School.

While Part 147 provides specific requirements of instruction for fixed-winged aircraft, it leaves the amount of learning about helicopters heavily dependent on each school. Part 147 schools have the freedom to determine how much time they want to spend on helicopter instruction on anything past the required *Level 1* knowledge on rigging helicopters. This choice in curriculum may result in knowledge gaps.

On-the-Job Training

For prospective mechanics, no public training programs exist to prepare them for heavy maintenance on helicopters. Heavy maintenance includes tasks such as overhauling landing gear components, inspection of flight critical components, and the relubrication of specific systems (Quantas, 2016). The closest comparison is from companies such as Airbus and the U.S. National Guard that offer on-the-job training for the helicopters used at their respective organizations, granted that the technician has received their A&P certification first. This type of training is often severely limited, and is focused to only teach what the technician would need to know while performing specific job tasks. While this assists with the current gap in training, helicopter technicians are often stuck, as they have a general idea of fixed-wing maintenance procedures from their prior A&P knowledge, but only have hands-on experience with the helicopters used at their employer. Another factor that is limiting the number of aircraft and powerplant technicians working with helicopters is the amount of training they receive related to helicopters while obtaining their Airframe and Powerplant certificates.

Airframe and Powerplant technicians are expected have a solid understanding and familiarity of: aircraft safety, hardware, tooling, and procedures. However, due to the possible gaps in their A&P training, technicians may have limited knowledge about how helicopter components work together, or how they can impact each other, resulting in unfamiliarity with components that would otherwise be known to them.

Importance of Proper Training

While the current maintenance training for helicopters is focused on theoretical learning in a Part 147 School, many of the helicopter manufacturers provide the hands-on training in order to increase learning and promote understanding of difficult subjects. Almost all major helicopter manufacturers offer some form of additional training.

Airbus, Robinson, and Bell, can be seen as examples, as all three companies train technicians specifically for maintenance on their helicopters. Airbus offers a self-assessment, an airframe refresher course, as well as various other courses, such as Mechanical Assembly, Airframe Repair, and Auto-Pilot Hydraulic Units (Airbus, 2017). Robinson Helicopter offers a $1,100 general maintenance course, with a requisite of already having an Airframe Mechanic Certificate, that specifically covers the maintenance specific to Robinson helicopters (Robinson, 2017). Bell Helicopter offers mechanical and avionics training for its helicopters as well (Bell, 2018). While it is a constructive solution for helicopter manufacturers to provide training for proper helicopter maintenance, it requires significant time, money and other resources. Smaller helicopter manufacturers may not have the resources to provide specialized training, so mechanics working those specific helicopters are at a disadvantage.

Another solution for providing sufficient hands-on learning to prospective helicopter mechanics is to increase the amount of time devoted to helicopter learning in Part 147 schools. If a Part 147-approved curriculum is developed that contains laboratory instruction specifically for flight-critical components on helicopters, students would be able to spend more time learning about these components in a safe environment.

There are three approaches to laboratory instruction: developmental, instructional and laboratories with the goal of research. Instructional laboratories focus specifically on skills and concepts that are expected to be known by engineering professionals (Feisel & Rosa, 2005). By the nature of laboratory instruction, most projects are done in small groups, which allows students the opportunity of also practicing communication and teamwork skills. Teamwork and communication are considered crucial to a student's learning process, and industry leaders such as the Accreditation Board for Engineering and Technology (ABET) stress the refinement of these skills in the learning environments of institutions (Lingard & Barkataki, 2011). There currently exists a need for such a curriculum to be developed for helicopters.

An additional resource that could be used to further the understanding of helicopter components is the use of accident case studies. Through the use of accident case studies the understanding of current faults in maintenance procedures can be increased, real world problems not experienced in a classroom setting can be introduced, and the students can be engaged by showing them the human aspect of errors (Saleh & Pendley, 2012). Accident case studies can be taught in various ways, such as reading accident reports, listening to recordings of flight data, or watching documentaries about series of events surrounding the incident. While students are given the opportunity to learn about safety culture from classes, case studies provide another method of instruction to increase the safety by ensuring more than one method to learning key-takeaways from lectures (Saleh & Pendley, 2012).

Helicopter accidents that were investigated by the National Transportation Safety Board (NTSB) were researched to provide an example of applicable case studies for helicopter training, focusing specifically on accidents due to improper maintenance. The NTSB cases DCA12MA020, WPR10FA371, and WPR16FA072 can potentially be used to help emphasize the importance of proper helicopter training.

Impacts of Improper Training

In accident WPR16FA072, a Bell-206 tour helicopter was flying in Hawaii on February 18th, 2016, when it experienced vibrations while in the air. The vibrations soon turned into a grinding sensation before the helicopter began to lose main rotor RPM. As the helicopter continued to lose its rotor RPM, it eventually stalled and began to fall into the water near the shoreline. Of the five people onboard, there were three serious injuries and one fatality. The NTSB conducted an investigation that discovered the maintenance technician did not apply grease to the forward coupling of the engine-to-transmission drive shaft, thus causing the failure of the drive shaft (NTSB, 2018).

Accident WPR10FA371was a Eurocopter AS350 helicopter flying in Arizona on July 28th, 2010, when it lost engine power. As the pilot began to perform autorotation procedures, the helicopter hit a concrete wall and burst into flames. There were three fatalities in total. Upon investigation, the NTSB determined the maintenance technician did not properly torque the nuts on the fuel inlet union, resulting in a separation between the fuel inlet union from the fuel injection manifold (NTSB, 2012).

In the case of DCA12MA020, a Eurocopter AS350 tour helicopter was flying in Nevada on December 7th, 2011 when the helicopter had an in-flight separation of the servo control input rod from the fore/aft servo, causing it to lose power and crash into the mountains. All 5 people onboard died. The NTSB determined three main causes for the accident: reusing a self-locking nut, improper installation of a cotter pin, and improper inspection of the parts after maintenance was completed (NTSB, 2013).

While all three of these incidents were caused by maintenance technician errors that could have been prevented through Airframe and Powerplant training, the technicians did not have the helicopter system understanding that would have prompted them to check vital connections, practices and procedures. Had they known the importance of each component of the helicopter, they would be able to not only ensure the quality of their work, but also have the experience to identify potential problems.

Conclusion

As of 2018, approximately 5% of the general aviation aircraft within the United States are helicopters. As aircraft with airworthiness certificates, they must be inspected and maintained by Part 147-certified Airframe and Powerplant mechanics. As the workforce of A&P personnel ages, an increasing number of technicians are being trained to replace retirements. In order to earn an A&P, a student must either attend at Part 147 school or complete on the job training. Within Part 147, a student is only required to complete lecture training on helicopters. As a result of this limited training, there exists a possible gap in helicopter knowledge. Major companies acknowledge this gap and are trying to correct it by providing supplemental instruction; however, these courses provide experience in only their brand of helicopters. By limiting the knowledge to only one brand of helicopters, mechanics are unable to have the same kind of freedom and experience possessed by fixed-wing aircraft mechanics. Part 147 curriculum should be reevaluated to include more instruction on helicopters. In its current state, the Part 147 curriculum allows the students to pass the Part 147 examinations required for an Airframe and Powerplant Certificate, however, it may lack the training necessary to be adequately prepared for the demands of the workforce.

Future Works

To address this lack of training for helicopter maintenance in Part 147 curriculum, an adjustment in the curriculum may be required to either increase the exposure to helicopter maintenance practices, or the limited time assigned to helicopters needs to be more focused towards hands-on learning. Hands-on experience is highly beneficial to students in the process of learning about safety. The authors believe the development of a laboratory project that models the stresses of components within a Computer Aided Design (CAD) software would be beneficial in teaching flight-critical components. Due to the complex nature of CAD, the project would require more time spent learning about helicopter components. Additionally, the CAD project would provide a more hands-on experience than a theoretical lecture.

Furthermore, assignments involving case studies of NTSB accidents DCA12MA020, WPR10FA371, and WPR16FA072 could also be incorporated into the curriculum. In order to test the effectiveness of such training, a pre- and post-survey as well as post-class interviews could be conducted.

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Collegiate Aviation Review International

Volume 37 | Issue 1 Peer-Reviewed Article #8

2-26-2019

General Aviation Pilots Transition to Advanced Cockpit Technologies and Adult Learning

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Pilots for many years have received training on the round instrument gauges. Can they now safely make the transfer to the new cockpit technologies? Studies show a cognitive deficit with pilots over the age of 40 making transitions to these advanced cockpits. Older pilots as well as older adult learners in general absorb and retain information differently than our younger counterparts. The training and instructional programs are now geared towards a one size fits all. According to the literature, problems seem to surface affecting older pilots. This article addresses these concerns.

Recommended Citation:
Kolmos, J.A. (2019). General Aviation Pilot Transition to Advanced Cockpit Technologies and Adult Learning. *Collegiate Aviation Review International*, 37(1), 117-128. http://dx.doi.org/10.22488/okstate.19.100208

Educational psychologists suggest that positive changes can be made for students in the area of adult education. This article will be looking specifically in the area of aviation and the transition of older pilots to technically advanced aircraft (TAA) and avionics. The learning process for these older pilots-- those over 40 and 50 years of age--should be approached in a different manor than present. Training and instructional programs are now geared towards a *one size fits all* and according to the literature, problems seem to surface that affect older pilots.

Pilots over 40 years and the Need for a Positive Change in Learning

Navigating an aircraft is a complex, time consuming and a highly-pressured activity and one that needs, to be explored in regard to new avionic technologies and aged pilots' abilities to safely transition to complex avionics. For "…older aviators, who typically experience age-related declines in cognitive abilities and visual acuity, these factors may play an even greater role during adverse weather conditions" (Kennedy, Taylor, Reade, & Yesavage, 2010, p. 489). O'Hare and Owen (2001) have stated that pilots equipped with more advanced avionics showed an increase in accident rates. "Comparing the numbers continuing on [in clouds] with those not continuing [visual conditions] shows a marginally significant difference between those using Global Positioning System (GPS) and those not" (O'Hare, & Owen, 2001, p. 80). O'Hare and Owen (2001, p. 81) also state "that as a result of the flight simulation study there is a tendency for pilots using a GPS navigation system [like the G-1000] in visual meteorological conditions (VMC) tend to behave differently from pilots using older methods of navigation, and at least two of these factors in decision making are age and recent flight experience."

Hamblin, Gilmore, and Chaparro (2006, p. 1979) state that "there can be a negative correlation with pilot's total flying time and their greater experience in traditional avionics may have more difficulty transitioning to Technically Advanced Aircraft i.e. computer screens (TAA)." He found that that pilots who accumulated a large amount of flight time in more traditional avionics setups had more trouble or even resisted transitioning to TAA. He also found that pilots who trained a flew using analog instruments acquired habits that were inadequate to learn and transfer to the new computer technology found on modern aircraft. However, research also showed that seasoned and experienced pilot's capacity and craving to learn are fundamentally the same as younger adult pilots under the age of 50 years when educators change the learning environment to address a slower learning rate and requirements for encouraging feedback (Broady et al., 2010). Difficulties with subjective learning because of age can be successfully neutralized by design and integration of positive encounters (Broady Chan, & Caputi, 2010). Broady et al. (2010) and Homko (2011) expressed that educators can enhance adult instruction in TAA for pilots over the age of 50 years by understanding their disposition toward technology.

There have been many studies of this using the quantitative methodologies. In setting the stage for a change in educational psychology and the need to understand learning for older adults this paper will present this prior research.

In the Kennedy et al. (2010) article looking at older pilots in particular, the sampling size used to conduct the testing of older pilots/younger pilot's verses moderate experience/high experience consisted of 72 pilots, 19 - 79 years of age, with two levels of IFR experience. The group with moderate experience was defined as having an IFR rating (instrument rated) or CFI (Certified Flight Instructor). The group considered with high experience was having a rating of CFII (Certified Flight Instructor-Instrument) or ATP (Air Transport Pilot). The study was modeled so that half the group were less than 40 years of age and the other half were 40 years and older. The two groups were further divided so that half of the *under 40* group were of moderate experience and the other half where considered high expertise. The *over 40* group was also divided the same way. Eligibility required a current FAA Medical Certificate.

Equipment used was a Frasca 141 flight simulator, “The simulator was linked to a computer specialized for graphics that generated a ‘through-the-window’ visual environment and continuously collected data concerning the aircraft’s position and communication frequencies” (Kennedy et al., 2010, pp. 490-491).” The software was designed to collect flight data regarding accuracy of landings and holding pattern decisions. The project occurred from 0900 to 1600; and, pilots had the preference of choosing the time to participate in the simulation. The procedure was to fly three Instrument Landing System (ILS) approaches to Runway 30 at San Jose (SJC) airport with a 200-foot decision height. Three approaches were to be flown to a touch and go or a missed approach. IFR conditions were presented with fog down to minimums and another approach where the fog caused conditions below approach minimums. Each subject was to do two turns in the hold and then to be vectored to a six-mile final. In conclusion, the study showed that according to Kennedy et al. (2010):

> The negative correlation found between performance on the dual task cognitive measures and age suggests that age-related differences may be due to decrements in attention rather than decision making per se. However, the dual task cognitive measures did not significantly predict flight performance. Only speed of processing performance accounted for the age-related differences in aileron control. The results indicate that age-related declines in cognitive ability may affect certain aspects of flying an aircraft. (p. 495)

The results shown above as well as some of the solutions presented by Homko (2011) and Broady et al. (2010) may provide guidance on the cognitive learning that pilots, especially pilots over the age of 50 years whose experience is in conventional aircraft, can be utilized effectively in a different approach to learning. The Aircraft Owners and Pilots Association (AOPA) through the Air Safety Foundation stated that simulation should be used more extensively. TAA training should rely heavily on integrating various levels of simulation using scenario-based training integrating full TAA systems and instructors’ stations to utilize different scenarios involving emergency and overload training. However, Computer Based Instruction (CBI) should be designed and implemented by taking into consideration the age and experience of the pilot. This will have an important effect on the transfer of learning from conventional to TAA. Kearns (2010) states “Clearly, the effectiveness of any e-learning [CBI] course will be directly linked to how the course is designed" (p. 28). How the course is designed and how effective it is in producing the desired results is the starting point for designing a course of study for the older, more experienced pilot. The focus of such a study would be pilots 50 years of age and over, who had many years using conventional avionics and successfully transitioned to TAA aircraft through a properly designed and executed course. Ideally such a design could be used for those pilots looking into transitioning to TAA. Has the research been investigated for such a course design? What would it consist of? Kennedy et al. (2010) in their concluding remarks, states:

> Our findings suggest that providing older pilots with focused training in the flight simulator for situations that can carry a high degree of risk in real life, coupled with speed of processing training may be an ideal way to improve older aviators' flight safety. (p. 496)

Learning Theories to Improve Pilots Over 50 Years Old and Aviators Performance
Constructivist Theories

McLeod (2018) in his article on Jean Piaget's Theory of Cognitive Development stated that *constructivism* is a learning theory by which a person comes to understand the information already possessed which has already been learned through that person’s experiences. It has its foundation in cognitive psychology and its approach to education emphasizes that knowledge comes into fruition to adapt to the world in which the person is operating. Piaget's theory of constructivism impacts learning curriculum because teachers must make a curriculum plan which enhances their students' logical and conceptual growth.

Constructivist learning is just that--a constructive process where the learner is building internal knowledge from personal experiences. This knowledge does not deny the real world but contends to understand it within the context of the persons own understanding of it. A person grows from sharing these perspectives and by responding to new perspectives or experiences changing their internal understanding (Bednar, Cunnigham, Duffy & Perry, 1995). The challenge of constructivism occurs when a person changes by letting go of control from learning from the instructor to the student. The student is encouraged to achieve agreed upon objectives.

The objectives should be designed around the students’ needs. This is based on their activities which emerge from the lives lived in context of their understanding and worldview. Hanckbarth (1996) states,

> The students should be working together with their peers in social construction of the meanings that are significant to them and the evaluation should not only be personalized but on going, it should be a shared analysis of their progress. (p. 11)

Bednar et al., (1995) in their article states that

> Agreeing with this view of knowledge, learning must be placed in a rich context, reflective of real-world context, for this constructive process to happen and transfer to environments beyond the school or training classroom. Learning through cognitive apprenticeship, mirroring the collaboration of real world problem solving, and using the tools available in problem solving situations, is

> key. How effectual or instrumental the learner's knowledge structure is in facilitating thinking in the content field is the measure of learning. (pp. 103-110)

Strengths and Weakness of Constructivism Theory

One of the strengths of this theory is that students learn by experimenting--not by being told what to do, but discovering it for themselves (Mayer, 2004; Kirschner, Sweller, & Clark, 2006). This can enhance and strengthen a learner's knowledge and experience in an area of study. This leads to its weakness. While perhaps good for experienced students, it may not be so for the novice. The argument is that *learning by doing* strengthens learning, however, critics say that this strategy has little evidence for support with novice learners (Mayer, 2004; Kirschner, Sweller, & Clark, 2006). Sweller (1988) argues that novices do not have the experience of developed mental models that would be necessary for a *learn by doing* method. Mayer (2004) also reviewed the literature and found that the data over the last fifty years supports this and that situations with novices should be guided.

Applying Constructivism in Educational Practice

In this context, these older pilots are experienced in the aviation field, so constructivist ideas would work well in this area of adult education. *Pedagogy* deals in the area of instruction with children, however, instruction of adults has been referred to as *andragogy*. Andragogical methodology considers differences in learning with the understanding that adults have more experiences and existing schemas from life than children do (Knowles,1984). The theory of constructivism stresses that cooperative learning environment based on mutual planning and learning fit the needs of the student. The objectives are diagnosed needs and interest, which is foundational to the student's ultimately reaching their goal. This is relevant because of the involvement that the learner has in their progress to understand key concepts that are involved in the principle being applied using or emphasizing constructivism in adult education.

The study of cognition has many applications for educational psychology. Teachers need to help students learn by way of organizing information and thereby helping the student to relate one thing to another (Skinner, 1968). Information that is new will usually be acquired when a person associates one thing with another already learned. The teacher can then help a student understand new ideas by relating them to old ones; this would be positive transference (Skinner, 1968). Learning will be slowed, however, if that person is having trouble relating this new information to the old. It will become ineffective (Skinner, 1968).

From an operate conditioning perspective Skinner (1968) has stated that students should be actively responding if learning is to be achieved. Cognitivists emphasize mental activity as opposed to physical, believing that if students have control, the student would then decide what information is needed.

Scaffolding

The FAA (2003) states: "Pilot training will require emphasis and focus on higher order thinking skills to help pilots learn how to think instead of simply what to think" (p. 12). Higher order thinking has been addressed using scaffolds as instructional procedures to provide temporary support for student's initial learning before they reach intended goals (Palincsar, 1986). Scaffolding is an important instructional concept because of the process it uses in guiding a learner from what they presently know to what is to be known. Vygotsky (1978) wrote that the notion of scaffolding was developed from "zone of proximal development" theory, which is, "the distinction between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (p. 86). Hogan and Pressley (1997) discuss scaffolding as modeling behaviors desired by offering explanations and having the students participate in their own verification of understanding the material.

Teaching Bloom's Taxonomy (Bloom, 1956) is a scaffolding device to improve higher order thinking (Hogan & Pressley, 1997). Through intellectual support scaffolding is used as an instructional device that provides the cutting edge of cognitive development to individual students (Hogan & Pressley, 1997).

Metacognitive skills, psychological type for heightened self-awareness, authentic learning, and cooperative learning - all cognitive processes and strategies used during problem solving are a part of scaffolding (Brown, 1987). The absence of such an integrated framework of scaffoldings can cause students to mindlessly and superficially attempt to problem solve without consideration of whether that idea makes sense on its own or how it integrates with other ideas (Pressley, Wood, Martin, King, & Menke, 1992).

Understanding Adult Learning

The field of adult education has grown since Knowles (1950) devised the term *andragogy,* which describes the way adults learn compared to pedagogy, or the way children learn (Henschke, 2009). Andragogy is based on certain assumptions and according to Knowles (1984) that as a person matures, learning becomes intrinsic and provides the motivation. Watkins and Marsick (2014) add five other factors to consider in adult education and learning:

- Their self-concept changes as it moves to being more independent.
- They accumulate knowledge from experience.
- Their readiness in relation to social roles.
- What is most relevant to them at the time.
- Their learning is centered on the problem at hand.

Educational theories have matured over time and andragogy may not be as widely accepted as it once was. Teaching of adults does have its challenges and the practice of adult education does have some exclusivities particular to it (Watkins & Marsick, 2014).

Adult education may have moved beyond andragogy, nevertheless, according to Merriam, Caffarella, and Baumgartner (2007) research has shown over the past decade for adults, learning from experience being self-directed are important for adult understanding. The discussion of adult educational development is a growing specialty in psychology that provides an understanding of an individual's learning preferences and capacity; similarly, cognitive science has added to our understanding of how the brain functions in all developmental stages. Educational psychology may have advanced beyond the terms understood as andragogy as a field of study and moved beyond, however adult learning is still learning how one beyond school age develops their skills from higher education to the workplace or even professional development (Watkins & Marsick, 2014).

How Constructivism and Scaffolding Used in Unison can Affect Change with Pilots

Constructivism considers mutual planning important by taking into account the needs of the student. It is built on a cooperative learning environment with the objective of achieving and forming learning objectives that are based on the interest of the student.

Scaffolding on the other hand looks at the higher order of thinking skills that a pilot must use. It takes the learner from the known to the unknown. Scaffolding is designed to model the desired behavior or change in the student by offering explanations and engaging the student and verifying that the student understands the information presented to them. Its aim is the higher order of thinking as presented in Bloom's Taxonomy (Bloom, 1956) providing the necessary intellectual support the student needs. Bloom’s Taxonomy is ideal in having students push the envelope of comfort and going a little beyond their personal comfort zones without being handheld by an instructor, building on the metacognitive skills along with cooperative learning for problem solving. It is these cognitive processes that allow the necessary strategies to develop for learning, especially in adults who are task oriented toward the goal that is set before them, such as learning a new avionics platform.

By combining constructivism, mutual planning, and understanding the specific needs of the student would have clear objectives. The goal is to develop the higher order of thinking skills to carry out the task by using the constructive blocks of Bloom's Taxonomy (Bloom, 1956). The development of Higher Order of Thinking Skills (HOTS), the older pilot can more easily transition to a very different type of avionics platform.

Analyzing the Evidence

Recent studies about age and learning have shown that even though some cognitive degradation occurs with age, older people’s ability and desire to learn are not significantly different than younger people when the learning is specifically changed to address their slower learning rate and need for positive reinforcement (Broady et al., 2010). Broady et al. (2010) showed that recent training and positive experiences could effectively counteract the challenges of cognitive losses due to age.

Constructivism has its roots in cognitive and biological sciences. Its emphasis is the different ways for example that knowledge is created to help one adapt to their environment. Learning is a constructive process, one block building on another. It comes from cumulative experiences and sharing of different ideas and then changing one’s internalized response to those ideas or views (Bednar et al., 1995). A pilot with years of flying experience has the background in aviation that an instructor can use in guided constructivism to provide the need in transitioning to TAA. This can have a positive effect in their learning and adaption to the new avionics platforms (Loyens, Rikers & Schmidt, 2008). This however cannot be self-regulated instruction but guided positive reinforcement coupled by a scaffolding methodology (Loyens et al., 2008; Brown, 1987). Homko (2011) stated:

> What can be taken from this observation is an understanding that older people could well be taught to use technology in much the same way as younger people are taught. However, the literature also suggests that at least two additional considerations are necessary in designing computer and technology education for older learners. First, consideration must be given to allow ample time for older people to master new skills. Second, care must be taken to treat any person learning to use technology in a positive manner that makes them feel like they are valued and that success is the expected outcome. While it is true that these two points ought to be considered for all learners, they nonetheless particularly pertain to older users. (p. 15)

Looking at the two suggestions that Homko makes, constructivism guided by way of scaffolding under a properly trained facilitator would help to fill this need. In constructivism with the student and facilitator, together they plan and diagnose the learner's needs and interests, which then can be properly designed. Using scaffolding with the constructivism designed earlier, the facilitator can develop the proper guidelines with the student for developing the supportive strategies needed to reach that higher order of thinking skills these aging pilots will need to use computerized avionics platforms. Together it will help bridge the learning gaps older pilots are having with the new systems by changing the way the curriculums are taught today.

Conclusion

In the literature review, it was shown that age and pilot effectiveness in cognitive abilities do deteriorate and that in advanced TAA aircraft, the effect is even more pronounced. It was also shown in the data analysis of the NTSB reports that pilots above the age of 40 in both glass and conventional flight decks are having more problems in aircraft accidents and incidents in comparison to their younger peers. The training industry as a whole needs to look at the recommended training programs suggested by AOPA regarding TAA aircraft.

Glass flight deck training requires system knowledge and cognitive training on regular and systematic bases. In other words, the old idea of training to pass a test was perhaps useful in its time, but with advanced aircraft avionics and the complications of the National Airspace System and the coming implementation of NextGen (Next Generation Air Traffic Control) this is proving not to be enough. Ground based training must also pull away from just the generic to aircraft specific in the realm of the glass flight deck classrooms. Pilots need to demonstrate that they possess at least the minimum knowledge of aircraft instrumentation and displays in order to safely operate aircraft that are equipped with these more advanced avionics platforms.

The literature review and the data has also shown that through a properly designed program and instruction, any pilot regardless of age can improve performance to acceptable levels to perform safe and successful flights when transitioning to TAA aircraft.

Scenario based training (SBT) can also be used to address learning problems with older pilots. According to Summers, Ayers, Connolly & Robertson (2007):

> …where the instructor introduces real life situations for the development of the pilot. This training is a scenario-based approach to training pilots. It emphasizes the development of critical thinking and flight management skills, rather than solely on traditional maneuver-based skills. The goal of this training philosophy is the accelerated acquisition of higher-level decision-making skills. Such skills are necessary to prevent pilot-induced accidents. (p.4)

This statement from Summers et al. (2007) suggests that SBT would adapt well to the pairing of constructivism and scaffolding.

With pilots transitioning to more advanced flight deck designs and higher performance aircraft, SBT provides a means of teaching pilots how to stay ahead of their aircraft. With the advances of avionics in today's fligtdecks, the needs for increased technical skills are apparent. If these skills are lacking the potential for accidents will be compounded. A new way of instructing and teaching is required to have pilots, especially older pilots, transition to these new platforms (Summers et al., 2007).

Scenario based training, similar to what 14 CFR Parts 121 and 135 use in their training programs known as Line Oriented Flight Training (LOFT). This exposes pilots to real world scenarios under the guidance of a flight instructor in a controlled environment to experience situations a pilot alone may not be able to handle. These advanced flight deck avionics platforms require the pilot to be properly trained and motivated under new learning theories in understanding the cognitive development of aging pilots in order to safely operate in the world of TAA. Coupling the learning theories of constructivist theory with scaffolding theory fits very well with scenario-based training and can have the positive effect especially on older pilots transitioning to these more complicated avionics platforms. Proper facilitator training in these concepts used with scenario-based training will help to develop the higher order of thinking skills and reaction for these older pilots that may ultimately produce the desired outcome of effective learning.

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Collegiate Aviation Review International

Volume 37 | Issue 1 Peer-Reviewed Article #9

2-27-2019

The Relationship between Time of Day and Student Check Ride Performance

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The purpose of this research was to investigate if there was a relationship between check ride performance and the time of day that these check rides occur. The population for this study included students in the flight training program at a midsized, midwestern university. The study utilized the results of more than 10,000 check rides, specifically examining the outcome with respect to time of day. A Chi Squared test yielded a significant finding for the data overall ($\chi^2=363.910$, $df=2$, $n=10998$, $p<.001$) indicating that there was a difference in the actual evaluation outcomes when compared to starting time versus the expected outcomes. Further study of chronotypes in aviation and specifically flight training was recommended.

Recommended Citation:
Goetz, S.C., Robertson, M.F., Harrison, B.T., & Romero, M.J. (2019). The Relationship between Time of Day and Student Check Ride Performance. *Collegiate Aviation Review International*, 37(1), 129-142. http://dx.doi.org/10.22488/okstate.19.100209

Fatigue has been a factor in numerous incidents and accidents in aviation including Go! Flight 1002 (National Transportation Safety Board [NTSB], 2009a), Northwest flight 188 (NTSB, 2009b), and Colgan Flight 3407 (NTSB, 2010). In addition, surveys have indicated that as many as 93% of pilots in Europe have had fatigue impact their ability to operate safely (European Cockpit Association, 2012). Roughly 50% have unintentionally fallen asleep while flying, and 25% woke to find their copilot asleep (BBC News, 2013). Members of the British Airline Pilot Association (BALPA) believe that fatigue is a greater threat to airline operations than terrorism (BALPA, 2018). The aviation industry is beginning to recognize the immense threat that fatigue creates in the safe operation of an aircraft. Most of the research on fatigue mitigation has focused on getting enough sleep and enforcing circadian rhythms (Flight and Duty Limitations, 2018), but little focus has been placed on how individuals experience fatigue within a given day.

Each person experiences a day in a different way; we have our chronotype, which is a personal pattern of circadian rhythms that influence our physiology and psychology (Pink, 2018; Randler & Frech, 2006, 2009). Everyone experiences physiological and psychological highs and lows throughout the day, with most individuals experiencing a peak in the morning and a physiological and psychological trough in the midafternoon. Chronobiologists have suggested that generally, people should not attempt to do activities that require focus and attention to detail during these physiological and psychological troughs (Pink, 2018).

The sleep-wake cycle is a major part of a person's chronotype. One's ability to get quality sleep and manage their sleep cycle effectively affects their productivity and performance during a given day and at different times of the day. There have been many studies that have investigated the sleep habits and management of sleep within the collegiate student population (Buboltz, Brown, & Soper, 2001; Hicks & Pellegrini, 1991; Lund, Reider, Whiting, & Prichard, 2010; Pilcher, Ginter, & Sadowsky, 1997; Singleton & Wolfson, 2009; Trockel, Barnes, & Egget, 2000). Additionally, some studies have focused on the relationship between the sleep-wake cycle and academic performance (Borisenkov, Perminova, & Kosova, 2010; Eliasson, Lettieri, & Eliasson, 2010; Medeiros, Mendes, Lima, & Araujo, 2010; Taylor, Clay, Bramoweth, Sethi, & Roane, 2011).

Problem

Since fatigue has been recognized as a threat to the safety of the aviation industry, it behooves aviation educators to help those entering the industry to understand the factors that can influence fatigue, including chronotype. Pilot trainees, or flight students, complete a test at the end of each flight course, referred to as a *check ride*. A check ride can be a three- or four-hour oral [verbal] assessment, and flight evaluation that takes a significant amount of focus and attention. The purpose of this research is to investigate if there is a relationship between check ride performance and the time of day that these check rides occur using extant data. This research could be helpful to improve safety and increase student performance in the flight training environment.

Research Question

The authors sought to answer the following research question:

> What is the relationship between the time of day a student attempts a check ride and the outcome of that check ride?

This question stemmed from the research of Eliasson et al. (2010), Lund et al. (2010), Pink (2018) in evaluation the academic performance of college students by understanding their chronotype as well as the NTSB recognition of fatigue as a major threat to the aviation industry as long ago as 2011 and every year since 2016 (NTSB, n.d.; NTSB, 2019).

Literature Review

College Student Sleep Habits

Lund et al. (2010) investigated the sleep patterns and predictors of disturbed sleep in the college student population. The authors found that from more than 1,000 students surveyed, greater than 60% were categorized as poor sleepers. Students that had trouble sleeping reported more problems with physical and psychological health issues. Many also reported that emotional and academic stress negatively impacted sleep quality.

The findings from Lund et al. (2010) were supported by Buboltz et al. (2017). Their study found that 73% of college students suffer from sleep disturbances. Many of the participants identified that they suffered from some type of anxiety and depression as a result of their sleep difficulties. Like the Lund et al. (2010) study, the Buboltz et al. (2017) study found that many college students sleep in on the weekends and subsequently, perceive less sleep difficulties on the weekend. The findings from these studies are consistent with other studies (Pilcher et al., 1997; Trockel et al., 2000; Hicks et al., 1991; Singleton et al., 2009) regarding the sleep habits of college students.

Relationship between Sleep and Academic Performance

Several studies link both sleep quality and quantity to academic performance. Eliasson et al. (2010) investigated the total sleep duration and the timing of the sleep to the academic performance of college students. Their results indicated that higher performing students had earlier bed and wake times, but did not find as high a correlation between total sleep and higher academic performance. The authors recommended that students attempt to adjust their class schedule to better fit their sleep/wake circadian rhythm. Trockel et al. (2000) found similar results in a study evaluating several variables and their relationship to academic performance. Of all the variables considered, sleep habits were found to have the greatest impact on improved academic performance--specifically earlier bed/wake times.

Another study by Singleton and Wolfson (2009) investigated the effects of alcohol use and sleep on academic performance of college students. While their focus was on the variable of alcohol, they indicated quality of sleep was more of a factor in daytime sleepiness rather than sleep duration. Singleton and Wolfson (2007) indicated that there was a relationship between daytime sleepiness and grades and recommended that more studies need to be done regarding the relationship between sleep habits and academic performance.

Chronotypes of College Students

In its most basic form chronotypes of individuals can be broken down into three categories. An individual is either a *lark*, an *owl*, or what is referred to as a *third bird* or a *hummingbird*. A *lark* typically rises early and feels energized in the morning and throughout the day and fades in the evening. *Owls* tend to wake long after sunrise and peak well into the late afternoon and evening. It is believed that 60-80% of the population falls within the *third bird* category, sometimes referred to as *hummingbirds*, where they are neither larks or owls (Pink, 2018).

An individual's chronotype changes throughout their life. As children, most of us start out as larks. Then, in the early teen years, individuals change to an owl. Next, in early adult hood, sometime after 20 years old, our chronotype changes more towards a lark or third bird (Pink, 2018). The exact point at which our nocturnal preference diminishes is unclear, but it is generally believed that it occurs after college (Hershner & Chervin, 2014).

All chronotypes have a sleep/wake cycle that is different. As mentioned earlier, owls tend to go to bed late and desire to sleep late. They are typically not at their best in the morning. Generally, it is recommended that owls should put off analytical tasks and important decision making to the evening (Pink, 2018). Other researchers have even found that owls are at a distinct disadvantage in the testing process because most testing occurs during a lark's peak hours (Randler & Frech, 2006, 2009). The research indicates that if college students are predominately owls, they should schedule classes, take tests, and study in the evenings and take advantage of the opportunities to learn and take evaluations during their best times.

Methodology

Sample

The population for this study was conceived as all university flight students. A sample was selected that consisted of the students in the flight training program at a midsized, midwestern university, and who underwent check ride events from January 1, 2006 to June 20, 2018. This timeframe was chosen for convenience as this encompasses the period that this particular flight training program has utilized electronic record keeping for flight training events.

Data

The data were requested from the flight training program after receiving approval for the study from the institutional review board. The data were de-identified prior to being delivered to the researchers for analysis. As such, the only data provided by the flight training program were those specifically requested, namely the hour that the evaluation began (hourly from 6am to 8pm), type of evaluation (oral, flight, or simulator), and outcome (satisfactory or unsatisfactory). First attempts only were requested to ensure that the same applicant did not appear in the data for the same event at the same certification level, in hopes of preserving the independence of the data for the Chi Square analysis. The nature of the data provided led to some limitations of the study, namely the inability to correlate any demographic information in the analysis. The data also lacked information about individual participant's aeronautical experience, such as their recorded flight experience, at the time of their check ride. The lack of information regarding total aeronautical experience meant that there was no way to account for this potential confounding variable.

Data Analysis Procedure

The analysis was a compilation of 15 separate Chi Squared analyses, one for each starting time by hour, and a 16^{th} of the overall data. The use of multiple tests led to the decision to adjust the critical *p* value to determine significance using the Bonferroni correction. With 16 tests and a planned significance of $\alpha=.05$, the researchers could determine statistical significance only for *p* values less than .003125. The limited nature of the data protected the identities of the students from the flight training program but prevented any analysis of the demographic information of the sample.

The sample provided was of reasonable size (n=11,011) and only included categorical data. The nature of the data led to the decision to use a contingency table and Chi Squared analysis, using SPSS v. 22.0, to analyze the data. The analysis was run to compare the type of event (oral, flight, or simulator) with the outcome of the event (satisfactory or unsatisfactory) and account for the time of day. This resulted in a three-variable contingency table. In reviewing the data, several outlier data points were found indicating evaluation events that occurred at abnormal times (between 9pm and 5am). When the faculty of the flight training provider were queried, they indicated that these were most likely events that were scheduled at times that would not create resource conflicts within the scheduling system, but the evaluations were likely not conducted at those listed times. The researchers were left with no way to ascertain the time that these evaluations occurred and so these 13 events were eliminated from the data analysis leaving a remaining sample size of n=10998. While the Chi Squared analysis indicated that some of the data were significant, the researchers could not determine what element was significant. To understand the underlying relevance and relationship between the variables, a post-hoc binary logistic regression was conducted.

Results and Discussion

The Chi Squared test yielded a significant finding for the data overall ($\chi^2=363.910$, $df=2$, $n=10998$, $p<.001$), indicating that there is a difference in the actual evaluation outcomes when compared to starting time versus the expected outcomes. Upon closer examination, several starting times were found to have significant impact on outcomes as well, specifically 8am-11am, 1pm, and 3 pm. The data are available for all times in Table 1.

In addition to the significance of the Chi Squared values, a Cramer's V was also calculated to give an idea of the strength of the associations found through the Chi Squared analysis. The values of Cramer's V indicate a weak relationship between time of day and outcome of the evaluation event for all separate times as well as entire dataset when viewed as a whole. The Cramer's V values for all the evaluation times can also be found in Table 1.

Table 1

Statistics for χ^2, degrees of freedom, n, χ^2 significance, and Cramer's V for all evaluation starting times by hour

Time	χ^2	*df*	*n*	χ^2 Significance	Cramer's V
6am			9		
7am	2.361	1	251	0.124	0.097
8am	124.557	2	3029	<.001*	0.203
9am	11.658	1	563	.001*	0.144
10am	31.314	2	1811	<.001*	0.131
11am	9.171	1	241	.002*	0.195
12pm	6.875	2	166	0.032	0.204
1pm	92.772	2	2684	<.001*	0.186
2pm	3.918	1	347	0.048	0.106
3pm	55.93	2	1721	<.001*	0.18
4pm	2.74	1	52	0.098	0.23
5pm	2.296	2	95	0.317	0.155
6pm	0.434	2	15	0.805	0.17
7pm			9		
8pm			5		
Total	363.91	2	10998	<.001	0.182

Note. Blank entries indicate statistics could not be computed because outcome was a constant. * indicates significance at a Bonferroni adjusted level of .003. Cramer's V significance levels identical to χ^2 significance levels.

The significance of the 8am, 10am, 1pm, and 3pm starting times are difficult to gauge because the p value returned simply indicated it was less than .001, but the adjusted residuals of those starting times provided us with an indicator of the strength of the significance. In all cases, the adjusted residuals for opposing outcomes were identical in magnitude but opposite in sign. Positive adjusted residuals indicated that the observed values were greater than expected while negative meant the opposite. The adjusted residual at 8am for satisfactory oral evaluations was 11.1 and for satisfactory flights was -11.2 indicating there were more satisfactory oral evaluations and fewer satisfactory flight evaluations than would be expected by chance. These indicate very significant statistical values at over 11 standard deviations. The adjusted residuals for the remaining three times ranged from -2.3 for satisfactory simulator evaluations at 3pm to 9.6 for satisfactory oral evaluations at 1pm. These adjusted residuals help to explain the differences that were found between the expected and observed outcomes for the type of exam within the same times as well. Statistically significant differences at the .05 level were found between satisfactory and unsatisfactory, for both oral and flight evaluations at 8am, 9am, 10am, 11am, 1pm, and 3pm. These data for the listed times, including adjusted residuals, can be found in Tables 2 and 3. The only time that there was a significant difference between outcomes for simulator evaluation was at 3pm.

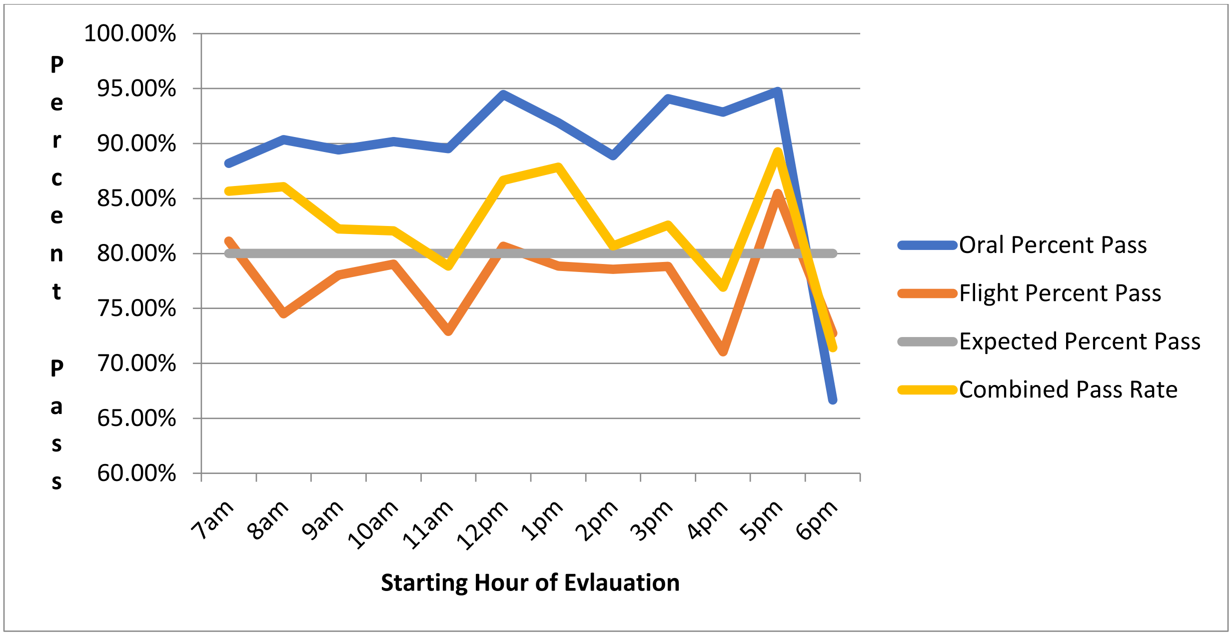

Figure 1. Oral, Flight, and Combined Percent Pass vs. Expected Pass Rate

Figure 1 gives an overview of the overall combined pass rates as well as each individual type; oral and flight. While the oral pass rate remains relatively high throughout the day, the flight pass rate seems to take a dip in the late morning as well as the late afternoon. These dips potentially could be explained by the students' chronotypes. An owl, for example, would expect a dip in focus and energy in the morning and gradually become more alert and focused as the day moves into the evening hours. The third bird that Pink (2018) refers to would be more likely to experience that same trough in focus and energy late in the afternoon.

Table 2

Count and Adjusted Residual Values by time: 8AM to 12PM

timeday				Outcome: Satisfactory	Outcome: Unsatisfactory	Total
8 AM	typeexam	Oral	Count	1993_a	213_b	2206
			Adj.Residual	11.1	-11.1	
		Flight	Count	608_a	208_b	816
			Adj.Residual	-11.2	11.2	
		Sim	Count	6_a	1_a	7
			Adj.Residual	.0	.0	
	Total		Count	2607	422	3029
9 AM	typeexam	Oral	Count	186_a	22_b	208
			Adj.Residual	3.4	-3.4	
		Flight	Count	277_a	78_b	355
			Adj.Residual	-3.4	3.4	
	Total		Count	463	100	563
10 AM	typeexam	Oral	Count	440_a	48_b	488
			Adj.Residual	5.5	-5.5	
		Flight	Count	1032_a	274_b	1306
			Adj.Residual	-5.2	5.2	
		Sim	Count	12_a	5_a	17
			Adj.Residual	-1.2	1.2	
	Total		Count	1484	327	1811
11 AM	typeexam	Oral	Count	77_a	9_b	86
			Adj.Residual	3.0	-3.0	
		Flight	Count	113_a	42_b	155
			Adj.Residual	-3.0	3.0	
	Total		Count	190	51	241
12 PM	typeexam	Oral	Count	68_a	4_b	72
			Adj.Residual	2.6	-2.6	
		Flight	Count	75_a	18_b	93
			Adj.Residual	-2.6	2.6	
		Sim	Count	1_a	0_a	1
			Adj.Residual	.4	-.4	
	Total		Count	144	22	166

Note. Each subscript letter denotes a subset of outcome categories whose column proportions do not differ significantly from each other at the .05 level.

Table 3

Count and Adjusted Residual Values by time: 1PM to 3PM and Total

				Outcome		
timeday				Satisfactory	Unsatisfactory	Total
1 PM	typeexam	Oral	Count	1700_a	150_b	1850
			Adj.Residual	9.6	-9.6	
		Flight	Count	652_a	175_b	827
			Adj.Residual	-9.5	9.5	
		Sim	Count	5_a	2_a	7
			Adj.Residual	-1.3	1.3	
	Total		Count	2357	327	2684
2 PM	typeexam	Oral	Count	64_a	8_b	72
			Adj.Residual	2.0	-2.0	
		Flight	Count	216_a	59_b	275
			Adj.Residual	-2.0	2.0	
	Total		Count	280	67	347
3 PM	typeexam	Oral	Count	396_a	25_b	421
			Adj.Residual	7.2	-7.2	
		Flight	Count	1013_a	272_b	1285
			Adj.Residual	-6.7	6.7	
		Sim	Count	9_a	6_b	15
			Adj.Residual	-2.3	2.3	
	Total		Count	1418	303	1721
Total	typeexam	Oral	Count	5132_a	502_b	5634
			Adj.Residual	19.0	-19.0	
		Flight	Count	4149_a	1165_b	5314
			Adj.Residual	-18.7	18.7	
		Sim	Count	36_a	14_b	50
			Adj.Residual	-2.5	2.5	
	Total		Count	9317	1681	10998

Note. Each subscript letter denotes a subset of outcome categories whose column proportions do not differ significantly from each other at the .05 level.

The Chi Squared analysis indicated that the data were significant at numerous times of day but could not reveal what about them was significant. The analysis also did not indicate what elements of the other two independent variables had significant impact on the outcome of the evaluation. To answer those, a binary logistic regression was conducted over all the data using SPSS V. 22.0. The regression model predicted 68% of the outcomes and used a cut value of .800. The cut value of .800 was chosen because the industry standard for check rides is an

80% first time pass rate. The regression model found statistical significance on the outcome for nearly all the times of day except 6am and 7pm, three of the training courses (two commercial experience courses and instrument certification), and oral evaluations. These data are displayed in Tables 4 and 5. It is interesting to note that all the β values for all the significant times were positive indicating that time of day, while statistically significant, may not have a practical significance. The least favorable time to begin an evaluation, according to the regression model, was 5pm. The course that a student is enrolled in has greater impact on the probability of successfully completing their check ride on the first attempt. The proficiency courses in preparation for commercial certification had the highest positive impact on check ride outcome (β= 1.014 for the first commercial experience course and β=1.342 for the second commercial experience course) while the certification courses, especially instrument certification had the greatest detriment (β=-1.101 for the instrument rating certification course). While the effect did not appear to be large, the probability of passing a check ride on the first attempt did vary by up to roughly one percent depending on the course the student is taking. The type of evaluation also impacted the probability of success with an oral evaluation being more likely to succeed (β=.527) while the flight is less so (β=-.638). It is interesting to note that only the flight evaluation was statistically significant (p=.043).

Table 4

Classification Table

			Predicted		
			Outcome		
	Observed		Unsatisfactory	Satisfactory	Percentage Correct
Step 1	outcome	Unsatisfactory	990	691	58.9
		Satisfactory	2832	6485	69.6
	Overall Percentage				68.0

Note. The cut value is .800

Table 5

Variables in the Equation

		β	*SE*	Wald	*df*	Sig.	Exp(β)	95% C.I.for EXP(β) Lower	Upper
Step 1	timeday			40.542	14	.000			
	timeday(1)	20.861	12717.089	.000	1	.999	1148114532.988	.000	.
	timeday(2)	1.793	.409	19.242	1	.000	6.006	2.696	13.379
	timeday(3)	1.683	.362	21.563	1	.000	5.381	2.645	10.949
	timeday(4)	1.747	.378	21.402	1	.000	5.736	2.736	12.021
	timeday(5)	1.835	.364	25.390	1	.000	6.263	3.068	12.786
	timeday(6)	1.562	.399	15.343	1	.000	4.769	2.182	10.419
	timeday(7)	2.036	.427	22.739	1	.000	7.662	3.318	17.694
	timeday(8)	1.868	.364	26.386	1	.000	6.479	3.176	13.216
	timeday(9)	1.735	.388	20.020	1	.000	5.671	2.652	12.129
	timeday(10)	1.875	.366	26.303	1	.000	6.522	3.185	13.353
	timeday(11)	1.473	.507	8.457	1	.004	4.363	1.616	11.774
	timeday(12)	2.415	.492	24.072	1	.000	11.190	4.264	29.364
	timeday(13)	1.591	.695	5.240	1	.022	4.907	1.257	19.154
	timeday(14)	21.265	12763.173	.000	1	.999	1719152707.934	.000	.
	course			301.070	11	.000			
	course(1)	-.260	.241	1.165	1	.280	.771	.480	1.237
	course(2)	.035	.214	.026	1	.871	1.035	.680	1.575
	course(3)	-.384	.207	3.437	1	.064	.681	.454	1.022
	course(4)	1.014	.234	18.763	1	.000	2.756	1.742	4.360
	course(5)	1.342	.246	29.799	1	.000	3.827	2.364	6.197
	course(6)	.065	.211	.094	1	.759	1.067	.706	1.612
	course(7)	-1.101	.236	21.704	1	.000	.332	.209	.528
	course(8)	-.078	.240	.106	1	.745	.925	.578	1.480
	course(9)	.236	.223	1.119	1	.290	1.266	.818	1.958
	course(10)	.399	.237	2.830	1	.092	1.491	.936	2.374
	course(11)	-.149	.243	.374	1	.541	.862	.535	1.388
	typeexam			328.171	2	.000			
	typeexam(1)	.527	.315	2.802	1	.094	1.693	.914	3.137
	typeexam(2)	-.638	.316	4.092	1	.043	.528	.285	.980

Note. Variable(s) entered on step 1: course, typeexam.

Conclusions

This study is a first look into chronotypes in aviation flight training. While the data show a possible relationship between check ride performance and time of check ride, the study ultimately led to more questions than answers about the effect of chronotype on collegiate aviation flight students. While the sample size was large, there are three major limitations of this study: (a) the use of only one school's data, (b) the limited timeslots for check ride starts (with most events beginning between 8 am and 3 pm), and (c) the lack of more detailed demographic and background information on the sample. The lack of demographic and background data makes it impossible to identify individuals' chronotypes or account for potentially confounding variables. Pink (2018) indicated that in the teen years most people transition to being owls and at around twenty years of age, preferences shift to a lark or third bird making it nearly impossible to determine the chronotype of the college age students in this study.

Recommendations

Further study of chronotypes in aviation and specifically flight training should be conducted. Most importantly, identification of participant chronotype in advance of measuring performance would have greatly improved analysis of study results. Future studies should seek a finer analysis of check ride characteristics to determine if chronotypes have more of an effect on oral exams, flight exams, or more complex types of check rides, such as instrument or flight instructor. Additionally, a study at an institution that trains and tests 24 hours a day would be valuable, such as at a simulator training institution. Fatigue has been recognized as a threat to aviation safety, but it seems to be one that can be overcome with proper understanding of what causes fatigue and mitigation techniques. Future research is indicated on the impact of teaching flight students about healthy sleep habits, healthy eating habits, healthy exercise habits, healthy ways to counter sleep debt, and their individual chronotype.

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Collegiate Aviation Review International

Volume 37 | Issue 1 Peer-Reviewed Practice #1

1-14-2019

A Laboratory Project to Enhance Wood Construction and Repair Understanding in a Part 147 School

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American aircraft have always incorporated wood as a primary structural material (FAA, 2018). Although metal has become the leading material in civil aircraft production, approximately 5% of the fleet still uses wood within structural components of the airframe. In order to maintain safe, airworthy aircraft, Airframe and Powerplant (A&P) certificated mechanics must be sufficiently trained in methods and practices approved by the Federal Aviation Administration (FAA). The current 14 CFR 147 training requirements for A&P schools list, at minimum, introductory teaching and understanding of wood building and maintenance concepts, but no hands-on projects or technique evaluation. This lack of hands-on education may leave A&P students unprepared as they enter their careers. Due to this discrepancy in training minimums and experience expectations, a new project was developed that better instructed students in the construction, inspection, and repair of wood structures by providing them hands-on experience. This multi-week project involved students, in groups of four, building a 1/8 scale, Sitka spruce truss fuselage of a light general aviation aircraft. Students were required to use method, techniques, and practices acceptable to the FAA for wood construction and inspection. Upon completion of their build, students were evaluated for the quality of their workmanship and adherence to design data. Finally, students were asked to anonymously self-evaluate their perceived gains in wood building and inspection techniques.

Recommended Citation:
Shipp, B.R. & Kozak, B.J. (2019). A Laboratory Project to Enhance Wood Construction and Repair Understanding in a Part 147 School. *Collegiate Aviation Review International*, 37(1), 143-156. http://dx.doi.org/10.22488/okstate.19.100210

For many years, wood was used as a main constructional element in the building of aircraft. While the practice is somewhat waning today, there are still a tenable number of these wood structured aircraft flying within the United States today. As these machines age, there is a continual need for qualified technicians to inspect, repair, and maintain them in a way that preserves their functionality and, most importantly, their airworthiness. The Federal Aviation Administration prescribes a set of regulations that must be met for an aircraft to remain airworthy, one of which is the need for Airframe & Powerplant certificated mechanics to perform the necessary maintenance. These A&P mechanics must be well versed in the methodologies surrounding wood inspection and repair, however their training requirements are surprisingly lax in this area. In order to improve A&P understanding of wood construction and repair, an A&P school has developed a new project that goes beyond the required minimum instruction set forth by the FAA. The goal of this new project has been to give students a hands-on active learning opportunity; an opportunity which helps improve their skills and technique with wood structures.

Overview of Wooden Aircraft Construction

Wood was a primary structural material during the beginning decades of aviation because there were few materials that could match its combination of strength, durability, low weight, and low cost (FAA, 2018). There are still a reasonable number of aircraft still flying that incorporate wood into their structures. Table 1 outlines a selection of popular aircraft designs containing wood. These aircraft were chosen based on their use in General Aviation (G.A.) in the U.S. With a United States G.A. fleet of approximately 199,300 fixed wing aircraft (FAA, 2017), these selected aircraft represent 4.96% of those registered within the U.S.

Table 1

Popular aircraft with wood structures registered in the United States as of 2018..

Type	Number Registered with FAA	% of G.A. Fleet
Piper J-3 Cub (and variants)	4,178	2.10%
Aeronca Champ	2,567	1.29%
Bellanca Citabria (and variants)	1,253	0.66%
Bellanca Viking (and variants)	660	0.33%
Pietenpol Air Camper	227	0.11%
EAA Biplane	70	0.04%
Pitts Special (and variants)	851	0.43%
Total of Select Aircraft	9,806	4.96%

*Data obtained from 2018 FAA aircraft registry

The Piper Cub's original production ran from 1937 through 1947, and saw nearly 20,000 aircraft produced (Smithsonian Institute, 2018). Piper Cubs were used widely in civilian and military flight training as well as serving as military observation aircraft (Smithsonian Institution, 2018). The popularity of the design has since led to modern manufacturers reproducing Cubs and Super Cubs, as well as Cub-inspired original designs that use modern material like carbon fiber ("Carbon Cub SS," 2018). The original Cub was made with a welded steel tube frame, but most models used a wooden wing spar underneath fabric covering. These aircraft were powered by reciprocating engines ranging from 40 to 65 horsepower (Smithsonian Institute, 2018), which yielded a docile aircraft for training and recreational flight. With their low fuel use, forgiving handling, and simplistic design, Cubs have remained prominent in American aviation.

Another prominent aircraft to be built from wood is the Champion originally produced by Aeronca, which entered production in 1945 ("American Champion 7EC Champ," 2009). The initial production run ended in 1951, but the American Champion company took over the design and resumed production during 1955 ("American Champion 7EC Champ," 2009). The Champ fuselage was constructed of wood stringers and formers, and the aircraft's wing spars were wood, with aluminum ribs and a fabric skin overlay (Davisson, 1997). Champs saw extensive use as flight school aircraft, as well as some models being used by the U.S. military (Visel, 2018). Derived from the Champ's design was the Citabria, an aerobatic rated taildragger ("American Champion Citabria," 2009) that has been in production since 1964. The Citabria design retained the wooden spars and fuselage paneling of its predecessor and has proven to be an inexpensive and enjoyable aircraft to fly ("Aircraft Spotlight," 2016). Bellanca Aircraft produced the Citabria design throughout the 1980s, however they were not Bellanca's first venture into wooden aircraft.

Bellanca produced their Viking model out of Minnesota beginning in 1967 (Cox, 2004), building the most substantial aircraft discussed thus far. The Viking featured a wing made from Sitka spruce and mahogany plywood, which yielded a strong, lightweight, and aerodynamically smooth lifting surface (Cox, 2004). In addition to this, the Vikings were four seat, retractable gear, high performance aircraft, with excellent handling characteristics ("Bellanca Super Viking," 1993). With its clean lines, large carrying capacity, and a 300-horsepower engine, the Viking placed itself in a different class of aircraft from the trainers and aerobatic aircraft previously mentioned. Bellanca's design was far more focused on luxury, receiving favorable reviews on its performance and handling, as well as having a range more suited to cruising instead of sport flying ("Bellanca Super Viking," 1993).

In the world of experimental or *homebuilt* aircraft, wood has remained a relevant material. The Pietenpol Aircamper was conceived and designed by Bernard Pietenpol, and first flew in 1928 (Pietenpol, 1991). The Aircamper design called for a wood structure for both fuselage and wing assembly. The plans specified the use of spruce, mahogany plywood, and white ash woods throughout. Most surfaces, such as fuselage sides and floor, as well as gusset plates, were to be mahogany plywood, while structural items like spars are Sitka spruce (Pietenpol, 1991). The assembly of the Aircamper was almost entirely glue based, with gusset plates added for extra strength. To this point, the Pietenpol plans stated: "There is no point in using a lot of nails. The strength lies in the gusset plate and gluing." (Pietenpol, 1991, p. 8).

A later design in the category of homebuilt aircraft was the EAA biplane. This aircraft was commissioned by Paul Poberezny, the founder of the Experimental Aircraft Association (EAA) ("1960 EAA Biplane," 2018). By 1960, a team of engineers and high school students had developed a design with wooden, fabric covered wings and a tube steel fuselage ("1960 EAA Biplane," 2018). The EAA biplane was sold only as a set of plans which provided the builder all they needed to know to construct their own aircraft. The authors were granted access to an EAA biplane that belongs to a Part 147 certificated mechanic school. This aircraft was donated to the school in a state of partial completion, which allowed students a chance to easily study the wooden construction of its wings. Pictures have been included in Figures 1, 2, and 3 to exemplify wooden structures as discussed in this paper.

Figure 1. A front quartering view of an EAA biplane used for maintenance instruction at a Part 147 Aviation Maintenance Technician School.

Figure 2. Image looking toward the centerline of the EAA biplane, depicting a close-up view of the internal structure of a wooden wing.

Figure 3. Wood structure inside a partially complete wing of the EAA biplane.

The Pitts Special has been another popular homebuilt biplane aircraft, with some of its variants including wood in their construction. Pitts Specials have been known as an aerobatic aircraft, not designed for comfort or travel. Pitts biplanes were described as "tiny, impractical, loud, and demanding" ("Budget Buy: Pitts Special," 2017); its sole purpose in existence was to provide a fun, thrilling ride to those willing to endure its abuses ("Budget Buys: Pitts Special," 2017). From decades old home build kits, to mass produced trainers, or the high-speed comfort of the Viking, wooden aircraft remain prevalent in the U.S. As can be seen in table 1, when the totals of these selected aircraft were combined, they represented 4.96% of the U.S. General Aviation fleet.

Aircraft Certification and Maintenance

Within the United States, all aircraft must comply with the requirements of the FAA to remain airworthy. According to the FAA, "An aircraft with a type certificate (TC) is airworthy when it conforms to its U.S. TC and is in a condition for safe operation." (Department of Transportation [DOT], 2017 p. I-1). Experimental aircraft do not have a Type Certificate and are therefore considered airworthy when in a condition for safe operation. For the aircraft mentioned above, and for many others under 12,500 lbs. gross weight, this determination of conformance and safety is made during detailed inspections every 12 calendar months, or every 100 hours of operation if the aircraft is used for hire (Inspections, 2018). These inspections must be performed by an appropriately rated mechanic (Inspections, 2018), and during these inspections, it is feasible that damaged or degraded wood structures may be found.

If defects are found that necessitate repair, mechanics must use the proper reference data to perform their work. Advisory Circular AC 43.13-1B is an FAA resource that has been considered acceptable data for repairs on non-pressurized, civil aircraft, and contains a wealth of information on wood construction. One difference between metal and wood construction is the wide use of adhesive bonds in wood assemblies. Critical factors like surface preparation, grain orientation, and clamping pressures must be considered during assembly, and approved glues must be used (FAA, 1998). Repairs to spars generally consist of splices with feathered surfaces and reinforcement plates, while skin repairs call for scarf patches, with a myriad of specific requirements (FAA, 1998). The technicians that have been charged with these repairs must possess a specialized skill set to execute proper, safe, and long-lasting repairs, and must also be certificated through the FAA in order to legally release the aircraft for return to service.

These specialized technicians are typically Airframe and Powerplant (A&P) certificated mechanics. Some technicians choose to work without their A&P, and these individuals must be supervised directly by another technician that is a certificated mechanic (FAA, 2013). Without an A&P mechanic directly involved in the maintenance being performed, the work is not allowed (Persons authorized, 2012). In order to sustain an airworthy fleet of wooden aircraft, it is imperative that A&P mechanics be well versed in the complex and demanding repair and maintenance of wood structures, however the training requirements in this aspect have been surprisingly lax. In order to obtain their A&P, mechanics must have had at least 18 months of experience relating to the specific certificate sought (airframe or powerplant) or have a combined 30 months of both (Experience Requirements, 1970). There is a second way of complying with the experience requirements: attending and graduating from an FAA approved aviation maintenance technician school (Experience Requirements, 1970).

For schools to be approved by the FAA, they must comply with 14 C.F.R Part 147, which specifies the organization, operation, and curriculum content of aviation maintenance technician schools. Airframe Curriculum Subjects, Appendix C to 14 C.F.R Part 147 (2018) specifically lists the following requirements related to wood structures as the minimum instruction on wood for A&P certification:

1. Service and repair wood structures.
2. Identify wood defects.
3. Inspect wood structures.

These tasks are held to a teaching Level 1, which requires no practical application or manipulative skill; only general knowledge and instruction by lecture (Airframe Curriculum Subjects, 2018). Of the three teaching levels, Level 1 is the least in-depth level, requiring students to only have general understanding. Many other subjects such as sheet metal, landing gear, and electrical tasks are held to Level 2 or 3, which mandates that students need to have a functional grasp of topics and be able to perform the work they are studying (Airframe Curriculum Subjects, 2018). Levels 2 and 3 require manipulative skill and practical applications of the topic at hand (Curriculum Requirements, 2018). The defining factor that separates Levels 2 and 3 is that Level 3 tasks must be executed to a level that could constitute return to service requirements (Curriculum Subjects, 2018). This means the student's work should meet manufacturer guidelines for work quality on airworthy machines. The lack of hands on training with wood structures presents the opportunity for a disconnect to develop between skills *taught* and skills *expected* of A&P mechanics.

Upon certification as an A&P mechanic, students who have only had an introductory training in wood structures would be allowed to perform repairs and modifications like those outlined in AC 43.13. According to the findings of research performed by Freeman et. al. (2014) on the subject of active learning, student performance shows a noticeable increase when lecture is coupled with active hands on learning, and that "students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning" (Freeman et. al., 2014). Even though Part 147 schools are fulfilling their minimum requirements by solely lecturing on wood structure construction and repair, lecture isn't always enough to teach safe practices.

It should also be noted that 14 C.F.R Part 65.81, General Privileges and Limitations (1980), which deals with mechanic privileges and limitations, states that a mechanic may not perform any work which they have not performed previously, regardless of their certification or ratings. The caveat to this rule is that a properly certificated and experienced mechanic may supervise the work, allowing the new mechanic a chance to perform the task at hand (General Privileges and Limitations, 2018). While it was feasible in decades passed that a fledgling mechanic would be given the chance to work under an experienced mechanic if they were going to maintain wooden aircraft, the number of certificated mechanics with woodworking experience is steadily declining (FAA, 2018).

Project

The use of laboratory-based training has been extensively used to increase student understanding of basic concepts and real-world problems (Lanza, 1984; Sundberg & Moncada, 1994; Mahendran, 1995; Burrowes & Nazario, 2008). Furthermore, hands-on training is a fundamental part of teaching technical topics (Wheway, 1991). To help close this gap in experience, a new project was developed for use in a Part 147 certificated school and has been implemented into the curriculum for two semesters. The project required students to build a simplified version of a wooden aircraft fuselage using FAA approved techniques and practices. The primary learning outcome of the project was to introduce student to the techniques used in wooden aircraft construction. There were some secondary learning outcomes as well, such as reinforcing in the students a sense of responsibility for the quality of their work and encouraging communication when working as a team.

During this four-week project, groups of three students were given ample supplies of aircraft-grade Sitka Spruce, T88 epoxy, tools, and engineering drawings of a truss structure. Multiple views of the expected truss can be seen in Figure 4. A 3D representation of the truss can be seen in Figure 5. This truss was a 1/8th representation of a simplified aircraft fuselage, and students were required to build it according to standard construction practices. By requiring students to adhere to standard practices such as those in AC 43.13, this exercise provided students hands on experience with wooden aircraft structures.

During the construction of the truss, students were expected to follow engineering drawings to measure and cut appropriate lengths and angles from Sitka spruce stock. Once students laid out their parts and prepared the surfaces to be bonded, they mixed and applied T-88 epoxy. This epoxy is a common two-part epoxy resin used by experimental aircraft builders and has been approved by the FAA for repairs on certificated aircraft. T88 was chosen because of its high strength, ease of application, and simple mixing characteristics (System Three, 2018). Once their epoxy was applied, students were expected to devise a clamping arrangement to hold their pieces together and provide ample pressure for curing, as seen in Figure 6.

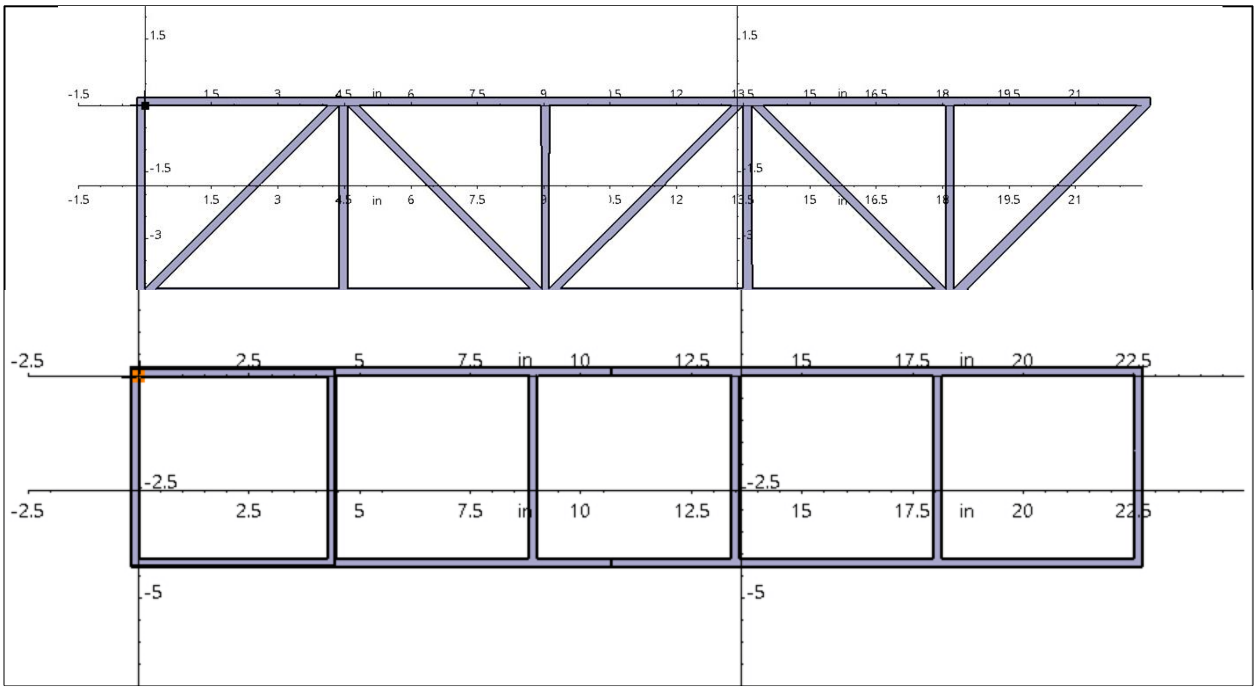

Figure 4. 3D CAD drawings used to create the engineering drawings that students were given to complete their build projects. Views shown: left side and top.

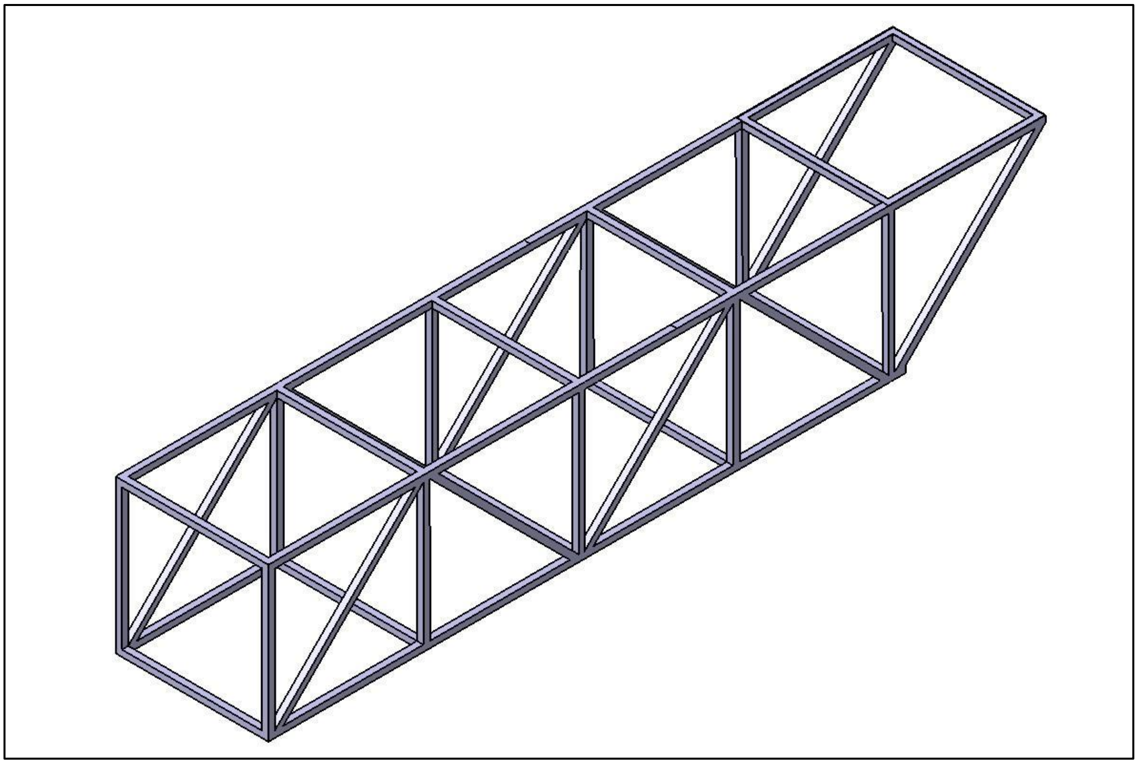

Figure 5. CAD isometric picture of the truss assembly.

Figure 6. Truss structure clamped in place to allow epoxy to cure during student build project.

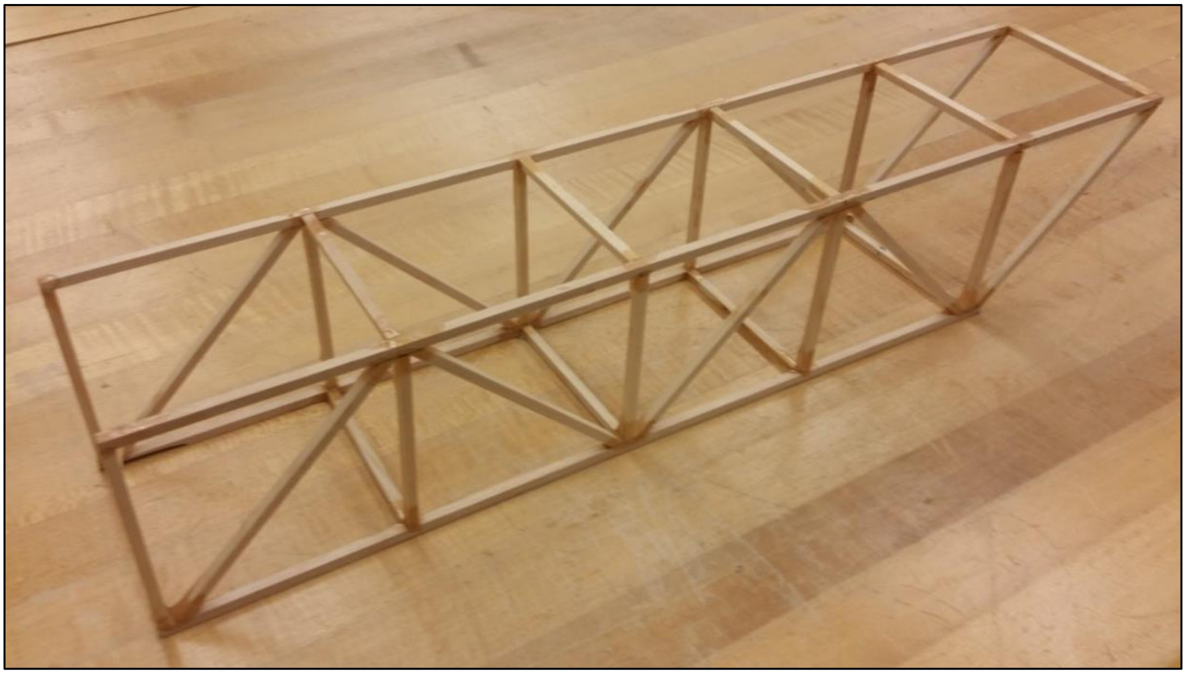

Figure 7. Isometric picture of a completed truss assembly as built by Part 147 students.

Upon finishing their build project, students were evaluated on the quality of their construction. Projects were inspected for clean, straight cuts at the proper angles. Trusses were measured for dimensional adherence to the engineering drawing provided. The structure was also checked for the straightness and symmetry of construction. Finally, students were evaluated on the appearance of their glue joints; excess epoxy was to be removed and gaps in joints were to be kept to a minimum. A finished truss assembly can be seen in Figure 7.

In order to document project outcomes at the end of the semester, the students who participated in the building exercise were asked the following questions, and asked to respond on a 5-point scale: “As a result of your work in this class, what GAINS did you make in the SKILL of building a model of an aircraft fuselage?” Responses can be seen in Table 2.

Table 2

Responses to “building skills” question

Gained a great deal (5)	4	Median	Standard Deviation
Gained a lot (4)	10	-	-
Gained somewhat (3)	4	-	-
Gained a little (2)	0	-	-
Gained nothing at all (1)	0	-	-
Totals-	18	4.0	0.67

“As a result of your work in this class, what GAINS did you make in the SKILL of identifying and explaining the wooden materials used within aircraft construction?” Responses to this question can be seen in Table 3.

Table 3

Responses to “wooden materials” question

Gained a great deal (5)	3	Median	Standard Deviation
Gained a lot (4)	10	-	-
Gained somewhat (3)	3	-	-
Gained a little (2)	2	-	-
Gained nothing at all (1)	0	-	-
Totals-	18	3.9	0.85

This practical, hands-on project was designed to give students an introductory view of working on a wooden structure. By teaching wood builds in this manner, the Part 147 school was able to exceed the Part 147 requirements of solely lecture exposure to wood structure. The goal of their exceedance was to better prepare A&P students to handle the complexities of maintaining America’s G.A. fleet.

Conclusion

While wooden aircraft may not be the primary representative of the G.A. fleet, they still represent a relevant portion of aircraft flying. Many designs utilize wood structures. As they age, these aircraft will suffer decay from decades of use, and accidents may happen necessitating repairs. The intricacies of wood structure repair and maintenance require A&P technicians to be well-versed in skills which are not well-taught in current Part 147 schools. By implementing this new construction project into their curriculum, steps are being taken toward better educating the current generation of students.

It should be acknowledged that implementing this project incurs additional burdens for Part 147 schools. The monetary cost for the supplies will exceed the typical budget that is required for a Part 147 curriculum that simply meets minimum requirements. Additionally, as Part 147 curriculum timelines are often densely-scheduled as is, the time commitment to afford students enough work time to complete their project may present a challenge for educators. Despite these challenges, this project should be considered as a supplement to Part 147 operations because of its potential benefits. By providing an opportunity to handle the material, use real-world tools and techniques, and evaluate the finished product, the Part 147 school’s new wood project gives students more experience with wood structures than is required by the FAA.

Future Works

In future semesters, the Part 147 instructors involved in this new course exercise plan to incorporate a destructive testing and failure analysis component to the project. It is expected that applying a load to the structure in a controlled and measurable fashion would allow the students to compare their construction techniques and evaluate how quality of workmanship affects the strength of the truss structure. The destructive portion of the project would also include an analysis of how and where their truss structure failed. By studying the appearance of the wood and epoxy joints in the truss, students would be able to better identify failure conditions present on actual airframes.

Another addition to the build project would be to include an assignment for the students to produce a 3D Computer Aided Design (CAD) model in a program that includes structural analysis capabilities. Students would apply the structural properties of the materials used in their build, namely Sitka spruce, then use the structural analysis tools to simulate the same mounting and loading conditions as applied to their physical models. The purpose of this assignment would be for students to compare the differences between CAD results and actual prototyping of structural designs. While CAD can be an extremely helpful tool in the design process, it is not always entirely accurate, and this project would help put a tangible example in front of students to learn from, better preparing them for their careers as technicians.

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Collegiate Aviation Review International

Volume 37 | Issue 1 Peer-Reviewed Practice #2

2-13-2019

Competency-Based Education: A Framework for Aviation Management Programs

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In recent years, the agencies that accredit collegiate aviation programs have moved to outcomes-based models. These models benefit from defined core competencies that can be used to drive the development of related program goals and student learning outcomes to ensure program consistency and quality. This article provides a brief description of the process that the faculty at a large midwestern university utilized to develop core competencies for its aviation management programs, and the set of competencies that resulted from the process.

Recommended Citation:
Mott, J.H., Hubbard, S.M., Lu, C-T., Sobieralski, J.B., Gao, Y., Nolan, M.S., & Kotla, B. (2019). Competency-Based Education: A Framework for Aviation Management Programs. *Collegiate Aviation Review International*, 37(1),157-174. http://dx.doi.org/10.22488/okstate.19.100211

As regional and professional academic accrediting organizations have moved in the direction of outcomes-based assessment over the past twenty or so years, virtually all of the various stakeholders, including those agencies, employers, and academic institutions, have sought the means to define and assess students' attainment of educational outcomes or competencies for their related academic programs. One of the challenges, however, has been the lack of standardization of the definition of competency-based education (Mintz, 2015).

The Council of Regional Accrediting Commissions (C-RAC) proposed that competency-based education is "an outcomes-based approach to earning a college degree," and that individual competencies are "statements of what students can do as a result of their learning at an institution of higher education" (C-RAC, 2015, p. 1). For the purposes of this article, the authors suggest that competency-based education may be viewed simply as an educational model in which the achievement of specific, program-related learning outcomes or competencies are prioritized over time spent in the classroom. According to the U. S. Department of Education (USDOE, n.d., p. 1), "transitioning away from seat time, in favor of a structure that creates flexibility, allows students to progress as they demonstrate mastery of academic content, regardless of time, place, or pace of learning." Hence, if the transition to outcomes-based learning and assessment is to be made successfully, it is important to develop a deep understanding of the particular competencies that form the core of the program in question. These competencies, once determined, will then form the framework for all learning activities associated with the program, and will provide a continuity across related courses.

The Aviation Management program in the Purdue School of Aviation and Transportation Technology was developed in the mid-1980s to fulfill a need for students interested in a career in aviation but wishing to focus on management competencies rather than the technical competencies and certification requirements found in the Professional Flight or Aeronautical Engineering Technology curricula. This program also served for a period of time as a vehicle for an approved Federal Aviation Administration (FAA) airway science curriculum under the FAA's Air Traffic Collegiate Training Initiative. Like the other school programs, Aviation Management began as a two-plus-two program; however, it has operated as a four-year program since the School ended the issuance of associate's degrees roughly five years ago. This model facilitates cooperation with partner programs at community colleges and other schools, which is consistent with other programs in agriculture and engineering at the University.

During the first few years of the program, air traffic control was given a major emphasis. As the program developed, this emphasis was expanded to give students opportunities to study several areas within the broader field of aviation management. Most importantly, two specialty areas were added to the curriculum – airline management and airport management. In the fall of 2007, air traffic control was dropped as a separate focus area, although students may still elect to participate in the FAA Collegiate Training Initiative program. Current students take a capstone course that allows them to work on an individual basis with a faculty member specializing in their area of interest. As with most management-related programs, Aviation Management leverages course offerings from other schools, particularly those of Purdue's Krannert School of

Management. The aviation faculty builds upon the knowledge acquired by students in basic courses and guides students as they apply that knowledge to the unique needs of the aviation industry.

Several specialized educational opportunities exist for aviation management students. First, Purdue University is one of 36 schools in the nation that historically participated in the FAA's Collegiate Training Initiative Program; students successfully completing a group of FAA-approved courses within the Purdue curriculum were eligible for alternate pools in the FAA air traffic controller hiring process, thereby improving their probabilities of selection. While recent FAA hiring procedures have reduced these opportunities, the competencies acquired from the program nevertheless are important for student success. A second opportunity is to finish coursework that will prepare a student to satisfactorily complete the Certified Member examination offered by the American Association of Airport Executives (AAAE). This serves to add value for those graduates seeking employment in the airport management career area. A third option for students is to earn academic minors. Many minors now exist for aviation management students. Two of these are in Management and Computer Information Systems. The Management minor is offered by Purdue's School of Management, and participation is highly encouraged by aviation faculty and advisors due to the practicality and relevance of the courses that comprise it. Purdue's Department of Computer and Information Technology offers the Computer Information Systems minor, and it is beneficial to students who want to enter the aviation industry in an information technology area. Students have also successfully completed minors in complementary disciplines that are compatible with their career goals, including minors in Hospitality and Tourism Management and in technical writing. In addition, a number of university-industry partnerships exist to enhance the quality of the program and to broaden student educational opportunities.

As a land grant institution founded under the Morrill Act, Purdue is the agricultural and mechanical university for the State of Indiana, and the School's mission is a reflection of the missions of the Polytechnic and Purdue University in serving *the citizens of Indiana, the United States, and the world through discovery that expands the realm of knowledge, learning through dissemination and preservation of knowledge, and engagement through exchange of knowledge*. The goal of the Aviation Management program, accordingly, is to produce aviation management graduates who are prepared to serve as aviation professionals with an understanding of aviation as an integrated transportation system, as well as a broad-based knowledge of the aviation industry. Student learning is advanced by discovery and engagement activities that enhance economic and social development with emphasis on airline, airport and air traffic control management. It is expected that program graduates have developed and demonstrated the ability to think clearly and analytically, and possesses effective skills in communication, leadership and organization. In addition, the expectation is that they are prepared to compete in a number of occupational areas within the aviation industry, including those areas emphasized by the program as noted above.

The Council of Regional Accrediting Commissions (2015) identified three approaches that competency-based programs may take: a course/credit-based approach, a direct assessment approach, and a hybrid approach. In a course/credit-based approach, the demonstration of the competencies is incorporated into a conventional curriculum that comprises a set of courses that need to be completed to earn credits towards a degree or credential. The programs based on this approach usually enroll students in traditional academic terms and award credit for courses upon successful completion. Students may choose to accelerate their learning and receive credit for the course after they have demonstrated the mastery of the competencies by passing a summative assessment. Institutions may choose to create two academic transcripts such that one displays the credits earned by the student and includes a grade point average, and the other specifies the competencies achieved (C-RAC, 2015).

The direct assessment approach represents a subset of competency-based education that is not based on semesters or academic terms, or on credits. Under this approach, conventional courses are disregarded and both the evaluation of student achievement and the award of a degree or the credential are based exclusively upon the demonstration of competencies. Programs based on the direct assessment approach allow students to progress through a course at their own pace rather than follow the traditional academic term pattern (USDOE, 2016, p. 1-2). A student may acquire the requisite competencies from multiple sources and at various times in addition to participating in the learning experiences provided by the institution. The duration of learning may differ for each student. The direct assessment methodology provides for alternative approaches to teaching and learning (Southern Association of Colleges and Schools Commission on Colleges [SACSCOC], 2013, p. 2).

Since this approach does not follow a conventional pattern by which grades are assigned and there is a limited timeframe to complete the courses offered, the transcript generated by the institutions following it indicate only the competencies achieved rather than grades or credit hours earned. Credit-hour equivalencies are established for direct assessment-based programs for student learning outcomes. The institutions may choose to issue a transcript that displays the course/credit equivalencies along with a competency transcript (C-RAC, 2015). Institutions are expected to do the following when establishing credit-hour equivalencies:

- Place emphasis on amount of learning that occurs rather than on the time required.
- Draw upon previously defined policies for credit hour allocation that are consistent with federal regulations.

Lastly, the hybrid approach is a combination of the course/credit based and the direct assessment approaches in which students are permitted to attain their degrees or credentials through a conjunction of direct assessment of competencies and of credit hours (C-RAC, 2015). The hybrid approach utilizes direct assessment for satisfying the requirements of one portion of the program and credit hours for the remainder of the program.

For the purposes of approval of competency-based education programs by their respective accrediting agencies, a systematic approach is followed in each of the three cases (C-RAC, 2015):

- For course/credit-based programs, when an institution offers a course using the credit-based approach, it must be approved by its regional accreditor as a substantive change. Post approval, the accreditor will provide the necessary guidance regarding the submission for approval of future competency-based programs.
- For direct assessment programs, institutions must submit their plans to their accreditor for approval as a substantive change before implementation. As per federal regulations, the accreditor is required to review the qualifications and sufficiency of faculty resources to maintain the program, and to evaluate the institution's methodology for determining credit hour equivalency.
- For hybrid programs, institutions must submit their plans for approval from their respective accrediting agency as a substantive change before proceeding with its implementation.

According to a report of the National Postsecondary Education Cooperative Working Group on Competency-Based Initiatives in Postsecondary Education (USDOE, 2002), "competency-based initiatives seek to ensure that students attain specific skills, knowledge, and abilities considered important with respect to whatever they are studying or the transitions for which they are preparing" (p. 9). While different competency-based educational models may take different approaches, the utilization of competencies through the implementation of any of these models requires that three different yet interactive components be developed:

1. A description of the competency,
2. A means of assessing the competency, and
3. A standard by which a student is judged to be competent.

It is the first of these components on which the remainder of this article is focused.

Identification of Core Competencies

Aviation Management programs at Purdue University are predominantly practical in nature; because of this, it is important that they stay current, which can be challenging due to the rapid rate of change extant in the air transportation industry. In addition to fundamental theories related to management and operation, the program aspires to equip students with the necessary skills and knowledge to ensure success, whether students' post-graduation plans are related to employment or to further education.

Researchers in various industries have advocated competency-based education for decades. Monjan and Gassner (1979) address a wide range of topics in competency-based education, ranging from program design to outcomes measurement. They raise the important point that the curriculum must reflect the industry's definition of competency, which emphasizes the requirement of a close connection between academia and industry. More recently, Kearns, Mavin, and Hodge (2018) explored the application of competencies specifically related to aviation education. These researchers addressed education and training for professional pilots, air traffic controllers, cabin crew and aircraft maintenance technicians, recognizing that such training must comply with regulatory standards. The *de facto* impact of regulatory compliance is that government regulatory agencies define educational competencies for flight crew, technician and controller training. Many of the competencies related to aviation management disciplines such as airline operations, revenue management and airport management are not regulated by the government, which allows a broader curriculum design based on the dynamic framework in industry and practice. As a result, there is a critical need to identify these competencies.

Purdue University's Board of Trustees adopted in 2014 a plan to transform its College of Technology, in which the former Department of Aviation Technology resided, into the Purdue Polytechnic Institute. All of the programs housed in this Institute would place a new emphasis on transformative, innovative educational methods using a learn-by-doing approach. The rationale for this transformation was formulated by Gary Bertoline, Dean of the College (Bertoline, n.d.):

> The twentieth century was built on the idea of the industrial age. Students were rewarded for having answers, not asking questions. We are now in the digital age. It's a very different skill set, and the expectations for graduates by business and industry are very different. (p.1)

One of the ten transformational goals set by the Polytechnic Institute was the move toward competency-based programs. The intent of this goal is the empowerment of students by providing them with direct and measurable learning objectives which emphasize creation, application, integration, and transfer of knowledge. Students receive rapid, differentiated support from faculty, who serve more as mentors and less in their traditional roles of deliverers of content.

In keeping with this transition to a competency-based educational model and given an understanding of the respective missions of the University, the Polytechnic, and the School, the aviation management faculty and the Industry Advisory Board for the Aviation Management program engaged in a series of meetings during the spring and fall semesters of 2018. The purpose of these meetings was to identify a set of core and sub-level competencies that would constitute the framework for the program as it continues to evolve with regard to new faculty and courses.

A consensus modeling approach was utilized to facilitate the process of developing both the core and sub-level competencies described herein. A high level of participation among both the faculty and industry representatives, all leaders in their respective areas, was obtained. Focus groups and documentary reviews were utilized as a means of gathering data to facilitate the collective identification of core competencies. Qualitative triangulation was applied to the resulting data to ensure its validity and reliability. In this context, the triangulation process involved the integration of competencies identified by three distinct groups: six faculty from the School's aviation management program, who provided a critically-important internal perspective from the educators directly involved with the program; two faculty from the Aeronautical Engineering Technology program, who provided an external input needed for the validation; and seven representatives from the aviation industry who employ graduates from the institution and who are, in some cases, graduates of the program themselves. Additional industry representatives reviewed the core and sub-level competencies after they were finalized in multiple break-out sessions during the Industry Advisory Board meeting in the fall semester of 2018 in order to register their consensus and made any needed adjustments to the proposed set of competencies.

The resulting core and sub-level competencies that emerged from this iterative process are described below.

Leadership

Successful aviation management graduates demonstrate leadership in executive positions at airlines, airports, and a variety of other aviation and aerospace organizations, including government agencies such as the Transportation Security Administration and the National Transportation Safety Board. To ensure that future graduates have the leadership skills required for success in these executive roles, program faculty and industry representatives have identified leadership as a core competency and are developing associated student outcomes to measure student progress.

Leadership requires a combination of analytical and interpersonal skills, as well as the ability to identify the context for action, and adapt quickly to changing circumstances. An innovative leader must be able to generate, develop and implement ideas, programs and initiatives in the context of a systematic process (Singer, 2014). Specifically, leaders must:

1. Generate favorable ideas and build a team to develop the ideas,
2. Work with the team to refine ideas and accurately estimate the value and costs of ideas,
3. Evaluate ideas using predefined criteria and objectives,
4. Identify the best ideas and develop supporting budgets and funding, and
5. Successfully deliver a final product that results from the ideas.

Leadership requires both independent skills and interpersonal skills that facilitate group processes and organizational success. Leaders must effectively identify and communicate how activities foster achievement of organizational goals and support the underlying organizational mission and vision. Identifying effective ways to communicate and motivate not only team members, but also a variety of internal and external stakeholders, is critical for success.

Leadership may be characterized by strategic thinking, planning, and flexibility, as well as the capability to envision success, communicate steps for success, and motivate the team to achieve success. Leadership may start with self-governance, evidenced through individual tasks that require planning, communication, execution and integrity. Building on self-governance, successful leadership then broadens to include not only personal presence, but also team presence and organizational presence (Eblin, 2018).

A critical component of leadership is ability of to focus on the system problem, rather than the immediate problem at hand (McClain, 2013). This is reinforced by military leadership models as well as by academic models. Developing student capabilities for systems thinking is a critical competency for leadership roles. Systems thinking includes the ability to effectively identify the situational context, as well as organizational and cultural components that affect the problem and can be leveraged to implement a successful solution.

Reflecting these important ideas, the leadership sub-level competencies in Aviation Management have been identified as follows:

1. Fostering actions towards achieving vision, mission, and goals of a project or activity;
2. Facilitating group processes; and
3. Utilizing situation, context, and cultural aspects of organizations effectively.

Subject Matter Excellence

Management is essentially the allocation of resources, including human, financial and physical, with the objective of achieving an optimal return for all stakeholders. While management in the context of general business is already sufficiently complex, aviation management further complicates this task by introducing operational, safety and regulatory compliance elements into its domain. Being a safety-critical industry from the outset, the air transportation industry has employed comprehensive regulations, rules, and policies for decades to manage these compounding objectives and to achieve a safe and orderly growth of air traffic. Therefore, subject matter excellence in the context of aviation management suggests compliance throughout all hierarchies in the air transportation system.

Air transportation is a customer-oriented industry facing numerous challenges within the context of daily operations. With over 43,000 flights per day in domestic airspace (FAA, 2018), an enormous amount of data is generated. The traffic volume, coupled with numerous changes that result from uncertainties introduced by weather and mechanical issues, constantly presents front-line practitioners with problems to solve with little-to-no time for preparation. The ability to make critical and timely decisions based on evidence, knowledge, and experience is the key to solving such operational challenges and facilitating a smooth flow of air traffic through the national air transportation system.

The actual operational environment in air transportation is challenging since data is often incomplete and conflicting. The ability to identity patterns and indicating variables in the presence of noise is a valuable skill that foster advances within the industry. Critical thinking skills to support the ability to identify meaningful information from complex data have been identified by the aviation management faculty members and by the Industry Advisory Board members to be essential for all aviation management students.

The air transportation industry is composed of various entities, including airlines, airports, and other essential suppliers. These business entities all share a similar goal, which is to maximize returns to their respective shareholders while fulfilling operational objectives. While it still holds that the primary mission of air transportation is the transport of passengers and freight from origin to destination, the nature of the journey has become far more diverse in recent years. The satisfaction of the rapidly-evolving associated demands of passengers and shippers suggests that related businesses can generate higher revenues from ancillary services in addition to that generated from core operations. This business acumen has been demonstrated by many global carriers to be the key for financial success and has provided indispensable support to such companies during adverse market environments (Qantas, 2018).

The related sub-level competencies for the subject matter excellence core competency have therefore been identified as:

1. Implementing and managing effective safety, health, and environment systems, using applicable laws, regulations, standards, and codes;
2. Effectively solving problems and making decisions;
3. Thinking critically; and
4. Possessing a satisfactory level of business acumen.

Ethics and Integrity

Integrity and ethical behavior are the foundation of mutual trust and serve as a basis for producing graduates who have the capacity to serve as organizational leaders. Managers in various aviation organizations, including airlines, airports, non-governmental and governmental entities are relied upon to conduct themselves in an ethical manner to ensure the safe and efficient flow of people and commerce around the world. Ethics and integrity are necessary core competencies for any successful aviation manager, and the School has developed objectives to enable students in the program to better understand these issues and to act accordingly in their professional careers.

In recent decades, ethics has become a more complex issue in aviation as the world has become more interconnected (Hoppe, 2018). An agreed-upon measure of ethical behavior is difficult to establish on a global scale; however, the benefits of such agreement and understanding are substantial. Unethical organizations are neither economically nor socially sustainable (Andrews, 1989).

Every organization requires ethical behavior and integrity as central components (Cowings, 2012). Ethics refers broadly to the understanding of right and wrong, and behaving ethically requires an individual to act in a way consistent with what is perceived as right. The recognition of unethical behavior is also key. Integrity is the ability of an individual to do the right thing even when not being monitored. A combination of these two concepts is essential to fostering an environment that is conducive to the nurturing of ethical behavior. Ethical behavior has several pillars developed by Andrews (1989):

1. The ethics of the individual,
2. The effect of the organization as an ethical environment, and
3. The actions developed by the organization to encourage ethical behavior.

To develop the ethics of the individual, students assess their own ethical proficiency inside and outside of the classroom environment. Through carefully analyses of ethical dilemmas, the individual can ascertain the effects of the organization as well as understand the social impacts of particular actions. Understanding the connection between the individual's ethics, organization and society as a whole improves the related procedures and policies of any organization.

In the aviation sector, unethical behavior can not only harm an organization's profitability, but can also negatively impact safety in what is widely recognized to be a high-consequence industry. Whether the aviation manager oversees maintenance, flight operations, safety, employee scheduling, airport operations, or aircraft leasing, proactive recognition of the impacts of ethical and unethical behavior is paramount to the success of the organization. With proper understanding of ethical issues and the ability to identify ethical behavior and to act with integrity, the graduate will be well-suited for a successful career as leader in the aviation industry.

Sub-level competencies that have been determined for the ethics and integrity core competency are:

1. Recognition of ethical issues;
2. Evaluation of different ethical perspectives, concepts, and risks;
3. Fostering of personal responsibility; and
4. Application of ethical perspectives, concepts, and maturity.

Communication

Students graduating from the program are expected to be able to communicate orally, in writing, and through visual and graphical presentations in ways that are appropriate to their fields of study and future careers. Effective communication is founded on information literacy, which involves the ability to use appropriate information to learn and explore ideas, demonstrate understanding of a subject, and convey conclusions effectively. At the embedded outcome level, effective communication assumes basic fluency with such things as grammar, organization and structure. It also focuses on being able to convey ideas concisely in ways appropriate for the context, audience and purpose. At this level, students should recognize that communication occurs within and across communities, such as academic, public or professional, where ideas are formulated, debated, and weighed against one another.

The conveyance of critical information is imperative within the aviation industry, and has been well documented (International Civil Aviation Organization [ICAO], 2015, 2016). Such information must be communicated through multiple channels, including written, verbal, and graphical. The ability to communicate effectively and the related core competency are inextricably connected with competencies in other areas, as well. As Vieira and Santos (2010) described in their study in communication competency for ground and aircraft crews, a high percentage of NASA Aviation Safety Reporting System reports directly or indirectly included problems associated with failures in interpersonal communications (p. 361). Lercel, Steckel, Charles, Patankar, & Vance (2015) placed competence in interpersonal communications as a high priority among those required for aviation maintenance technicians at air carriers, repair stations, manufacturers, and aviation maintenance training institutions, and note that communication is critical for a technician's ability to "relay discrepancy or work order signoffs, and shift turnovers - two activities where technicians must effectively communicate in detail the work they have completed or the work needing completion" (p. 41-42). Clearly, communication is considered a fundamental required competency impacting safety, airworthiness (ICAO, 2015), and other critical operational outcomes in aviation, as well as a cornerstone for business and management.

Sub-level competencies for the communication core competency may be divided into those associated with written communication, oral and interpersonal communication, and visual communication. Those sub-level competencies related to written communication are:

1. Understanding the context of and purpose for writing, including considerations of the audience and the circumstances surrounding the writing tasks;
2. Utilizing appropriate genre and disciplinary conventions; and
3. Utilizing appropriate sources and evidence.

Sub-level competencies associated with oral and interpersonal communication are:

1. Clear and consistently-observable organizational pattern,
2. Thoughtful and effective choices of language, and
3. Presenting a clear and consistent central message.

Sub-level competencies associated with visual communication are:

1. Clear and consistent organizational pattern,
2. Effective use of graphics, and
3. Presence of a clearly-communicated central message.

Teamwork

The aviation industry is global in nature and requires collaborative synergy from all stakeholders. The ability to work effectively as a team and facilitate teamwork is essential to aviation managers and, by extension, to management students, since successful teamwork can significantly enhance desired outcomes (Lerner, Magrane & Friedman, 2009). It is imperative for future aviation leaders to obtain knowledge and achieve a thorough understanding of the merits of teamwork as preparation for managing a high-performance aviation organization. Group research projects, presentations, assignments, and practical exercises are all good means to help shape these needed abilities, which simultaneously reflect the necessary attributes of course materials and activities.

Numerous researchers in aviation, medical and other high-consequence industries praise teamwork as a fundamental ability of professionals (Lacerenza, Larlow, Tannenbaum & Salas, 2018), which in return encourages collegiate aviation programs to embrace the incorporation of teamwork into pedagogical content. It is critical for aviation managers to facilitate their programs, strategies or initiatives through a collective and collaborative fashion. Teamwork is particularly important in safety management. As Reason (1997) described, accidents can happen due to organizational risks; namely insufficient management, supervision, cooperation, leadership, or the lack of teamwork, when completing a mission. As an example taken from aircraft leasing, when the decision to lease or renew a fleet or single aircraft is made, that decision typically involves experts from finance, engineering (engine or avionics), flight, marketing, logistics, quality assurance, cabin services, and training centers. To ensure that program graduates are able to make significant contributions, the ability to successfully work as part of a team must be developed before they enter the workforce (Thompkins, 2015).

Students graduating from Purdue University should be able to work effectively with others in various ways, including working in cross-cultural situations and in a global civil society. Interpersonal skills include the ability to work effectively with others both in professional practice and outside of the discipline, in leadership roles, and as members of a team. Intercultural knowledge is founded on the ability to appreciate and critique multiple perspectives including one's own, and to engage in civil discourse on complex global issues. It requires respect for and responsiveness to the beliefs and practices and cultural and linguistic needs of diverse populations. Students can acquire and practice these skills in ways appropriate to their fields of study and future careers through team projects incorporated into aviation management curriculum.

Accordingly, the associated sub-level competencies for the teamwork core competency are as follows:

1. Facilitation of team member contributions and management of conflict,
2. Development and completion of tasks as an individual contributor, and
3. Development of skills to facilitate immersion with individuals from different cultures.

Individual Resilience and Innovation

Individual resilience is the ability to persevere in the face of adversity and changing circumstances, and innovation is the ability to creatively seek solutions and find opportunities in changing environment. The value of resilience and the importance of being an innovator has become increasingly recognized; "Resilience is not only needed to be developed as an innovator, but just as a human. Life is full of ups and downs, but how you recover and move forward is not just important to how we learn, but how we live" (Couros, 2015, p. 30). Perhaps the concepts derive from age-old concepts that recognize the importance of action, as evidenced by the Chinese proverb, *The person who says it cannot be done, should not interrupt the person doing it.*

Successful aviation management graduates must have the ability to demonstrate resilience and innovation in executive positions at airlines, airports, and a variety of other aviation and aerospace organizations, including government agencies such as the FAA, TSA and NTSB. To ensure that future graduates have the resilience and innovation skills required for success in these executive roles, the School has identified individual resilience and innovation as a core competency and is developing associated student outcomes to measure student progress.

Resilience and innovation are evolving concepts that encompass system identification, resilience objective setting, vulnerability analysis, and stakeholder engagement. The implementation of this framework is focused on the achievement of three resilience capacities: adaptive capacity, absorptive capacity, and recoverability (Francis & Bekera, 2014). Resilient organizations and innovative organizations tend to share essential core competencies related to adaptability and innovation as well as self-efficacy. These competencies (Breazeale, 2012) include:

1. Being connected to others,
2. Being flexible,
3. Being able to make realistic plans and take action to carry them out,
4. Being able to communicate well with others and problem-solve both individually and with others,
5. Being able to manage strong feelings,
6. Being self-confident,
7. Being able to find purpose and meaning,
8. Being able to see the big picture,
9. Being able to appreciate and use humor appropriately,
10. Being able to take care of yourself, and
11. Being able to care for others physically and emotionally.

All of these components, if properly incorporated as required student outcomes, will produce graduates with the resilience to tackle current as well as future (as yet unknown) problems and challenges. Key activities that foster these competencies include the following:

1. Realizing that process is more important than the end-goal,
2. Design thinking is the way to teach students to solve real-world problems,
3. Engaging students instead of lecturing to them,
4. Developing/encouraging creativity versus content, and
5. Inspiring students to think differently.

Bloomberg (2014) summarized the thoughts of Woods as related to the concept that resilient organizations and innovative organizations share essential core competencies, suggesting that “being able to anticipate, being able to proactively learn,” are at the intersection of these concepts, and noting that “proactive learning means you don’t wait for the big signal, the major event to occur that says ‘Hey! Learn! Change! Revise everything! A big thing happened!’ Because if you wait for a big thing to happen, it’s usually bad” (p. 1). In fact, innovation requires disruption, the “big signal” to which Woods refers, and disruptions are usually surprising. As a result, proactive learning, which could also be called planning ahead, is essential for organizational innovation. How does one design an organization that is both resilient and innovative? Woods suggests “a layered network of human social systems that are able to handle surprise, and not get trapped at a narrow level where locally, everyone is behaving in a reasonable, adaptive way, but when you put them all together it’s completely maladaptive from a broader perspective” (p. 1).

Sub-level competencies related to the core competency of individual resilience and innovation therefore include:

1. The ability to adapt and innovate; and
2. Willingness to engage, along with a belief that the task can be accomplished.

Next Steps

Assessment of competencies requires the development of related student learning outcomes. Once competencies are determined, it is useful to summarize the them, along with the related student outcomes, in tabular form. Each of the primary competencies may be presented in a separate table; the related student outcomes may be presented in the table rows, along with criteria for determining whether students' proficiency levels may be categorized as developing, emerging, or proficient. The use of these proficiency level descriptors is recommended to provide a common reference point for assessment purposes (North & Schneider, 1998).

The proficiency level descriptors suggested here provide a delineation of three stages of development of critical aviation management skills that students are expected to acquire as they achieve increasing degrees of proficiency within the program. Ideally, these descriptors should classify student knowledge, skills, and abilities across a spectrum, identifying what the student needs to know and can accomplish upon entering and exiting each of the three levels. They are intended as a guide for both instruction and curriculum development (Torlakson, 2012).

The organization of the proficiency level descriptors represents aviation management skills development across a continuous spectrum of increasing proficiency, starting with basic competencies students possess when they enter the program, and concluding with the lifelong learning in which all aviation professionals engage. The three levels represent three stages of development, describing expectations for knowledge and skills at each level as the breadth of capabilities expands and concepts transition from ideas to practice.

The three suggested proficiency level descriptors for aviation management programs are as follows:

1. **Emerging:** Students within this category generally make rapid progress, learning basic aviation skills for immediate needs, as well as beginning to employ appropriate academic terminology.

2. **Developing:** Students within this category are challenged to increase their aviation management skills in an increasingly greater number of situations, and to learn a wider variety of terminology, applying their knowledge and skills in a more cultivated manner appropriate to their level of experience.

3. **Proficient:** Students within this category continue to learn and apply a range of high-level skills in multiple and varied of frames of reference, including comprehension and synthesis related to advanced technical projects. This stage is indicative of a high degree of engagement in required academic tasks across a broad range of content areas.

The student outcomes relative to each of the three descriptors are expected to be described using appropriate Revised Bloom's Taxonomy action verbs (Krathwohl, 2002). For example, the first two Bloom's levels, *Knowledge* and *Comprehension*, would map to the *Emerging* proficiency level descriptor suggested here. Related action verbs are such terms as *define*, *describe*, etc. The mapping of the six Bloom's Taxonomy levels to the three proficiency level descriptors is straightforward.

As the development of the competency-based education model to be employed in the program progresses, program faculty will develop the related student learning outcomes based on the competencies presented herein, using the suggested proficiency level descriptors to delineate the outcomes into measurable categories. Associated leadership competencies will then be measured for the three levels (developing, emerging and proficient) of student achievement.

Conclusion

It is anticipated that the process described in this article of determining program competencies and developing the associated student learning outcomes using the suggested proficiency level descriptors will lead to a more comprehensive and consistent learning process across the courses that comprise the aviation management curriculum. In addition, it is expected that the streamlining of competencies will result in a more robust assessment process. These anticipated advantages will serve to improve the overall quality of education for program graduates and lead to increased satisfaction among all of the stakeholders. It is hoped that the description of this development process and the related core competencies resulting from it will benefit faculty in other aviation programs that wish to move to competency-based educational models. The authors wish to suggest that faculty at other institutions consider the competencies proposed herein for potential adoption, tailoring them as necessary to fit situations unique to their respective programs, and that they also consider adoption of the related competency development process.

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Collegiate Aviation Review International

Volume 37 | Issue 1 Proceedings of the 2018 UAA Annual Conference, Article #1

1-3-2019

Aviation in the Ville: Promoting Science and Civic Engagement through Aviation

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Aviation in the Ville is an ongoing collaborative series of activities designed to promote diversity in aviation by introducing aviation topics to the youth of an underrepresented neighborhood and proving discipline-specific service learning opportunities to aviation undergraduate students. Situated in three interrelated settings: in-school, after school, and over the summer, this paper focuses on the initial analysis of data collected during the 2018 summer camp. Utilizing a qualitative, participatory action research model, and drawing on the Harvard Family Research Project out-of-school performance measures, a number of themes emerged which seem to support the effort.

Recommended Citation:
Bollock, N.K. & Belt, S.M. (2019). Aviation in the Ville: Promoting Science and Civic Engagement through Aviation. *Collegiate Aviation Review International*, 37(1), 175-182. Retrieved from http://ojs.library.okstate.edu/osu/index.php/CARI/article/view/7804/7207

In July of 2018, the aviation department of Saint Louis University (SLU) offered an aviation program as part of a month-long youth summer camp for underrepresented inner-city children. On the last day of the camp, the group visited the Center for Aviation Science where SLU flight instructors provided the children with discovery flights. During the field trip, a camper declared to one of the undergraduate aviation counselors, "One day I want to fly an airplane with you as my co-pilot." To an individual not in the aviation industry, this kind of statement might be little more than cute or endearing, but to those in the aviation industry such sentiments are encouraging and crucial. Though the industry is filled with opportunity, there is a need to communicate those opportunities and to foster the necessary academic preparation, particularly to underrepresented groups. With support from American Airlines, the Aviation Science department is developing a multifaceted outreach and exploration program. This program seeks to connect aviation undergraduate students with elementary school children and teachers of a neighborhood located in North Saint Louis by providing activities designed to apply relevant aviation topics and concepts to age appropriate learning outcomes. In this way, Aviation in the Ville works to share the love of aviation with a group who may not otherwise be exposed to the field and foster greater accessibility to the pilot profession. It also hopes to provide SLU aviation students with an experience of cultural immersion and service learning that is directly associated with their chosen profession. Furthermore, utilizing a model of participatory action research, the research team seeks to identify best practices in order to enable the industry better to promote the field of aviation to young people of color in ways that help them to thrive and persist as they acquire the skills and educational background necessary to become successful aviation professionals.

Background

Aviation in the Ville concentrates on three different constituent groups: underrepresented elementary school children, undergraduate students majoring in aviation, and elementary school teachers. Located in a historic African American neighborhood that is rich in heritage but now struggles with high levels of poverty and crime, the program has three interrelated objectives. The first objective is to enhance elementary school education through the exploration of various aviation topics. The second objective concentrates on promoting the diversity awareness of undergraduate students through service learning. These two objectives are addressed in three settings: in-school, after school, and over the summer. The in-school component has been implemented as an enrichment elective in a neighborhood public elementary school. After school activities currently run on Saturday mornings at a community outreach facility which also hosts the month-long summer camp. Finally, the third objective involves providing aviation topics as professional development for elementary school teachers. An initial half-day program has been offered at SLU with plans for additional activities. The following discussion focuses on the first objective by sharing preliminary findings from the most recent summer camp aviation program.

Methodology

Aviation in the Ville is a participatory action qualitative research with a transformative interpretive framework. During the summer camp, there were a total of 10 youth participants. The group was 100% African American and roughly balanced between male and female (six and four, respectively). There were eight camp counselors, two of whom were SLU aviation undergraduates. The objective of this phase of the study was to gain a better understanding of the effect of such a program on the participating children. This was achieved by assessing the academic performance and youth development of the participants throughout the camp. Observations, surveys, reflections, worksheets and focus groups were used to collect data. The data analysis was performed using Creswell's data analysis spiral (Creswell, 2007). Drawing on the Harvard Family Research Project's (2004) Academic Performance and Youth Development Performance Measures, themes were developed using initial coding, NVivo coding and process coding. Member checking, methodological triangulation, data triangulation, researcher triangulation, and environmental triangulation were used to determine validity.

Findings and Discussion

Several themes were identified in the analysis phase. Themes indicating *Academic Performance Measures* and *Youth Development Performance Measures* included: Change in Behavior, Comfort with taking Tests, Academic Knowledge in Specific Content Areas, and Connectedness to the Program.

Change in Behavior

The change in behavior in children in this research appeared to be due to specific stimulus like rewarding with candy for correct answers, one-on-one session with the camp counselors, conducting interesting activities, and peer engagement.

Rewarding with candy. When camp counselors asked questions in the camp about various aviation aspects, the youth did not initially appear to be interested in answering them. However, when camp counselors said that they would give out candy for correct answers, the children became more enthusiastic and raised their hands to answer questions.

Conducting interesting activities. In the same way, there was a noticeable difference in behavior when conducting certain activities. The children participated in activities like building and launching water bottle rockets and Estes rockets with a higher degree of interest than some of the more class-room style activities. During these activities, they took greater responsibility and demonstrated qualities like leadership, commitment, patience, and engagement. Additionally, by conducting interesting activities with children, there was less struggle to gain and maintain attention and participation. Figure 1 highlights several activities from the summer camp.

Figure 1. (Left) Rocket building activity. (Right) Flight simulator exercise.

One-on-one sessions. Change in behavior was also observed during one-on-one sessions with the camp counselors. The children who received one-on-one attention appeared to be more productive and performed better on worksheets compared to those who did the activities and worksheets on their own. Thus, one-on-one guidance with the camp counselors in outreach programs appeared to help the children to engage and succeed.

Peer engagement. Finally, a change in the behavior of the children was observed during peer engagement. For example, at first, one participant was not interested in building water bottle rockets and stated that he did not want to do the activity because he thought it was stupid. The activity leader allowed the participant to go into another room and sit quietly so that he did not disturb the other children. While in the other room, the participant could see the other children building the rockets. After some time, he quietly returned to his seat and started doing the activity. Once the participant saw other children doing the activity, he became interested in participating.

Comfort with Taking Tests

Initially, the observational data suggested that the youth were not interested in doing worksheets or taking tests (see Figure 2). However, with the support of one-on-one sessions, and simulator-based tasks, a number of participants appeared to become more engaged and began to respond favorably to the worksheets and tests. The figure below shows the survey data related to engagement and comfort with worksheets and tests. At the end of each week, the campers completed satisfaction surveys related to the activities of the week. Of the 27 responses, only five responses (18.5%) indicated that they did not like the worksheets or taking tests (see Figure 3).

Figure 2. One-on-one instructional sessions improved participant engagement in completing worksheets and assessments.

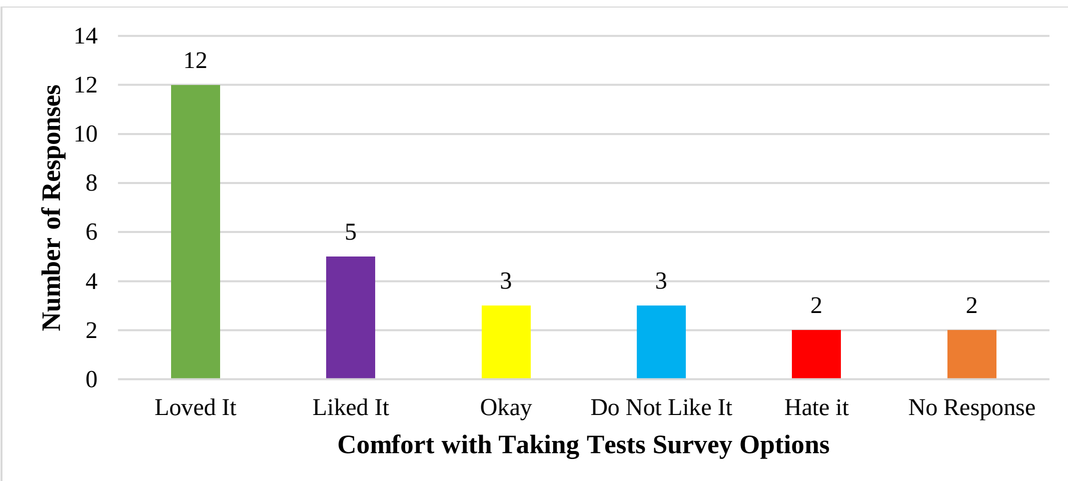

Figure 3. Survey data related to comfort with taking tests and completing worksheets.

Academic Knowledge in Specific Content Areas

On the final day, the youth went on a field trip to the Center for Aviation Science where SLU flight instructors took them on discovery flights. During the flights, the instructors quizzed the children on various topics that were covered in the camp. The instructors were asked to complete a brief survey about the quality of the responses and indicate if they needed to provide any help with the topics (see Figure 4). According to the data, it appeared that most of the time participants were able to relate aviation concepts and academic knowledge in specific content areas like the four forces, primary flight instruments, and degrees of freedom, without help.

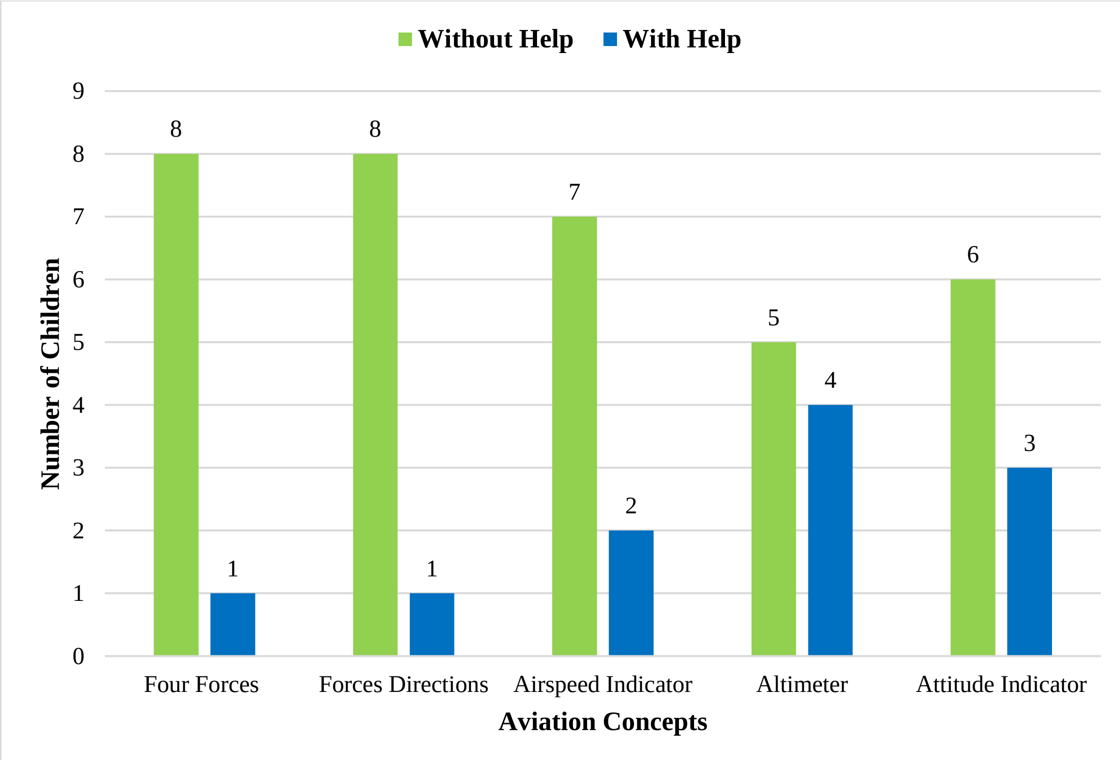

Figure 4. Survey data related to academic knowledge in specific content areas from nine participants. Data of children those who answered questions with help and without help.

Connectedness to the Program

At the conclusion of the camp, youth were asked to complete a satisfaction survey. The data from the below figure suggested that most of the youth in the program liked the aviation activities and would attend the camp again. Specifically, they enjoyed flying the simulators the best. Most of the students in the program intended to attend the program again and would recommend the camp to their friends. Perhaps the ultimate achievement of the program was that among the ten participants, four indicated a desire to become pilots (see Figure 5) in the future.

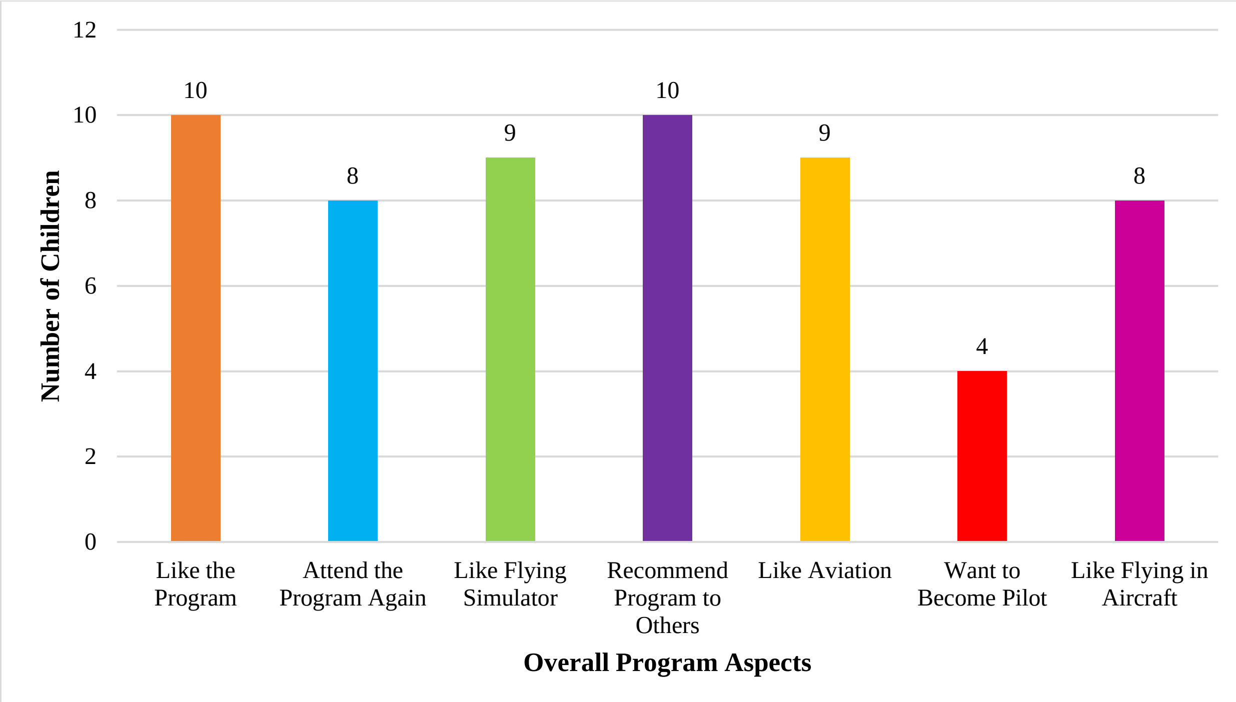

Figure 5. Data from child post checklist collected on the last day of the camp from 10 participants.

Conclusions

Overall, the summer camp appeared to be effective. The data suggested that the program positively supported a variety of Academic Performance Measures and Youth Development Performance Measures and the camp program was able to create interest in elementary youth towards aviation. Finally, the themes represented initial indications of best practices which will be developed and assessed in subsequent outreach activities.

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UNIVERSITY AVIATION ASSOCIATION

Collegiate Aviation Review International

Volume 37 | Issue 1 Proceedings of the 2018 UAA Annual Conference, Article #2

1-23-2019

Gender Balance in Aviation

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Women continue to be a minority in STEM related industries today and are grossly under-represented as professional pilots. To exacerbate this disparity, there is a pilot shortage in the United States. Fewer women than men are earning degrees in STEM degree programs, except in the Life Sciences. Universities must foster a gender balance in aviation degree programs by increasing the female student population at the college level to help create a pipeline of female pilots for the aviation industry. Universities and colleges should establish outreach programs that promote and support female STEM awareness as well as establish industry relationships to create collegial partnerships that lead to recruiting female students.

Recommended Citation:
Halleran, M.S. (2019). Gender Balance in Aviation. *Collegiate Aviation Review International*, 37(1), 183-190. Retrieved from http://ojs.library.okstate.edu/osu/index.php/CARI/article/view/7821/7216

There is a pilot shortage in the Unites States and women are the solution to this problem! Colleges and universities should take the initiative to increase the female student population in aviation and STEM related degree programs. By increasing the female student population in STEM degree programs, with emphasis on the aviation and aerospace industries, a gender balance for the pilot career path could occur. Airline pilots today are required to earn a Bachelor's Degree. To address the current pilot shortage, it makes sense to increase the number of female pilots at the collegiate level.

Problem

In the United States, there is a pilot shortage and women are under-represented as airline pilots at 4.2%.

Purpose

This paper will demonstrate that there is not a gender balance in aviation in the United States.

Discussion

STEM refers to the fields of *science, technology, engineering*, and *mathematics*. There is no standard definition of a STEM occupation as STEM incorporates professional and technical support occupations in the areas of life and physical sciences, computer science and mathematics, and engineering. Less agreement has been made on the inclusion of educators, healthcare professionals, and social scientists in STEM (Beede et al., 2011; U.S. Census Bureau, 2010). At the university level, STEM includes aviation and aerospace related programs.

As depicted in Table 1, fewer women than men are earning degrees in STEM degree programs except in the Life Sciences. The share of STEM degrees is even smaller for women of color. In 2014–2015, women of color earned a small percentage of bachelor's degrees across all STEM fields: Black women at 2.9%, Latinas at 3.6%, and Asian women at 4.8% (National Center for Education Statistics, 2016; 2017).

Women remain a minority of STEM workers in the United States. Women made up less than one-quarter (24%) of those employed in STEM occupations in 2015 (Noonan, 2017). A substantial gender gap in engineering and computer occupations contributes to women's overall underrepresentation in STEM. In 2016, women in the United States represented 25.5% of computer and mathematical occupations, and 14.2% of architecture and engineering occupations (Bureau of Labor Statistics, 2017). For women of color, this gap is even wider. Latinas and Black and Asian women made up slightly less than 10% of working scientists and engineers in the United States in 2015 (National Science Foundation, 2017).

Table 1

United States STEM Statistics (Catalyst, 2018)

Percentage of Degrees Earned by Women in Postsecondary Institutions (2014–2015)			
	Bachelor's	**Master's**	**PhD**
Biological and biomedical sciences	59.0%	57.3%	53.3%
Mathematics and statistics	43.0%	40.6%	27.9%
Physical sciences and science technologies	38.5%	37.5%	34.3%
Engineering and engineering technologies	18.7%	25.2%	23.2%
Computer and information sciences and support services	18.0%	30.4%	22.5%
All STEM fields	35.1%	32.7%	34.4%

Women are significantly underrepresented in high-tech occupations. In 2016, women accounted for one-fifth or less of those employed in these jobs, to include: software developers, applications and systems software at 20.0%, computer network architects at 9.7%, and aerospace engineers at 7.8% (Bureau of Labor Statistics, 2017). Even in these high-paying STEM jobs, women earn less than men. In the United States, women in computer, engineering, and science occupations were paid an estimated 79.2% of men's annual median earnings in 2016 (U.S. Census Bureau, 2017).

While most non-STEM related industries have made significant efforts to attract the female customer in the last few decades, the aviation industry is still lagging. As an example, long gone are the cars that would require the smaller-framed female driver to bring cushions along, however that is not the case with most new aircraft (Goyer, n.d.).

Females are grossly underrepresented in aviation occupations. In fact, the percentage of female pilots in the United States is lower than the meager 7.8% for female aerospace engineers. The statistics for the number of pilots in the United States show an enormous disparity between genders. The percentage of total female pilots (not including certified flight instructors) in the United States (US) is 6.7%. The percentage of female certified flight instructors is 6.5% (Federal Aviation Administration [FAA], 2017). See Tables 2 and 3.

Table 2

Estimated Active Pilot Certificates Held by Category and Age Group of Holder

Age Group	Type of Pilot Certificates							Flight Instructor 2/	Remote Pilot 2/
	Total	Student	Sport	Recre-ational	Private 1/	Commercial 1/	Airline Transport 1/	CFI 3/	
Total	**584,361**	**128,501**	**5,889**	**178**	**174,517**	**112,056**	**163,220**	**104,382**	**20,362**
14-15	259	259	0	0	0	0	0	0	0
16-19	16,491	12,697	16	3	3,482	293	0	56	214
20-24	57,599	31,808	112	28	14,815	10,058	778	3,637	1,388
25-29	64,176	26,837	201	30	13,698	17,703	5,707	8,101	2,397
30-34	55,351	17,693	239	12	13,167	12,011	12,229	11,884	2,761
35-39	50,246	12,314	234	10	12,342	8,997	16,349	11,919	2,564
40-44	44,770	6,212	292	9	12,577	7,513	18,167	10,691	2,217
45-49	49,254	5,571	427	11	13,322	7,417	22,506	11,642	2,143
50-54	56,377	4,962	676	11	16,929	8,214	25,585	10,614	2,094
55-59	59,558	4,069	933	19	20,822	8,966	24,749	9,733	1,746
60-64	52,066	2,847	993	15	21,015	9,275	17,921	8,703	1,425
65-69	36,580	1,798	807	14	15,516	8,598	9,847	7,572	893
70-74	23,543	954	560	9	9,758	6,762	5,500	5,499	376
75-79	11,018	328	266	3	4,382	3,574	2,465	2,683	118
80 and over	7,073	152	133	4	2,692	2,675	1,417	1,648	26

1. Data current as of December 31, 2016 (FAA, 2017)
2. Includes pilots with an airplane and/or a helicopter and/or a glider and/or a gyroplane certificate. Pilots with multiple ratings will be reported under highest rating. For example a pilot with a private helicopter and commercial airplane certificates will be reported in the commercial category.
3. Not included in total active pilots
4. Certified Flight Instructor

As depicted in Table 3, Female Airline Transport Pilots (ATP) in the U.S. = 4.2 %; Female Commercial Pilots = 5.4%; and Female Student Pilots = 12.4%. Out of 163,220 airline pilots in the United States, only 6,888 of them are female pilots. However, Table 3 lists all airline pilots, and 19,229 of them are age 65 or over, which means they cannot fly for an airline due to age restrictions. Airline pilots in the United States have mandatory retirement at age 65. So the female percentage of ATPs from ages 21-64 equates to 4.6%. Also included in the total number of airline airplane pilots are helicopter, glider, and gyroplane pilots.

Table 3

Estimated Active Women Pilot Certificates Held By Category And Age Group of Holder

Age Group	Type of Pilot Certificates							Flight Instructor 2/	Remote Pilot 2/
	Total	Student	Sport	Recre-ational	Private 1/	Commercial 1/	Airline Transport 1/	CFI 3/	
Total	**39,187**	**15,971**	**223**	**15**	**10,009**	**6,081**	**6,888**	**6,848**	**793**
14-15	48	48	0	0	0	0	0	0	0
16-19	2,382	1,955	2	0	396	29	0	9	10
20-24	6,852	4,449	18	5	1,508	819	53	350	67
25-29	6,075	3,266	21	5	1,164	1,229	390	688	132
30-34	4,493	1,974	14	0	927	820	758	931	107
35-39	3,658	1,373	7	1	723	558	996	979	98
40-44	2,731	683	6	0	595	423	1,024	852	61
45-49	2,684	606	13	0	634	339	1,092	836	80
50-54	2,794	584	25	0	776	356	1,053	670	95
55-59	2,775	486	48	1	1,028	407	805	563	74
60-64	2,240	304	31	0	1,026	418	461	451	44
65-69	1,295	143	16	1	634	350	151	269	19
70-74	718	69	15	1	387	186	60	143	4
75-79	278	22	5	1	148	79	23	66	2
80 and over	164	9	2	0	63	68	22	41	0

1. Data current as of December 31, 2016 (FAA, 2017)
2. Includes pilots with an airplane and/or a helicopter and/or a glider and/or a gyroplane certificate. Pilots with multiple ratings will be reported under highest rating. For example a pilot with a private helicopter and commercial airplane certificates will be reported in the commercial category.
3. Not included in total active pilots
4. Certified Flight Instructor

Conclusions

Women continue to be a minority in STEM related industries and are grossly under-represented as professional pilots. Fewer women than men are earning degrees in STEM programs except in the Life Sciences. Universities must foster a gender balance in aviation degree programs by increasing the female student population at the college level to help create a pipeline of female pilots for the aviation industry.

Recommendations

Airline pilots today are required to earn a bachelor’s degree. To address the current pilot shortage, it makes sense to increase the number of female pilots at the collegiate level. In order to increase the female student population, outreach programs are suggested with the intent of increasing female enrollment in STEM education. Examples of outreach programs are *mentoring programs* which pair up alumni with current female students or *ambassador programs* which pair up current female students with accepted female students before they matriculate.

Colleges need to do a better job in advertising STEM degree programs to junior high and high school students so connecting with guidance counselors would be a good start. Hosting summer camps and workshops for STEM students such as *Introduce a Girl to Flying Workshop* would reach the 6-8th grade demographic. Universities should also work with organizations like the Women in Aviation International. This organization hosts a yearly conference that promotes females in aviation-related STEM fields.

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Collegiate Aviation Review International

Volume 37 | Issue 1 Proceedings of the 2018 UAA Annual Conference, Article #3

3-7-2019

Investigation of the Potential for an Aircraft Dispatcher Shortage in the United States

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This research effort determines current and projected demand for aircraft dispatchers and compares that to the education and training or the "production" of new aircraft dispatchers by Federal Aviation Regulations (FAR) Part 65 certificated schools in order to determine the extent of a potential shortage and define what may constitute sufficient numbers that are necessary to support a growing industry. A shortage of aircraft dispatchers will exert an adverse operational impact on the work of both pilots and aircraft maintenance technicians (AMTs). Unlike the shortage of pilots and AMTs, which have received attention from policymakers and practitioners, there has been limited, if any, serious attention to the possibility of a comparable shortage of aircraft dispatchers. This research effort represents an initial and modest contribution towards addressing the need to investigate the potential for an aircraft dispatcher shortage in the United States. In the main, it involves a review of the census data of certificated aircraft dispatchers from 2011-2017, which was secured from the Federal Aviation Administration and a survey of 54 of the 57 FAR Part 65 certificated schools listed with the Federal Aviation Administration. The authors plan to secure funding to conduct a survey to determine the aircraft dispatcher needs of the 168 FAR Part 121 certificate holders that offer domestic scheduled service as well as domestic and foreign scheduled operations.

Recommended Citation:
Manderino, F.J. & Nettey, I.R. (2019). Investigation of the Potential for an Aircraft Dispatcher Shortage in the United States. *Collegiate Aviation Review International*, 37(1), 191-196. Retrieved from http://ojs.library.okstate.edu/osu/index.php/CARI/article/view/7800/7267

There has been extensive discussion about the shortage of airline pilots (Armstrong 2015) and aircraft maintenance technicians (Mark, 2018a, 2018b). This shortage has even received attention in Congress, as evidenced by a Congressional hearing on the subject in April 2014 (Jansen, 2015) and the subsequent launch of a program to address the shortage. Against the background of airline pilot and aircraft maintenance technician shortages are projections of historic growth in airline service and aircraft purchases by both Boeing and Airbus.

Using aircraft age, relative airplane economics, maintenance requirements and overall market environment, as well as firm aircraft orders and options, Boeing (2015) has forecasted the need for 38,050 airplanes valued at $5.6 trillion over the next 20 years through 2034. Not to be outdone, Airbus (2015) projects 32,585 total new aircraft deliveries between 2014 and 2034. Of that number, 31,800 are passenger aircraft and 800 aircraft are freighters.

Problem & Purpose

Unfortunately, concern about the shortage of airline pilots and maintenance technicians appears to ignore the supply of aircraft dispatchers who are operationally indispensable. Practically all airlines, ranging from the major airlines to the regional airlines, rely on aircraft dispatchers to operate effectively.

This research effort reviews the current demand for aircraft dispatchers and compares that to the *production* of new aircraft dispatchers by FAR Part 65 schools in order to determine any potential shortage. With funding, this research will define the numbers of aircraft dispatchers that will be necessary to support industry growth.

Methodology

The first step in the research process involved obtaining census data of certificated aircraft dispatchers from 2011-2017 from the Federal Aviation Administration's (FAA) Indianapolis Flight Standards District Office.

After obtaining the census data of certificated aircraft dispatchers, a listing of FAR Part 65 certificated schools was secured from the FAA. The FAR Part 65 certificated schools are schools that the FAA has authorized to train candidates for aircraft dispatcher certification.

The third step in the research process comprised the administration of a four-question survey instrument to 54 of the 57 listed FAR Part 65 schools. The survey was conducted from September 7– 23, 2018. Six responses were received. The four survey questions were:

- How many aircraft dispatchers have you graduated successfully this year?
- How many have you graduated each year during the past 10 years?
- How many students graduate from your school successfully each year out of the total number of entrants at your school?

- Can you provide any data on how many of your graduates are hired within one month? Graduates hired within two months? Graduates hired within three months?

Findings

Analysis and review of the 2011-2017 census data of certificated aircraft dispatchers indicated there were 5,153 employed by operators who hold eight different types of certificates.[1] At 2,745, the largest group of aircraft dispatchers were employed by air carriers that operate under FAR Part 121, followed by 2,103 aircraft dispatchers employed by FAR Part 129 certificate holders. The number of aircraft dispatchers employed, drops drastically from 2,000 to the 230 employed by FAR Part 135 operators, as depicted in Figures 1 and 3 below.

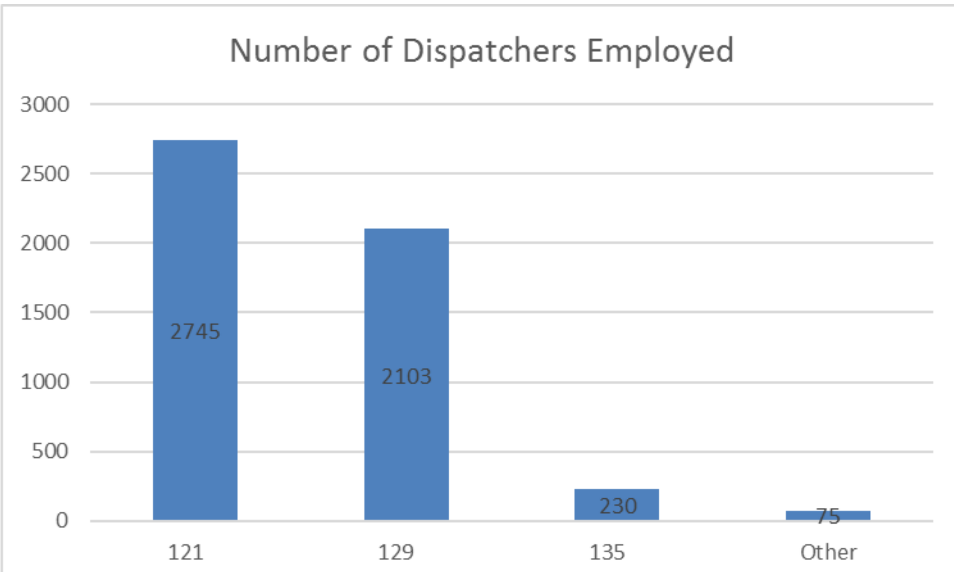

Figure 1. Number of aircraft dispatchers employed by the leading three employers.

The remainder of the certificated aircraft dispatchers employed are depicted in Figures 2 and 3 below. For purposes of specificity, these sums are wholly disaggregated as follows; FAR Part 137 (8 dispatchers), FAR Part 135 (230 dispatchers), FAR Parts 135 and 121 (32 dispatchers), FAR Part 133 (6 dispatchers), FAR Part 129 (2,103 dispatchers), FAR Part 125 (12

[1]The eight certificates comprise a joint Part 121/135 certificate and the following certificates:
Part 91 (General Aviation Operations) – GENERAL OPERATING AND FLIGHT RULES
Part 121 (Air Carrier Operations) – OPERATING REQUIREMENTS: DOMESTIC, FLAG, AND SUPPLEMENTAL OPERATIONS
Part 125 (Air Carrier Operations) – AIRPLANES HAVING A SEATING CAPACITY OF 20 OR MORE PASSENGERS OR A MAXIMUM PAYLOAD CAPACITY OF 6,000 POUNDS OR MORE; AND RULES GOVERNING PERSONS ON BOARD SUCH AIRCRAFT
Part 129 (Foreign Air Carrier Operations) – FOREIGN AIR CARRIERS AND FOREIGN OPERATORS OF U.S.-REGISTERED AIRCRAFT ENGAGED IN COMMON CARRIAGE
Part 133 (Rotorcraft Load Operations) – Part 133 - ROTORCRAFT EXTERNAL-LOAD OPERATIONS
Part 135 (Air Taxi and Commuter Operations) – COMMUTER AND ON DEMAND OPERATIONS AND RULES GOVERNING PERSONS ON BOARD SUCH AIRCRAFT
Part 137 (Agricultural Operations) – AGRICULTURAL AIRCRAFT OPERATIONS

dispatchers), FAR Part 121 (2,745 dispatchers), and FAR Part 91 (17 dispatchers), as well as 75 dispatchers employed by "Other," for a total of 5,228 dispatchers.

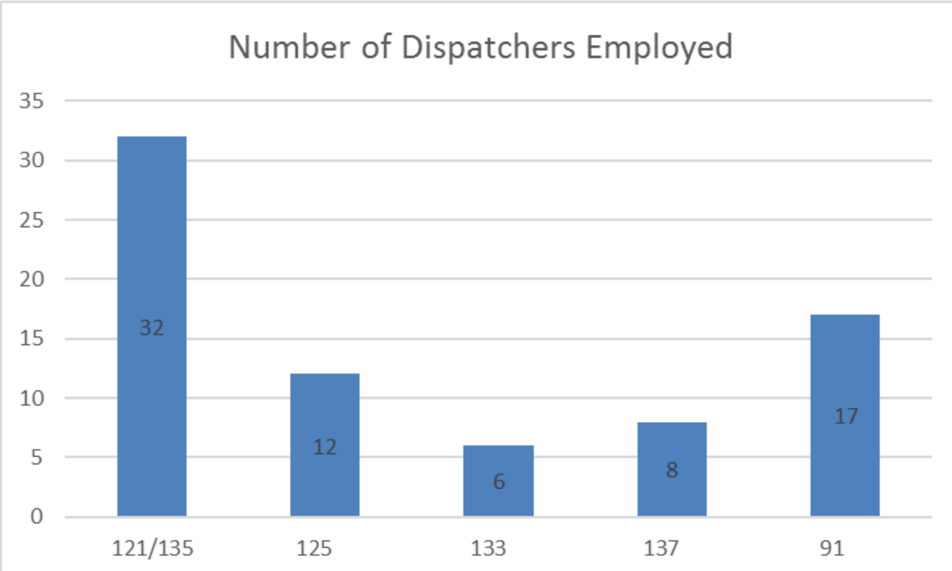

Figure 2. Number of dispatchers employed by the trailing five employers.

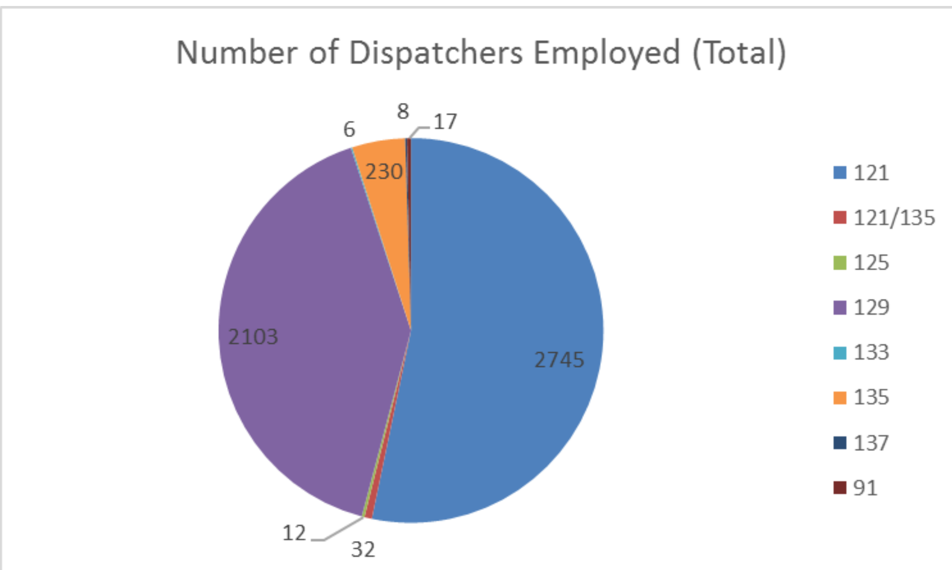

Figure 3. Number of total dispatchers employed.

Against the background of the preceding listings of certificated aircraft dispatchers employed between 2011 and 2017, is the informative set of statistics about the numbers of aircraft dispatcher certificates processed by the FAA during the same period. The annual number of aircraft dispatcher certificates processed between 2011 and 2017 are depicted in Figure 4, culminating in a total of 10,667 certificates.

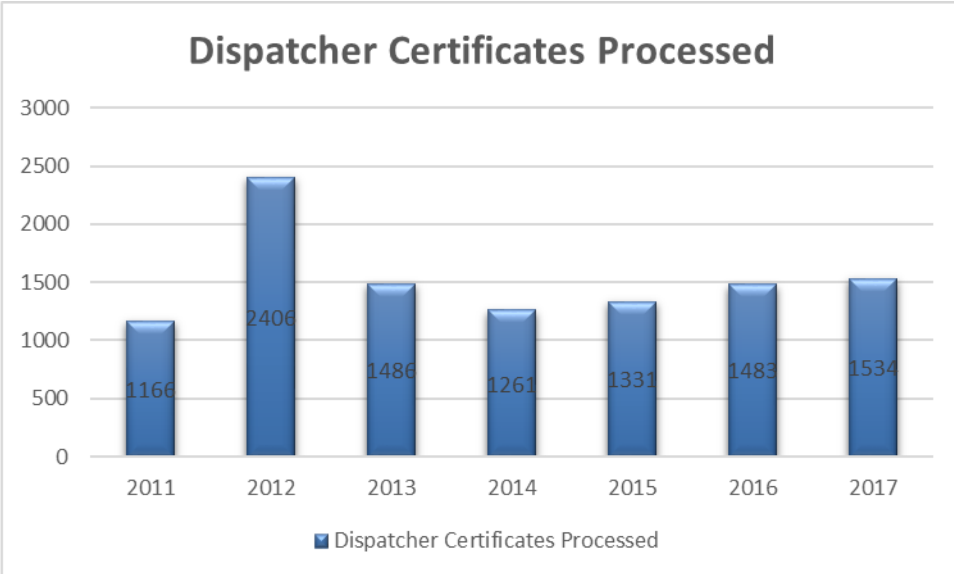

Figure 4. Dispatcher certificates processed by the FAA in 2011-2017.

Next Steps

A census of certificated aircraft dispatchers from 2011-2017 revealed 5,153 dispatchers were employed in the eight different certificate categories; interestingly, more than double that sum of aircraft dispatcher certificates (n = 10,667) were processed by the FAA during the same timeframe of 2011-2017. This suggests a finding that the field currently has an adequate supply of certificated aircraft dispatchers.

The past seven years cannot necessarily be expected to represent future demand for certificated aircraft dispatchers. It will be necessary to survey the leading employers of certificated aircraft dispatchers--namely, FAR Parts 121 and 129 operators--to determine their expected needs over the next five to seven years, and compare that with the projected supply over the same timeframe.

The next steps of this research effort shall therefore comprise conducting a needs assessment of the demand for aircraft dispatchers by FAR Parts 121 and 129 operators over the next five to seven years using a survey instrument. The list of FAR Part 121 operators, which has already been secured from the FAA, shows 168 certificate holders. It will be necessary to secure extramural funding to support survey dissemination and synthesis of the findings.

The successful acquisition of extramural research funding will also support an intensive effort to improve the response rate of the earlier survey of FAR Part 65 schools--beyond six out of the 54 schools surveyed. In the absence of further research, it may suffice to conclude that a review of the number of aircraft dispatchers employed and the number produced during the 2011-2017 timeframe, indicated there was no shortage of dispatchers in 2011-2017.

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